Models of Public-Private Partnership in R&D being practiced in America, Europe, Israel and Australia

United States of America

1. Introduction

The United States has long been, and still is, at the forefront of cutting-edge science, technology and innovation. This position has been maintained owing to it being a predominantly free market economy and having a historically robust research and development (R&D) ecosystem. The R&D enterprise in the United States (US) is funded primarily by the federal government and a private sector that includes industry and non-profit entities. Additionally, state, regional, and local governments provide a relatively small but growing contribution. While the Federal Government can provide, through funding and policy frameworks, an environment that supports science and technology-based innovation, the private sector and academia are principally responsible for directly maintaining and expanding the US R&D enterprise and thereby driving innovation.

USA is ranked fourth according to the Global Innovation Index Report 2017-18 and second according to the Global Competitiveness Report 2017-18, published by the World Economic Forum (WEF). The strength of United States comes from its performance in sub-indices of 'Efficiency Enhancers' and 'Innovation and Sophistication', where it stands on rank first and second respectively. These sub indices reflect a strong factor of production and a vibrant innovation ecosystem. A few of the other indicators have been enlisted in the table 1 below:

Table 1 Global Rankings of USA, as based on S&T related indicators.

S. No	Indicators	Global Rank
1.	Expenditure on education, % GDP[a]	54
2.	Research & development (R&D)[a]	4
3.	Gross expenditure on R&D, % GDP[a]	10
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	1
5.	QS university ranking, average score top 3[a]	1
6.	University/industry research collaboration[a]	4
7.	Capacity for Innovation[b]	2
8.	Company Spending on R&D[b]	2
9.	Availability of Scientists and Engineers[b]	2
10.	Quality of Scientific Research Institution[b]	2
11.	Publications[c]	1
12.	H-index[a]	1
13.	Intellectual Property Rights[d]	1

14.	PCT Patents[b]	10

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

Remarkably, USA is one of the high income group economies that have remained amongst the top five in 'Innovation Quality' since the inception of the GII metrics. The latest rankings position USA on the first position, which can be attributed largely to an improvement in the score in patent families (GII Report 2017-18). USA holds top ranks in a wide range of indicators, such as, citable documents, QS university ranking, computer software spending, venture capital deals, IP receipts, global R&D companies, state of cluster development, and cultural and creative services exports etc.

The Federal Government has certainly given a push to the entrepreneurial activity and the efforts have yielded in fruitful results. A large number of programs, initiatives and schemes have helped to strengthen the 'Capacity for Innovation' of America. Fostering public-private partnerships has been one of the methods for addressing the various challenges that the US innovation ecosystem faced. The programs described in the following sections have contributed towards the nation's research enterprise by developing long-term partnerships among industry, academia and government.

2. Programs/Schemes/Organizations

2.1 Industry/University Cooperative Research Centers Program (I/UCRC)

Background

The I/UCRC Program (https://www.nsf.gov/eng/iip/iucrc/about.jsp) of USA was drafted in 1973 and established in the 1980s in order to develop and foster collaborations amongst the academia, government and industry. This program is supported by the US government's National Science Foundation (NSF) and has been operative and standing viable for close to four decades, unruffled by the changes and shifts in political scenarios and other archetypes that transpired over this long time period (Gray et al., 2015). However, the program has been subjected to certain adjustments in this course of time. A few modalities were introduced in between and some were later abandoned nonetheless keeping the original solicitation similar and stable since mid-1980s.

Prior to the I/UCRC Program, industry and academia relationships existed through industry/university (I/U) linkage mechanisms (e.g., affiliations, institutions, centers). These tended to be one-sided relationships, in the favor of either the university faculty member performing the research or the industrial organization that requested a solution to a specific problem, characteristically devoid of collaboration. I/UCRC Program established a model to offer mutually beneficial collaborations through knowledge exchange and technological advancements (Gray *et al*., 1998).

Objectives of I/UCRC

Fostering collaborations between the industry and university, primarily for the following rationale

- Contributing to the U.S. research enterprise by developing long-term partnerships among industry, academia and government,
- Leveraging NSF funds with contributions from the industry to support graduate students in performing industrially relevant research,
- Expanding the innovation capacity of the U.S. competitive workforce through partnerships between industries and universities,
- Encouraging nation's research enterprise to remain competitive through active engagement with academic and industrial leaders throughout the world.

Governance and Organizational Structure

Each center undertakes research, vetted by an Industrial Advisory Board (IAB). This board ensures that the research being conducted is not of interest to a single company but caters to and is in alignment with the needs of all the members of the consortia. As and when deemed pertinent, an I/UCRC also involves in associations at an international level for advancing its goals and aims. A typical structure of organization of an I/UCRC has been depicted in figure 1.

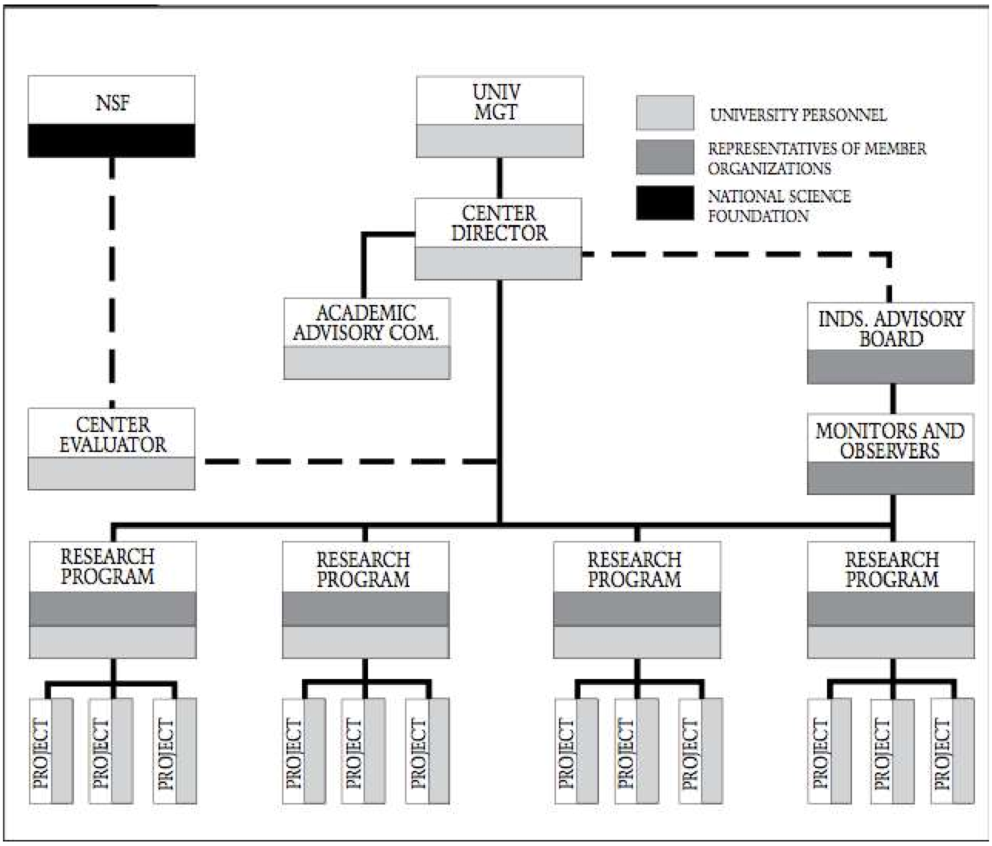

Figure 1 Organizational Structure for a typical I/UCRC
Source: Adapted from Gray, D.O. & Walters, G.W. (1998)

A research center in the I/UCRC model is developed and operated at the university level with faculty serving in administrative roles. For-profit, non-profit, and government organizations join the center as industrial members and take an active role in the center administration, with a representative from each organization serving on the center IAB. The IAB identifies industry needs and determines which research projects to fund. This collaborative model supports effective and efficient R&D processes among and between the public and private sectors. The program promotes collaboration both real-time as well as virtual.

I/UCRC Model: The I/UCRC model incorporates the characteristics of other mechanisms of university-industry linkages like research units, industrial affiliates and R&D consortia, thus it can be called a hybrid model of university-industry linkage (Fig. 2).

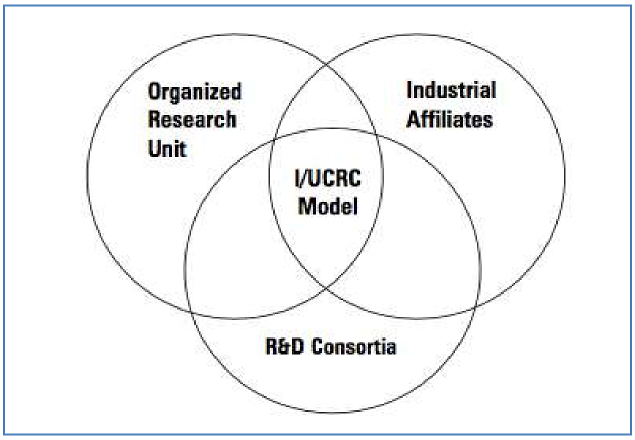

Figure 2 I/UCRC Hybrid Model
Source: Adapted from Gray, D.O. & Walters, G.W. (1998)

Research Unit – an organized unit at a fundamental level i.e. a semi-autonomous organization based in a university but independent of its academic departments.

Industrial Affiliates – backed and supported by number of industries. This format safeguards that research being conducted at the center shall cater to multiple firms and not just interest a single firm or department, thereby ensuring precompetitive and generic research work.

R&D Consortia – the research conducted is of the 'technology pull' format i.e. the requirement of the industry and not on the 'technology push' format i.e. the government's idea of industrial needs.

In addition, this model offers hope for the conduct of money intensive research projects, which neither the industry or government/federal agency could afford to invest. The I/UCRC Program bridges the gap between industry and academia by producing collaborative, industrial-relevant, yet fundamental, research. Many industrial organizations do not have the expertise or resources to conduct the fundamental research that leads to foundational advancements in industry. While industry performs an estimated 70% of U.S. R&D, only 17% of fundamental research is performed by industry (National Science Board, 2014). Similarly, many academic researchers do not have the industrial experience to undertake long-term industry needs and develop applicable research. Academia performs only 20% of U.S. applied (National Science Board, 2014). Through collaborative research, industries gain and maintain a competitive position in the global marketplace, while researchers and universities increase research output, leading to intellectual property and technology transfers. The I/UCRC model (figure 3) caters to the cuts performed in the federal R&D, lack of fundamental research in the industries, academia's financial needs and many more requirements.

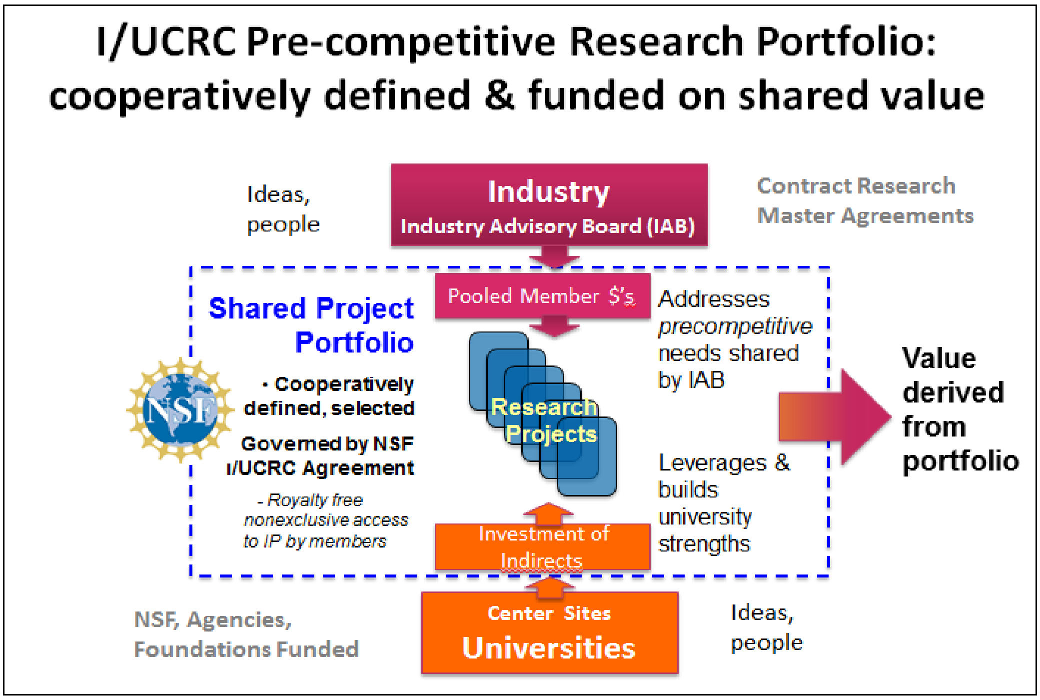

Figure 3 Structure and characteristics of an I/UCRC

Source: https://www.nsf.gov/eng/iip/iucrc/industry.jsp

Funding

I/UCRC program intends to provide funds for effectuating partnerships amid the universities and businesses and grow them into long standing associations so that tangible outcomes can be achieved. The Centers are industry led research consortia based in universities. Each of the Center is invested in by NSF. Even though there are single university Centers, high emphasis is laid on the formation of multi-university Centers. The benefits from multi-university Centers are manifold including pooling of resources and generation of quality data. The funds are provided as seed support for establishing the Center along with supporting the management of the Center. The funds from NSF are not intended at covering the entire cost of activities being performed by the center. Additionally, the funds provided by the NSF cannot be utilized for covering the expenses of a project conceptualized by the members of a Center. The project and its undertakings are to be financed through the members of the Centre only (NSF 2013a).

The I/UCRCs have been able to generate backing from the industry and private sector close to 10 times the support offered by NSF, summarizing a notable return of the investment (Figure 4).

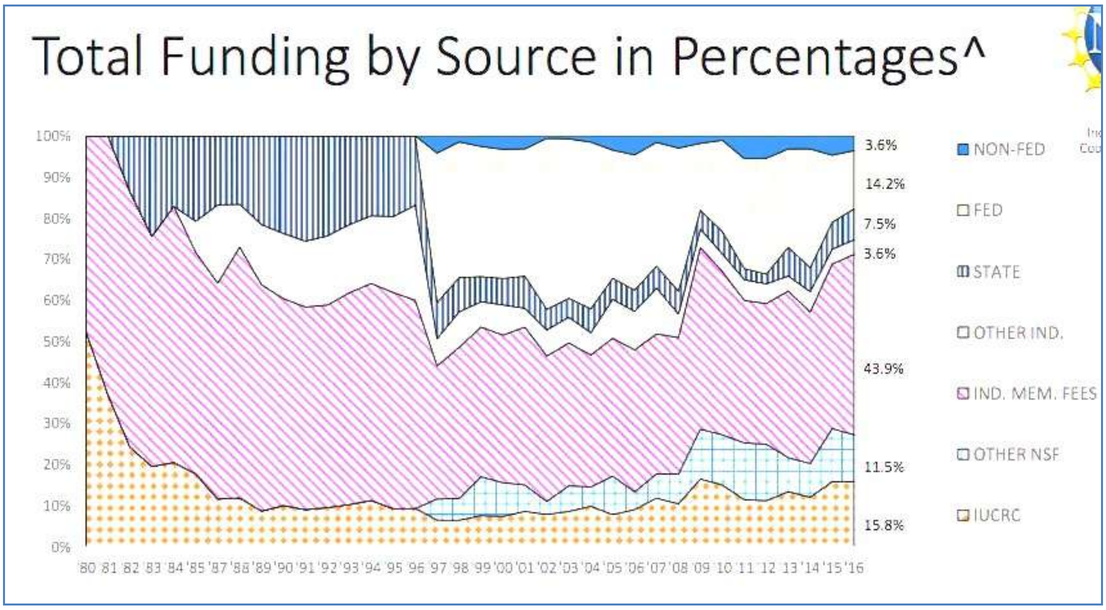

Figure 4 Total Funding by Source in Percentages

Source: McGowen, L. & Leonchuk, O., 2016.

As of financial year (FY) 2015-16, there are 68 centers in operation in the United States across 200 universities and a few handful in Europe and Asia. The Centers are funded for a period of five years, which can be renewed further after evaluation.

The industry does not take university as a convenient and cheap contractor; on the contrary it dives into long standing partnerships with the universities for backing fundamental and applied research along with teaming up with other partners of the consortia. Even though the vital objective of the industry is to commercialize knowledge and technology, the firms do take keen interest in education of the students as well as publishing their findings in due time

Over the time period of past four decades the I/UCRC's have not only led way for fruitful collaborations resulting in industrially relevant research, transfer of ideas from the academic sector to the private sector but have also generated a pool of talented human resource (graduates and undergraduates) possessing an industrially oriented mindset. The member companies hire 30% of these graduates. This is an evidence of the fact that this program is helping in building a strong work force for the nation. The I/UCRCs have also become a leading example in the model of "leveraged" funding, as the total funding by the industrial sector and other organizations amount up to 10 times the investment of NSF.

The I/UCRC program has also been combined with other programs initiated by NSF in a manner that the R&D activities of other initiatives may either presage or accede the activities of a Center. Other programs that have been combined with I/UCRC program are –Small Business Innovation

Research Program (SBIR)/ Small Business Technology Transfer Program (STTR), Grant Opportunities for Academic Liaison with Industry (GOALI), Partnerships for Innovation: Accelerating Innovation Research-Research Alliance (PFI:AIR-RA)

Output and Impact

A few I/UCRCs have emerged as recognized centers for globally competitive innovative research. Scientific breakthroughs that are relevant industrially do not take place *in silos* but are a result of multi-disciplinary associations and partnerships that involve intellect and efforts of both the domains – the academia and the businesses. This program has essentially created a platform for the scientists and business minds to work together with each other's vision and requirements. The program is far-reaching and provides benefits both monetary and non-monetary in nature to the centers.

- Centers established through the program are diverse in domains of S&T (manufacturing, computer science, advanced electronics, biotechnology etc.), number of research personnel, budget ($300,000 to $15 million), number of industrial members.

- Results and outcomes of the Centers have been relevant and substantial. The table 2 depicts the outcomes of the program, in the financial year 2015-16 (https://projects.ncsu.edu/iucrc/NatReports.htm).

Table 2 Outcomes of the Program in FY 2015-16

Number of Centers in Operation	68
Number of Industry Members	1227 (~18 members/Centre)
Number of Scientists	1041
Number of Research Staff	189
Number of Post Doctoral Fellows	195
Number of Doctoral Graduates	1098
Number of Students for Masters Degree	618
Number of Undergraduate Students	605
Number of Projects Undertaken	1063

Number of Publications	2074

- Table 3 depicts that in the recent years an annual turnover of 50 patents, invention disclosures, 10 spin-offs and so on, were reported from almost all of the centers (Koschatzky *et al*., 2015).

- Bestowed with national award - *Technology Transfer Society of America*, for notable technology transfers.

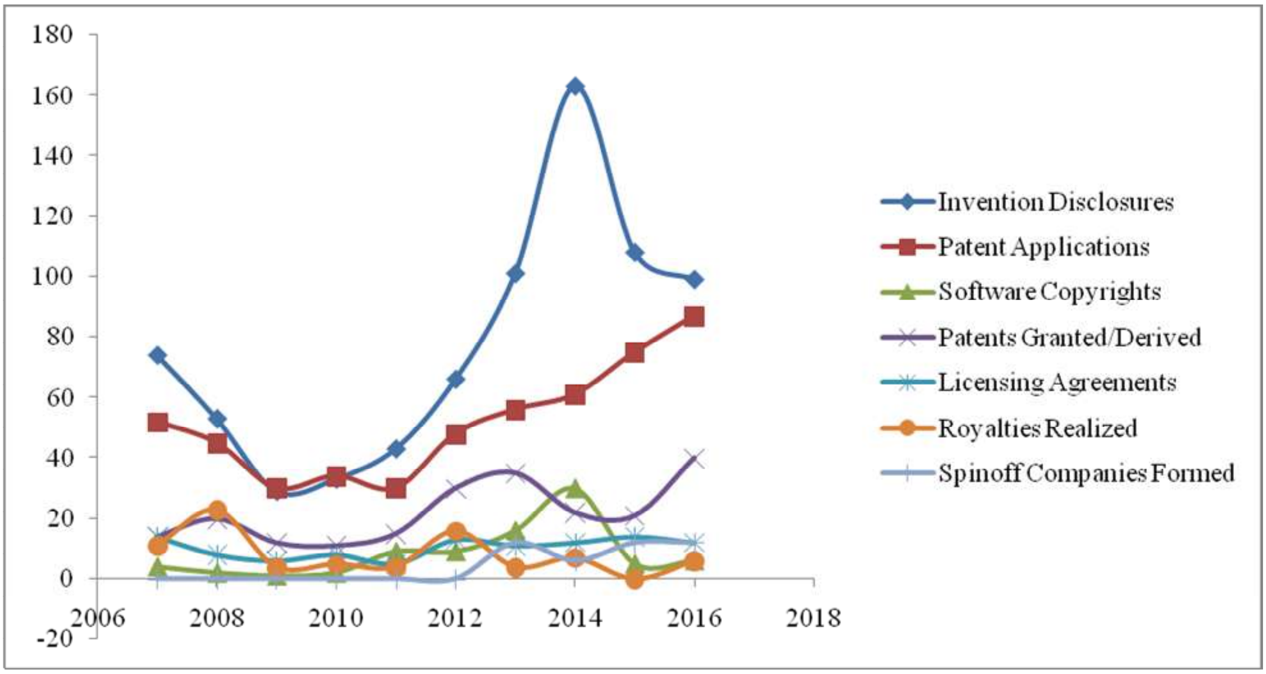

Table 3 Intellectual Property Events of the Program Reported from 2006 to 2016

Intellectual Property Event	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Invention Disclosures	74	53	29	33	43	66	101	163	108	99
Patent Applications	52	45	30	34	30	48	56	61	75	87
Software Copyrights	4	2	1	2	9	9	16	30	5	6
Patents Granted/Derived	14	20	12	11	15	30	35	22	21	40
Licensing Agreements	14	8	6	8	5	13	11	12	14	12
Royalties Realized	11	23	4	5	4	16	4	7	0	6
Spinoff Companies Formed	-	-	-	-	-	-	12	6	12	12

Source: *https://projects.ncsu.edu/iucrc/PDFs/CD%20Reports/CD%2005-16.pdf*

Some amount of prosperity gained and the assets accumulated through the I/UCRC program can be explained through the following points -

- *Impact on the efficiency of R&D:* It has been reported that participation in I/UCRCs has lead to the members amplifying and streamlining their research work. Working in the umbrella of a center also offers its members a cushion for performing high-end yet risky research activities.
- *Impact on generation of Intellectual Property (IP)-* Although the pre-competitive research being performed at the centers is shared amongst the members, the focus is to protect the research results through IPRs. The centers consistently indulge in protection through patents, invention disclosures, design protection, etc. and commercialization through technology transfers, licensing, assignment etc.
- *Impact on resource usage* – As the centers are a platform for performing priority, high-end and risk oriented research beneficial to all the partners, the investments made towards the research allow for procuring sophisticated infrastructure and other resources, which may not be possible for an individual entity to procure, use and maintain. Therefore, the pooling of resources impacts the research in a huge manner.
- *Impact of human resource generation*– The centers have been highly instrumental in training and preparing graduates of the next generation. Industries have reported the students/graduates of I/UCRCs being rather more productive and efficient as compared to the other graduates. Hiring from the center saves the firm the time taken for training the student according to the requirement of that firm.
- *Self-sustenance of the centers* –The main aim of the program has been to establish long-term associations between the stakeholders for generating fruitful research and technology breakthroughs. A few of the centers have been sustaining since the past thirty years, with NSF funding for the initial ten years only. A few like Edison Welding Institute, have also gained international eminence. Since the inception of the program approx. 70 I/UCRCs have graduated from the program and are not funded by the NSF any more.

From 2007 onwards, a communication entitled '*Compendium of Industry-Nominated Technology Breakthroughs of I/UCRCs*' is published annually. The latest edition available (2016; http://faculty.washington.edu/scottcs/NSF/2016/NSF-book-2016-Final.pdf) documents the research work undertaken by the centers for the time period September, 2013 to end of 2015.

This edition lists 50 technological findings encompassing the work of approx. 180 universities and 775 partners from the private sector working under the ambit of nearly 77 centers. A few examples derived from the compendium are:

- Berkeley Sensors and Actuators Center (BSAC) and Smart Dust: Research on “Smart Dust”, autonomous network of highly miniaturized “motes” containing microradios and microsensors, was begun at BSAC over ten years ago. This led to a $1.7 million DARPA “Smart Dust” program and eventually led to a groundswell of industrial and new venture capital investments in wireless sensor networks (WSN). Market forecasts of more than $10B/year, now seem like low estimates as the technology promises to revolutionize homeland security, environmental control, power management, and infrastructure monitoring. BSAC research has also contributed to the creation of long list of start up companies.

- Center for Process Analytical Chemistry (CPAC) and New Sampling and Sensor Initiative (NeSSI). Researchers at CPAC pioneered research on the development of devices allowing continuous analysis of chemical samples extracted from process equipment. The commercialized outcome of this work was NeSSI. It has been used for years by the petrochemical, chemical, and oil refining industries to more accurately monitor and control their production facilities. Firms have estimated tens of millions of dollars in cost savings per year.

2.2 National Network for Manufacturing Innovation (NNMI)

Background

The NNMI was initiated in 2011, when the President’s Council of Advisors on Science and Technology (PCAST) documented the necessity for increasing the footmarks of applied R&D in the sector of advanced manufacturing. The NNMI program, also called as ‘Manufacturing USA’, entails a grid of research institutions in the country. The main focus area of this network is to develop and commercialize manufacturing technologies through means of PPP between the Federal Government, U.S. industry and universities. This program has been modeled on the lines of Germany's Fraunhofer Institutes and consists of 14 institutes (https://www.manufacturingusa.com).

Objectives

Each institute is a PPP model with aim of promoting strong and long standing R&D in the field of manufacturing. The program provides for (a) enhanced and high end infrastructure that is required for the academia and the industry to work together for resolving problems that are pertinent to the industry, and hold relevance in the manufacturing sector, (b) transfer of technologies from the universities to the businesses, and (c) training of the work force/ development of human capital and education. The major goals of the program are mentioned in figure 5:

Figure 5 NNMI Program Goals

Source: 2015-NNMI-Annual Report

Institutes: The research activities of each centre have two essential components:

1. Those related to an individual "Center for Manufacturing Innovation" or Institute
2. Those that are synchronized across the Network or "Network for Manufacturing Innovation"

The core components of the manufacturing innovation ecosystem of each institute are mentioned in figure 6. The institutes undertake the activities, which culminate into long-standing and sustainable innovations in the manufacturing domain. These institutes, which are placed in different states of the country, along with federal support also receive substantial amounts of backing from the state agencies and therefore are a part of the regional innovation strategies. A significant area of concentration of the NNMI Program is to connect manufacturing with innovation. To accomplish the said goal, the emphases of the institutes include:

- Undertaking ambitious applied R&D, and manufacturing scale-up assignments for reducing the costs, risks and time involved in the process of taking new manufacturing technologies and modifications in the existing technologies and services to the market.
- Devising and implementing novel programs of training and education.
- Advancement and creation of pioneering protocols/practices for integrating within the supply chain supply and adding newer technologies into the existing chain.
- Undertaking outreach programs for engaging with the SMEs and large corporates.

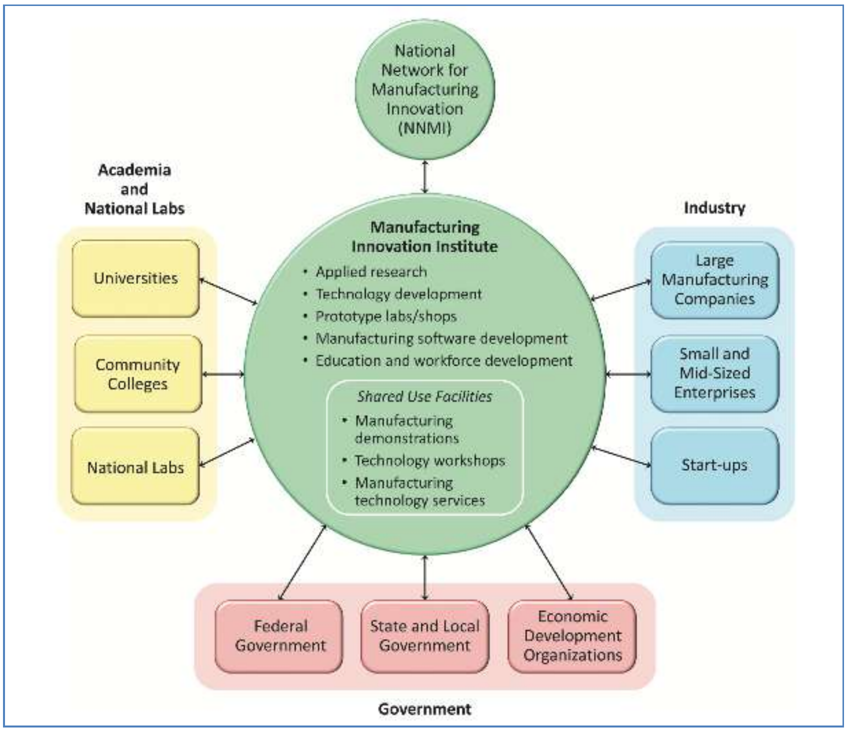

Figure 6 Elements of the Manufacturing Ecosystem

Source: 2015-NNMI-Annual Report

The core group constitutes of the institute's that aid in the transition of the ideas from the stage of laboratory-prototype up to the stage of manufacturing scale-up i.e., from manufacturing readiness levels (MRLs) 4 to 7.[1]

The institutes are established and function with the pre-requisite that resources from the non-federal sources must either equate or exceed the resources gained through federal sources, during a period of 5-7 years from the year of institute establishment. It is expected for the institutes to convert into self-sustaining models after the early period of federal support. The currently active fourteen institutions are:

1. America Makes (https://www.americamakes.us/), Youngstown, Ohio
2. Advanced Functional Fabrics of America (AFFOA) (http://go.affoa.org/), Cambridge, Massachusetts
3. American Institute for Manufacturing Integrated Photonics (AIM Photonics) (http://www.aimphotonics.com/), Albany, New York
4. Advanced Robotics Manufacturing (ARM) (www.arminstitute.org/), Pittsburgh, Pennsylvania
5. Advanced Regenerative Manufacturing Institute (ARMI) (https://www.armiusa.org/), Manchester, New Hampshire
6. Clean Energy Smart Manufacturing Innovation Institute (CESMII) (https://www.cesmii.org), Los Angeles, California
7. The Digital Manufacturing and Design Innovation Institute (DMDII) (http://www.uilabs.org/innovation-platforms/manufacturing/), Chicago, Illinois
8. Institute for Advanced Composites Manufacturing Innovation (IACMI) (https://iacmi.org/), Knoxville, Tennessee
9. Lightweight Innovations For Tomorrow (LIFT) (https://lift.technology/), Detroit, Michigan
10. NextFlex (https://www.nextflex.us/), San Jose, California
11. National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) (http://www.niimbl.us/), Newark, New jersey
12. Power America (https://www.poweramericainstitute.org/), Raleigh, North Carolina
13. Rapid Advancement in Process Intensification Deployment Institute (RAPID) (https://www.aiche.org/rapid), New York, NY
14. Reducing EMbodied-energy And Decreasing Emissions (REMADE)

[1]Manufacturing Readiness Level (MRL) – An assessment method devised by the Department of Defense (DOD), USA for gauging the level and maturity of manufacturing fitness. The measure is similar to the technology readiness levels (TRL) gauge. MRLs are utilized for general evaluation and reckoning for industries and rather specifically for determining the capabilities of plausible suppliers.

(https://remadeinstitute.org/), Rochester, New York

In effect to realize the strategy of revitalizing the American Manufacturing, the Revitalize American Manufacturing and Innovation Act of 2013 (RAMI Act) has authorized the Department of Commerce to set-up and arrange a nationwide grid comprising of all the individual institutes. The network so formed, enables the individual institutions to share their expertise and practices, and address the gaps in the manufacturing domain of the nation.

Governance

The network of institutes is convened by the Advanced Manufacturing National Program Office (AMNPO), as passed in the RAMI Act. This office is staffed with representatives from different Federal Agencies, which have missions related to manufacturing, along with fellows from manufacturing industries and universities.

Presently all the institutes are lead by the Department of Defense (DoD) and Department of Energy (DOE) on behalf of the US Government. These sponsoring agencies, in addition to providing funds, also incorporates lessons learned by previous institute cycles, identifies a lead service for each institute, assembles technical teams, and provides the acquisition strategy to support cooperative agreement.

Each of the Institute also establishes its own governance structure with distinct responsibilities and roles of different participants. A Board of Directors, consisting of representatives from industry and academia looks after the modalities of the Institute. An Institute can also establish a Technical Advisory Committee (TAC) and the Education and Workforce Development Committee (EDWC), as initiated by AFFOA. The members of the Board and other members of the Institute serve in a fiduciary capacity and do not represent the interest of their home organizations.

Funding

The institutes under the Manufacturing USA initiative are funded by the U.S. Government through a private-public partnership model. The fu8nds are granted through a method of cooperative agreement. The federal funding level is typically $70-110M, matched or exceeded by funding from private industry and other non-federal sources, with a minimum 1:1 cost share.

Example of an Institute:

America Makes, the National Additive Manufacturing Innovation Institute (https://www.americamakes.us/)

Mission: To accelerate the adoption of additive manufacturing technologies to increase domestic manufacturing competitiveness.

Locations: Main hub, Youngstown, Ohio; Satellite: El Paso, Texas

Established: October 2012

Consortium Organizer: National Center for Defense Manufacturing and Machining (NCDMM), headquartered in Blairsville, PA

Funding: Federal, $56M, including support from DoD, DOE, NSF, and NASA;; Non- federal, $58M (planned funding over five years)

Members: 177 Membership, as of September 2016, consisted of -

- 46 large business, 62 small businesses
- 40 academic organizations (universities, community colleges, and research institutions)
- 14 government organizations that have signed the America Makes Membership Agreement
- 11 non-profit organizations that include four professional societies and a business incubator
- 4 Manufacturing Extension Partnership (MEP) centers

America Makes is one of the first institutes under this initiative and within three years of its existence it had devised a 'process flow', which has made it a sustainable model (figure 7). This mechanism of process flow has been devised to produce adequate benefits to the member organizations (industry, academia, government, and others) for incentivizing their association with and investment in America Makes.

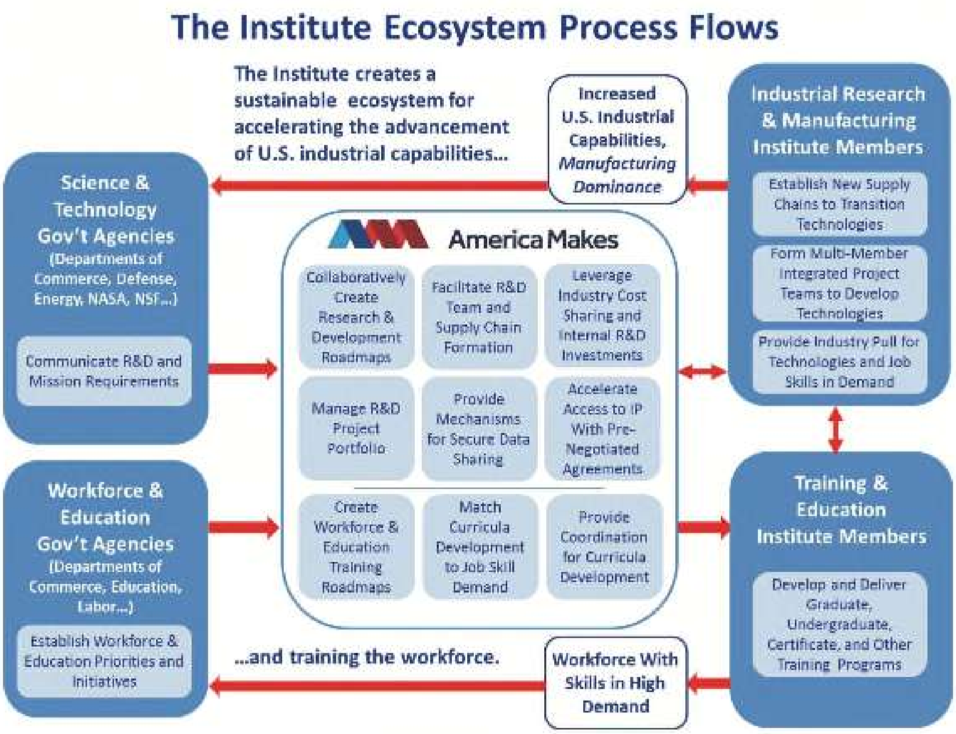

Figure 7 Process Flow of America Makes

Source: 2015-NNMI-Annual Report

Impact

Industry and academia are responding to the Manufacturing USA public-private partnership model. In FY 2016, the eight operating Manufacturing USA institutes had 830 members. These included 548 manufacturing firms (66 percent); 177 educational institutions (21 percent), including universities, community colleges, and other academic institutions; and 105 other entities (13 percent), including Federal, state, and local government, Federal laboratories, and not-for-profit organizations. Of the manufacturers, 361 (66 percent) were small businesses with 500 or fewer employees and 187 (34 percent) were large manufacturers (https://www.manufacturingusa.com/sites/prod/files/Manufacturing%20USA-Annual%20Report-FY%202016-web.pdf).

In FY 2016, matching funds provided approximately two-thirds of the funding for institute expenditures, significantly exceeding program design specifications. The remainder of the institutes' funding came from the lead funding agencies. With total institute expenditures in the fiscal year of $333,808,455, Federal program funds totaled $114,893,428 (34 percent) and non-program matching expenditures totaled $218,915,027 (66 percent).

Success Stories

- A project team at America Makes, in partnership with small business and part manufacturer Oxford Performance Materials, demonstrated a high performance polymer as a viable material choice for air and space vehicle applications. This project developed and distributed the first widely-available materials design database for any polymeric additive material, sharing critical design guidelines with the industry and demonstrating the ability to reuse feedstock materials, thereby greatly reducing the overall manufacturing cost.

- Through a Google.org Impact Challenge grant, America Makes, in collaboration with the Veterans Administration and 3D Veterans, brought hands-on, project-based technology training to U.S. veterans at an Additive Manufacturing Bootcamp held in San Antonio, TX.

- Green Dynamics, a California-based technology startup, led a project that originated with the Department of Defense's Adaptive Vehicle Make program. The project team developed design software that will help small wind turbine blade manufacturers by reducing the wide-ranging expertise needed to analyze a complex turbine or blade system. The software has applications beyond the wind power sector—it can be used for other products with crosssectional geometry, like a propeller, bicycle frame, or car chassis, for example, and may help introduce advanced materials such as carbon fiber into new markets. Green Dynamics is actively working to take the product to market.

- With support from PowerAmerica, Virginia Tech researchers developed a high-density AC adapter for laptop computers that will reduce the size of wall adapters by more than 50 percent, making this technology more transportable. The adapter increases efficiency so less energy is consumed during the charging process. PowerAmerica is now helping the researchers find U.S. industry partners to scale up development for manufacturing in the United States.

2.3 Grant Opportunities for Academic Liaison with Industry (GOALI)

Background

Grant Opportunities for Academic Liaison with Industry (GOALI) is a program, lead by the NSF, which calls proposals entailing collaboration amongst the industry and academic/research institutes. This program aims at promoting U-I partnerships by providing funding/fellowship support to a varied mix of U-I linkages. However this program is different from other programs in that that it is not an individual program and can be applied to in addition to a standing NSF proposal. The academicians/researchers can submit proposal for funding either jointly with a regular grant proposal or as a supplement to an existing NSF-funded award. This program was initiated in 1995.

The solicitation and description of the program lays special emphasis and focuses on making the opportunity affordable for:

- Interdisciplinary university-industry teams to conduct collaborative research projects, in which the industry provides critical research expertise, without which the likelihood for success of the project would be diminished
- Faculty, postdoctoral fellows, and students to conduct research and gain experience in an industrial setting
- Industrial scientists and engineers to bring industry's perspective and integrative skills to academia.

Objectives

This program aims at high-risk/high-gain research activities that concentrate at fundamental research, finding newer solutions to the generic issues, discovering novel approaches, evolvement of U-I joint educational programs, direct transmission of knowledge and resource amongst the academia and the industry. This bonus program of the NSF basically seeks to provide endowment for transformative studies and research that either lie outside the scope of industrial funding or would not be funded by a private business stand-alone, due to certain other reasons.

A long term objective model of the GOALI program has been depicted in figure 8.

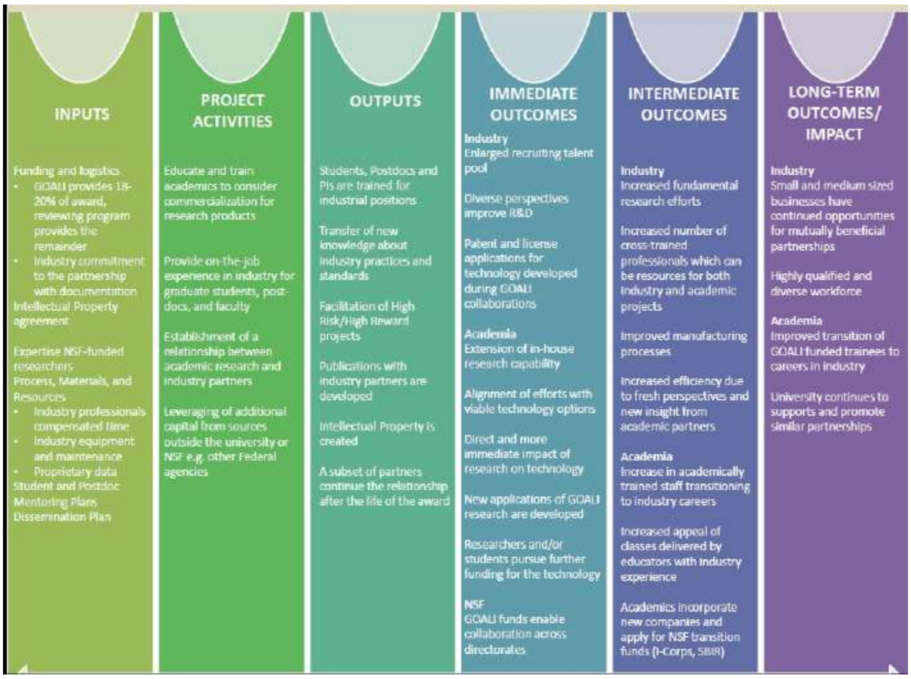

Figure 8 Long-term Objective Model of GOALI

Source: www.reginfo.gov/public/do/DownloadDocument?objectID=53356701

Funding

The GOALI program provides funds and support for developing creative models of collaboration and partnerships between the industry and the academia. The program account has described a few exemplary modes of collaboration, such as -

- Visit to an industrial facility by a faculty (3 to 12 months) for fostering long-term I-A collaboration
- Visit to an industrial facility by a faculty (2 to 6 months), at the initiation of a 3-yr academia-based project with the target of translating the research results to the industry at the end of the project
- Academic support for cooperation of scientists and industry personnel on a research project of interest to both the partners
- Provision for supporting cross disciplinary research or study programs by fostering interaction of 2 or 3 professors from different sectors/departments with one or more than

one industry personnel in a virtual yet effective U-I group

- Visit to an academic institution/university by industrial representatives (engineers, scientists, managers, technology operators) for developing effective collaboration programs of research, education etc. This mode also enhances development of strong industry relevant curricula.

Program Mechanisms

The 'program solicitation' circulates guidelines and information describing the features of the GOALI program and the different mechanisms by which U-I partnerships/associations can be formed. It is mandatory for the proposer to contact the suitable NSF Program Director (of their research domain) prior to submitting a proposal. The program mechanisms are as follows:

1. Program 1: Industry - University Collaborative Projects
   Opportunities are devised for encouraging either individuals or small groups to partner and form U-I collaborations. The projects (education or research) are jointly designed by the industrial and university scientists keeping in mind their interests and needs. The investigators from the academia along with their research students are motivated and pushed to undertake some research activities at the site of the partnering industry. This method offers a unique prospect for companies, including small industries, to add to the influence of their research strengths by collaborating with the efforts of the university. Multidisciplinary studies/projects comprising of more than one faculty member, each from different department, interacting with the industry personal (one or more) in real or virtual U-I groups are encouraged. This method helps in training the students and developing their overall skills as they are subjected to exposure to the working of the private sector. They also gain mentorship from the industrial colleagues thereby enhancing their employment opportunities in the industries. The funds provided by NSF are meant for educational/research activities being undertaken by the university only.

2. Program 2: Faculty and Students in Industry
   This program brings forth opportunities for researchers from the academia to gain experience and insight of the industrial set-up. The proposal must describe the plan of collaboration between the university and industry along with research plan. There are varied opportunities for realizing the partnership through the faculty and students in the industry and a few of them have been described below -

- *Faculty in Industry* – Provides a platform for the faculty from the domains of science, engineering, and mathematics to undertake investigative studies at the industry for a time period of three to twelve months. The awards range from $30,000 to $75,000. Of the total requested grant, up to 20 percent can be used by the faculty and his/her students for research expenses and travel.
- *Postdoctoral Industrial Fellowship* – Provides a platform for the fellows from the domains of science, engineering, and mathematics to undertake full time research studies, under the guidance of an academic and an industrial supervisor at the industry. NSF provides an award of the amount of $75,000 per year for a time period of 1-2 years.

- *Graduate Student Industrial Fellowship* - Provides a platform for the students from the domains of science, engineering, and mathematics to undertake part-time or full- time research studies, under the guidance of an academic and an industrial supervisor at the industry. An award of up to $30,000 for one year is provided which includes the stipend of the student, 10% grant for the academic faculty mentor plus the travelling expenses of the graduate student.
- *Undergraduate Student Industrial Fellowship* – Platform for undergraduate students for undertaking summer research internships, or 1-2 semester part-time/full-time work in an industrial set-up, under the supervision of a mentor both from the academia and the industry.

3. Program 3: Industry Engineers and Scientists in Academia

   This mode of the program makes opportunities for an industry person to partner with the academic community. The industry representative may act as a co-supervisor for a student from the university or as a co-principal investigator in a project, the proposal of which is submitted by the host academic institution on behalf of the partnering investigators. Throughout the duration of the project, it is essential for the industrial representative visiting the university to hold his/her original position in the industry.

Two schemes for the above stated mode of partnership are:

- *Industry Presence on Campus* – Visit by industry personnel to the university campus for a time period of 2-12 months. This visit may be for undertaking collaborative research study, guiding innovative technology or partaking a teaching module/modify the curricula or all. The annual award budget is of the amount $75,000 for one year, which incorporates the par-time salary of the industry personnel, expenses of the teachers and student visit to the industrial site, costs of teaching enhancement etc.

- *Industry-Based Graduate Assistantship* – This mode allows for a permanent employee of an industry to enter the academic campus as a part-time student for continuing/completing his/her graduate studies, essentially leading to a Ph.D. award. The proposal statement should consist of the details of the industrial contribution, which also determines the amount of award. However typically an award of upto $30,000 per year for a time period of one year is provided.

2.4 Small Business Innovation Research (SBIR) Program

Background

The SBIR (https://www.sbir.gov/about/about-sbir) program is one of the most successful examples of U.S public-private partnerships. Initiated in the year 1982 under the aegis of the 'Small Business Innovation Development Act' the SBIR program was intended at invigorating technical/technological revolutionary innovation amongst the private sector essentially the small businesses. This also aimed at bolstering the U.S. economy by motivating the small enterprises and industries to innovate and market their research. The SBIR, through means of competitive award based funding program, enables small enterprises to engage in Federal R&D funding, explore their potential for technological inventiveness and finally incentivizes them to commercialize the research and earn profits. This program largely enhances the 'entrepreneurial spirit' of the country by involving the small enterprises in the field of national R&D.

Governance

The nationwide program is lead by the Small Business Administration (SBA)'s Office of Investment and Innovation (OII) and is currently administered by 11 Federal Agencies, which are - Department of Agriculture (USDA), Department of Commerce (DoC), Department of Defense (DoD), Department of Education (ED), Department of Energy (DOE), Department of Health and Human Services (HHS), Department of Homeland Security (DHS), Department of Transportation (DOT), Environmental Protection agency (EPA), National Aeronautics and Space

Administration (NASA) and National Science Foundation (NSF). The SBA issues a 'Policy Directive', which provides guidance to the federal agencies for general functioning and operation of the program. The SBA is also given the responsibility of evaluating the progress and evolvement of the SBIR program.liging as The participating agencies include federal agencies having an extramural R&D budget of $100 million or more. These agencies are mandatorily required to allocate 3.2% (FY 2017) of the said budget towards SBIR. However, the program guidelines are established individually by each of the agency and they also designate the areas and topics of R&D in their solicitations.

Objectives

The prime task of this program is to back technological excellence and innovation by means of investments from the federal government in domains and areas critical to the American economy. The goals of the program are four fold–

- Meet Federal research and development needs
- Stimulate technological innovation
- Increase private-sector commercialization of innovations derived from Federal research and development funding
- Foster and encourage participation in innovation and entrepreneurship by women and socially or economically disadvantaged persons

Funding

The SBIR Program is structured under three stages/phases –

Phase I – Proof of Concept. To establish a strong technical worth, evaluate its feasibility and commercialization potential, the Federal Government provides an award funding to small businesses to conduct R&D activities. The time duration of this fund is 6-12 months. Through this phase the Federal Agencies, both assess the merits of the research work and the performance of the small enterprises for building a base for Phase II funding.

Phase II – Research and Development. On the basis of sufficient merits, scientific excellence and feasibility of the research being undertaken, the federal agencies decide for or against the funding of phase II. The duration of this funding is for a time period of two years.

Phase II – Commercialization. The aim of this final stage is for the small enterprises to pursue commercialization of their R&D outcomes, resulting from Phase I and II R&D activities. However, Phase III is not funded through the SBIR program. Nevertheless, certain federal agencies may support 'non-SBIR funded R&D or production contracts' for services, processes, products etc. anticipated for use by the Federal Government.

2.5 Small Business Technology Transfer (STTR) Program

Background

The STTR program (https://www.sbir.gov/about/about-sttr#sttr-program) was initiated in 1992 as a result of the Small Business Research and Development Enhancement Act of 1992. The main aim of the program is to bridge the gap between fundamental sciences and commercialization of its results. The constitutional purpose of the STTR Program is to encourage partnerships amongst innovative 'small business concerns (SBCs) and research institutions' through federally-funded R&D. This program aids small businesses and research through means of funding support for commercialization of innovative technologies. A distinctive feature of the STTR program is the mandatory collaboration of a small business with a research institution (Phase I and II).

Objectives

The program goals as stated by the SBA are to -

- Stimulate technological innovation.
- Foster technology transfer through cooperative R&D between small businesses and research institutions.
- Increase private sector commercialization of innovations derived from federal R&D.

Governance

The SBA being the main governing body of the program is directed to issue an 'STTR Program Policy Directive', which lays down the foundation of guidelines for the federal agencies partaking in the STTR program. This obligation has been laid down by the Small Business Act and ensures that the policy directives thus issued sets forth a guide to conduct and manage the program.

The federal agencies, which have an extramural research budget of $1 billion or more are necessitated to allocate 0.3% of the above stated research budget to STTR program. Presently, this program is being implemented by five federal agencies [Department of Defense (DoD), Department of Energy (DoE), National Aeronautics and Space Agency (NASA), National Institute of Health (NIH) and National Science Foundation], which design the R&D topics and solicit for application in the designated domains. Proposals are accepted from small businesses only.

Funding

The STTR Program, like SBIR is also organized into three phases –

Phase I –The aim of Phase I is to ascertain merit, viability and market potential of the R&D activities and to evaluate the performance of small businesses. This assessment makes base for Phase II funding of the program. The time duration of Phase I funding is 12 months.

Phase II – Research and Development. On the basis of sufficient merits, scientific excellence and feasibility of the research being undertaken, the federal agencies decide for or against the funding of phase II. The duration of this funding is for a time period of two years.

Phase II – Commercialization. The aim of this final stage is for the small enterprises to pursue commercialization of their R&D outcomes resulting from Phase I and II. However, Phase III is not funded through the SBIR program. Nevertheless, certain federal agencies may support 'non-SBIR funded R&D or production contracts' for services, processes, products etc. anticipated for use by the federal Government.

The basic features of the SBIR and STTR programs have been illustrated in the figure 9.

	SBIR	STTR
Phase I duration	6 months	12 months
# participating agencies	11	5
Size Phase I award	Up to $150,000	Up to $150,000
% extramural R&D budget [FY16]	3.00%	0.45%
IP allocation agreements required	No	Yes
RI or FFRDC participation required	No	Yes
PI employment	Small business	Small business or RI
Applicant	Small business	Small business

Figure 9 Basic Features of SBIR and STTR

Source: *(sba_office_of_investment_and_innovation_sbir-sttr_presentation_nagesh_rao)*
FFRDC- Federally Funded Research and Development Centers

RI – Research Institute

Achievements of the SBIR/STTR programs:

- According to a testimony document of the Small Business Technology Council (SBTC) (Glover, 2016), seventeen other countries worldwide have adapted the flagship SBIR/STTR program of the United States. The SBIR/STTR program is not a permanent program and needs reauthorization periodically by the United States Congress, which is usually integrated with each new budget. The success of the program can also be gauged through the fact that it has been reauthorized continuously since its inception (i.e. 34 years for SBIR and 25 years for STTR).
- In the years (2012-16), despite accounting for only 2.5-3.0 % of the total extramural research budget of federal agencies, the SBIR/STTR program has led to generation of 22% of the key innovations.

- The SBIR program till date has resulted in 70,000 issued patents, nearly 700 public companies, and approximately $41 billion in venture capital investments.

1. Genzyme Corporation – An American biotechnology oriented entity, which concentrates its work towards the treatment and management of rare genetic disorders, renal diseases, endocrinology, oncology, organ transplant and biosurgery. In 1990 when Genzyme was a comparatively smaller business, it secured the SBIR phase II grant (Figure 10). The company then went on to acquire other laboratories and technologies from another small enterprise, called Impath, which had also secured SBIR funding.

By the year 2010, Genzyme acquired the position of third largest biotech company in the world with its reach globally. It was then acquired by the French drug maker Sanofi-Aventis. From that time onwards, Genzyme has been operating as a subsidiary of Sanofi and has made a mark in nearly 40 countries.

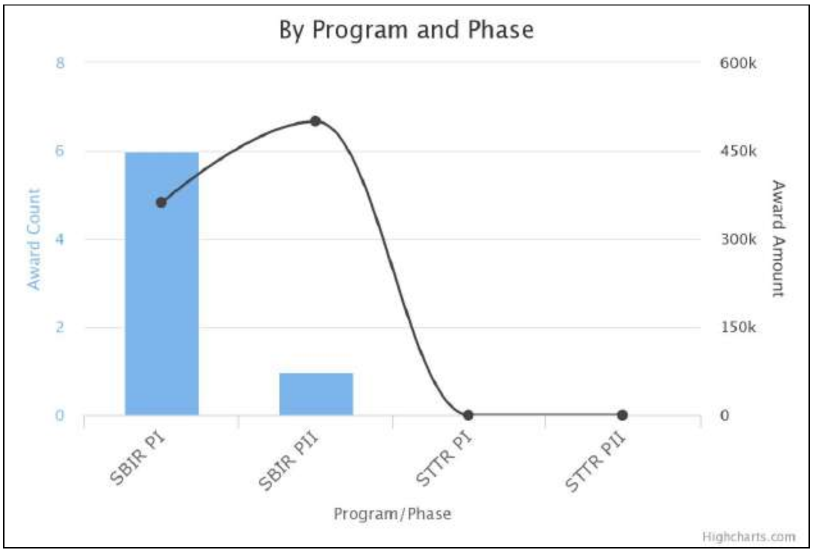

Figure 10 SBIR Funding secured by Genzyme Corporation

Source: https://www.sbir.gov/sbirsearch/detail/174646

2. Cytex Therapeutics, Inc. – This Company works in the domain of designing implants generated from 3-D woven textiles that have been conceived for devising cartilage. This cartilage can be used in the treatment degeneration of cartilage (in knee and hip). The Company first secured funding in the year 2007. The project representing Phase I STTR was devised at Massachusetts Institute of Technology, USA, aimed at developing an implant that was suitable for total resurfacing of the section of the joint affected by retrogressive diseases like osteoarthritis. The various grants secured by the company at different times starting from 2007 up till 2017 has been illustrated in figure 11 and 12.

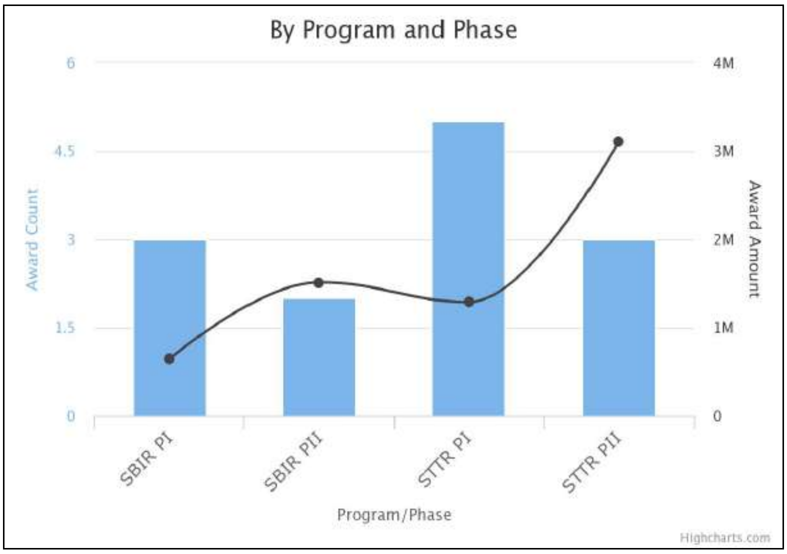

Figure 11 Funding secured through SBIR and STTR

Source: https://www.sbir.gov/sbirsearch/detail/401444

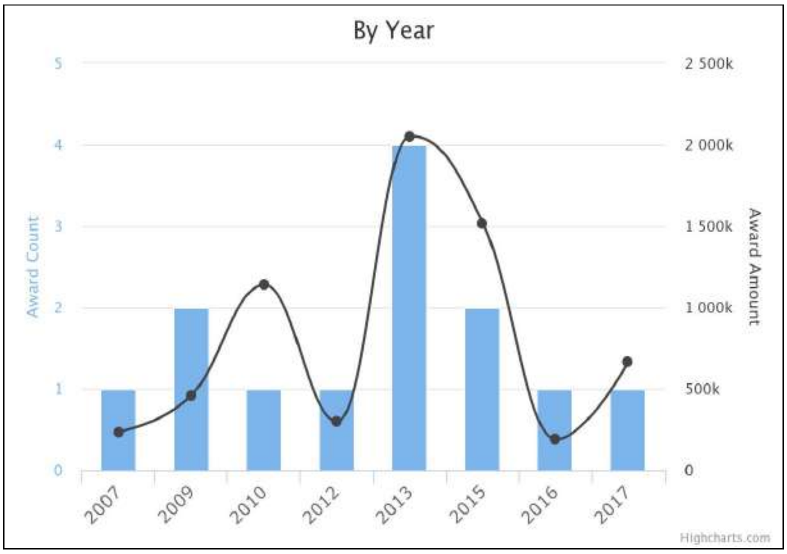

Figure 12 Funding secured at different times from 2007-17

Source: https://www.sbir.gov/sbirsearch/detail/401444

Other success stories of the SBIR/STTR program are listed below (figure 13):

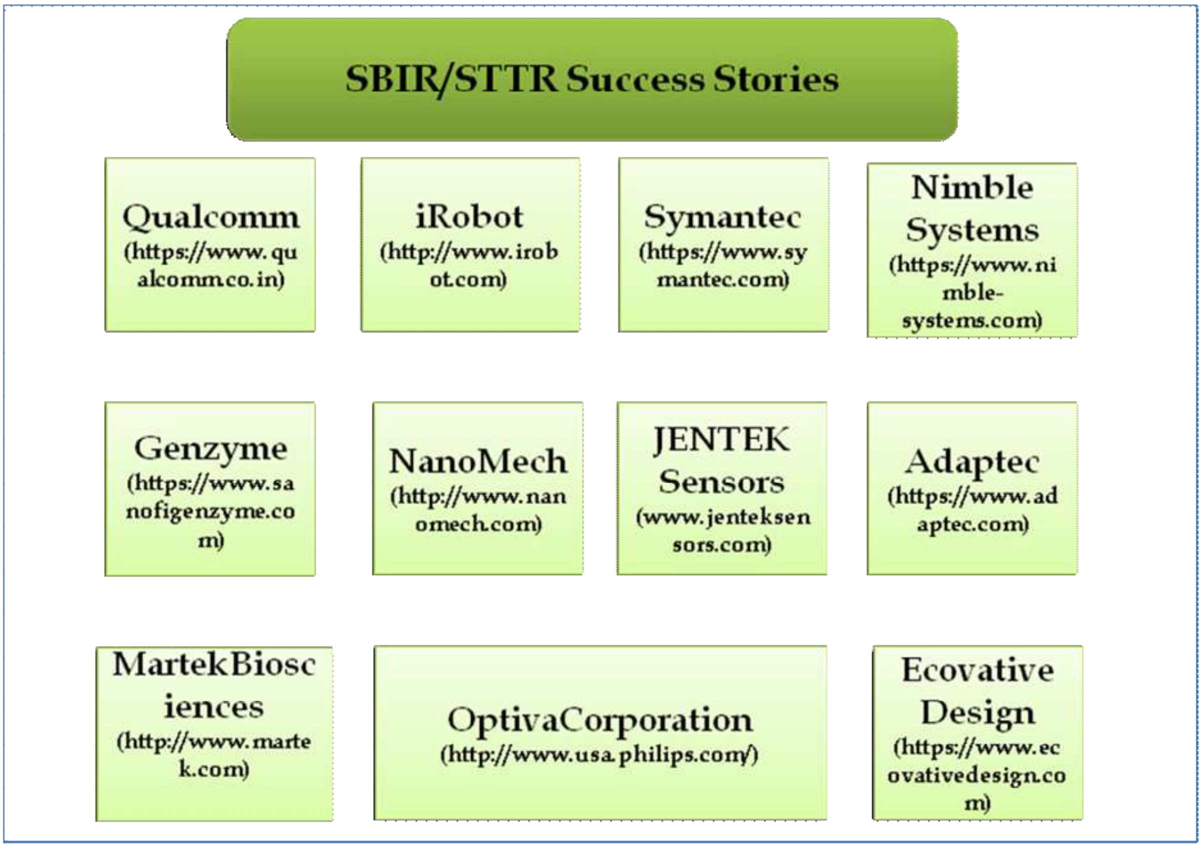

Figure 13 A few of the successful ventures emerging from the SBIR/STTR program

2.6 Engineering Research Center (ERC) Program

Background

Yet another initiative of NSF is the establishment of a conspicuous program called *Engineering Research Center (ERC) Program*, in 1984. The ERCs are interdisciplinary hubs, set up in the universities of USA in close association with the private sector. These university-led institutions have been developed through the support and backing of NSF Directorate of Engineering. Each ERC works on a specific engineering need of the country. The ERC program is very competitive and therefore only a few of the ERCs are awarded the grant out of a large number of proposals.

Objectives

Each ERC has been established with a goal to realize innovations and develop technologies that posses the potential for transforming the existing products/processes/services or brace the emergence of novel industries. Another aim of this program is to generate graduates in the domain of engineering who possess the qualities of innovative intellect, diversified outlook and effective technology leadership.

Each of the established ERC (figure 14) works towards the achievement of the following three missions –

- **Cross-disciplinary and Structured Research**— The centers bring forth collectively the diverse disciplines of engineering and science for working towards issues crucial to the engineering industry and shall bolster the competitiveness of the US industry globally. The research conducted at the centers, lies at junction of two cultures i.e. the analysis-driven and innovation-driven.
- **Education** —Each center has established a system and practices an approach wherein the graduates work in multi-disciplinary domains in association with the industry partners. The education is unified and combined with industry-driven research and industrial practices of building competence. The graduates emerging out of the ERCs posses not only fine knowledge of their domain but also posse's excellent leadership plus management skills.
- **Private Sector Partnership and Technology Transfer**— These centers are an excellent platform for collaborations between the universities and the industries. The industry is implicated in action with the ERCs at every step of the process of such as planning, collaborative research, student mentoring, and engagement in establishing proof-of-concept models.

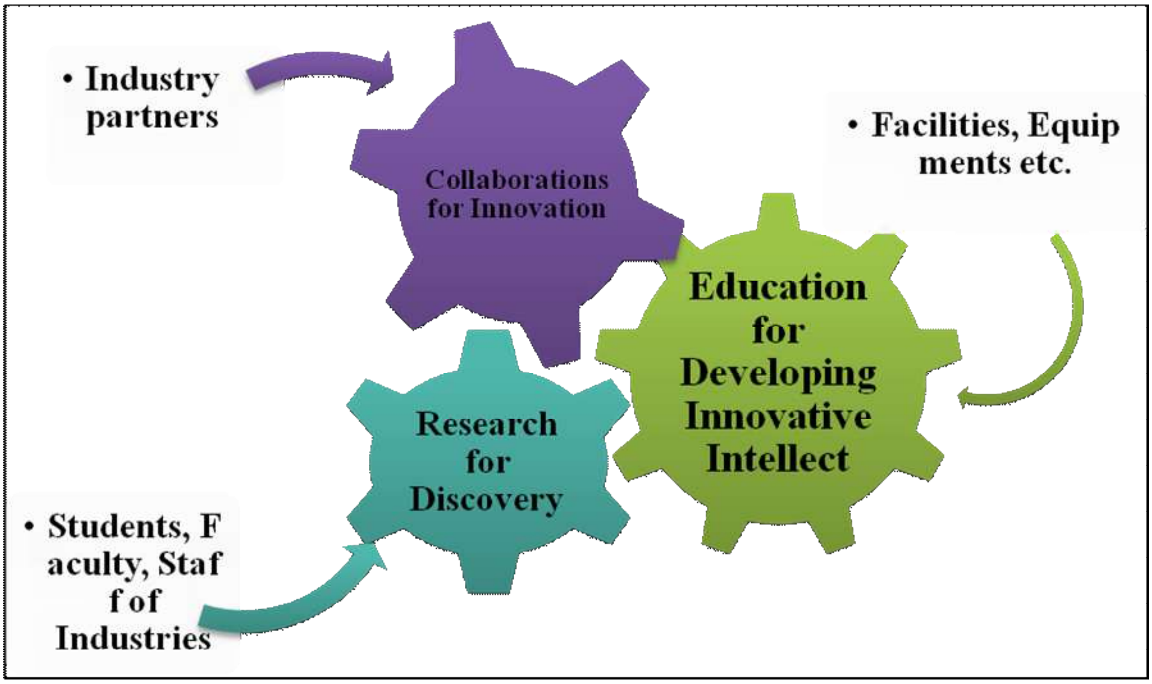

Figure 14 A complex and interdependent ERC structure

Every established center involves a tripartite partnership of the academia, NSF (state/local or other federal agency may participate) and the industry (ERC Overview Fact Sheet_2016.pdf). The NSF, according to the program provides support to each ERC for a time period of 10 years. Since the inception of the program, close to 65 ERCs have been established all across the United States. The number of ERCs presently in operation is 17 **(**ERC Overview Fact Sheet_2016.pdf) enlisted in table 2. Approx. 31 centers have gained self-sustainability as of the FY 2015 from the 38 centers that had graduated starting from 1985 up till 2014 (NSF 2013b). The annual funding for each ERC, by NSF, in FY 2016, ranged from an amount of $2.68 million (for centers in the period prior to their graduation) to $3.5 to $4.8 million per year for continuing centers. The table below enlists ERCs along with their year of establishment. [2]ERCs set up before 2008 are termed as second-generation ERCs and programs founded in or after 2008 are third-generation ERCs.

[2]The first generation of NSF ERCs began between 1985 and 1990 and encouraged academic institutions to focus education on manufacturing and commercial design. This first generation comprised 18 centers.

Table 2 ERCs in operation as of FY2017

Center	Lead Institution	Year Founded
i. BIOTECHNOLOGY AND HEALTH CARE		
Center	**Lead Institution**	**Year Founded**
ERC for Revolutionizing Metallic Biomaterials	North Carolina A&T State University	2008
Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies	North Carolina State University	2012
NSF Engineering Research Center for Sensorimotor Neural Engineering	University of Washington	2011
ii. ADVANCED MANUFACTURING CENTERS		
Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT)	University of Texas at Austin	2012
ERC for Biorenewable Chemicals	Iowa State University	2008
ERC in Compact and Efficient Fluid Power	University of Minnesota, Minneapolis	2006
Center for Structured Organic Particulate Systems	Rutgers University, New Brunswick, NJ	2006
iii. ENERGY, SUSTAINABILITY, AND INFRASTRUCTURE		
Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center	North Carolina State University	2008
Lighting Enabled Systems & Applications ERC	Rensselaer Polytechnic Institute	2008
ERC for Quantum Energy and Sustainable Solar Technologies (QESST)	Arizona State University	2011

ERC for Re-Inventing America's Urban Water Infrastructure (ReNUWIt)	Stanford University	2011
ERC for Ultra-wide Area Resilient Electric Energy Transmission Networks (CURENT)	University of Tennessee–Knoxville	2011
ERC for Bio-mediated and Bio-inspired Geotechnics	Arizona State University	2015
Nanosystems ERC for Nanotechnology Enabled Water Treatment Systems	Rice University	2015
iv. MICROELECTRONICS, SENSING, AND IT		
ERC for Power Optimization for Electro-Thermal Systems (POETS)	University of Illinois at Urbana-Champaign / University of Arkansas / Stanford University / Howard University	2015
ERC for Collaborative Adaptive Sensing of the Atmosphere (CASA)	University of Massachusetts Amherst	2003
ERC for Extreme Ultraviolet Science and Technology (EUV ERC)	Colorado State University / University of Colorado at Boulder / University of California at Berkeley / Lawrence Berkeley National Laboratory	2003
ERC on Mid-Infrared Technologies for Health and the Environment (MIRTHE)	Princeton University	2006
Center for Integrated Access Networks (CIAN)	University of Arizona	2008
Nanosystems ERC for Translational Applications of NanoscaleMultiferroic Systems	University of California, Los Angeles	2012

Proposal Requirements

The stipulations for attaining an ERC are rather more demanding than that of I/UCRCs. A few compulsory stipulations are: a) a proposal for an ERC must comprise of multi-institutions, with one lead institute and a maximum of four domestics partner institutions, b) minimum three faculty members should be part of the ERC proposals along with three students, c) the lead university should be the one that caters to a large number of students. The proposal for the grant of a Center needs to lay out in detail a system, research focus, work plan, dedicated research program, education program, the configuration as envisioned, list of collaborators and affiliated institutes and a pre-college education scheme. In addition, the proposals need to chalk out the details of the innovation environment of the proposed ERC i.e. the advisory boards. Details about the Industrial or Practitioner Advisory Board(I/PAB) are required to be submitted in the proposal, also including the terms of agreement of membership, collaborations with other universities, or other promoters (state/local government) of entrepreneurship, translational research associations, infrastructure present with the university, human resources (directors, managers), technical facilities etc. The outright spread of these requirements and details of activities impedes certain small universities to apply for the grant as lead institutes. However associating with larger and more resourceful universities strengthens the research base of such universities and also helps them in building a reputation.

2.7 Defense Advanced Research Promotion Agency (DARPA)

Background:

The agency, which was established in 1958 as Advanced Research Promotion Agency (ARPA), has been since the last sixty years enduring to bring about innovative breakthroughs by means of critical investments in the domain of national security. The agency, originally created in response to the launch of Sputnik 1 by the Soviet Union (and other missile achievements of the Soviet) was initially called ARPA. It was later renamed to Defense Advanced Research Promotion Agency (DARPA, http://www.darpa.mil/). DARPA devises and implements R&D projects for expanding the bounds of S&T, even beyond the requirements of the U.S. military, by partnering and joining hands with government, academia and industrial partners.

This agency of the United States Department of Defense (DoD) has since its inception worked with players inside and outside the government sector for developing novel, advanced technologies and has also transformed certain revolutionary ideas that seemed impossible into possible competencies. The significant outcomes comprise of not only tactical military proficiencies, like that of 'precision weapons and stealth technology', but also include capabilities of use to the civilian society, such as the miniaturized Global Positioning System (GPS) receivers, voice recognition and language translation, unmanned aerial vehicles etc. DARPA was designed to pursue opportunities that will lead to a transformational change and not only to an incremental advancement in the existing technical scenario.

Mandate:

"DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research bridging the gap between fundamental discoveries and their military use."

Objective:

"To make pivotal investments in breakthrough technologies for national security."

The prime objective of DARPA is to expedite the technology excellence concerning the US military thereby being prepared for any scientific/technical surprise and prevent it from sabotaging the security interests of the nation, by financing and patronizing progressive, high-payoff R&D.

In order to work towards achieving its goal, the agency banks upon a myriad range of performers. These performers apply cross-disciplinary approach, both, to enhance the knowledge generated through basic research activities and for creating novel innovations that shall address the practical issues. The scientific explorations and analysis undertaken by DARPA traverse the entire spectrum of activities from the ones performed at the laboratories to the stage of technology demonstration in the various domains like, material science, computer science, medicine, physics, chemistry, biology, mathematics, neurosciences etc (http://www.darpa.mil/our_work/).

Characteristics of DARPA

The agency is basically a mission oriented organization that focuses on projects rather than on programs and is not bound by the requirements of the military withal acknowledges to the needs of the military. Be that as it may, DARPA being the major innovation agency of the DoD, DARPA aims at implementing projects that have a definite time period yet result in revolutionary impacts and outcomes. In its entirety, the agency does not actually undertake or perform research; however, it conceives, supports and finances projects thereby acting as a facilitator/broker between the actors and users. In coherence with its mission statement, DARPA strives for accomplishing R&D projects of distinct scales and risk levels.

Other characteristics of DARPA and its strategy of work include -

- An investment firm, not a research lab, no established constituency
- Methodically looks for and exploits externally bred ideas
- Adaptability, skill of swiftly exploiting rising situations
- Emphasis on highly focussed investments as well as high technical risk projects
- Coalesces fundamental and applied research, development along with demonstration
- Proactive program management
- Program managers bestowed with both technical as well as fiscal power to drive the efforts
- Varied and flexible performers
- Steady connections with the end user

Governance

DARPA upholds a modest, flat and brisk organization. The organization is headed by a Director, who reports to the Director of Defence Research & Engineering (DDR&E). The DDR&E is answerable to the Under Secretary of Defence for Acquisition, Technology and Logistics, who further reports to the Secretary of Defence.

A deputy director is secondary to the director and there are also directors and program managers for the standing offices. All these individuals including the support staff under the standing offices report to the Director of DARPA.

The research at DARPA is executed under the sub head of six technical offices charged, which are accounted for developing advanced technologies. There are two additional offices, which manage special projects and also look after the move/conversion of the technologies developed through funds of DARPA into DoD capabilities. There are other support offices as well that work for the benefit of the industry.

DARPA being a relatively small and flat organization and containing a single level of management between the director of the agency and the program managers the dynamics of working are rather strong and swift. The flow of ideas is quick and eminently effective. The people associated with DARPA comprise of nearly 220 employees - 120 technical staff and other 100 program managers in the six technical offices. Also the term of the directors and program manager is limited from 3 to 5 years and renewals are rare. The constant flux of new directors and managers entails a flow of novel ideas and thoughts, which is crucial for an agency like DARPA. A schematic outline of the organization of DARPA and domains of the respective programme offices is presented in figure 15.

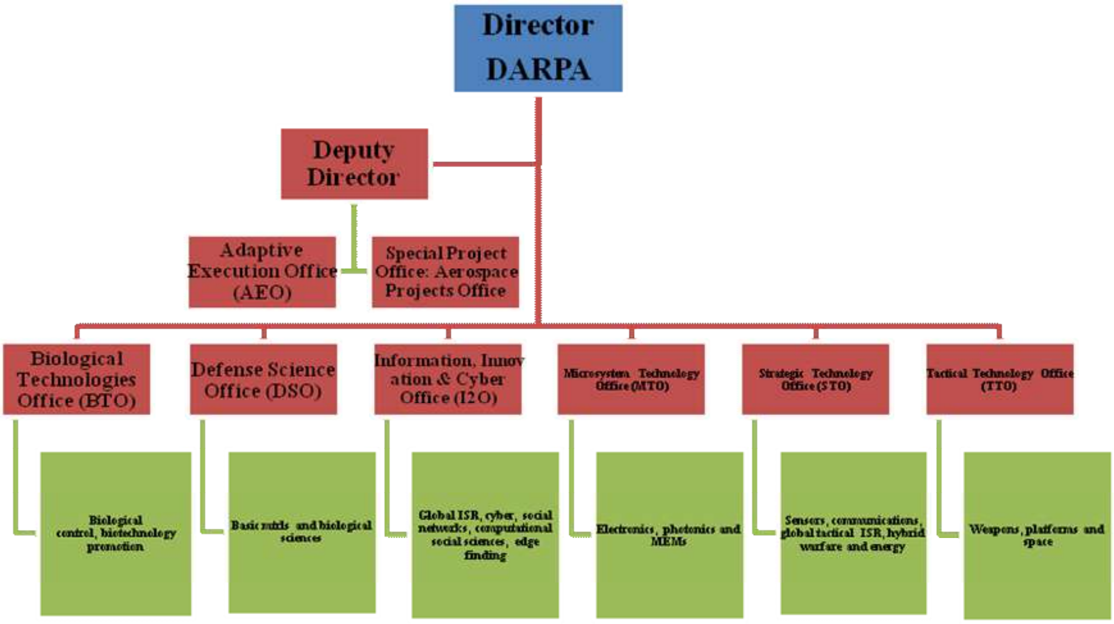

Figure 15 Schematic outline of organization of DARPA

The major prerogatives of the varied program offices are as listed:

1. **Biological Technologies Office (BTO):** The BTO arm of DARPA focuses on advancing and reshaping biotechnology by taking leverage from the advances made in the domains of engineering and information sciences. This program office deals with infectious diseases, synthetic biology, neuro-technology etc. and aims at exploring the ever-increasing intersections between physical sciences and life sciences.

2. **Defense Sciences Office (DSO):** This office aims at identifying and pursuing high-payoff research activities/promising research being undertaken across a wide range of areas in engineering and sciences. These initiatives are transformed into novel, breakthrough technologies. Presently the themes and domains in which DSO works include exploring fundamental studies, heightening scientific discoveries and creating strategically key outcomes. The programs undertaken by the DSO focus on bridging the gap between basic sciences and military applications.

3. **Information Innovation Office (I2O):** This office sponsors research in three main domains (cyber, analytics and symbiosis) for developing advanced technologies which establishes information advantage for the US and its confederates. It also works with an aim of ensuring as well as providing 'technological superiority' for the US by scouting all the data and information that could prove to be a military gain.

4. **Microsystem Technology Office (MTO):** Since 1991,the MTO has been making investments in the area of 'Compact Microelectronic Components' such as microelectromechanical systems (MEMS), computing, microprocessors and photonic devices. These investments have lead to advancements in the domains of radars, high-energy lasers, infrared imaging etc. In order to address the challenges of the future (microsystems area), the MTO is now also working on three overlapping domains i.e. Tactical Information Extraction, Spectrum and Physics Interfaces and Globalization.

5. **Strategic Technology Office:** The STO works for enhancing the military effectiveness, cost advantage and versatility by scouting for technologies that facilitate fighting as a network. The areas in which STO works are: Communications and Networks (C&N), Battlefield Management Command and Control (BMC2), Surveillance and

Reconnaissance (ISR), Intelligence, Foundational Strategic Technologies and Systems and Electronic Warfare; Positioning, Navigation, and Timing (PNT).

6. **Tactical Technology Office (TTO):** The TTO works in the area of Air, Space, Ground and Maritime (surface and undersea) systems. Novel revolutionary platforms in the above mentioned areas are demonstrated through high pay off, high-risk research.

DARPA's Strategy

To complete its mission and all the activities, DARPA concentrates on the following three interdependent yet rewarding objectives:

- Manifestation of breakthrough competencies for the national security
- Catalyzing a structure of highly specialized and accomplished technology base
- Maintenance of DARPA as a robust and dynamic organization.

For fostering relationships based on win-win situation for all the players and stakeholders, DARPA collaborates and networks with a large number of agencies. The research is conducted by means of a wide array of private and public sector performers vide nearly 2000 grants, contracts and certain other agreements. The agency is also responsible for holding national level seminars and technology competitions through which novel ideas and innovative activity is promoted.

Funding

The funding structure of the organization is also ambitious and limited resources give rise to competition for financing the best ideas, internally as well as externally.

Each project undertaken through DARPA investment is managed by an ardent and pro-active program manager. Increased funding is a method of rewarding quality performance in case of DARPA.

Even though the DARPA is an independent organization, it receives a budget, which is distributed with strategic oversight and policy directives. The principal conferees of grants from DARPA are the researchers and research organizations from universities and industries. A small amount of funds are awarded to federally funded laboratories and the other government agencies. Start-ups have also played a lead role in cases where the technology possessed substantial commercial potential or when the ideas of DARPA could impact the long-standing competitiveness of the existing products of the firms. The agency acts as a channel for advancement and novelty by seeding research groups working in capable technology domains, investing continuously in the elemental technology base from the stage of development up until the stage of proof-of-concept.

DARPA has also funded large-scale demonstrations that actually included a large number of small and individual components. In this case the agency had to act as a 'System of Systems' i.e. it had to fund the work that was required to weld and meld the different components/systems together into forming a new capability with enhanced competency.

Success Stories

1. **Unmanned Aerial Vehicles (UAVS)**

   DARPA has invested in UAV development since the 1960s, a time when the concept of using UAVs engendered widespread skepticism within military circles. The timeline of development of present day UAVs is presented below.

Table 4 Timeline of development of UAVs

Year	Initiative	Impact
1962	DARPA pioneered early unmanned vertical take-off and landing (VTOL) technology, partnering with the U.S. Navy to develop the QH-50 Drone Anti-Submarine Helicopter (DASH).	This platform could carry antisubmarine torpedoes and gave destroyers the ability to attack enemy submarines far beyond the range of their anti-submarine rockets.
1970s	DARPA initiated project Teal Rain, focused on improving unmanned aircraft engine performance and design. At the same time, DARPA began work on the first small, low-observable, remotely piloted vehicle (RPV) for the Navy. DARPA funded the development of small, airborne sensor technologies for use in UAVs	The new design demonstrated the ability to carry significant payloads for operationally required durations.
1980s	DARPA support led to the development of	The components were included into other

	the Amber long-endurance UAV	systems and lead to the development of other UAVs
1990s	DARPA sponsored development of the RQ-4 Global Hawk, the world's first and only successful operational high-altitude long-endurance ISR UAV	Used extensively in Iraq, Afghanistan and other operational areas around the world.
1996	DARPA launched its Micro Air Vehicle (MAV) program, which focused on smaller unmanned airborne systems designed to scout local terrain.	Outcome of this effort was the T-Hawk UAV, a VTOL ducted fan with a 13-inch diameter, equipped with video cameras and infrared sensors and used to search for roadside bombs in Iraq and other ISR missions.
2000s	DARPA initiated a demonstration Unmanned Combat Air Vehicle program to advance cooperative mission planning, vehicle autonomy and manned-unmanned teaming concepts of operation	With input from the Navy and Air Force, this program evolved into the Joint Unmanned Combat Air Systems program, which in turn led to production of the Navy's X-47B unmanned combat air vehicle demonstrators for carrier operations, which have completed a number of firsts aboard U.S. aircraft carriers.
2005	DARPA pushed the UAV envelope again under its Nano Air Vehicle program by developing flapping-wing-based hovering systems with a hummingbird-like appearance for indoor and outdoor ISR missions.	Featuring wingspans of just six inches and weighing under an ounce, these systems demonstrated the first-ever controlled hovering and fast forward flight of any air vehicle system carrying its own energy source and using only flapping wings for propulsion and control.

Source: https://www.darpa.mil/attachments/DARPA2015.pdf

IMPACT: As a direct result of DARPA's efforts, UAVs can operate today for longer periods at higher altitudes than ever before—while gathering unprecedented amounts of data and providing high-resolution imagery for worldwide operations. UAVs have also become the focus of enormous entrepreneurial creativity and investment outside the DoD, which has fueled civilian commercial markets. In addition to law enforcement and public safety agencies, companies are developing concepts and plans for UAVs to contribute to power line monitoring, crop assessments, wildfire spotting, mining, logging and the provision of remote communications links—not to mention early adoption by Hollywood and related entertainment industries.

2. Infrared Night Vision Technology

Infrared imaging is the technique in which there is detection on the basis of thermal wavelengths and without the requirement of light. Highly heat-sensitive imagers can detect enemies who are in camouflage during the day or night, and can determine not just the presence of a vehicle but whether it has been operated recently by detecting residual engine heat.

There are various night vision related DARPA programs, which have now been transitioned into US military offices like Army Research Laboratory, Army Space and Missile Defense Command, Air Force Research Laboratories, Air Force Special Operations Command, Naval Research Laboratory, Office of Naval Research and Marine Corps Systems Command.

The applications of the infrared sensors include clip-on thermal sights for surveillance and targeting by snipers, surveillance applications on ships, and technologies to aid helicopters when landing in brownout conditions. With these beneficial applications comes wider geographic availability of this advanced technology, underscoring the reality that even sophisticated products offer only temporary advantages.

DARPA's work has helped U.S. warfighters operate and dominate at night by delivering such products as night driving aids, thermal weapon sights and tank sights for vehicles. Moreover, DARPA's research has catalyzed dramatic reductions in pixel sizes and, consequently, in device size, weight, power needs and cost. Expensive and cumbersome systems that could only be mounted on large platforms like aircraft, tanks and ships are now becoming affordably available as head- or rifle-mounted devices and other Army and Marine Corps dismount systems. In particular, DARPA-enabled infrared night vision capabilities are set to be incorporated in hand held and rifle-scopes through the U.S. Army PEO Soldier Thermal Weapon Sight and Enhanced Night Vision Goggle programs.

3. **Stealth Revolution**

The process of development of Stealth aircrafts began in the 1970s and 1980s in the USA when it realized that its aircrafts were vulnerable to detection and attack by the enemy. The requirement was for the aircrafts to be integrated with radar-guided surface-to-air missiles (SAMs) and air-launched radar-guided missiles, all networked with early-warning, acquisition, and targeting radars, and coordinated within sophisticated command and control frameworks.

HAVE Blue was the first combat stealth aircraft developed by DARPA by 1977. Next, TACIT Blue aircraft was developed, which finally led to the development of B-2 stealth bomber.

Stealth aircraft destroyed key targets in conflicts in Iraq, both in the 1991 Desert Storm operation and in 2003 during Operation Iraqi Freedom; in Afghanistan during Operation Enduring Freedom in 2001; and in Libya in 2011. Complementing the key contributions of stealth capabilities in these missions was Department of Defense's use of other technologies, including DARPA-enabled precision-guided munitions, which were deployed by stealth and non-stealth aircraft. Since their initial development and deployment, stealth technologies have been applied to a wide range of weapon systems and military platforms, among them missiles, helicopters, ground vehicles and ships.

2.8 Partnerships for Innovation (PFI)

Background

The PFI program of the NSF contained by the Division of Industrial Innovation and Partnerships (IIP) offers scientific researchers the prospect of transforming novel information and knowledge into socially beneficial entities by means of translating the research efforts and developing technologies and catalyzes alliances that accelerate innovative activity.
Previously the program had two complementary sub programs a) Building Innovation Capacity (BIC), and b) Accelerating Innovation Research (AIR).
Both these programs dealt with and were initiated for translating the research of academia into

commercial opportunities. However each program dealt with different stage of the translation process. Overall, the PFI program provided prospects for connecting novel knowledge for the benefit of the society through its translation and partnerships for encouraging and accelerating entrepreneurship.

The program was recently (2018) reconstructed, subsuming the two sub programs. The revamped program consists of two tracks - PFI-Technology Translation (PFI-TT) and PFI-Research Partnerships (PFI-RP).

Objectives

- Identifying and supporting Foundation-sponsored research and technologies that have the potential for accelerated commercialization
- Supporting prior or current NSF-sponsored researchers, institutions of higher education, and non-profit organizations that partner with an institution of higher education to undertake proof-of-concept work, including the development of technology prototypes that are derived from NSF-funded research and have potential market value;
- Promoting sustainable partnerships between Foundation-funded institutions, industry, and other organizations within academia and the private sector with the purpose of accelerating the transfer of technology;
- Developing multi-disciplinary innovation ecosystems which involve and are responsive to the specific needs of academia and industry;
- Catalyzing professional development activities, mentoring, and best practices in entrepreneurship and technology translation for faculty, students and researchers;
- Expanding the participation of women and individuals from underrepresented groups in innovation, technology translation, and entrepreneurship.

a) Technology Translation (PFI-TT)

This sub-component program enables a formerly funded NSF-researcher with an opportunity for taking ahead the results of previously performed research work, for developing new technical innovations, which possess the capability of commercial success and societal impact. The projects approved for the grant are anticipated to demonstrate 'proof-of-concept, prototype, or technology development and scale-up', along with providing exposure to the students and faculty as well as engaging them in entrepreneurial and innovative activity. This sort of activity can possibly lead to engaging partnerships and collaborative opportunities, generation of novel intellectual property, creation of novel commercial products for the needs of the society.

This sub program has been conceived with the aim of supporting applied research and early stage prototyping activities, which focus on solving challenges.

The program is anticipated to deliver results such as technological developments, commercial outcomes, products causing societal impacts etc. (ideally under a SBIR/STTR-funded start-up company or under a license to an established corporation in the intended field of use);

The anticipated program outcomes from PFI-TT will be technological developments that inform a path toward commercial reality and societal impact (ideally under a SBIR/STTR-funded start-up company or under a license to an established corporation in the intended field of use); the development of collaborations between faculty, students and individuals knowledgeable about market need (e.g., potential customers, individuals with business and technology commercialization experience, potential investors, etc.); the engagement of faculty and students in technology translation and entrepreneurial/innovative thinking; and the inclusion of women and individuals from underrepresented groups in the technology development/entrepreneurial endeavor.

- **Technology Development**

The development of basic research into deployed technology is often depicted as a sequence of phases from basic research through proof-of-concept, prototype iteration, product development and finally commercialization, with each phase having unique and often significant challenges to be overcome. PFI-TT is aimed at advancing knowledge along this continuum for projects with technology innovation(s) coming forth from the basic research/ discovery phase. The research funded should identify the next stage of technology/knowledge gap(s) or barrier(s) that must be overcome as part of the path from the basic research discovery to eventual successful commercialization and societal benefit. The PFI-TT program provides funds for overcoming significant technological challenges that have been identified as hurdles in the technology translation process towards commercialization.

- **Commercialization Potential**

Another dimension of the path from basic discovery to successful commercialization involves an understanding of various business and commercial aspects of translating the innovation towards market application, such as market need, value proposition, target industry sector, potential customer segments, potential channels, and early understanding of the supply-chain, product-market fit, development of a preliminary intellectual property strategy (freedom to operate, patentability, copyright, trade secret, etc. as applicable), regulatory issues, etc. The expectation is that, over the course of the project, the participant with "technology commercialization experience in the targeted field(s) of application/industry sector in the field of use of the proposed technology" will lead the effort to advance the team's understanding of the business aspects of the project alongside the team's technical progress. Together, this should inform the ensuing commercialization strategy (such as SBIR/STTR funding of a spin-out company, licensing to a more mature corporation, etc.)

- **Collaborations**

Collaborations are encouraged and, are aimed at accelerating the development of the proposed technology towards the anticipated market application. Collaborators may include individuals/entities internal and/or external to the proposing organizations and may be included in the budget or not.

b) Research Partnerships (PFI-RP)

The Research Partnerships (PFI-RP) track provides an opportunity to support technology development activities through a multi-organization collaboration. NSF recognizes that interdisciplinary collaboration is often needed to achieve successful technology development. This program supports a research consortium ecosystem focused on a clear project thrust and allows for partnerships between academic researchers and a variety of third-party organizations (such as industry, non-academic research organizations, federal laboratories, public or non-profit technology transfer organizations, and/or other universities) to conduct applied research in highly collaborative, multidisciplinary teams, on problems typically beyond the reach of a single researcher. The goal of the RP track is to catalyze robust and synergistic partnerships and collaborations between government, academia, and other public and private entities to drive and accelerate the translation of federally-funded fundamental research results into innovations that, through technology development and commercialization, will have a significant economic and societal impact.

Special interest is focused on affording opportunities for:

- Interdisciplinary university-industry teams to conduct collaborative research projects, in which the industry research participant provides critical research expertise, without which the likelihood for success of the project would be diminished.
- Faculty, postdoctoral fellows, and students to conduct research and gain experience in an industrial setting; and industrial scientists and engineers to bring industry's perspective and integrative skills to academia, with a strong emphasis in the participation of women and individuals from under-represented groups.
- Participation of other non-profit organizations with deep research and development expertise to facilitate technology translation activities
- Leveraging the capabilities of consortia such as (but not limited to) NSF-funded consortia to develop technological innovations from prior funded basic research results.

Funding

The budget for PFI-TT proposals is up to $200,000 for 18 months per award; approximately 30-45 awards are anticipated.

The budget for PFI-RP proposals is up to $750,000 for 36 months. Approximately 10-15 awards are anticipated.

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Canada

Contents

1. Introduction

Canada is the second largest country in terms of area on the globe, located in the western hemisphere, in the continent of North America. A major part of the Canadian landmass is snow-covered for most part of the year. However, it is a developed economy, and strives towards further economic development by expanding its R&D and innovation ecosystem. The Global Innovation Index ranking of Canada is 18 (as per GII Report-2017). In Global Competitiveness index, the rank of Canada is 14/137 (as per GCI Report-2017).

The main institutions in Canada that take care of the scientific and industrial development and their collaborations are the National Research Council (NRC), Natural Sciences and Engineering Research Council of Canada (NSERC), the Social Sciences and Humanities Research Council, the Canadian Institutes of Health Research Industry Canada and Health Canada. These organisations run various programs for the promotion of collaborative research, some of which are Industrial Research Assistance Program (IRAP), Network of Centres of Excellence, etc.

The other innovation indicators and Canada’s rank in those are tabulated below.

Table 1: Global rankings of Canada, based on S&T related indicators.

S. No.	Indicator	Global Rank
1.	Publications[a] (2016)	9
2.	H-Index[b] (2017)	5
3.	Intellectual Property Rights[c](2017)	11
4.	Expenditure of Education[b]	40
5.	Gross Expenditure on R&D[b] (% of GDP) (2017)	22
6.	Research and Development[b](2015)	15
7.	Global R&D Companies, avg. Expend. Top 3, mn $US[b]	16
8.	QS University ranking, avg top 3[b]	5
9.	Availability of Scientists and Engineers[d]	4
10.	Capacity for Innovation[d](2017)	23
11.	Quality of scientific research institutions[d] (2017)	9

12.	Company spending on R&D[d] (2017)	31
13.	University-industry collaboration in R&D[d](2017)	24
14.	PCT Patents[d]	20

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

2. Programs/Schemes

2.1 IRAP (Industrial Research Assistance Program)

Background

The Industrial Research Assistance Program (IRAP; https://www.nrc-cnrc.gc.ca/eng/irap/) is a program of the National Research Council (NRC), Canada that has been designed to boost the innovation ecosystem in the country, by providing support to the Small and Medium Enterprises (SMEs). This support is in the form of technology assistance, providing market access and strengthening the innovation capacity of the SMEs. This is to ultimately raise the capacity of the SMEs to contribute to the economy of Canada, given the huge potential that they have. The IRAP analyses the challenges faced by the SMEs in Canada, and facilitates their resolution by providing R&D expertise and technology assistance.

History

In the post World War arena, economic and industrial development was considered a very important component to be politically strong. Canada wished to expand and improve its industrial base, by supporting research and development (R&D). Hence, IRAP was initiated under the management of NRC in 1962. It was one of the very first programs started by Canada to step-up the innovation environment by by providing R&D support to the industrial base.

However, with time the focus of IRAP shifted to the SMEs, as per the needs of the industry (both large and small) in Canada. The evolution of the agenda and its coverage is summarized in the timeline below:

- **1962-78**

IRAP provided assistance in terms of technology and finances, to all industries- large and small alike.

- **1978-84**

There was a greater focus on SMEs, even though assistance was provided to the large industries as well. The program was classified as:

1. IRAP-M: Laid greater stress on the small projects of the SMEs
2. IRAP- L: Assistance was provided for 'Laboratory Investigations' – comprising of both small scale and large scale projects.
3. IRAP-H: For supporting the companies that employed undergraduates.

- **1984-88**

Two new sub-programs of IRAP were designed as mentioned below:

1. IRAP-R: Designed primarily for 'Technology Transfer', as a part of the collaborative R&D.
2. IRAP-S: Had an international element, facilitating collaborations between international firms that could transfer technology to the Canadian companies.

- **1989-99**

All the sub-programs of IRAP were consolidated into the following two programs:

1. Technology Enhancement (TE) that improved the technical competence of SMEs, by focussing on small projects.
2. Research, Development and Adaptation (RDA) that stressed on complex and unproven projects and technologies.

- **2000-08**

More and more focus on the global participation of Canadian SMEs. Also, for funding SME projects, IRAP and Technology Partnership Canada (TPC) joined hands.

There was an emphasis on the growth of the small sized industries into medium sized industries. This was done by spending on less number of large-scale projects, rather than more number of small-scale projects.

- **2009-11**

In the wake of the global financial meltdown of 2008, the budgetary contributions to IRAP were almost doubled, to sustain the industrial growth of Canada, as a part of the economic recovery plan, termed as " Canada's Economic Action Plan".

- **2012**

In response to the Jenkins Report, the funding was increased for IRAP, and new sub-program named ‘Concierge’ was started.

Mandate

The mandate of IRAP is economic growth of Canada, by strengthening its industrial output. To fulfill this mandate, there are two main objectives adopted by IRAP are:

1. Providing assistance to the Small and Medium Enterprises (SMEs)- firms with not more than 500 employees. The assistance is in the form of development and commercialization of the technology.
2. Supporting the collaborations of the SMEs with institutions, that can aid in the achievement of the first objective.

Mission

Speed-up the growth of SMEs by providing them with technical and financial assitance and supporting their collaborations with R&D institutions.

Vision

Be the most impactful program of its kind in the world, where Canadian firms go first to transform their ideas into commercial success.

Values

- Provide effective and fundamental service to clients
- Respect and invest in the value of people
- Support and foster partnerships
- Maintain and enhance technical credibility
- Ensure accountability for quality service and effective use of resources

Goals

- Support SME innovation
- Strengthen technology-based communities
- Increase the client base of IRAP

Types of services and assistance provided

1. **Advisory Services**

   Advice related to market expansion, collaborations, technology and innovation- at each and every step from the development of technology to its conceptualization is provided by the program.

2. **Funding to the companies**

   The funding provides support for R&D commercialization of the SMEs. It is not to be paid back by the SMEs. The funding falls under two main cateogaries:

   - <u>Core IRAP funds</u>: These funds are continuous, i.e. they are not stopped after a particular time period. For example: the Youth Program, Conceirge, etc.
   - <u>Temporary programs</u>: These programs are funded uptill five years, and are also supported by other departments of the Government of Canada. Examples of temporary programs include Business Innovation Access Program (BIAP), Canada Accelerator and Incubator Program (CAIP), Digital Technology Adoption Pilot Program (DTAPP), etc.

3. **Funding to the organisations**

   Financial support is provided by IRAP to various institutions (that could be based in industries, universities, innovation centres, etc) that are not-for-profit and that can provide innovation services to the SMEs.

4. **Assistance to the government departments**

   IRAP provides support to the various departments of the government in terms of guidance on other innovation programs. The expertise of the IRAP is often found useful by the other departments, which then decide on the amount of funding and allocation of resources and funds to the various programs. Due to this service provided by IRAP, the SMEs find it easy to seek every type of support from one single point.

Location

Fig 1: Location of IRAP centres and Research Facilities

Source: https://www.nrc-cnrc.gc.ca/eng/reports/2017_2018/dp.html

There are a total of 230 Industrial Technology Advisors (ITAs) that support and deliver the IRAP. These ITAs are located in five regions across Canada, which are:

1. Atlantic & Nunavut
2. Quebec
3. Ontario
4. Prairies
5. Pacific

All the ITAs are qualified professionals in engineering and science, and experienced in management of SMEs before they join the IRAP. The main functions of the ITAs are:

- Look for SMEs that can gain assistance and guidance from the IRAP services.
- Communicate with the SMEs as to what are the challenges they face, and how those could be addressed by the IRAP, its funding and guidance provisions.
- Provide the required assistance to the SMEs from the stage of conceptualization of the idea to the commercialization of the technology.

Governance and management

The IRAP functions under the administrative control of the National Research Council (NRC) Canada. The NRC is an organisation for promoting research and innovation in Canada and ulimately contribute to its economic growth. It partners with industry in Canada, so that the benefits of research in the universities could reach the people, through commercialization of technology.

The management of the IRAP is carried out by:

A. Senior Executive Committee of the NRC, which is composed of
    a. President
    b. Vice Presidents (5)
    c. Secretary General
    d. Director General of Human Resources branch
    e. Director General of IRAP
    f. Chief Financial Officer
B. Advisory Board
C. Advisors (10-12)
D. Innovation Network Advisors (INAs)
E. Innovation Technology Advisors (ITAs)

Finances

Between 2012-13 and 2015-16, IRAP had distributed over $869 million in contributions to SMEs and organizations through core and temporary funds.

Table 2: Finances between 2012-16 (in million $)

Program	Field	2012-13	2013-14	2014-15	2015-16	Total
IRAP Core (Youth, Firms, Organizations and Concierge)	Contributions	170.87	189.41	188.09	203.07	751.43
	Operating Costs	45.47	48.58	54.25	54.12	202.42
	Total IRAP Core	**216.34**	**237.99**	**242.35**	**257.18**	**953.86**
Temporary (BIAP, DTAPP, CAIP,	Contributions	26.54	37.88	21.73	32.00	118.10
	Operating	2.79	2.86	0.3	0.5	6.45

CHTD CHVI)	Costs					
-	**Total Temporary**	**29.33**	**40.71**	**22.04**	**32.50**	**124.56**
Total		**245.67**	**278.70**	**264.38**	**289.66**	**1,078.41**

Source: IRAP comptroller

Impact

- Strengthened the innovation capacity of many SMEs in Canada
- It facilitated the growth of many SMEs in Canada
- It contributed in a positive way to the economy of Canada

Success stories

a) Automation of manufacturing of advanced water purifier by *Saltworks Technologies* with the help of NRC-IRAP

Saltworks Technologies (https://www.saltworkstech.com) is a company based in British Columbia, Canada that helps the industries in managing and treating the polluted and waste water in order to prevent them from causing environmental pollution. One of the products developed by the company is a semi-permeable ion-exchange memberane, that allows substances to selectively pass through, thereby filtering out the waste. This product is in high demand as it is required by various large scale industries like oil, gas, mining, etc. And there is all the more requirement of the product, as the concerns of degraded environment are higher than ever.

However, the process of production of this membrane was manual, and not automatic. Due to this, the company was not able to meet the demand of its ever growing market. So in order to speed up the production of manufacturing through automation, Saltworks Technologies sought help of IRAP-NRC.

The company had realized that the only way the manufacturing process could be sped-up was through digital technology, and it was a risky venture to adopt a a new technology for manufacturing the membrane, something that had never been done before globally. However, with the guidance, advice and funding from IRAP, the company was successfully able to develop such a manufacturing process.

In the entire process, care was taken that the intellectual rights of the company are not infringed upon. In order to automate the membrane manufacturing process, only internal expertise was used for production of high precision membranes at a large scale in a short period of time.

After the successful automation, the production scale and speed has become seven times more than before, and it is exected that it would eventually become 20 times more.

b) Thymox®

It is a biodegradable disinfectant for agriculture that was developed by the company Groupe Poly-M2 (http://polym2.com). A microbiology R&D laboratory was created for developing Thymox®.

The president of the company, Serge Auray wished to develop such products, which not only take care of the sanitation and are effective, but are also good for the environment and the human and animal life, as it is well known that all types of pathogens are prevalent in the crop production and animal sector.

In the year 2001, Serge Auray contacted the National Research Council Industrial Research Assistance Program (NRC-IRAP). Industry Technology Advisor (ITA) for NRC-IRAP had pointed that the creation of a natural disinfectant which would equallyefficient as chemicals(that are much more aggressive and used on a larger scale) had great potential in such a scenario.

With the help of NRC-IRAP and advice from Dr. Sylvain Quessy (ITA), professor and director of the Department of Pathology and Microbiology at Université de Montréal's Faculty of Veterinary Medicine, Mr. Auray decided to take further the strategy and technique for this idea. After the many interactions, he gathered his own microbiology team for research and development and set up a laboratory to develop his product on his own.

The NRC-IRAP helped the company to structure the methodology and to properly evaluate the steps to take, which gave it a good strategy for the management of intellectual property.

In the year 2003, the Groupe Poly-M2 launched the other division- Laboratoire M2. In the proceeding years, Laboratoire M2 collected many agricultural bacterial strains and developed a bank of around 3000 strains.

An intensive laboratory research program was started, which led to obtaining a DIN (Drug Identification Number) from Health Canada for Thymox®.

Officially launched in 2008, Thymox® was the first agricultural disinfectant to obtain the EcoLogo certification under CCD-166 in Canada. It is now sold in a concentrated form to makers of disinfectant products destined for the agriculture market. Its formulais now patented in 35 countries and in 7 languages.

Alongwith Thymox®, Laboratoire M2 also established an emergency response unit and expert laboratory services for animal production. The team of researchers created a certified protocol for cleaning and disinfecting alongside Health Canada, as well as three guides for the Quebec Federation of Pork Producers.

Since 2009, Thymox® sales have doubled each year. Thanks to the support of NRC-IRAP and investments from Groupe Poly-M2, the Laboratoire M2 now has many more employees as compared to what was their initial number. It continues to design products and services for industries that are subject to very high standards of disinfection and traceability.

The company believes that the support of NRC-IRAP has fuelledthe strategic thinking and united a solid scientific team. Laboratoire M2, now recognized as a leading-edge company in veterinary sanitation and agri-food biosecurity, was awarded the Green Chemistry Innovation Award by the Centre québécois de valorisation des biotechnologies (CQVB).

c) In 2004, Éric Simoneau, a graduate of HEC Montreal's business administration program, and David Gingras, a graduate in automated production engineering from École de technologie supérieure (ÉTS), came up with the idea of designing a wheelchair that is two times lighter, more durable and more affordable than a traditional wheelchair.

"At first, the new thing was to use carbon," explains Éric Simoneau, President of Motion Composites Inc. "We had already come up with a concept, gathered a small amount of start-up capital and we knew that, at the time, there was no wheelchair made from composite materials on the market. However, we still had to build it." Georges Lagacé, an Industrial Technology Advisor (ITA) for the National Research Council of Canada Industrial Research Assistance

Program (NRC-IRAP), assembled a team of professionals in health and other sectors to assist in the company's progress.

"We put Éric and David in contact with André Dubois, an expert in the finite element analysis of composite materials. He turned out to be such an amazing resource person that he still works as a consultant for the company," says Georges.

The first project with NRC-IRAP allowed Motion Composites to finalize the design, establish the materials, and initiate the building phase. Shortly after, Éric and David began to build their first prototype. In the spring of 2006, a second project was started, during which, economic and technical difficulties arose. NRC-IRAP resources allowed them to find subcontractors who could help with these issues.

Hamid Ould Brahim, an ITA with expertise in composite technology, helped resolve the technical issues by sourcing a local company that developed a stronger, less expensive glue. Meanwhile, Louis Renaud, an ITA who specializes in the health sector, advised them on how to penetrate the complex Quebec market. With the assistance of NRC-IRAP, Motion Composites overcame many major obstacles, such as optimizing the various building materials, the structure, the mechanisms, the mounting plates for the wheels, and resolving production issues.

"NRC-IRAP's support allowed us to resolve various technological issues and to implement our production system," says Éric. "We knew that our product was interesting, but it was not yet feasible at the commercial level. We needed to go further."

A third project with NRC-IRAP began in 2010 to improve their wheelchair, while reducing its production cost, and to develop a range of wheelchairs for both target clients, i.e. children and people with bariatric problems (obesity).

In 2011, Motion Composites had the wind in its sails. "Without NRC-IRAP's credibility and its network of contacts, we would not have been able to complete the funding process with the other partners," says Éric. In addition to NRC-IRAP's assistance, the company also relies on support from Canada Economic Development, the Regional Economic Intervention Fund (FIER), Sustainable Growth, Montcalm Local Development Centre, Emploi-Québec, Investissement Québec, and from the Achigan Montcalm Community Futures Development Corporation.

Throughout the process, the financial assistance from NRC-IRAP allowed Motion Composites to hire specialized employees to help achieve their technical objectives. “We went from the concept stage to the production stage in 12 months, a record performance thanks to the support from NRC-IRAP,” adds Éric. Motion Composites manufactures approximately 1,500 Helio wheelchairs each year. With a team of 17 permanent employees and 8 representatives, the company plans to grow throughout North America.

d) Failure of power due to transformer failure or any other reason usually leads to financial repercussions for the industry and electricity producers alike.

In 2011–2012, the collaboration of the National Research Council of Canada- Industrial Research Assistance Program (NRC-IRAP), the Quebec firm ndb Technologies Inc. (ndb) (https://www.ndbtech.com) led to addressing this problem by developing the best portable system in the world for detecting and locating potential partial electrical discharges and overheating in power transformers, identification of which would lead to prevention of power failure.

Electricity producer companies in Canada such as Hydro-Québec (http://www.hydroquebec.com/residentiel/) did not have any instruments that could locate such current problems effectively. But it is also true that a single damaged transformer results in a loss of several millions of dollars per device.

Determined to find a solution to this problem, ndb Technologies Inc., founded in Quebec City in 1991, first obtained the support of NRC-IRAP in 2009. The company then obtained financial assistance for the electronic, mechanical and software design of the AE-150, which has become the first device in the world to use acoustic and electrical waves simultaneously for more accurate detection.

The AE-150 is one of a kind for accurately locating defects related to overheating and partial electrical discharges in high-power transformers.

The expertise of NRC-IRAP was very useful to ndb. Marc Quintin, the NRC-IRAP Industrial Technology Advisor (ITA), helped ndb to structure the project more effectively, identify new suppliers and leverage strategic information. Mr. Quintin also provided invaluable assistance with intellectual property management.

As a result of developing the most advanced device in the world for accurately detecting partial discharges in power systems with the support of NRC-IRAP, ndb saw its revenues triple since 2009, the area of its plant quadruple and its credibility increase tenfold. Approximately 30 jobs have also been created, 14 of these in R&D.

Exports outside of Quebec have also risen from 57% to more than 83% over the same period.

In addition to NRC-IRAP funding of approximately $500,000 from 2009 to 2012, ndb obtained essential expert advice from Marc Quintin. ndb’s adoption of an agreement negotiation strategy with its partners and a rigorous scientific approach for the project stemmed from his recommendations.

Until now, the AE-150 has generated direct financial benefits of more than $1.5 million. The AE 150, as the most innovative device for locating partial discharges in transformers, has been a major driver for ndb. It has enabled ndb to better position itself and improve commercialization of its entire product range.

ndb has become the benchmark for preventive maintenance of power systems around the world: its device is commercialized with transformer manufacturers and power producers in some 15 countries on all continents.

"Our technical advisor continues to provide a great deal of expert advice in many areas as well as technology monitoring that is very beneficial to us. The reports we are required to submit to NRC-IRAP also help us structure, manage and monitor our projects more effectively," said Mr. Hamel. ndb is aiming to achieve growth and continuous development of its solutions in order to become a global leader focused on the optimal reliability of power systems.

e) In a small industrial town near Windsor, Ontario, visionary Grant Bourdeau has used his extensive automotive experience to launch a health products manufacturing firm. “While looking for manufacturing opportunities in natural health products (NHPs), I realized this industry could benefit operationally from the automotive industry’s rigors, disciplines and quality controls,” says Bourdeau, president and chief executive officer of Suntrition, which manufactures NHPs (nutraceuticals) and sports nutrition supplements.

After identifying a booming global market for nutraceuticals, Bourdeau in the past three years has taken Suntrition sales from $1.5 million to $6 million. He credits much of his success to the National Research Council (NRC) Industrial Research Assistance Program (IRAP), which helped him transform his idea of connecting the unconnected into a reality of rapid growth and limitless potential.

According to Industrial Technology Advisor (ITA) Vladimir Franjo, IRAP supported Bourdeau's innovative thinking with strategic support, critical connections and financial assistance that were vital to Suntrition's evolution. "We also helped Suntrition set priorities for development and growth—and the top three were marketing, process improvement and human resources."

One of Bourdeau's chief challenges was defining a sales and marketing strategy. Franjo connected him with an industry marketing consultant who helped develop initiatives to ensure Suntrition's long-term sustainability. These included conducting market research, identifying markets and products that would lead to sustainable growth, and positioning the firm with customers as a supplier who brought exceptional value to the table. Suntrition then rebranded itself as "the leader in small-batch oral-dose manufacturing" for products such as vitamins, dietary supplements, cold remedies and sleep aids.

Bourdeau reports that "we have been able to attract not only established market leaders in the nutraceutical industry, but also many newcomers." And everyone is noticing: In 2012, Suntrition was ranked by Profit magazine as #88 of the Top 200 fastest growing companies in Canada.

To ensure that Suntrition's brand promise was backed by products and services that meet the stringent safety and quality standards of nutraceutical production, the company adopted lean manufacturing systems. Value-stream mapping helped Suntrition analyze inefficiencies in operations, management and manufacturing, then implement productivity improvements, higher output and better quality control. "In addition, our new $3.5 million 36,000-square-foot (11,000-square-metre) state-of-the-art facility was designed and built to superior pharmaceutical standards," says Bourdeau. "This positioned us to become NSF Good Manufacturing Practices Certified for Sport™—a world-class certification held by just four companies in Canada." This designation allows Suntrition to be the supplier of record for some of the world's most prominent NHP marketers. Process mapping has also identified the right enterprise resource planning (ERP) software, in which Bourdeau has invested a half-million dollars.

Managing a high-growth company requires a strong, specialized workforce—and with IRAP's help, Suntrition identified human resources needs and began filling positions with top talent. In the past three years, the company has increased its employee base by over 200 per cent. A strategic hire was a mechanical engineer charged with implementing lean manufacturing company-wide. Bourdeau also engaged a regulatory affairs specialist, general manager and head of operations while building a customer-centric business development team.

An introduction by Franjo to a renowned scientist, inventor and IRAP client has enabled Bourdeau to take Suntrition "where no one has gone before." He hired Indrajit Sinha, PhD, as chief scientific officer, then partnered Suntrition with Sinha's business, Biomedcore, which had developed a breakthrough technology to individualize cancer therapy. The technology can quickly match the right drug to the right patient and has the potential to redefine cancer treatment. By applying its experience in process innovation to leading-edge science, the company will be making an impact on individualized healthcare as well.

Underlying Bourdeau's drive is his passion for "the societal benefits of health and wellness, and an uncompromising focus on these core values." Combining this with his openness to ideas from inside and outside the industry, Bourdeau creates collaborative environments that are conducive to breakthroughs.

- **Concierge**

Concierge (https://concierge.innovation.gc.ca/en/home) is a program managed under NRC-IRAP, with the aim of catering to the needs of small and medium enterprises (SMEs), that includes providing them free advice about business innovation and growth and helping them get in touch with funding schemes and other support programs. The work of Concierge is carried out through the Innovation Advisors, that are located in different parts of the country, and that have expertise in businesses. Hence, their entrepreneurial experience is of immense importance for the SMEs and upcoming start-ups.

The program was started after the Jenkins report of 2011 titled: '*Innovation Canada: A Call to Action*', which recommended the initiation of a Concierge like program, that would facilitate

SMEs with the support, advice and funding required. Other important recommendations of the report included:

- Expanding the Industrial Research Assistance Program (IRAP) through starting various pilot programs, for specific SME services.
- Providing a centralized "concierge" service, and a website to make it easy for the businesses to access the services and support that they require.
- Collaborating with various businesses/ programs/partners, in order to frame an innovation methodology for all businesses.

Hence, Concierge was started in response to the 2011 Jenkins report, to primarily provide advice and support to the SME sector in Canada and boost the innovation ecosystem.

Success stories

a) IverFashion benefitted from Concierge support

IverFasion (http://apt613.ca/iverfashion/) is a company set up in 2013 in Ottawa Canada, that designs innovative and comfortable clothing for people who use wheelchairs. The company was established by an entrepreneur named Travis Iverson, who is himself quadriplegic, and wished comfortable and good-fit clothes for himself.

The company sought Concierge support for boosting its business.

The Innovation Advisor at Concierge understood the needs of the start-up in comprehensive manner and then supported the company by providing a list of all the programs that would provide funding and support and also referred the company to the business contacts that could support them.

It led to the company flourishing and fulfilling the clothing needs of the many disabled people in Canada.

- **Canada Accelerator and Incubator Program (CAIP)**

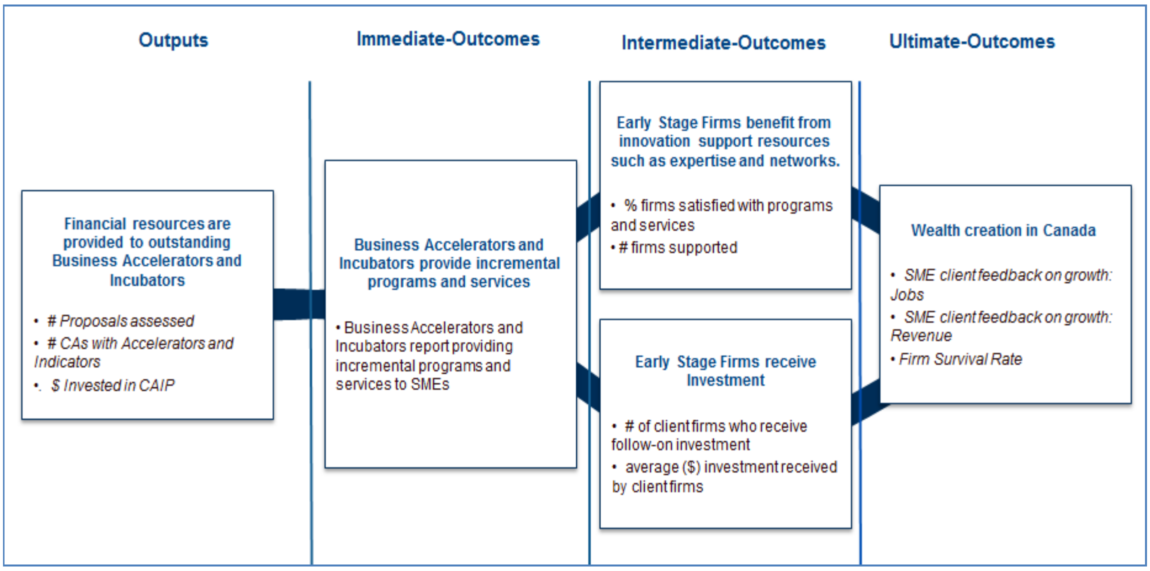
The Canada Accelerator and Incubator Program (CAIP) is a program that is managed and delivered by NRC-IRAP. It is a funding program for a period of 2014-2019, that provides funds (non-repayable) to accelerators and incubators that meet the strict eligibility and selection criteria. The funding is to increase the output of the SMEs, in order to turn them into successful large scale businesses.

CAIP is a 100 million program, to fund select businesses for a period of around five years.

The program CAIP was conceptualized by Finance Canada (http://www.fin.gc.ca/fin-eng.asp), however NRC-IRAP had a good reputation of delivering and supporting commercialization of technology, hence it was chosen to deliver CAIP.

Objective

The objective of CAIP is to establish outstanding business incubators and accelerators that can develop innovative SMEs, which would themselves represent superior early- stage investment opportunities through innovation assistance services and programs in Canada. The program logic is described below.



Contribution Agreements

The contribution agreements are basically contracts between NRC-IRAP and CAIP recipients that detail the key terms, conditions and obligations under which NRC-IRAP will make contribution payments to the recipient.

Contribution agreements were negotiated between CAIP recipients and NRC-IRAP regional offices based on the original proposal of each applicant, the framework of the Financial Administration Act (FAA) and the Directive on Transfer Payments. All CAIP recipients are required to demonstrate matching contributions on at least a 1:1 basis during the period of the contribution funding.

- **Business Innovation Access Program (BIAP)**

BIAP was administered and delivered by NRC's Industrial Research Assistance Program (IRAP), whose main objective was to strengthen innovation in small and medium-sized enterprises (SMEs) by:

1) supporting SMEs in Canada (financially and in terms of business advice) in the development and commercialization of technology, and

2) participating in initiatives within regional and national institutions that promote the development and commercialization of technologies by SMEs.

BIAP was officially launched in 2014 and it ended its functions in 2016. Under IRAP's governance, BIAP made contributions to SMEs to collaborate with universities and publicly funded research organizations on research and development (R&D) projects focused on commercialization.

Achievements

A total of 392 projects were approved in fiscal year 2014/15.

Based on the Canadian Business Patterns database, more than half of firms supported by BIAP are considered small (53%) and close to one third are considered micro (29%); only 11% of the SMEs were medium-size businesses. Using Statistics Canada classification, a total of 26 out of the 85 funded SMEs are located in rural areas (30%), the remainder being located in areas where the population exceeds 30,000.

As per the program foundational documents, 500 SMEs were expected to benefit from BIAP funding between 2013/14 and 2015/16. The same resources were allocated to the Program, but had to be used over two years instead of three. Despite this, BIAP is gaining traction at a rapid rate, having achieved approximately 75% of its target within its first year.

2.2 Mitacs

A not-for-profit organisation in Canada, Mitacs (https://www.mitacs.ca/en) has collaborations with the industrial base, the universities, the provincial and central govenments in the country. These partnerships are designed to support the innovation ecosystem in Canada, through various training and research programs. There are 25 offices of Mitacs in Canada for promoting innovation through collaborations with the industry, academia and the government.

Background

In the year 1999, Mitacs was founded as a part of the Network of Centres of Excellence in Canada, however, its main aim then was to support all sorts of research (basic, applied and industrial) in mathematics and related disciplines.

In the year 2003, Mitacs launched a research internship program where it wanted to boost the employment of highly qualified scientists in the private industrial sector.

Mitacs started its services for all disciplines in 2007, and most of the services were based on the demand of the academic and industrial sector. These disciplines included management of research and development, development of professional skills, etc.

Mitacs became completely independent in 2011, after which it focussed completely on translational and applied research, in order to boost innovation in Canada. It has been partnering with the industry, academia and the government alike.

Mitacs Programs

Each Mitacs initiative rests on a collaborative foundation comprised of industries, researchers, universities, and not-for-profits (NFPs) from across sectors and academic disciplines. Today, this innovation network includes thousands of companies and researchers across the country who have taken part in Mitacs programs that seek to advance new ideas, products and processes. This proven approach supports the creation of new innovation partnerships and facilitates lasting relationships that ultimately result in more aligned and connected research and development. Building a stronger culture of cooperation is foundational to the success of the country's competitiveness and the creation of a vibrant and dynamic innovation ecosystem.

Mitacs believes that in order to be successful, this innovation network must reflect the diversity of Canadian society. Diversity allows for multiple viewpoints that challenge one another to produce better outcomes. Through its commitment to diversity both within its programs, and as an organization, Mitacs is nurturing a more robust community of innovators that spans across geographical location, sector, discipline, and population.

Mitacs' suite of programs includes:

- **Mitacs-Accelerate**, graduate-student led industrial R&D internships as a platform for technology transfer and commercialization;
- **Mitacs-Globalink**, bringing top international students to Canada and sending Canada's best students abroad to foster international innovation networks;
- **Mitacs-Elevate**, industrial R&D management training and industrial research experience for postdoctoral fellows through classroom and on-site learning;
- **Mitacs-Step**: Develop business-ready skills through professional skills workshops for graduate students and postdocs led by industry leaders; and
- **Mitacs-Converge**, growing Canadian small to medium-sized enterprises through R&D projects with multi-national companies and Canada's post-secondary institutions.

Mitacs Accelerate

Mitacs Accelerate enables Canadian companies and NFP (not-for-profit) organizations to address their business needs through research partnerships with the country's top universities, professors, and graduate students. For over a decade now, the Accelerate program has offered work-integrated learning opportunities that support demand-driven research projects that stimulate innovation. This program promotes cutting-edge R&D, and cultivates a skilled-workforce that is innovation-literate and well- positioned for success in the global economy.

Objectives

In 2016, the objectives of the Accelerate program were to:

a. Provide host companies with access to cutting-edge research and skills;
b. Provide graduate students and postdocs with applied research experience in a private-sector setting; and
c. Provide academic researchers the opportunities to integrate challenges and opportunities from industryinto their research programs.

Governance and Funding

Mitacs functions under the supervision of a Board of Directors and a Senior Management Team (SMT). While the Board is mainly comprised of individuals from the industrial sector, a number of Directors are members of Mitacs-partnered universities.

Mitacs also receives financial support from provincial and federal governments and agencies, Canadian universities and corporations, and foreign governments and universities. Because Mitacs works to increase business investment in the Canadian research and development sector, it receives substantial funding from industrial sources, amounting to $127 million over the past six years alone. Mitacs' governance structure also includes the Mitacs Research Council (MRC), a body which provides "scientific leadership and critical assessment of Mitacs programs."

Achievements

Based on these objectives, Mitacs contributed to the following results in the 2016-17 fiscal year:

1. Increased collaboration and knowledge transfer between academic and industry in various sectors of the Canadian economy;
2. Creation of job opportunities for graduate students and postdocs in various disciplines;
3. Improved employability of graduate students and postdocs in their field;
4. Increased retention of domestic and international graduate students and postdocs in Canada after completing their studies; and
5. Increased investment in R&D and innovation of participating companies.

In the year 2016, Innovation, Science and Economic Development Canada (ISED) (https://www.ic.gc.ca/eic/site/icgc.nsf/eng/home) funding that provided to Accelerate supported:

- 3,381 Accelerate internships;
- 2,226 interns, 60% of whom were first-time participants;
- 1,519 professor participants from nearly 40 academic disciplines at 65 Canadian universities;
- 1,366 public- and private-sector partners, 55% (746) of which were SMEs.

The 2016-17 ISED (Innovation, Science and Economic Development Canada) contribution of $24 million for Accelerate assisted in leveraging the overall Accelerate program into a program worth $91.7 million (including $30.5 million in-kind support). This program included an industry cash contribution of $26.6 million and helped support a 10% increase in the total number of internships delivered this year in comparison to last fiscal. The demand for the Accelerate program continues to exceed delivery with 4,569 internship applications received in the 2016-17 fiscal year.

Success stories

a) The impact of sprinklers needlessly watering a sidewalk may seem minor, but for professional sports leagues or farmers, every drop of water can add up to millions of dollars lost on their fields. This, in addition to the value of clean water and its conservation, led InteliRain– an Alberta based start-up, to seek ways of improving the design of inefficient outdoor sprinklers that waste water. Realizing that wind was disrupting the efficiency of his sprinklers, InteliRain CEO Cam Cote sought to resolve the issue with the help of mathematician Yile Zhang. Through the Mitacs Accelerate program, Yile, a postdoc at the University of Alberta, set out to develop a mathematical equation that could direct a computer in the sprinkler nozzle to account for windy conditions. Finding no previous existing research on which to model the invention, Yile designed a solution from scratch. Through this research, Yile designed an algorithm that takes into account the space of the lawn and speed of the wind, and developed new robotic sprinklers that can adjust the spray patterns. This invention increases efficiency by up to 200 percent! This new design also takes less time to install, which will save InteliRain's clients time and money. With the product already drawing interest from clients in the United States and Canada, InteliRain has applied to patent the technology, and will soon take the innovative product to market.

b) Consumers are not always aware of what's recyclable in their communities, which can result in common items like milk cartons ending up in the landfill. Through Mitacs Accelerate, electrical engineering PhD student, Rahma Zayoud, teamed up with Dr. Habib Hamam at the Université de Moncton to find ways to keep milk containers out of the landfill. By partnering with The rm opak, a regional packing company, Rahma was able to incorporate radio-frequency identification (RFID) technology to solve the issue. By attaching an RFID tag to the carton, a technology commonly used in commercial and consumer applications, it makes it easier for recycling services to detect the presence of milk cartons, better adjust their routes and scheduling, and ensure that the cartons make it to the appropriate recycling destination. Through this project, retrieval of cartons that end up in a landfill anyway is similarly efficient. Already, the team has seen some promising results, publishing articles and presenting at a conference.

c) The mining sector plays a critical role in the Saskatchewan economy — it accounts for 1 in every 16 jobs in the province, with a total payroll of $1.5 billion. While the health and productivity of mine employees has considerable economic and social impact in the province, these factors are not widely understood. Through the Mitacs Accelerate program, Professor Lorna Butler and her team at the University of Saskatchewan's College of Nursing and the International Centre for Northern Governance and Development tried to address this issue through a research partnership with the International Mineral Innovation Institute (IMII). Professor Butler's research team is identifying the predictors of health and health behaviours that could decrease absenteeism and consequently increase the productivity of both mines and their employees. "The goal of our research is to determine ways to promote health and employee wellness as a way to increase productivity by linking healthy workplaces with healthy employees at mine sites throughout Saskatchewan," explains Professor Butler. Given the mining industry's provincial prominence and economic impact, buy-in from citizens is crucial to this sustainability: "The people of Saskatchewan are actively demanding that the mining industry achieve a 'social license to operate' when considering environmental and social impacts," Professor Butler explains. "We want to extend that expectation further by helping to ensure the province's mining industry is at its most effective in supporting the health of its workers and its workplace."

d) After completing her undergraduate degree in Computer Science, and working in IT for a few years, Caroline Mattos wanted to grow her career and gain international experience. She applied for the Master of Science in Applied Computing (MScAC) degree program at the University of Toronto. The MScAC degree is a two-year program that pairs graduate students with information technology companies for internships. Through Mitacs' embedded internship initiative, Caroline was able to join forces with Toronto- based identity and authentication provider, SecureKey, to undertake an Accelerate internship. "As an immigrant in Canada, I thought my Mitacs internship was an ideal chance to broaden my professional network in Toronto... My internship was the first step in that direction," says Caroline. During her internship, she was responsible for looking at existing methodologies that could improve SecureKey's processes, and to develop a living document that employees can refer to, to better understand SecureKey's product requirements and challenges. When Caroline finished the MSc in Applied Computing, she was motivated to continue her professional journey in Canada. She was hired as a full-time business analyst shortly after her internship.
e) In addition to interning with a Halifax-based medical company through Mitacs Accelerate, Dalhousie University postdoc Hamed Hanafi was also pursuing a personal goal of becoming an

entrepreneur and getting a passion project off the ground. With the help of his Dalhousie Accelerate supervisors, Professor David Roach from the Rowe School of Business, and Professor Jan Haelssig from the Faculty of Engineering, Hamed has started a company to develop technology that will make continuous positive airway pressure (CPAP) therapy more comfortable for patients. “The gold standard for treating sleep apnea is CPAP machines. However, patients don’t use the machines because they are very uncomfortable,” explains Hamed. Over one in four Canadian adults is at risk of suffering from sleep apnea, which causes pauses in breathing or shallow breaths while they sleep. Taking a cue from a Dalhousie alumnus, a founder in the company he’s partnered with for his Accelerate project, Hamed came up with a novel idea: a device that makes sleep apnea machines more personalized for users. His start-up, NovaResp Technologies, focuses on this approach to CPAP with a device that uses sensors to continuously tune the sleep apnea machine according to each patient’s need. When his Mitacs Accelerate project is done, Hamed plans to develop a prototype, and then start a pilot study with patients in Halifax.

2.3 Idea to Innovation Program (I2I)

The Idea to Innovation (I2I) program (www.nserc-crsng.gc.ca) is supported by Natural Sciences and Engineering Research Council of Canada (NSERC).

NSERC
CRSNG

Objective

The objective of the Idea to Innovation (I2I) Grants program is to further the development of rising technology originating from the academia and colleges and promote its transfer to a new or established Canadian industry. The I2I Grants provide funding to the faculty members of the universities to support research and development projects, which havehighly recognized technology transfer potential. This is done through set phases by providing crucial assistance in the early stages of technology validation as well as market access.

About the program

The program proposes four distinct funding options, which are specified by the fitness of the technology or the involvement of an early-stage investment entity or an industrial partner.

1. In the Market Assessment, NSERC shares costs of an independent and professional market study with the institutions (including the industry liaison office [ILO] or its equivalent).
2. In the Phase I, all the direct costs of research are entirely supported by NSERC
3. In the Phase II, the costs of researchare shared with a private partner. The technology development may begin with a Phase I project (Reduction-to-Practice Stage), followed by a Phase II project (Technology Enhancement) or, if the development is at a later stage, it can start directly with a Phase II project. In any case, the combination of Phase I and Phase II is limited to a maximum of three years' funding for any given project.
4. Phase IIB

Eligible research and development activities include (but are not limited to):

- refining and implementing designs;
- verifying application;
- conducting field studies;
- preparing demonstrations;
- building prototypes; and
- performing beta trials.

- **Market Assessment**

Market Assessment projects are designed to enable organisations to do a market study for a product, process or technology that they plan to develop. Comprehending market potential is important when developing a new technology.

The Market Assessment funding option is a tool to help recognise industry and market problems. It can be used to better position a proposed technology in an I2I application (to provide the reviewers with a better understanding of the market for a given technology) or identify the appropriate NSERC program.

The market assessment generally precedes a Phase I proposal, if the applicant and ILO (or its equivalent) have not yet developed an understanding of the potential market.

The main aim of the market assessment is to address certain issues such as, whether the market presents a problem or an opportunity and what its magnitude is,and in case of a problem, how would that be addressed, and at what cost. It may then include analysis on whythe problem has not been solved already, what sort of barriers exist, and how those barriers can be overcome.

Market assesment can also include undertaking surveys and polls as well. Also, the market size needs to be clearly established.

NSERC co-supports up to three-quarters of the costs of the project contracted out to a consultant, with the institution providing the balance in cash (a person employed part-time or full-time at an ILO or its equivalent cannot act as an external consultant on an I2I Market Assessment project). Funding is available for up to 12 months, with a maximum contribution from NSERC of $15,000.Funding is non-renewable.

- **Phase I – Reduction-to-Practice Stage**

Phase I reduction-to-practice projects are designed to advance promising technologies in order to attract early-stage investment and/or to build valuable intellectual property (e.g., strengthening the commercial value of the technology, broadening patent claims or strengthening licensing opportunities) in anticipation of transferring the technology to a new or established company.

One of the main reasons why Phase I proposals are rejected is that the technology is at too early a stage to be eligible for the I2I Grants. Phase I proposals must be based on strong scientific evidence and present the following elements:

The technology must be sufficiently mature. The basic parameters of the concept must have already been explored, and sufficient testing should have been done to assess the potential of the innovation to work in a "product" environment or for its intended purpose. There must be a clearly identified and well-described potential market. Meaningful letters of support from potential receptors, end-users/clients and industrial value-chain players may be very useful. The content of the technology transfer section should address the essential questions asked through the market assessment portion.

Involvement of experienced business mentors is recommended when the team is planning to spin off a new company.

A company may be involved as a testing bed for the technology (i.e., potential client). However, when a collaborating company is the intended receptor for the technology (i.e., the company that will market the end product), the cost of the project should be shared with this partner and the application submitted as a Phase IIB proposal.

Funding is available for up to 12 months, at a maximum of $125,000, and is non-renewable. NSERC will assume 100 percent of the direct costs of research for Phase I projects.

Each project is expected to have a "go/no-go" decision point, representing the achievement of a predefined scientific or engineering milestone, at the end of Phase I when either seed funding will be provided by an early-stage investment entity or the technology will be further developed with an established or start-up company.

All Phase I proposals require a plan describing how a partnership will be established with a Canadian company that has the capacity to commercialize the research results. Although a business partner is not a pre-requisite for Phase I applications, a demonstration of interest may strengthen the proposal. It is expected that technologies implicitly or explicitly committed to a specific receptor organization or industrial partner will be submitted as Phase II applications. This may not apply if the intention is to create a spin-off company.

NSERC offers an I2I Phase IB supplement. This funding, up to $60,000 for six months, can be made available for successfully completed Phase I projects with high promise to secure an investor or a licensing company. ILOs or their equivalent should contact their NSERC staff for more information.

- **Phase II – Technology Enhancement**

Phase II projects are designed to provide scientific or engineering evidence establishing the technical feasibility and market definition of the technology, process or product. Phase II projects require an early-stage investment entity (Phase IIA) or a company (Phase IIB) to share the costs of the project. The supporting organization is expected to participate actively in the planning of the project. The proposals fall into two categories according to the partner involved as described below.

- **Phase IIA – Early-stage Investment Partner**

Proposals with an early-stage investment entity must be designed with a "go/no-go" decision point, after six to 18 months, representing the achievement of a predefined scientific or engineering milestone that justifies moving forward by further developing the technology either through a new (i.e. start-up) or established company. NSERC can support up to two-thirds of the costs of the project with the early-stage investment entity providing the balance in cash. Funding requested from NSERC should not exceed an average of $125,000 per year.

The partnering firm must provide input into the technology transfer plan and contribute at least a third of the funds required for the project.

It is expected that the collaborator has the financial strength to carry the project into Phase IIB or directly to market. If this seed funding will support a spin-off or entrepreneurial start-up, the financial standing of the firm will be closely scrutinized in the evaluation. The technology transfer terms must be disclosed.

The science has to be substantiated to the point that its end product is easily identifiable. Thorough market research is required and potential buyers/markets must be specified. Meaningful letters of support from potential receptors, end-users/clients, industrial value-chain players are very useful.

Well-justified budgets are a prerequisite, and indications of future financial requirements, as well as the plan to secure these funds, should be provided.

Involvement of experienced business mentors is required when the team is planning to spin off a new company. Projects that achieve critical milestones may be pursued during another 6 to 24 months period with either the newly created company or an established Canadian company providing the cost-sharing arrangement for Phase IIB projects are met.

- **Phase IIB – Partnership with a Canadian Company**

Most of the requirements for Phase IIA listed above also apply to Phase IIB applications. As well, if the development of the technology was supported by a previous I2I phase, proof that the objectives of the earlier project were achieved must be provided, specifically:

- the "prototype" must already be in existence;
- a strong business plan is required;
- involvement of experienced business mentors is required when the team is planning to spin off a new company;
- the receptor capacity to manufacture, distribute, license, etc. must be substantiated;
- adequate budgets are required to show that the product will be at the marketing/manufacturing stage at the end of the Phase IIB Grant; and
- the "in-kind" contributions should be fully justified as they will be carefully scrutinized.

Phase IIB proposals with a Canadian company are expected to be completed within two years, and funding requested should not exceed $350,000 for the duration of the project. NSERC may fund up to half the cost of the project, with the company providing the other half through a combination of cash and in-kind contributions. Each case will be evaluated on its merits;

however, it is expected that the cash component should equal at least 40 percent of the amount requested from NSERC.

The industrial partner must have, or be able to acquire by the end of the project, the technical capability to undertake any further development necessary to take the product or process to market. The company receiving the technology should be prepared to carry out a market study, product/process development, engineering, and sales and marketing planning required to establish that a technology is viable, and to enter the market successfully.

The ILO or its equivalent is expected to assist the applicant(s) and the partner in developing proposals, identifying markets and negotiating licensing or other such arrangements.

2.4 Collaborative Research and Development (CRD) Grants

Natural Sciences and Engineering Research Council (NSERC) is the organisation that invests in discovery, innovation and the use of technology for the benefit of people. NSERC assists the creation and transfer of knowledge and the training of personnel/scientists in the natural sciences and engineering (NSE) through strategic investments in Canadian science and technology (S&T). The strategic outcome of these investments is to support innovation through the efficient use of new infrormation in the NSE in Canada. NSERC supports not only the basic university research but also funds research through partnerships among academia, governments and the businesses.

The CRD program (www.nserc-crsng.gc.ca) is being administered by the NSERC, however it is also a part of the Government of Canada's primary S&T policy. The innovation strategy of Canada that includes 'Achieving Excellence [2001]' and 'Mobilizing Science and Technology to Canada's Advantage [2007]' lay strong emphasis on the S&T collaborations between the companies, academic and public sectors.

Objective

The Collaborative Research and Development (CRD) Grants have the main objective of giving companies that operate from a Canadian base the access to the knowledge, expertise, and educational resources available at Canadian eduational institutions and to give training to students in essential technical skills required by industry. These sort of collaborations are going to benefit both the partners, and would boost the overall industrial/economic status of Canada.

About CRD Grants

The CRD program has been designed to support and promote the collaborative projects between the industrial and academic partner. The costs of the project are borne jointly by NSERC and the industrial sector. Most of the projects are for around 2-3 years, however, the duration of the projects might range from 1-5 years in duration.

The topic of the CRD project can be anything that falls in the domain of NCE (Natural Sciences and Engineering) and something that can yeild commercial value to the industry, and the national economy. Any project with short-term, medium-term or long-term objective that benefits the people, is eligible.

However, any such project that focuses on the application of the already existing technology, or the one which is close-ended, and is not likely to yield any tangible results is not eligible.

Beneficiaries

The CRD program benefits three cateogaries of partners:

- Industry
- Academic researchers/scientists
- Qualified personnel (that undergo training)

The industrial partners benefit in terms of the knowledge, expertise and human resource that the academia provides, that gives birth to innovative ideas and help their translation into economic benefits. The academia gains in terms of finances, and getting an environment to convert their ideas into something tangible and useful. The qualified personnel benefit by acquiring valuable skills, and getting an opportunity to work with the best minds and gain industrial experience.

Industrial Participation

Every project must be supported by at least one eligible industrial partner that must fulfill the following criteria:

- It must collaborate at all the stages of the research project (i.e., proposal development stage and, as the project unfolds further, interact frequently with the academic partners, students and other research personnel and provide inputs on the project);
- It must demonstrate a clear intention on how to proceed with the project and the capacity to exploit the research results within Canada; and
- It must contribute to the direct project costs. If there is more than one industrial partner, then they must jointly provide contributions of amount equal to, or greater than, the amount requested from NSERC. The condition is that the industrial cash contribution

must be at least half of the NSERC request, with the balance provided as in-kind contributions to the project by the industrial partner(s).

Intellectual Property (IP) sharing

The IP policy of NSERC lays stress on the fact that whichever projects are supported by NSERC, should benefit the country and its people. For most of the projects, a copy of the final and signed research agreement that is compliant with NSERC's IP Policy between the industrial partner(s) and the university covering, at a minimum, the entire duration of the grant—must be provided to NSERC within six months from the date of the conditional offer.

Financial Value

Typical grants range between $10,000 to $500,000 per year. Companies must contribute an amount equal to the amount requested from NSERC; the minimum cash contribution from the company must be at least one-half of the amount requested from NSERC, while the other half may be in the form of in-kind contributions.

Governance

The CRD program is located within the Research Partnerships Programs (RPP) Directorate of NSERC, which is led by the Vice-President, RPP. Within the Directorate, the program is administered by Directors, Portfolio Managers, Account Managers and Program Officers from three RPP Divisions (also referred to as "RPP Sectors"): Bio-Industries; Environment and Natural Resources; and Information, Communications and Manufacturing (ICM).

2.5 Networks of Centres of Excellence

In 1989, the Natural Sciences and Engineering Research Council, the Social Sciences andHumanities Research Council, the Canadian Institutes of Health Research, Industry Canada andHealth Canada collaborated creating a joint initiative known as Networks of Centres ofExcellence of Canada (NCE; http://www.nce-rce.gc.ca/index_eng.asp). The NCE program seeks to bring together expertsacross multiple disciplines in order to solve major economic, social and health issues that are ofcritical importance to Canadians.

As of 2017, NCE-funded networks and centres have helped train more than 48,000 highly qualified personnel, and created 147 spin-off companies and 1,332 start-up companies.

Objectives

The objectives of the NCE program are:

- Address the social and economic challenges of Canada by boosting its innovation and research capabilities
- Focus on application of basic research outputs, and commercialization of technology
- Improve R&D capabilities of the private sector
- Train and skill qualified people in R&D and its applications

The main aim of these centres is to share knowledge, expertise and resources so that newtechnologies can be brought to market faster. These centres are able to stimulate commercialization activity that may never have taken place without their formation.

Funding

Approximately 90 million dollars annually are contributed to the program from government, industry and not for profit organizations who also provide expertise in addition to financial support. Approximately two billion dollars have been invested in commercialization, research and knowledge translation by the NCE from the time of its creation in 1989.

As a result of those investments, the NCE has received approximately 1.5 billion in contributions from industry and other partners. In 2013-14, more than 3700 partners in Canada and abroad participated in the program; including 1496 from industry.

Governance/Administration

The Networks of Centres of Excellence program is jointly administered by Canada's three research granting agencies:

- Canadian Institutes of Health Research (CIHR),
- the Natural Sciences and Engineering Research Council (NSERC) and
- the Social Sciences and Humanities Research Council (SSHRC).

This is done in partnership with Innovation, Science and Economic Development Canada (ISED) and Health Canada.

There are various committees for managing other aspects of the governance and performing different functions, which include:

- A Steering Committee made up of the presidents of the three granting agencies and the deputy ministers of both ISED and Health Canada oversees the Networks of Centres of Excellence. The President of the Canada Foundation for Innovation (CFI) sits on the committee as an observer.

- The Steering Committee is assisted by the NCE Management Committee, which is made up of a vice-president from each of the three granting agencies, the assistant deputy ministers of ISED and Health Canada, as well as the associate vice-president of the NCE.
- Day-to-day administration of the NCE centres and networks is provided by the NCE Secretariat. The Secretariat runs periodic national competitive processes through which successful applicants are chosen on the advice of a number of expert panels and selection committees.

Selection Process

In order for industries to avail the services of the NCE program, they are selected through a highly competitive process that follows a multiple stage process which includes top experts conducting a comprehensive review. To make sure that the process is as impartial as possible, the program uses a peer-review system, which is an assessment of the proposals by non-partisan experts in their respected fields.

Achievements

Since the NCE's inception, it has helped train more than 45,000 personnel, as well as aided in the creation of 143 spin off companies and 910 start-up companies.

Among the commercialization highlights of these centres are:

- **Centre for Drug Research and Development (CDRD)** - Has evaluated 825 Technologies thus far for their commercial potential. Of which, 125 were selected for incubation within the CDRD, of those 47 have successfully advanced toward commercialization.

- **Wavefront** – 75 new companies have been created. An independent, third party analysis concluded that Wavefront has generated $4.80 per every dollar invested in it, and produced almost 37 million dollars in GDP across the Canadian economy.
- **Canadian Digital Media Network (CDMN)** – Has helped 104 Canadian companies, land in 19 countries to increase business opportunities internationally. As a result, these companies now have a presence in markets such as the U.S., Brazil, Australia, United Arab Emirates, Germany, Costa Rica, the U.K. and China.

In addition to NCEs, and CECRs we have also chosen to examine Business-LedNetworks of Centres of Excellence (BL-NCEs). BL-NCEs are large-scale collaborative networks headed by not-for-profit industry syndicates that seek to increase private sector investments in Canadian research, and to accelerate the process of translating research into commercial products and services. These networks handle real world challenges facing Canadian industry. Some of the commercialization highlights that can be attributed to the work of BL-NCEs include:

- **CQDM**- The launch of five start-up companies can be attributed to CQDM-supported research this includes NDEI Inc., a company that has beencommercializing biomarkers for diagnosing schizophrenia and bipolar disorder, which will lead to better care of Schizophrenic patients and the development of more effective drugs.

- **Green Aviation Research and Development Network** – (GARDN) has been involved in the development of advanced algorithms that enable airlines to reduce fuel burn and CO2 generation in the cruise and descent phases of flight.The software has been implemented on the CMA-9000 flight management system, which is being installed on 300 Sukhui Superjet 100 Russian regional airliners, and an additional Airbus A300 and A310 airliners.

Success stories

Of the numerous centres to qualify for the program there are countless success stories examples of which include:

- The Stem Cell Network: This network's research has led to 399 patent applications, 60 issued patents, 43 licenses granted, and the formation of 11 start-up biotechnology companies and the creation of a new Centre for the Commercialization of Regenerative Medicine (CCRM).
- Graphics, Animation and New Media Canada – (GRAND) has helped expose over 300 SMEs to technologies being developed in labs all across Canada, which includes more than 120 research demonstrations and the commercialization of 11 new technologies.

- Canadian Institute for Photonic Innovations – CIPI/Canadian Photonic Industry Consortium - CPIC (1999-2013): CIPI's research has led to 15 start-ups of which 8 are still active. Funded over 500 projects, and provided 2300 person years of training.
- "Fixing" Atrial Fibrillation Earlier Would Benefit Millions Of Canadians: People living with atrial fibrillation (AF), a chronic progressive disease are between 350,000 and 700,000 Canadians, or about 1 percent to 2 percent of the country's population. A promising long-term

solution is a minimally invasive procedure – called cryoballoon ablation – that uses technologies developed and manufactured by Medtronic (Montreal) and Baylis Medical Company Inc. (Montreal). This procedure is primarily used on patients with later stage AF and not responding to treatment. Researchers believe using it earlier, or closer to the time that AF is diagnosed, would allow many more people to live better lives without a life-long medication regimen.

The Cardiac Arrhythmia Network of Canada (CANet) has brought together government officials, health care authority representatives, industry, academic researchers, engineers, social scientists, and physicians in a clinical trial involving 300 patients at 20 sites across Canada. The study is to compare the efficacy of drugs versus early surgical intervention, and simplify the surgery to treat more patients in a cost-effective manner. The procedure uses a radiofrequency trans-septal needle, made by Baylis Medical, and a cryoablation balloon catheter, made by Medtronic, to destroy tiny areas in the heart that cause rapid and irregular heartbeats. Researchers believe using this procedure early in a person's condition (i.e. in younger adults) could stop AF from reoccurring later in life – preventing premature deaths and saving the healthcare system hundreds of millions of dollars in direct and indirect costs. Patients who have the surgery go home within 24 hours and feel recovered within a couple of days. The study is one of several CANet-funded projects aimed at reducing AF-related emergency department visits and hospitalizations by 20 percent, while opening new markets for Canada's life sciences companies. Money is also a factor. AF is one of the higher cost chronic conditions in the Canadian health care system, and medications are cheaper than surgery – at least in the short term. To address this issue, the project will draw on CANet's interdisciplinary network to study whether the procedure makes sense from a cost perspective. The cryoablation balloon catheter was invented in Quebec by CryoCath Technologies, which has a long history of collaborating with researchers at the Montreal Heart Institute, including Andrade and many others now associated with CANet. Medtronic acquired CryoCath Technologies in 2009, and since then has expanded its R&D and manufacturing workforce to over 550 in Quebec, while continuing to collaborate with academia, including seven current projects with CANet. Medtronic Canada's president, Neil Fraser, also sits on CANet's board of directors and business advisory committee. Medtronic already produces more than 100,000 cryoballoon units annually, with the majority sold to international markets. The device is able to reduce surgery times by about 20 percent – an important consideration for hospitals that want to offer the procedure to more patients. Previous studies have also shown cryoablation has longer term benefits compared to drug therapy. Yet, despite these advantages, the company still faces challenges in growing its market. The other industry partner in the trial, Baylis Medical, invented what Skanes describes as a "slicker and more useful version of the age old blunt needle technique" so that physicians can gain access to the left side of the heart. Once the puncture is done, Medtronic's cryoablation balloon catheter can be navigated into the left atrium to treat the arrhythmia. The CANet trial will examine how the Baylis transseptal tools including the NRG FR Transseptal Needle, TorFlex Sheath, and ProTrack Wire compares to standard transseptal tools. Baylis generates about 98 percent of its sales from exports and forecasts growing its Canadian operations from about 250 to 400 employees by 2020. The company's new $40 million R&D and production facility in Mississauga, Ontario will enable it to increase production, expand its product portfolio and branch out to new global markets.

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Germany

Contents

1. Introduction

Germany is one of the leading countries in Europe and around the world as far as innovation is concerned. Germany invest around 2.41 of its GNP into R&D. The Federal Ministry for Economic Affairs also stresses the importance of diversity in research. This may be one of the reasons Germany excels across the board. It also explains why 80 billion euros is being allocated to research and development. Germany takes investment to the next level and is the second biggest global investor, after the USA. Germany is in the top 10 countries that devote a large percentage of economic output to research and development. It is also in the top 10 countries who create new innovations. The combination of investment in research, the actual R&D process, and new innovations per capita plants Germany in the top 10 of The Global Technology Index 2015.

Table1: Global ranking of Germany, as based on S&T related indicators.

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	53
2.	Research & development (R&D)[a]	8
3.	Gross expenditure on R&D, % GDP[a]	9
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	2
5.	QS university ranking, average score top 3[a]	11
6.	University/industry research collaboration[a]	8
7.	Capacity for Innovation[b]	5
8.	Company Spending on R&D[b]	4
9.	Availability of Scientists and Engineers[b]	11
10.	Quality of Scientific Research Institutions[b]	11
11.	Publications[c]	4
12.	H-index[a]	3
13.	International Property Rights Index[d]	16
14.	PCT Patents[b]	7

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

Germany has been branded as "Europe's strongest economic and industrial power", considering how much time and effort Germany puts into research, technology, science, and education. Germany also has a history of being scientifically minded. It won the first Nobel Prize in 1901, and before World War II had more Nobel laureates for science than any other country.

Germany has been an academic powerhouse for a long time, and as such education is the backbone of Germany's technological advances. According to The Federal Ministry of Education and Research, "the goal is for good ideas to be translated quickly into innovative products and services. This is because innovative solutions are the factors that drive our prosperity and support our quality of life."
The effective and efficient collaboration between the Public Research institutions and Private Industries as recognized as one of the important factors which contributes to the robust economy and competiveness of Germany. In this Chapter we explore the following Institutions, Schemes and Program promoting Public Private Partnership for Research and Development in Germany.

- Fraunhofer Institutes
- Research Campus
- EXIST
- Industrial Collective Research for SMEs
- Central Innovation Program for SMEs (ZIM)
- Validation of technological and social innovation potential of scientific research VIP+

2. Programs/Schemes/Organizations

2.1. Fraunhofer Society

Background

The Fraunhofer Society of Germany or the Fraunhofer Research Organization was established on March 26th, 1949 in Munich and is presently one of the largest non-profit organizations in Europe. It was founded by representatives from the industry and academia along with the government of Bavaria, and the nascent German Federal Republic. It was a post war (1939-1945) effort to strengthen the faltering German economy through fast translation of basic research conducted in the universities and research organisations through very well organised net working with industries in general and SMEs in particular. The society was named after Joseph Von Fraunhofer (6 March 1787–7 June 1826), who is a world renowned researcher, inventor and entrepreneur. He worked extensively in the area of optics and discovered "Fraunhofer absorption lines" and "Fraunhofer diffraction". He also made major improvements to glass manufacturing processes and transformed it into a profitable venture. The main focus of Fraunhofer Institutes is in developing innovative solutions which provides direct industrial and social benefit.

The Fraunhofer Society currently operates sixty nine (69) Institutes across Germany which works on areas of the engineering and natural sciences. The research portfolio of Fraunhofer cover a broad range of topical issues, which also are in sync with the High-Tech Strategy, including energy and housing, transportation and mobility, resource-efficient manufacturing, information and communication technologies (ICT), protection and security, as well as healthcare, nutrition and environment.

It is widely acknowledged that the Fraunhofer model is contributed greatly towards Germany's competitive advantage as compared to other European nations. It is believed that this model helped Germany to deal with the shocks of the global financial crisis in 2008 in a better manner than other industrialised nations. Presently, Germany out performs the rest of the European countries and the United States in terms of exports and GDP growth. The competitive edge of Germany is often ascribed to its ability to generate highly-skilled work force along with robust system which interfaces academic learning with practical, industrial appropriate skills. Germany's small and medium enterprise (*Mittelstand*) is strenghtened by a network of mutually supporting industrial associations and public research organizations that can address multifaceted technological challenges and disseminate technology through partnership in a time bound manner. The Fraunhofer model plays a pivotal role by supporting these aspects of German competitive strength.

Objectives

The translation of basic research conducted in the universities/research organizations in order to benefit the German industry in general and SMEs in particular is the main mission of Fraunhofer institutions. Therefore, institutes are geared to generate technologies leading to development of products and processes and industries are enabled to conduct experimental test for their innovative equipments and industrial processes on pilot manufacturing lines. In this process, the production of a continous stream of well trained technicians and engineers which can strengthen the industrial sector is also given due importance.

Vision

As formulated in the new Guiding Principles issued in 2016, The vision of Fraunhofer is to be an innovation driver, leading strategic initiatives to master future challenges. Other points addressed in the Guiding Principles include optimizing collaboration with customers and promoting interdisciplinary cooperation between institutes.

One of the policy goals of Fraunhofer Society is to "create dynamic and performance-enhancing networks in the science system." Fraunhofer intends to do so by expanding networking and cooperation academic and non-university research organizations.

On these lines, with the support of a central moderation team, Fraunhofer has established new communication processes and networking instruments to drive forward its innovation initiatives. It includes the creation of "Industrial Data Space e.V.," which is a non-profit association founded in 2016 in which Fraunhofer along with more than 42 members in eight different countries have taken the first decisive step toward shaping tomorrow's digitally connected industry. This is in response to the industry's growing need to secure their data exchange and protect proprietary data sovereignty. This has been taken to another level by launching two related initiatives based on the Industrial Data Space architecture. The Material Data Space helps assure digital sovereignty throughout the supply chain and over the entire product lifecycle and the Medical Data Space provides a secure environment linking medical research to clinical practice.

Table 2: Salient features of the organization

Number of Research Units	**69**
Number of Scientific Staff (Scientist and Engineers)	**24,458**
Annual Research budget	**2.1 billion euros**
Revenue earned through Contract Research	**1.9 billion euros**
Patent applications	**608**
Active patents (Total)	**6752**

Source: Fraunhofer Annual Report, 2016

Funding Sources and Finances

Fraunhofer's funding is derived from various sources, including a) Federal, State, and European Union public funding, b) Contract research fees from industry and public organizations, and c) Intellectual property liscensing.

The Fraunhofer Society generate an annual business volume of nearly €2.1 billion. Of this sum, €1.9 billion is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue derives from contracts with industry and from publicly financed research projects. In consultation with their customers and project partners, the Fraunhofer Institutes develop and optimize processes, products and systems to the point of industrial or commercial maturity. The base funding provided by the German Federal Ministry of Education and Research (BMBF) and the state governments in a ratio of 90:10 covers the remaining 30 percent of Fraunhofer's funding needs. This base funding is utilised principally to finance pre-competitive research in areas of future importance to industry, society and government.

Table 3: Summary of the Fraunhofer-Gesellschaft's business development in 2016

Summary of the Fraunhofer-Gesellschaft's business development in 2016	**Year (2016)**
Business volume in € million	2081
Contract research	1879
Defense research	114
Major infrastructure capital expenditure	88
Breakdown of expenditure in %	
Personnel expense ratio	59
Non-personnel expense ratio	30
Capital expenditure ratio	11
Contract research funding in € million	
Project revenue	1386
Industrial revenue	682
Public-sector revenue[1]	704

Funding requirements	493
Sources of contract research funding in % [2]	
Projects	74
Industry	37
Public sector[1]	37
International revenue in € million[3]	304
Patent applications per year	608
Active patent families[4] **at year end**	6762
Employees at year end	24 458

Source: Fraunhofer Annual Report 2016

1. Public-sector funding includes Germany's federal and state governments, the European Commission and other sources (research grants, other R&D, non-R&D).
2. Funding sources for the operating budget including imputed depreciation of investments (excluding research institutions in the setup phase and change in reserves).
3. Revenue from work with international customers and partners (incl. income generated by international subsidiaries with third parties).
4. Sets of patents taken in various countries to protect a single invention.

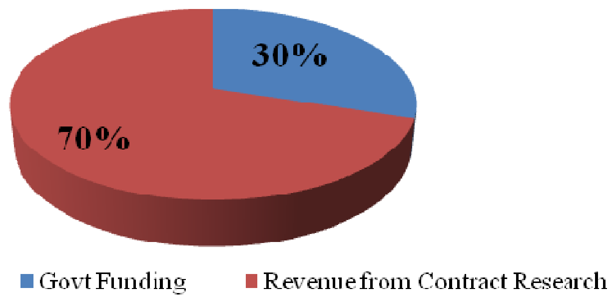


Figure 1: Funding proportion between Government funding and funds from Contract Research

Table 4: Financial Report for Fraunhofer Group (2016)

S.No	Fraunhofer Group Name	Total Expense (€)	Total Income (€)

1.	Fraunhofer ICT Group	257056.9	257057
2.	Fraunhofer Group for Life Sciences	175752.9	175752.9
3.	Fraunhofer Group for Light & Surfaces	156439.9	156440
4.	Fraunhofer Group for Materials and Components – MATERIALS	485435.9	485435.5
5.	Fraunhofer Group for Microelectronics	414094.1	414094.2
6.	Fraunhofer Group for Production	265785.6	265785.4
7.	Fraunhofer Group for Defense and Security VVS	113736.10	113735.9
8.	Other entities, not included in the Fraunhofer Groups	15524.50	15524.5
9.	Centrally managed entities	197436.60	197436.4

Source: Fraunhofer Annual Report 2016
Note: Total Espences= Operating expenses + Capital expenditure; Total Income=From external sources+ Base funding

There are in total 84 companies covering a wide sectoral range where Fraunhofer holds shares. Out of these, Fraunhofer have transferred technologies to 61 companies and the remaining 23 companies hold strategic alliance. During 2016, there was substantial activity in Fraunhofer's investment portfolio and supported 41 new spin-off projects during 2016. Around €1.6 million was used to acquire equity interests in private companies. The Fraunhofer added 7 companies to its investment portfolio and divested its shares in 8 companies. The proceeds from the disposal of equity investments in 2016 amounted to €12.3 million.

Organisational Structure and Governance

Fraunhofer has an Assembly of Members comprising of 1130 members, out of which 213 are ordinary members, 907 are official members, one honorary senator and 10 honorary members (Some members discharge multiple functions). The Assembly of Members elects the senate. A maximum of 18 members are elected from the field of science, business and industry and public life. A total number of 7 members are delegated from Government institutions (4 representing national government institutions and 3 representing the local government). And from the Scientific and Technical Council, three members are further selected.

Among its members, the senate elects a chairman and two deputy chairman subject to a maximum term of three years. An Executive board comprising of 5 Members is selected by the Senate. The Presidential Council consists of the Executive board members and the seven chairs (one each from the seven Fraunhofer groups). The Scientific and Technical Advisory Board has 150 members, out of which 85 are delegated institute managers while 65 are elected representatives from the scientific and technical staff of each institute.

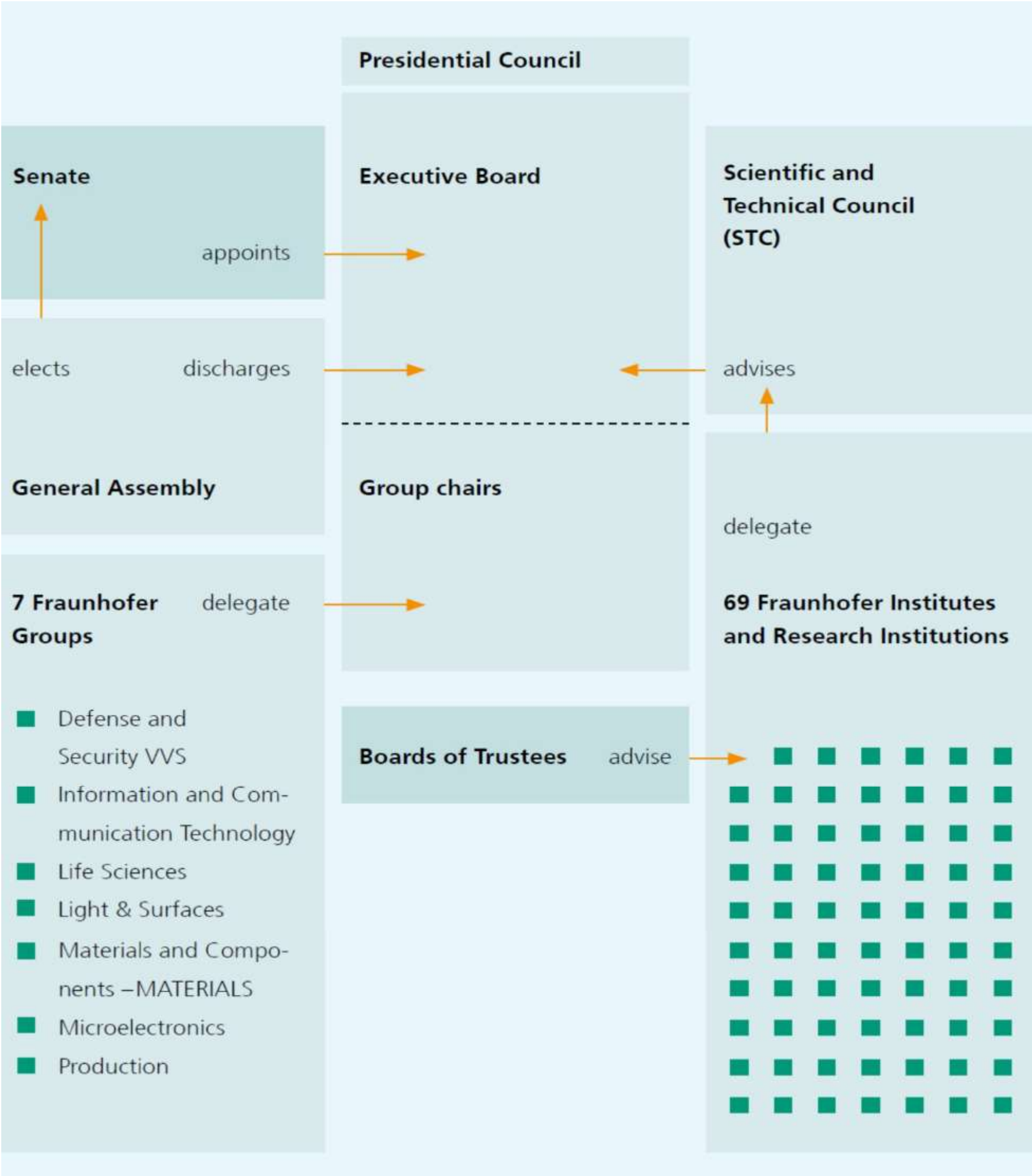


Figure 2: Structure of the Fraunhofer governance model

Source: Fraunhofer Annual Report 2016

The 69 research institutes and units under the Fraunhofer umbrella are advised by the Advisory Boards. The Fraunhofer research institutes are organised under seven major groups i.e., Information and Communication Technology, Defense and Security, Life Sciences, Light and Surfaces, Materials and Component Materials, Microelectronics and Production.

Each research institute under the Fraunhofer society is headed by a Director, preference are given to individuals who combine scientific achievement with entrepreneurial experience. Typically, the Directors serve on boards of directors of German companies. The individual Fraunhofer institutes enjoy the autonomy of determining their internal organizational structure, setting up their own separate profit centers, , and utilise basic funding according to their organisational needs. Each institute is advised by an Advisory Board, which is comprised of representatives from industry, the scientific community, and the public sector.

Fraunhofer undertake quality-assured planning processes in order to synchronize the composition of its broad research portfolio with the dynamically changing conditions of the research market. The market orientation and core competencies of each Fraunhofer Institute is defined by its immediate market environment and networking with the scientific community.

The seven Fraunhofer Groups provide a platform for coordination and networking by bringing together institutes with related areas of expertise. Institutes with complementary domains can come together and form Fraunhofer Alliances, which enables them to develop and market technologies for specific applications on a collaborative basis.

Fraunhofer identifies upcoming business areas and trending innovative technologies with considerable market potential and high social impact. These important lead areas are then persued mainly as in-house research programs conducted by a consortium of institutes which are selected through a competitive process.

Fraunhofer work in close cooperation and coordination with academic institutions/universities and share teaching and training responsibilities, conducts joint contract research and tech transfer. Almost all the directors of the Fraunhofer institutes hold the additional position of a University Chair thus seamlessly contributing towards collaborative research activities and effectively involved in training the future scientific manpower. This is one of the most important feature of the Fraunhofer Model.

Fraunhofer has global outreach though its subsidiaries in Europe, North America and South America and representative offices in Asia and the Middle East. They form a bridge to the world's main regions of current and future economic and scientific growth. Numerous strategic partnerships with organizations of excellence around the world strengthens Fraunhofer's international portfolio.

Table 5: List of Fraunhofer Subsidiaries

S. No	Fraunhofer Subsidiaries	Founded
1	Fraunhofer USA	1994
2	Fraunhofer Sweden	2001
3	Fraunhofer Portugal	2008
4	Fraunhofer Austria	2009
5	Fraunhofer Italia	2009
6	Fraunhofer Chile	2010
7	Frauhofer UK	2012

Source: Fraunhofer Annual Report 2016

To promote scientific excellence, Fraunhofer introduced the use of research performance indicators in 2016. These indicators are specifically adapted to Fraunhofer's mission and the results are analyzed and discussed internally. Communication is also growing in importance as a value creation factor. In 2016, as a means of continuously improving the effectiveness and efficiency of the measures Fraunhofer defined methods for measuring their success together with a set of communication performance indicators aligned to the pre-existing strategic objectives**.**

The prevelance of strategic partnerships in the Fraunhofer institutions with important companies provides momentum to the activities related to contract research. This facilitates the identification of the R&D needs of a company and narrow down on the promising areas of collaborative activities. Subsequently, this structured and coordinated process leads to the formation of a consortium of institutes which can work on the customer-specific R&D project. This targeted approach enables successful business models to be identified and supported at corporate level and thereby benefits the research providers. The provisions of having an "embedded scientist," in which a company deputes a member of its research staff to work at a Fraunhofer Institute on a joint project to analyze the company's R&D requirements is an example of this concept in practice.

The structural growth of Fraunhofer is based on the continuous expansion of the Fraunhofer Institutes through the integration of external research institutions and the creation of new project groups. Generally, project groups are established initially for five years duration. The project groups are evaluated at the end of this period in order to gauge their eligibility for further support in the context of the Fraunhofer funding model. The critical parameter in such an evaluation is whether the entity's competency profile is a strategic fit within the existing R&D portfolio of Fraunhofer. Additionally there must be adequate resources under the Fraunhofer model to cover the project group's medium-term funding requirements including additional base funding. During the year 2016, the following five new projects groups passed this evaluation test:

- The Fraunhofer Project Group for Personalized Tumor Therapy, at Fraunhofer ITEM in Regensburg
- The ATZ Development Center – energy, resources, materials, at Fraunhofer UMSICHT in Sulzbach-Rosenberg
- The Project Group for Processing Technologies in Lightweight Construction, at Fraunhofer IPA in Stuttgart
- Integration of the former German Plastics Institute (DKI) as a new branch of Fraunhofer LBF in Darmstadt
- The Project Group for Components and Systems Design of Electrical Energy Storage Systems, at Fraunhofer IFAM in Oldenburg

Fraunhofer also established two new Fraunhofer Institutes and one new Fraunhofer Research Institution during 2016, all three were initially established as project groups or institute departments which were positively evaluated and earned the stature of independent instituttions.

Following such an evaluation mechanism, the Halle branch of the Fraunhofer Institute for Mechanics of Materials IWM became an independent entity on January 1, 2016, which is later on known as the Fraunhofer Institute for Microstructure of Materials and Systems IMWS based in Halle (Saale). The new institute has already forged numerous Fraunhofer Alliances and is imparting strength to the Fraunhofer Group for Materials and Components – MATERIALS.

The Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV was established in July 2016, with twin sites in Augsburg and Garching. Fraunhofer IGCV was formed by merging the Functional Lightweight Design (FIL) branch of the Fraunhofer Institute for Chemical Technology ICT, the Project Group for Resource-efficient Mechatronic Processing

Machines (RMV), formerly a part of the Fraunhofer Institute for Machine Tools and Forming Technology IWU, and the Working Group on Metal Forming and Casting at the Technical University of Munich (TUM).

The Fraunhofer Institute for Mechatronic Systems Design IEM in Paderborn, founded on January 1, 2017, is a perfect example of the emergence of an institute from a project group. It started out in 2011 as a project group at the Fraunhofer Institute for Production Technology IPT and five years later obtained the status of a Fraunhofer Research Institution. Now, it has been recognized as a full-fledged Fraunhofer Institute.

Fraunhofer Subsidiaries and international units

Fraunhofer manages and operates its R&D activities outside Germany through the intermediary of four international subsidiaries as well as two foundations and one non-profit association, which in turn run their own research units.

Fraunhofer USA: It was established in 1994 and Fraunhofer USA, Inc. is a wholly owned, not-for-profit subsidiary of the Fraunhofer-Gesellschaft headquartered in Plymouth, Michigan. Under the umbrella of Fraunhofer USA, seven Fraunhofer Centers conduct research for public-sector organizations, academic institutions and industrial clients. Based on provisional data of Fraunhofer USA, during 2016, the budgeted expenditure amounted to around €37 million, while its contract research revenue totaled around €19 million. Within US, the Center for Molecular Biotechnology CMB with revenues equivalent to €5 million, was the best-performing Fraunhofer Center in the United States.

Fraunhofer's Austria: Fraunhofer Austria Research GmbH, was initiated during 2009 and headquartered in Vienna. The Fraunhofer-Gesellschaft is the sole owner of this not-for-profit, limited-liability company. It manages the activities of two Fraunhofer Institutes - the Visual Computing unit in Graz and the Production Management and Logistics unit in Vienna. Fraunhofer Austria's total budget in 2016 was €4 million and its contract research revenue reached €2.5 million.

Fraunhofer Italia: During 2009, Fraunhofer founded a not-for-profit subsidiary Fraunhofer Italia Research Konsortial-GmbH with headquarters in Bolzano along with the Trade Association of South Tyrol. The Fraunhofer-Gesellschaft holds 99 percent of the shares in this entity. The Fraunhofer Innovation Engineering Center IEC in Bolzano receives base funding from the Independent Province of Bolzano in South Tyrol. Under the terms of the province's current research funding program for the period from 2015 to 2018, the center can expect a total of around €4.9 million in base funding from this source. Fraunhofer Italia had an operating budget of €1.2 million during 2016, of which approximately €0.5 million was covered by project contract revenue.

Fraunhofer UK: Fraunhofer UK Research Ltd., established in 2012 is a wholly owned subsidiary of the Fraunhofer-Gesellschaft with headquarters in Glasgow, Scotland. It jointly manages the Fraunhofer Centre for Applied Photonics CAP in a collaborative venture between the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg, Germany, and the University of Strathclyde in Glasgow. During 2016, Fraunhofer UK's operating budget amounted to €2.7 million, of which €1.3 million was covered by project revenue from contracts with third parties.

Fraunhofer Chile: Domiciled in Santiago de Chile, the Fundación Fraunhofer Chile Research (a not-for-profit foundation) was set up in 2010 which is wholly owned by the Fraunhofer-Gesellschaft and operates two research centers. Fraunhofer Chile's operating expenditure during 2016 amounted to €5.0 million and revenue from its projects with third parties was just under €0.9 million.

Fraunhofer Portugal: Associação Fraunhofer Portugal Research is a not-for-profit organization which was established during 2008 as a collaborative venture between the German and Portuguese chambers of commerce. The Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions AICOS currently operates under the umbrella of this association. Fraunhofer Portugal generated contract revenues of €1.4 million in 2016 and its total expenditure amounted to €2.7 million.

Fraunhofer Sweden: The Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik was founded in 2001 as a not-for- profit foundation under Swedish law. The Fraunhofer-Gesellschaft and Chalmers University in Gothenburg have equal voting rights on the foundation's board of trustees. The foundation manages the activities of the Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC, which was established in collaboration with the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern, Germany. The subsidiary generated project revenues of €3.5 million from contracts with third parties, and its research budget amounted to €5.0 million.

Fraunhofer has only one subsidiary in Germany i.e., PIA gGmbH. In Germany, a new consumer protection law was introduced that requires insurance service providers to inform clients of the risks associated with their pension plans in a standardized format which facilitates comparison with similar products. PIA was created in 2015 as a not-for-profit limited-liability company with the registered name "Produktinformationsstelle Alters- vorsorge gemeinnützige GmbH", based in Kaiserslautern and wholly owned by the Fraunhofer-Gesellschaft. The purpose of PIA is to serve as an independent evaluator for pension insurance products by providing risk-benefit analysis. PIA works under contract to the German Federal Ministry of Finance (BMF) and generated revenues of €1.0 million in 2016.

Apart from its subsidiaries, the spin-offs created by former Fraunhofer employees constitute major Fraunhofer's equity interests thorugh acquiring a minority shareholdings. Spin-offs also play a very important channel through which Fraunhofer can capitalize on its IP portfolio. During the initial stages of the spin-off companies from the Fraunhofer Institutes, the Fraunhofer Venture department typically provides support to the founders of these companies. Fraunhofer may also opt to sign a technology transfer agreement with the spin-off and capitalize IP by entering into equity sharing mode. The generation of returns from the technology transfer agreements, promotes entrepreneurial thinking and enhances cooperative networks with businesses. Moreover, spin-offs with substantial technological capital benefits the economy through job creation and strengthens industry with their technological edge. During the year 2016, 41 new spin-off projects were supported by Fraunhofer Venture, and 22 new businesses were established as spin-offs Companies.

Under the "FFE – Fraunhofer Fosters Entrepreneurship" program, funds totaling €0.5 million

were granted to ten spin-off projects in 2016. Through another related scheme, the "FFM – Fraunhofer Fosters Management" program, which was designed to hone the management skills of the executives of start up companies, seven startups where Fraunhofer holds equity share were given financial support totaling €0.3 million.

Govt Bodies	Industries	Associations	Research Institutions
NITI (National Institution for Transforming India) Aayog, Govt. of India	Bosch	CII (Confederation of Indian Industries)	TERI (The Energy and Research Institute)
MoHI & PE (Ministry of Heavy Industry and Public Enterprises),	Tata Motors	IWTMA (Indian Wind Turbine	Indian Institute of Technology - Madras

Govt. of India		Manufacturers Association)	(IIT-M)
IREDA (Indian Renewable Energy Development Agency Ltd.), Govt. of India	Pidilite Industries	SIAM (Society of Indian Automobile Manufacturers)	BML (Brij Mohan Lal) University
MNRE (Ministry of New and Renewable Energy), Govt. of India	Wipro Technologies	Charging Interface Initiative e.v (CharIN)	
NISE (National Institute of Solar Energy), Govt. of India	Roland Berger	Bertelsmann Stiftung	
MoUD (Ministry of Urban Development), Govt. of India	Siemens	International Solar Alliance (ISA)	
NIUA (National Institute of Urban Affairs), Govt. of India	Ernst & Young		
NPC (National Productivity Council), Govt. of India	Kirloskar Group		
NSDC (National Skill Development Council of India), Govt. of India			
Coimbatore City Municipal Corporation, Govt. of Tamil Nadu			
Cochin Smart Missions Ltd, Govt. of Kerala			

Source: https://www.fraunhofer.in/en/about-fraunhofer-office-india/engagement-with-india.html

Fraunhofer Representative Office India

The Fraunhofer Representative Office in Bangalore was established in 2012 and officially represents the Fraunhofer in India and actively bridges between Indian customers and Fraunhofer scientists. Fraunhofer works with 30 of the 50 leading companies in India and conducted 1.3 million euros worth of research projects during 2012 (recheck) with various Fraunhofer institutes. IIT Madras and IIT Indore have signed MoU's with Fraunhofer for various collaborative activities.

Intellectual Property Profile

During 2016, the Fraunhofer Society was ranked among the Top 100 Global Innovators. For every working day there were more than three invention disclosures and more than two patent applications. Fraunhofer employees submitted a record 798 invention disclosure reports in 2016, which is the highest annual invention disclosure till date. The total number of newly registered German patents granted to Fraunhofer increased to 3114. The active licensing agreement was raised to 3210 with the addition of 401 new licensing agreements in 2016. Compared with the year 2015, the licensing fee revenue increased by 4% during 2016 reaching €143 million.

The earnings potential of the Intellectual Property (IP) are rigorously evaluated and patents from different institutions are grouped together according to their specific applications. This creates new opportunities for generating income from licensing agreements and R&D projects. In 2016, targeted IP portfolios were clubbed together on thematic areas such as “glass,” “bionics,” “smart home” and “e-health,” each group comprising relevant patent families gathered from the work of multiple institutes.

Fraunhofer has already built up strategic long-term partnership with commercialization partners in the U.S. and Asian markets. During 2016, such partnerships resulted in 2 patent sale agreements, 4 prosecutions for IP law infringements, and 5 licensing agreements. Such partnerships apart from increasing project income, enhances access to local networks, builds on market intelligence and further augments the understanding of national legal systems.

The Fraunhofer Future Foundation is another instrument that promotes the commercialization of Fraunhofer technologies. It identifies crucial in-house research projects with high potential for future market and provides funding for these projects. This approach enables the fast commercialization of the research findings through licensing agreements with high-tech companies. Sometimes, startups are formed specifically for the purpose of technology commercialization.

Table 7: List of Fraunhofer Institutes and their features

S. No	Name of the Institute	Estd.	Location	Core Competencies	Publications (2012-2016)	Patents (2012-2016)
1.	Algorithms and Scientific Computing SCAI Website: https://www.scai.fraunhofer.de/	1992	Sankt Augustin	Computational science, Optimization and bioinformatics, Designs and optimizes industrial applications, Implements custom solutions for production and logistics, Offers calculations on high-performance computers	183	452
2.	Applied and Integrated Security AISEC https://www.aisec.fraunhofer.de/en.html		München/ Garching	Embedded Security, Security Evaluation, Hardware Security, Product protection, Services and application security, Automotive security, Secure software engineering, Industrial security	135	N.A
3.	Communication, Information Processing and Ergonomics FKIE https://www.fkie.fraunhofer.de/	2009	Wachtberg	Command, Control and Reconnaissance *Creating Situational Awareness out of Sensor Data* *Providing Support for Command and Control* Explore command and control systems under information processing, architectural and ergonomic perspectives	809	Not Available (N.A)
4.	Fraunhofer Institute for Applied Information Technology (FIT) http://www.fit.fraunhofer.de/en.html		Sankt Augustin	Communication, Digitization, Information Engineering, Industry 4.0 projects and IoT solutions	210	N.A
5.	Computer Graphics Research IGD https://www.igd.fraunhofer.de/e	1991	Darmstadt	Computer Graphics; Computer Vision; Human Computer Interaction; Interactive Simulation Computer Modelling	449	N.A

	n					
6.	Digital Media Technology IDMT https://www.idmt.fraunhofer.de/en.html	2004	Ilmenau	Audiovisual media Developing groundbreaking technologies for the digital media domain	209	65
7.	Embedded Systems and Communication Technologies ESK https://www.esk.fraunhofer.de/en.html		München	Connected Mobility, Industrial Communication, Smart Grid Communication, Telecommunication	68	3
8.	Experimental Software Engineering IESE https://www.iese.fraunhofer.de/en.html	1996	Kaiserslautern	Scalable System Engineering, Software enabled innovations, High quality complex information system and embedded systems.	304	N.A
9.	Industrial Engineering IAO https://www.iao.fraunhofer.de/lang-en/about-us.html	1981	Stuttgart	Corporate development and wok design, Service and human resource management, Engineering system	241	N.A
10.	Industrial Mathematics ITWM https://www.itwm.fraunhofer.de/en/about-itwm.html	1995	Kaiserslautern	Data Management, Modeling, Simulation, Optimization, Quality Assurance/ Risk Management	391	80
11.	Intelligent Analysis and Information Systems IAIS https://www.iais.fraunhofer.de/en/institute/about-us.html	2006	Sankt Augustin	Big data analytics, Image processing, Entreprise information integration, Intelligent media and learning, Marketing, market research and media analysis, Preventive security, Business modeling and analysis	351	N.A
12.	Medical Image Computing MEVIS https://www.mevis.fraunhofer.d	1995	Bremen	Diagnostic software, Image guided therapies, Clinical trials and pharma, Quantitative pathology	36	6

	e/en/about-mevis.html					
13.	Open Communication Systems FOKUS https://www.fokus.fraunhofer.de/en		Berlin	Smart mobility, Digital public services, Collaborative safety and security, Future applications and media, Software based networks, Quality engineering, Visual computing	352	11
14.	Optronics, System Technologies and Image Exploitation IOSB https://www.iosb.fraunhofer.de/servlet/is/12481/		Karlsruhe	Information management and production control, Interoperability and assistance system, Scene analytics, Systems for measurements, control and diagnosis, Variable image acquisition and processing, Video exploitation system, Visual inspection system, Optronics, Water and mobile systems	701	45
15.	Secure Information Technology SIT https://www.sit.fraunhofer.de/en.html		Darmstadt	Security Evaluation and Verification Security Integration and Advancement Security Management	181	N.A
16.	Software and Systems Engineering ISST https://www.isst.fraunhofer.de/en.html		Dortmund Berlin	Digitization in Logistics Digitization in HealthCare Digitization in Service Industries	31	N.A
17.	Transportation and Infrastructure Systems IVI https://www.ivi.fraunhofer.de/en.html	1998	Dresden	Intelligent Transport Systems Vehicle and Propulsion Technologies Electromobility Energy Systems Civil Protection and Security Process Data Analysis	38	12
18.	Biomedical Engineering IBMT (https://www.ibmt.fraunhofer.d	1991	Sulzbach	Medical Biotechnology Ultrasound Biomedical Engineering	270	37

	e/en.html)					
19.	Cell Therapy and Immunology IZI (https://www.izi.fraunhofer.de/en.html)	2005	Leipzig	Molecular Diagnostics Cell and Gene therapy Drug design and target validation Biosystem Integration and Process Automation Molecular and Cellular Bioanalytics Cell-free and Cell-based Bioproduction	446	195
20.	Interfacial Engineering and Biotechnology IGB (https://www.igb.fraunhofer.de/en.html)	1962	Stuttgart	Interfacial Engineering and Materials Science Molecular Biotechnology Physical Process Technology Environmental Biotechnology and Bioprocess Engineering	288	590
21.	Marine Biotechnology and Cell Technology EMB (https://www.emb.fraunhofer.de/en.html)	2008	Lübeck	Marine Biotechnology Cell Techniques for Prevention & Diagnostics Translational Medicine & Cell Technology Cellular Biotechnology	No data found	14
22.	Molecular Biology and Applied Ecology – Division Applied Ecology IME (https://www.ime.fraunhofer.de/en.html)	2001	Schmallenberg	Functional and applied genomic Industrial Biotechnology Sustainable Agricultural Production Environmental Risk Assessment Biomedical Analytics Predictive Clinical Models	556	127
23.	Process Engineering and Packaging IVV (https://www.ivv.fraunhofer.de/en.html)	1965	Freising	Process Development for Plant Raw Material Food Process Development Product Safety and Analytics Machine and Process Design Process Development for Polymer Recycling	279	N.A
24.	Toxicology and Experimental		Hannover	Drug Development	255	N.A

	Medicine ITEM (Toxicology and Experimental Medicine ITEM)			Chemical Safety and Assessment Translational Biomedical Engineering Personalized Tumor Therapy		
25.	Applied Optics and Precision Engineering IOF (https://www.iof.fraunhofer.de/en.html)	1991	Jena	Optical design, Simulation and analysis Micro and Nano-structuring Optics and Photonics Materials Coating and Surface Functionalization Diamond-Based Ultra-Precision Processing Materials processing using ultrashort laser pulses Micro-Assembly and System Integration Laser Development and Non-Linear Optics Measurement Methods and Characterization	921	456
26.	Organic Electronics, Electron Beam and Plasma Technology FEP (https://www.fep.fraunhofer.de/en.html)	1991	Dresden	Flat and flexible products Coating of metal sheets and strips Electron beam applications Coating of components Precision coating Flexible organic electronics Microdisplays and sensors	67	139
27.	Laser Technology ILT (https://www.ilt.fraunhofer.de/en.html)	1998	Aachen	Lasers and Optics Laser Material Processing Medical Technology and Biophotonics Laser Measurement Technology and EUV Technology	427	203
28.	Material and Beam Technology IWS (https://www.iws.fraunhofer.de/	1991	Dresden	Laser based ablation and cutting Microtechnology-Micro and nano structures Special joining technologies	400	89

	en.html)			Thermal surface technology Additive manufacturing and printing, Chemical surface and reaction technology Competence material characterization and testing		
29.	Physical Measurement Techniques IPM (http://www.ipm.fraunhofer.de/en.html)		Freiburg	Optical systems and imaging procedures for the analysis and modification of 3D structures. Laser scanners, fast image processing and camera systems. New optical and sensor-based measuring systems. Manufacture and optimization of materials with special physical properties	311	27
30.	Surface Engineering and Thin Films IST (https://www.ist.fraunhofer.de/en.html)	1990	Braunschweig	Surface optimization, modification, patterning and coating in the following areas: Mechanical engineering, tools and automotive technology, Aerospace, Energy and electronics, Optics, Life Science and ecology	171	25
31.	Applied Polymer Research IAP (https://www.iap.fraunhofer.de/en/fraunhofer-iap.html)	1991	Potsdam	Biopolymers, Functional polymer systems, Synthesis and polymer technology, Life sciences and bioprocesses	306	137
32.	Building Physics IBP (https://www.ibp.fraunhofer.de/en.html)	1959	Holzkirchen	Acoustics Building Chemistry, Building Biology, Hygiene Energy Efficiency and Indoor Climate Life Cycle Engineering Hygrothermics (interdependence between	190	17

				moisture and temperature)		
33.	Ceramic Technologies and Systems IKTS (https://www.ikts.fraunhofer.de/en.html)	1991	Hermsdorf	Structural Ceramics Environmental and Process Engineering Energy Systems / Bio- and Medical Technology Materials and Process Characterization Electronics and Microsystems	557	231
34.	Chemical Technology ICT (https://www.ict.fraunhofer.de/en.html)	1959	Pfinztal (Berghausen)	Mobile and static energy storage through applied electrochemistry Development, manufacture and application of propellants and explosives Characterization of energetic materials and systems in terms of their properties and effects in defense and civil applications Application-oriented development of plastic components Development of environmentally-friendly synthesis, production and recycling processes Drive systems for future mobility concepts Decentralized and Mobile Energy Technology, Continuous Chemical Process Engineering (Flow Chemistry), Microfluidic Analysis Systems, Medical Sensors and Technical Sensor Systems and Microtechnology for Nanoparticles. Use of fiber composites in lightweight construction, especially in the automotive sector	295	16
35.	High-Speed Dynamics, Ernst-Mach-Institut	1959	Freiburg	Modern protection concepts and new materials are analyzed with regard to high-dynamic	225	N.A

	EMI (https://www.emi.fraunhofer.de/en.html)			loading, sensor systems are developed for their application in ballistics as well as practice-oriented engineering software. Provide safety, efficiency and robustness analyses of technical systems and develop sensor systems for safety and security applications Develop processes of materials and structures to improve the crashworthiness of vehicles Validation of safety of batteries and energy storages for electromobility Ensure safety of space missions Analyze near-earth objects and search for measures to protect planet Earth against their impact Develop hardware and software for CubeSat satellites Characterization, modeling, testing and optimization of aviation-related materials, structures and components, especially in the field of lightweight Aviation design		
36.	Manufacturing Technology and Advanced Materials IFAM (https://www.ifam.fraunhofer.de/en.html)	1974	Bremen	Component manufacture using powder technology Manufacture and optimization of innovative metallic materials with unusual property profiles Joining of substrates using an adhesive to form a material-fit joint by applying adhesive	406	75

				bonding technology Development of a variety of casting processes and materials for different applications Development of electrical components and systems for electromobility Development of Fibre Reinforced Plastics (FRPs) for various application		
37.	Mechanics of Materials IWM (https://www.iwm.fraunhofer.de/en.html)	1971	Freiburg	Multiscale, experimental and computational design of materials for multifunctional tasks Innovative manufacturing processes for precision contours and functional components with defined property profiles Solutions for reducing friction and for abrasion protection for bearings, seals and drive systems Qualification of materials and components for mobility, energy, machinery and engineering Reliable systems for energy conversion and energy storage, material qualification for power plant technology	624	16
38.	Non-Destructive Testing IZFP (https://www.izfp.fraunhofer.de/en.html)	1972	Saarbrücken	Development of Electronic Modules for Intelligent non destructive Testing Development of sensor technologies for condition monitoring, evaluation and life cycle management Developing intelligent testing methods for the determination of materials characteristics Optimizing production processes using non destructive testing technologies	136	68
39.	Silicate Research ISC (server issue)		Würzburg	Development of innovative functional and sustainable materials in the areas of glass, glass ceramics, ceramics, plastics (including	162	105

				inorganic-organic hybrid polymers) as well as on sol-gel and smart materials. Processing technologies for the modification, finishing or functionalization of materials		
40.	Solar Energy Systems ISE (https://www.ise.fraunhofer.de/en.html)	1978	Freiburg	Silicon Photovoltaics Solar thermal technology Building energy technology Hydrogen technologies for energy production	1284	167
41.	Structural Durability and System Reliability LBF (https://www.lbf.fraunhofer.de/en.html)	1962	Darmstadt	Design assessment, dimensioning and service life of components and structures Development of innovative plastic material for varied applications Monitoring and enhancement of the mechanical properties of products with the help of advanced methods of structural dynamics and signal processing, and through integration of novel sensors and actuators functional reliability, availability and maintainability of a complex entity of interconnected technical elements	324	N.A
42.	Systems and Innovation Research ISI (http://www.isi.fraunhofer.de/isi-en/index.php)	1972	Karlsruhe	Analyzes the origins and impacts of innovations Conducts research on the short- and long-term developments of innovation processes and the impacts of new technologies and services Provides recommendations for action and perspectives for key decisions to the industry, politics and science communities.	352	55
43.	Wind Energy and Energy System Technology	2009	Bremerhaven	Offers a unique testing infrastructure, state-of-the-art laboratories and measurement	203	N.A

	IWES (https://www.iwes.fraunhofer.de/en.html)			equipment that allow the systematic identification and reduction of development risks regarding wind energy. Conducts specialist research in the areas of energy management and energy system technology, finding solutions for economic and technical problems relating to the energy transition		
44.	Wood Research, Wilhelm-Klauditz-Institut WKI (https://www.wki.fraunhofer.de/en.html)	1972	Braunschweig	Develop wood-based materials and natural fiber-reinforced composites as well as image-processing procedures for process and quality control Comprehensive measurement and assessment of indoor air pollution and consumer-oriented products Develop eco friendly paints and adhesives on the basis of vegetable oils, sugars, lignin and waste materials. Conduct research projects on the complex themes of formaldehyde testing methods and gluing, bonding and adhesives for products with and from renewable raw materials. The combination of simulation with building-physical and mechanically-constructive investigation methods Development of hybrid fiber composite materials with thermoplastic and thermoset matrix, additive manufacturing, the production and application of technical textiles and the recycling of polymeric composites	129	62
45.	Applied Solid State Physics IAF	1957	Freiburg	Develop transistors, monolithic integrated circuits (ICs) and modules for a broad	651	N.A

	(https://www.iaf.fraunhofer.de/)			spectrum of applications Develop photodetectors and semiconductor laser Development of novel materials to realize new device concepts and to improve and extend current devices such as intentionally doped single-crystalline diamond layers for use in quantum technologies		
46.	Electronic Nano Systems ENAS https://www.enas.fraunhofer.de/en.html)	2008	Chemnitz	Offers research and development as well as services in the following main fields: Smart Systems Integration Micro and Nano Systems Reliability Printed Functionalities Back-End of Line for microelectronics and nanoelectronics D integration	426	55
47.	High Frequency Physics and Radar Techniques FHR (https://www.fhr.fraunhofer.de/en.html)		Wachtberg	Numerical calculation of electromagnetic fields, which forms the basis for the characterization of scattered fields and the design of innovative antennas and antenna arrays Innovative and complex assemblies in the microwave and millimeter wave range Highly complex mathematical operations for	53	N.A

				the processing of single and multi-channel signals for scene reconstruction in the form of position and motion parameters for detected targets or the generation of radar images Development of techniques for the non-cooperative classification of air, sea and land vehicles which are based directly on the measured radar signatures. Radar for Space Observation Satellite orbital mechanics, the space debris situation in near-Earth space, the tasks, modes of action and structure of individual satellites, high-precision orbit determination to estimate collision probability as well as re-entry forecasts		
48.	Integrated Circuits IIS (https://www.iis.fraunhofer.de/en.html)	1985	Erlangen	Advanced audio and video technologies Develops communication solutions for different industries and applications. Non-destructive monitoring along the entire product life cycle, ranging from raw materials via production towards recycling. Develops wireless communication, positioning and identification technologies for connected digital applications in the markets for production, logistics, security, mobility and sport/fitness Smart sensors, integrated circuits and software solutions for a better everyday life Develop suitable smart object technologies such as RFID, wireless sensor networks and real-time positioning and navigation	646	N.A

49.	Microelectronic Circuits and Systems IMS https://www.ims.fraunhofer.de/en.html)	1982	Duisburg	Devices and technologies related to CMOS processes and smart sensor High temperature electronics Biohybrid systems for bio sensors Electronic embedded systems Distribution systems and networks Chip design and fabrication Read our circuits and infrared sensors Pressure sensor systems and medical implants	111	59
50.	Microsystems and Solid State Technologies EMFT (https://www.emft.fraunhofer.de/en.html)		München	Development of molecules and particles with new properties and extended functionalities, and integrating them into various substances. Development of smaller, more efficient and multifunctional sensor systems to enable new areas of application. Developing micropumps for micro dosing systems. Developing foil technologies for designing and building flexible systems Design testing and system integration	87	39
51.	Photonic Microsystems IPMS (https://www.ipms.fraunhofer.de/en.html)		Dresden	Spatial Light Modulators Wireless Microsystems Micro scanning mirror system for reading barcode and data code, highly miniaturized displays, ultra-compact laser projection systems, endoscopic image acquisition as well as triangulation. Environmental Sensing technology for analytics, medical applications and industrial metrology Nanoelectronic technologies Smart Micro-optics	235	626

				Micromachined ultrasonic transducers Developing of new class of electrostatic bending actuators (NED) End-of-Line Standard Substrates for organic electronics		
52.	Reliability and Microintegration IZM (https://www.izm.fraunhofer.de/en.html)	1991	Berlin	Wafer Level System Integration Environmental & Reliability Engineering System Integration & Interconnection Technologies RF & Smart Sensor Systems	425	46
53.	Silicon Technology ISIT (https://www.isit.fraunhofer.de/en.html)	1994	Itzehoe	Special solutions for marine environment using microsensorsystems Advanced device and process development of application-specific power semiconductors (IGBTs, diodes, MOSFETs) Development of optical Microsystems including fast laser scanners, laser beam steering systems, microlenses, wafer-level-micro-optics, beam forming elements, aperture stops, micromirror arrays etc Development of customer-oriented silicon-based microsystems for biosensors in miniaturized and mobile analysis platforms Wearables and Printed Electronics for applications in sports, health and data transfer and analysis systems	76	70
54.	Telecommunications, Heinrich-Hertz-Institut HHI (https://www.hhi.fraunhofer.de/en.html)	2002	Berlin	Photonic Networks and systems Photonic components Fiber optical sensor systems Wireless communications and networks Video coding and analytics Vision and imaging technologies	1019	N.A

55.	Environmental, Safety and Energy Technology UMSICHT (https://www.umsicht.fraunhofer.de/en.html)	1998	Oberhausen	Development of materials of bio-based plastics and recyclate-based plastics. Product and process developments, simulation, production scale-up and additive manufacturing of plastics. Fine and specialty chemicals, polymers, fuels and biofuels Optimization of energy flows, raw material flows and waste streams through sustainability assessments and through optimization of processes and plants Provision of bioenergy and biogas, utilization of residues, nutrient management and recovery as well as decentralized production and marketing of bio-based conversion products (biochar, synthesis gas, and pyrolysis condensate)	162	N.A
56.	Factory Operation and Automation IFF (https://www.iff.fraunhofer.de/en.html)	1991	Magdeburg	Reliable Systems for Efficient and Sustainable Production Resource Efficient Production and Logistics Convergent Infrastructures Digital Engineering and Industry 4.0 Smart Work Systems for future production requirements	146	N.A
57.	Machine Tools and Forming Technology IWU (https://www.iwu.fraunhofer.de/en.html)	1991	Chemnitz	Additive manufacturing Assembly engineering/Robotics Cutting/Removal Determination of characteristic values Forming Industry 4.0 Joining	367	1

				Lightweight construction Machine tool Mechatronics/Adaptronics Medical engineering Micro- and precision manufacturing Production management Simulation Tool and mold making Virtual reality		
58.	Manufacturing Engineering and Automation IPA (https://www.ipa.fraunhofer.de/en.html)	1970	Stuttgart	Covers entire automotive value chain and helps companies to develop and implement comprehensive solutions Adaptive manufacturing and automation solutions based on electronics and Microsystems Developing energy-efficient and attractive solutions for industries.	479	N.A
59.	Material Flow and Logistics IML (http://www.iml.fraunhofer.de/en.html)	1981	Dortmund	Automation and Embedded Systems Enterprise Planning Environment and Resource Logistics Health Care Logistics International Enterprise Development Information Logistics and Decision Support Systems Intralogistics and IT Planning Transport Control Systems Integration of Sensor Systems Procurement & Finance in Supply Chain Management Production Logistics	115	N.A

60.	Production Systems and Design Technology IPK (https://www.ipk.fraunhofer.de/en/homepage/)	1976	Berlin	Managing Enterprises Developing Products Manufacturing Products Joining and Coating Automation Micro Production Quality Control Machine und Plant Maintenance	270	N.A
61.	Production Technology IPT (https://www.ipt.fraunhofer.de/en.html)	1980	Aachen	Process technology for fine machines and optics Production machines for precision technology, plastic replication, fiber-reinforced plastics and laser system technology Production quality and metrology Technology management, forecasting and planning	365	3
62.	International Management and Knowledge Economy (https://www.imw.fraunhofer.de/en.html)		Leipzig	International country, industry and technology comparisons Country- and region-specific status analyses Analysis of the development of specific markets Location and impact analyses market research and benchmarking Projects, studies, strategies on innovation transfer and management, clusters and networks and company development and internationalization Project management Feasibility and foresight studies Developing and implementing strategies in the field of research and development (R&D) Monitoring research institutions, nationally	15	N.A

				and internationally		
63.	Fraunhofer Headquarters Fraunhofer-Gesellschaft (https://www.fraunhofer.de/en.html)		München		N.A	2780
64.	Information Center for Regional Planning and Building Construction https://www.bau.fraunhofer.de/en/fab/IRB.html		Stuttgart	Knowledge and information transfer to all building-relevant target groups Inquiries in professional data bases of the building sector Provision of professional information for education and further training Development and operation of Internet portals Organization and execution of conferences, fairs and workshops Publication and distribution of research results Press and public relations activities concerning the following instruments Newsletter Building Research Press releases on relevant topics and events in expert editorial offices and associations	2	N.A
65.	Integrated Systems and Device Technology (https://www.iisb.fraunhofer.de/)		Erlangen	Developing simulation programs for semiconductor process steps, manufacturing equipment, semiconductor devices, as well as for integrated systems Material research related to semiconductors optical, laser, and scintillator crystals pyro-, and piezoelectric materials battery materials capacitor materials printable electronics	377	40

				Semiconductor technology lines, cleanroom infrastructure, metrology on Si and SiC for custom processes and prototype devices; nanotechniques, particle / thin-film systems Customer-specific active and passive electron devices on silicon and silicon carbide for application in power electronics, microelectronics, and sensors, including novel device concepts New methods and materials for packaging, cooling, lifetime and failure analysis, and reliability, analysis of failure mechanisms after lifetime and reliability tests Efficient, compact, and robust power electronic systems for all kind of vehicles, comprising electric drives, battery systems, and charging infrastructure for electric cars, further applications in aviation and shipping Power electronic systems on all levels of power grid, e.g., electronic components for HV DC transport, local DC micro grids or integration of electrical storages and regenerative sources in the power grid. Monitoring, Coupling and Management of electric and non-electric energies and development of necessary interfaces for implementing a sustainable energy		

				infrastructure, especially for industry-size environments.		
66.	Microstructure of Materials and Systems https://www.iwm.fraunhofer.de/en/press/press-releases/07_10_16_foundationofnewfraunhoferinstituteimws.html	2016	Halle	Research on microelectronics and microsystem technology components Exploring new potential for the use of polymers Development of new materials for applications in medical engineering and biotechnology Develop new materials to make photovoltaics more cost effective, more efficient and more reliable Research on the latest generation of lighting technology and improve the reliability, efficiency and color stability of LEDs.	70	8
67.	Polymeric Materials and Composites- Check it out –not an independent institute?? (https://www.iap.fraunhofer.de/en/research/pyco1.html#tabpanel-3)		Teltow	Thermosets Inorganika Semi-finished Components, Materials, FRP Recycling & Repair Alternative Hardening Methods Displays	11	137
68.	Fraunhofer Institute for Mechatronic Systems Design (https://www.iem.fraunhofer.de/en.html)		Paderborn		31	N.A
69.	Fraunhofer Research Institution for Casting, Composite and Processing Technology		Augsburg	Material and component analysis, prototyping, process chain analysis, technology consulting, and training	1	N.A

	(https://www.igcv.fraunhofer.de/en.html)					
70.	Fraunhofer Application Center Large Structures in Production Technology (https://www.hro.ipa.fraunhofer.de/en.html)		Rostock	Production Technology Automation Technology Quality Technology Company and Production organisation	No data found	N.A

Manpower

Each Fraunhofer institute is paired with a German university and typically utilizes promising students from the universities as part-time researchers. After such exposure the students are well equipped to work in industrial settings and can easily be absorbed in the industrial sector, thereby creating a steady and continual well trained workforce for the industry. R&D activities are conducted by their own professional staff, post-doctoral fellows as well as undergraduate students.

Table 8: Trend of R&D workforce composition (2011-2016)

R&D Workforce	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Trainees	**488**	**470**	**494**	**480**	**452**	**472**
Graduate, undergraduate and school student	**5765**	**6403**	**6694**	**6619**	**6554**	**6654**
Scientific, technical and administrative personnel	**14073**	**15220**	**16048**	**16687**	**17078**	**17332**
Total	**20326**	**22093**	**23236**	**23786**	**24084**	**24458**

Source: Fraunhofer Annual Report, 2015 &2016

Achievements:

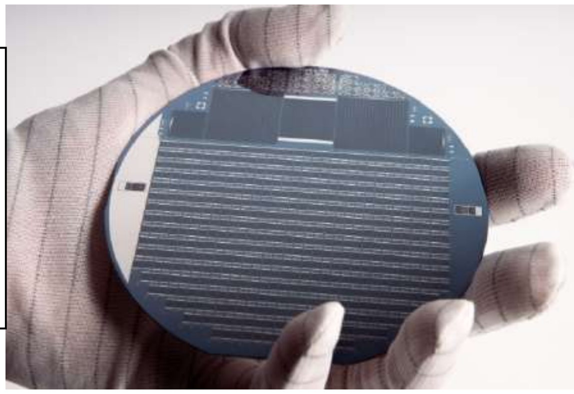
- More than three invention disclosures per working day
- More than two patent applications every working day
- Fraunhofer is among the Top 100 Global Innovators
- In 2016, Fraunhofer was recognized as the top German research organization in terms of number of inventions, patent applications, and ownership of industrial property rights.
- For 10 successive years, Fraunhofer ranked among10 - 20 most prolific patent applicants as per German Patent and Trade Mark Office, and has consistently held positions ranging between 5th and 10th in the register of trademarks.
- According to the European Patent Office (EPO) Fraunhofer was ranked 45th among the most active patent applicants in 2016.

Success Stories

- Developed by Fraunhofer Institute for Integrated Circuits (IIS) in 2000
- The most popular format for audio coding
- Earned a revenue of around €100 million in 2005

III-V Multi-Junction Concentrator Solar Cells

Developed by the Fraunhofer Institute for Solar Energy Systems ISE in 2013



Care-o-bot

Developed by Fraunhofer Institute for Manufacturing Engineering and Automation in 2015

A mobile robot assistant to support humans in their daily life in:

- Hotels
- Home

Struvite fertilizer

Eco-friendly Organic plant fertilizer from Wastewater

Developed by Institute for

E-puzzler

A pattern recognition machine.

Can digitally put together finely shredded paper.

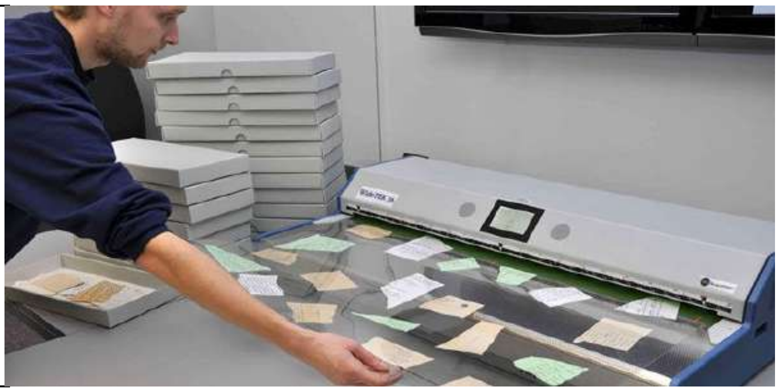
Automatically reconstructs documents

Organic electronics

More Light and Energy from Wafer-thin Molecular Layers.

Using a type of dye commonly used in the production of road signs

Won the German future Prize 2011



IND2UCE – Integrated Distributed Data Usage Control Enforcement

IND2UCE provides Comprehensive security measures to protect business data from undesirable usage

Strengthen trust in modern information technology by ensuring data protection.

Developed by Fraunhofer Institute for Experimental

Artificial Cornea- ArtCornea®

Blindness is often caused by corneal diseases.

Corneal transplant is a solution, but in many cases donor corneas are hard to come by.

Table 9: Current outstanding Innovations arising out of the Fraunhofer Institutions*

S. No	Current Research/Innovations	Institution (s)
Health and Environment		
1	**Personalized Radiotherapy** (https://www.medgadget.com/2016/05/new-real-time-radiotherapy-planning-tool.html) ➢ User friendly planning software ➢ Produce optimal personalized treatment plans to assist radiologist and Oncologist	Fraunhofer Institute for Industrial Mathematics ITWM *in collaboration with* • Massachusetts General Hospital, • Heidelberg University Hospital, • German Cancer Research Centre (DKFZ) and • University Hospital of Munich
2	**Cold Pasteurization** (https://www.igb.fraunhofer.de/en/research/competences/physical-process-technology/aseptic-systems/stabilization-of-foodstuffs-and-plant-based-extracts/pressure-change-technology.html) ➢ Physical process to increase shelf life of liquids without affecting their nutritional properties.	Fraunhofer Institute for interfacial Engineering and Biotechnology, IGB
3	**Shirt with integrated Sensors** (https://www.iis.fraunhofer.de/en/ff/sse/mks/prod/fitnessshirt.html) ➢ Functional clothing equipped with pressure, deformation, temperature and proximity sensors providing vital feedback	Fraunhofer Institute for Silicate research ISC and Fraunhofer Institute for Silicon Technology ISIT
4	**Fertilizers from liquid Effluent** (https://phys.org/news/2016-04-livestock-manure-mineral-fertilizers-soil.html) ➢ Converting agricultural effluent into Ammonium sulphate, phosphate salts and Humus soil improvers	Fraunhofer Institute for interfacial Engineering and Biotechnology IGB
5	**Seaweed powder as salt substitute** (https://www.fraunhofer.de/en/press/research-news/2016/July/seaweed-instead-of-salt.html)	Fraunhofer Institute for Process Engineering and Packaging IVV
Communication and Knowledge		
6	**Worldwide Digital Radio 2** (https://www.fraunhofer.de/en/press/research-news/2016/May/digital-radio-for-th-world.html) ➢ New Digital Radio Standard	Fraunhofer Institute for Integrated Circuits IIS
7	**High performance compact light projectors** (https://www.fraunhofer.de/en/press/research-news/2016/May/little-projectors-that-pack-a-big-punch.html) ➢ Novel design approach for Array projection ➢ Applied in Welcome light carpet ambient light option in BMW and other cars	Fraunhofer institute for Applied Optics
8	**Display and Sensors for data goggles** https://www.fep.fraunhofer.de/en/press_media/Pressemitteilungen2016/15_2016.html?	Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP

	wcmmode=disabled Enable control of the miniature Screen by eye movements	
9	**Virtual reality technology for videoconferencing and movies** (https://www.fraunhofer.de/en/press/research-news/2016/september/beam-me-up-to-the-video-conference.html) ➢ Digital representation of a person using 3D Human body reconstruction technology. ➢ Records three dimensional model of a person from every side including all body movements, typical gestures and facial expressions and digitizes the data for 3D projection.	Fraunhofer Institute for Telecommunications, Heinrich- Hertz –Institute HHI
10	**5G wireless communication standards** (https://www.hhi.fraunhofer.de/en/press-media/news/2016/testing-of-the-next-generation-mobile-wireless-standard-5g-in-berlin.html)	Fraunhofer Institute for Telecommunications, Heinrich- Hertz –Institute HHI, Fraunhofer Institute for Integrated Circuits IIS, Fraunhofer Institute for Applied Solid State Physics IAF, Fraunhofer Institute for Open Communication Systems FOCUS
11	**3D Sound for the Opera 2** (https://www.fraunhofer.de/en/press/research-news/2016/May/3D-sound-for-the-zurich-opera-house.html) ➢ Uses Spatial Sound wave technology ➢ Create 3D sound experience ➢ Simulates any kind of room acoustics	Fraunhofer Institute for Digital Media Technology IDMT
	Protection and Security	
12	**Gas sensitive fire detectors** (https://www.fraunhofer.de/en/press/research-news/2015/september/gas-sensors-sound-the-smoldering-fire-alarm.html) ➢ Gasochromic sensor ➢ First truly viable alternative to conventional gas sensors	Fraunhofer Institute for Physical Measurement Techniques IPM
13	**Detection of safety-critical worker alertness** ➢ Detects physical and psychological warning signs ➢ Stress, overload, fatique, poor concentration and motivation or emotional instability	Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE
14	**Protection against allergies** (https://www.fraunhofer.de/en/press/research-news/2016/september/risks-in-your-food.html) ➢ Precise allergen detecting ➢ Analyzing food allergies ➢ Characterizing allergens ➢ Reducing allergenic potential	Fraunhofer Institute for Process Engineering and Packaging IVV, Fraunhofer Institute for Cell Therapy and Immunology IZI and Fraunhofer Institute for molecular Biology and Applied Ecology IMF
15	**Rapid pathogen detection** (https://www.fraunhofer.de/en/press/research-	Fraunhofer Institute for interfacial Engineering and Biotechnology IGB

	news/2016/July/rapid-test-identifies-disease-pathogens.html) ➢ Rapid pathogen detection similar to pregnancy test	
16	**Biological pest control** (https://www.ime.fraunhofer.de/en/presse_medien/Sterile_insect_techn.html) ➢ Species specific control measures ➢ Environmentally friendly	Fraunhofer Institute for molecular Biology and Applied Ecology IMF
17	**Low Cost, reliable biotesting**	Fraunhofer Institute for molecular Biology and Applied Ecology IMF
	Mobility and Transportation	
18	**Telemetry for the Internet of Things** (https://www.iis.fraunhofer.de/content/dam/iis/en/doc/lv/ok/IoT_Telemetry_Platform_Flyer_en.pdf) ➢ Improves the efficiency of wireless telemetry systems ➢ Through data fragmentation and time-division-multiplexed data stream	Fraunhofer Institute for Integrated Circuits IIS
19	**Pixel headlamps** (https://www.iaf.fraunhofer.de/en/media/press-releases/pixelheadlights.html) ➢ Glare reduction during night driving	Fraunhofer Institute for Reliability and Micro-Integration IZM in collaboration with Infineon, Osram, Hella and Diamler
20	**Better cabin air quality** (https://www.ibp.fraunhofer.de/en/Press/Press_releases/pm_19062017_siae_2017.html) ➢ Prevents dehydration of the mucous membranes of the nose and mouth during air travel ➢ Delivers humidified air at the face level of passengers ➢ Positive impact on passenger’s feeling of well-being	Fraunhofer Institute for building Physics IBP
21	**Mass produced mini- submarine** (https://www.fraunhofer.de/en/press/research-news/2016/February/mass-produced-underwater-vehicles.html) ➢ For Research as well as industrial purposes ➢ Prospecting for oil and gas and other resources and geological ➢ Profiling in preparation for laying underwater cables or installing anchoring systems ➢ Floating structures such as offshore drilling platforms and wind turbines	Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB
22	**Active vibration damping 2** *(www.mdpi.com/2076-0825/5/1/7/pdf)* ➢ A software tool that is capable of damping the	Fraunhofer Institute for Structural Durability and System Reliability LBF

	amplitude of Engine vibrations. ➢ Involves the use of adaptronic systems.	
	Production and Services	
23	**More robots for SMEs** (https://www.ipa.fraunhofer.de/en/press/2016-04-21_Flexible-robot-systems-for-digitalized-production.html) ➢ SMErobotics initiative has developed smart robot systems tailored specifically to the needs of SMEs ➢ Work with and alongside their human colleagues, without the need for a protective barrier. ➢ New intuitive programming techniques and robust, sensor-monitored program execution	EU project Coordinated by the Fraunhofer Institute for Production Engineering and Automation IPA
24	**A machine to harvest cauliflower 2** (https://www.fraunhofer.de/en/press/research-news/2016/May/automatically-harvesting-cauliflower.html) ➢ The VitaPanther machine is set to fully automate the highly selective harvesting of cualiflowers	Fraunhofer Institute for Factory Operation and Automation IFF together with ai-solution GmbH and five other cooperation partners
25	**Cutting costs in turbine manufacturing 1** (https://www.fraunhofer.de/en/press/research-news/2015/august/cutting-costs-in-aircraft-turbine-production.html) ➢ A specially developed software ➢ Ensure economic viability ➢ Users can determine not only the manufacturing costs, but also the primary energy requirement and CO2 balance	Fraunhofer Institute for Production Technology IPT with RWTH Aachen’s Machine Tool Laboratory WZL and EMAG ECM GmbH
	Energy and Raw materials	
26	**Solar cell technology revolution 2 (Joseph von Fraunhofer Prize winner 2016)** (https://www.fraunhofer.de/en/press/research-news/2016/May/changes-in-solar-cell-technology.html) ➢ New generation of highly efficient silicon solar cells ➢ Uses “Laser Fired Contact (LFC)” process ➢ Greater solar cell efficiency and reduced production costs.	Fraunhofer Institute for Solar Energy Systems ISE
27	**Biogas from straw 1 (Awarded German agriculture industry’s 2016 prize)** (https://www.ikts.fraunhofer.de/en/departments/environmental_process_engineering/production_biogas.html) ➢ Heavily compressed straw biogas pellets ➢ Offer an alternative input platform for biogas plants	Fraunhofer Institute for Ceramic Technologies and Systems IKTS
28	**Storing power underwater** (https://www.greentechmedia.com/articles/read/fraunhofer-races-hydrostor-for-underwater-storage)	Fraunhofer Institute for Wind Energy and Energy Systems IWES

	➢ Based on spherical pumped storage plants that use the water pressure at great depths to pump out large hollow containers using excess power, and then harness the high pressure of the water flowing back to generate power when required	

Source: Fraunhofer Annual Report 2016

Conclusion

The Fraunhofer model is probably the world's most studied applied research organization, with many countries examining the feasibility of adopting the model in concordance to their requirement. Its contribution to Germany's continuing strength in "traditional" industries such as automobiles and machinery which have taken a back seat in other developed economies is truly commendable. A study commissioned by the Science and Technology Committee, U.K. House of Commons concluded in 2011 that "the name Fraunhofer resonates across the world and is widely associated with an impressive network of German technology and innovation centres." During 2010, David Willetts, the UK's Minister of State for Universities and Science, commented that "The Fraunhofer Institutes have been a key part of Germany's success in advanced manufacturing and high grade engineering".

However, it is also important to develop a holistic perspective and not to highlight the Fraunhofer model in isolation because many other factors in the German innovation ecosystem and global market forces have contributed to its resounding success. The high demand for capital goods/machinery generated by emerging economies and the ability of the German innovation ecosystem to cater to this demand, competitive currency, continual worker training programs, policies to support the retention of skilled workers during economic downturns, and a dense network of supporting institutions, including financial support from localized banks with long-term relationships with Mittlestand firms contributed greatly to the success of the ***Fraunhofer Model***.

2.1. Research Campus – Public-Private Partnership for Innovation

The German Federal Ministry of Education and Research (BMBF)'s program "Research Campus – Public-Private Partnership for Innovation" supports large-scale and long-term cooperation between science and industry. This funding scheme supports exploratory research related to complex and multi-faceted topics with high research risks and great potential for quantum leap innovations. It covers a broad range of sectors such as energy system, infectious disease diagnosis, materials development and innovative production technologies. Universities, research institutes and companies intent on long term collaborative research are eligible for funding through the "Research Campus" initiative.

Research factories for new technologies

During 2017, there are nine Research campuses spread all over Germany. These nine research campuses provides a single roof under which researchers from universities, research establishments and companies can work together. Some of the research campuses are equipped with special research factories where new technologies and processes can be rigourously tested . This leads to cutting-edge technological solutions for health, mobility and environmental applications.

Table 10: The Nine Research Campuses, Work areas and Location

Research Campus	Research Domain	Location
ARENA 2036	Development of multifunctional composite materials	Stuttgart
Digital Photonic Production	3D printing and construction of composites	Aachen
Electrical Nets of the Future	Direct current voltage for power transmission	Aachen
EUREF	E-mobility and mobility and urban concepts	Berlin
INFECTOGNOSTICS	Efficient and rapid on site proof of Infection agents	Jena
M2OLIE	Medical intervention environment regarding cancer	Mannheim
MODAL AG	Mathematical optimization of complex processes	Berlin
Open Hybrid LabFactory	Hybrid light construction for automobiles	Wolfsburg
STIMULATE	Screening of minimal-invasive methods in medicine	Magdeburg

The joint research and technology transfer approach os actively supported by the fact that all the partners work together in a single location (Research Campus) where they work unitedly for the relaisation of a shared research goal. In this model of collaborative research, future applications are already taken into account when research projects are initially conceived. This expedites the process translating research outputs into innovative products, processes and services. Research campuses also take teaching resposibilities for university students as well as young scientists, and thus contributes to the supply of skilled professionals for the German economy.

The BMBF is supporting the research campuses, which were selected by an independent jury, with up to €2 million per year for a period of up to 15 years. On top of that, partners from science and industry provide a great deal of their own funding for the research campus. Binding agreements govern the cooperation among partners and intellectual property in particular. These agreements are the basis on which the research campuses are founded. They allow the research campuses to develop long-term research agendas and work on sustainable solutions to problems.

i. **ARENA** (**A**ctive **R**esearch **E**nvironment for the **N**ext Generation of **A**utomobiles) **2036**

ARENA2036 is the biggest and the most prominent research platform for mobility in Germany. It was launched during 2013 as a part of the "Research Campus – Public-Private Partnership for Innovation" scheme undertaken by the BMBF. The supervision of ARENA2036 is the responsibility of the lead partner - Project Management Agency Karlsruhe (PTKA). The European Regional Development Fund (ERDF) supported the building of the new research factory itself by providing additional financial resources. The main aim of this initiative isto realize the objective of developing a fully digitized vehicle. This platform gives support to the whole value addition chain right from the initial conceptualization upto the implementation stage. ARENA2036 works at the interface of science and industry and is working as the initiator of sustainable automotive engineering and production for the coming generation of vehicles, whereby mobility based on flexibility is taken as key element.

Figure 3: The agile factory of the future in the ARENA2036 research factory.

Source: ARENA2036

The ARENA2036 research campus works in the flowing four interconnected research areas:

- LeiFu (Intelligent lightweight design with functional integration)
- DigitPro (Digital Prototype – new materials and processes)
- ForschFab (Research Factory – production of the future)
- Khoch3 (Creativity, Cooperation, Competence Transfer)

Based on the main objective of developing mobility solutions for the future, new project proposals are being continuously developed. Various stakeholders from science and industry work closely together under the same roof of ARENA2036. The partners come with different sets of competencies ranging from ergonomics, lightweight construction and production technology. *Such a combination of competencies, disciplines, and perspectives which are pervasively supported by ARENA2036 guarantees the development of innovative project ideas.*

Vision and Mission

ARENA2036 – The Flexible Factory for the Car of the Future

The year 2036 will mark the 150th anniversary of the car and ARENA2036 is an ambitious research program with a long-term goal of bringing forth the future generation of cars by the year 2036. The overarching goal of ARENA2036 "Lightweight design with integrated functionality in the versatile factory of the future – ARENA2036 as the pacemaker for sustainable automotive engineering for the next generation of cars."

Its ambitious vision is composed of the following three strategic goals:

- **Product2036:** Redefining the future car byexpanding the borders of lightweight design based on multi-functionality and new materials.
- **Production2036:** Developing highly efficient and versatile production factory.
- **ARENA2036:** Fostering a novel research environment designed to shape the transformation of technology for mobility.

This innovative approach adopted by ARENA2036 promotes the consolidation of existing competencies in the Stuttgart region regarding lightweight design and production. ARENA2036 will contribute in strengthening Baden-Württemberg's world leading position in the automotive industry in the long run. Over and above the requirement of close link between science and industry, such an approach needs coordinated interaction between lightweight design research and production technologies. The research campus provides such a platform where such interaction and close knitted activity and collaboration can take place.

Scientific Partners

- German Institutes of Textile and Fiber Research Denkendorf (DITF)
- German Aerospace Center (DLR)
- Fraunhofer Society for the Advancement of Applied Research
  - Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)
  - Fraunhofer Institute for Industrial Engineering (IAO)
- **University of Stuttgart (**https://www.uni-stuttgart.de/en/**)**
  - Institute of Aircraft Design (IFB)
  - Institute for Parallel and Distributed Systems (IPVS)
  - Institute for Plastics Technology(IKT)
  - Institute of Textile Technology and Process Engineering (ITFT)
  - Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW)
  - Institute of Human Factors and Technology Management (IAT)
  - Institute for Internal Combustion Engines and Automotive Engineering (IVK)
  - Institute of Electrical Energy Conversion (iew)
  - Institut for Educational Science, Department of Vocational Business and Engineering Education (BWT)
  - Institute of Power Transmission and High Voltage Technology (IEH)
  - *Institut für Polymerchemie* (IPOC)
  - Institute of English Linguistics (IfLA)
  - Institute of Industrial Manufacturing and Management (IFF)

- Institute of Mechanical Handling and Logistics (IFT)
- *Institut für Strahlwerkzeuge* (IFSW)

Industrial Partners

- Altair Engineering GmbH, Unterschleissheim, (http://www.airframer.com/direct_detail.html?company=127598)
- BÄR Automation GmbH, Gemmingen (https://www.baer-automation.de/en/)
- BASF SE (https://www.basf.com/en/company/about-us/sites-and-companies/europa-overview/BASF-in-Germany.html)
- Robert Bosch GmbH, Gerlingen, (https://www.bosch.de/en/)
- Constellium, Landau (http://softalloys.constellium.com/extrusion-plants/landau-germany)
- csi Verwaltungs GmbH
- Daimler AG, Stuttgart, (https://www.daimler.com/en/)
- DXC Technology, Boeblingen (http://www.dxc.technology/)
- DYNAmore – Gesellschaft für FEM Ingenieurdienstleistungen GmbH, Stuttgart, (https://www.dynamore.de/en)
- EWS Weigele GmbH & Co. KG, Uhingen, (http://www.ews-tools.de/en.aspx)
- FARO Europe GmbH & Co. KG, (https://www.faro.com/location/faro-europe-gmbh-co-kg-office-north/)
- Festo Vertrieb GmbH & Co. KG
- Hewlett Packard Enterprise
- KUKA Aktiengesellschaft
- Pilz GmbH & Co. KG
- Plug & Play Germany GmbH
- Research Institute of Automotive Engineering and Vehicle Engines Stuttgart (FKFS)
- SCHUNK GmbH & Co. KG
- Siemens Aktiengesellschaft
- TRUMPF GmbH + Co. KG

ii. Digital Photonic Production

The Digital Photonic Production (DPP) research campus was established during January 2015 at the RWTH Aachen Campus. The main aim of the Digital Photonic Production (DPP) Research Campus is to develop new production methods using light as a tool. The primary focus is on the utilization of high-performance, short-pulse laser technology that can imprint exceptionally fine structures on functional surfaces. Among other various applications, this technique can be used to structure smart phone displays with higher resolution screens. Apart from employing additive manufacturing methods (direct photonic production), the DPP research campus will also conduct research on manufacturing techniques using ultrafast lasers (femto photonic production) as well as new kinds of Vertical Cavity Surface Emitting Laser (VCSEL) beam – for example to selectively functionalize nano-scale layers (nano photonic production). The BMBF intends to fund the DPP research campus to the tune of 2 million euros per year for up to 15 years.

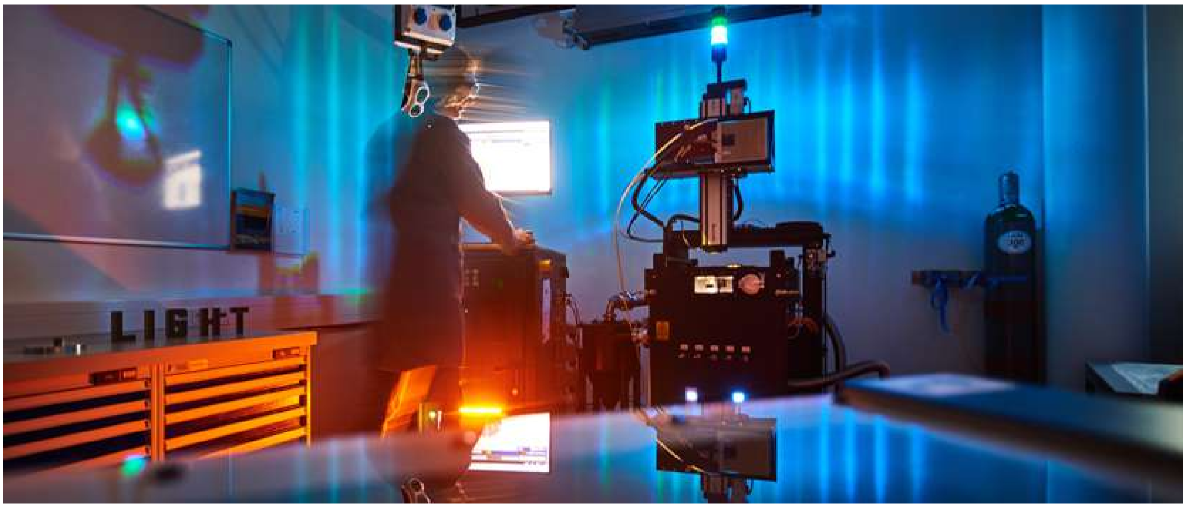


Figure 4: Lightweight construction using light as a tool
Source: Fraunhofer ILT, Aachen / Volker Lannert

A laser beam is the only tool that can execute commands as fast as a computer computes data. The Digital Photonic Production (DPP) Research Campus is developing new methods and fundamental physical effects in order to utilize using light as a production tool. The research campus is gearing up to discover the vast opportunities production technologies based on photons for applications in the areas of mobility, energy, health and information and communication technologies. Some examples for the application of photon based productions include the laser-based manufacturing resource-optimized metallic components from digital data using 3D printers, or the large-scale printing of extremely minute structures on functional surfaces using high-performance short-pulse lasers.

Many constituent institutes of Fraunhofer and RWTH Aachen are working in collaboration with various SMEs, in this research campus. Such close collaboration facilitates sharing of equipment and research facilities risks mitigation along with cross pollination of ideas. RWTH Aachen also provides training to the industrial partners. The industry personel can enter into the initial and continuing training programmes of RWTH Aachen and even earn doctoral level qualifications. The university on the other hand benefits from the application orientation of the industry and their systematic approach toeards innovative.

The New DPP Industry Building on the RWTH's Melaten site which was opened in 2016 is the central building from where the DPP Research Campus operates. The office accommodation and laboratories inside the research campus can be rent out by the partners. The joint laboratory and open-space areas which are designed to encourage free interaction and exchanges between various partnering research members supports the process of invention and innovation.

Scientific Partners

- Access e.V.
- Fraunhofer Society for the Advancement of Applied Research
    - Fraunhofer Institute for Laser Technology (ILT)
    - Fraunhofer Institute for Production Technology (IPT)
- **RWTH Aachen University**
    - Aachen Center for Integrative Lightweight Production (AZL)
    - Chair for Digital Additive Production (DAP)
    - Chair for Laser Technology (LLT)
    - Nonlinear Dynamics of Laser Manufacturing Processes Instruction and Research Department (NLD)
    - Chair for Technology of Optical Systems (TOS)

Industrial Partners

- 4JET Technologies GmbH
- AixPath GmbH
- Aixtooling GmbH
- AMPHOS GmbH

- BMW AG
- EdgeWave GmbH
- EOS GmbH
- Exapt Systemtechnik GmbH
- Fionec GmbH
- Innolite GmbH
- KEX Knowledge Exchange AG
- LighFab GmbH
- ModuleWorks GmbH
- MTU Aero Engines AG
- PHILIPS
- Pulsar Photonic GmbH
- Siemens AG
- SLM Solutions GmbH
- TRUMPF Laser- und Systemtechnik GmbH
- WBA Aachener Werkzeugbau Akademie GmbH

iii. Flexible Electricity Networks

In order to evolve innovative and efficient energy systems based electricity grids for the needs of the future, technologies that are able to handle the large input of energy from renewable and decentralized sources needs to be developed. The Flexible Electricity Networks Research Campus (FEN Research Campus for short) is particularly focused towards achieving this goal and will make far reaching contribution towards a reliable, sustainable and affordable energy supply systems.

The interdisciplinary team working in the FEN Research Campus comprise a number of institutes of RWTH Aachen University, national and international partners from different industrial sectors. The research focuses on the development and integration of technologies related to direct current (DC). The various partners conducts collaborative research on areas such as high-efficient DC-DC converters for the medium voltage distribution grids. The research domains ranges from automation and control, standards and norms, grid planning, cloud platforms for smart energy services, components and power electronics. Apart from scientific and technological issues, the research campus also attend to social issues such as societal acceptance as well as ecological, biological, and economic aspects.

Figure 5: Special computer for real-time grid simulation
Source: E.ON ERC, (c) Peter Winandy

The translation of the research outputs into commercially viable products and services are taken up by the industrial partners. The research campus also takes part in international exchange programmes and conducts various training modules for students at the RWTH Aachen University.

The FEN on the RWTH Aachen University Campus, Melaten, catalyses a rigorous and effective transfer of knowledge among all the involved stakeholders. Moreover, the location of the Research Campus in Aachen which is situated at the border region between Germany, the Netherlands and Belgium is ideal for collaboration among the neighbouring European nations.

Scientific Partners

- **RWTH Aachen University**
  - Institute for Automation of Complex Power Systems (ACS)
  - Institute for Energy Efficient Buildings and Indoor Climate (EBC)
  - Institute for Future Energy Consumer Needs and Behavior (FCN)
  - Institute for Applied Geophysics and Geothermal Energy (GGE)
  - Institute of Power Systems and Power Economics (IAEW)
  - Institute of Industrial Engineering and Ergonomics (IAW)
  - Institute of Electrical Machines (IEM)
  - Institute for High Voltage Technology (IFHT)

    - Institute for Power Electronics and Electrical Drives (ISEA)
    - Institute for Urban and Regional Planning (ISL)
    - Institute of Political Science (IPW)
    - Institute of Landscape Architecture (LA)
    - Institute for Power Generations and Storage Systems (PGS)
    - Text Linguistics and Technical Communication / Human-Computer Interaction Center (TKTK/HCIC)
- **Aachen University Hospital**
    - Institute of Occupational Medicine (IASA)

Industrial Partners

- AixControl GmbH
- ASM Terni S.p.A.
- B.A.U.M. Consult GmbH
- Cryptotec AG
- E.ON SE
- ESA Elektroschaltanlagen Grimma GmbH
- ESKA Erich Schweizer GmbH
- Fuji Electric Europe GmbH
- GE Energy Power Conversion GmbH
- Hager SE
- Hitachi Europe GmbH
- Hyosung Corporation AG
- Infineon Technologies AG/Infineon Technologies Bipolar GmbH & Co. KG
- Mitsubishi Electric Corporation
- MR Maschinenfabrik Reinhausen GmbH
- Murata Manufacturing Co., Ltd.
- National Instruments Germany GmbH
- Phoenix Contact GmbH & Co. KG
- Schaffner Deutschland GmbH
- Siemens AG
- Sprint Capital Japan Ltd.
- Vacuumschmelze GmbH & Co. KG
- Westnetz GmbH

iv. InfectoGnostics

The reliable diagnosis of infectious diseases is the most initial and crucial part of the treatment process. Presently, there is a great emphasis on developing non-invasive, patient-friendly approaches to isolate and identify microbial pathogens. Along with rising antibiotic resistance, developing methods for detecting antimicrobial resistances in order to support the decisions for employing appropriate antibiotic treatment needs to be fast-tracked. The development of novel and rapid tests could support the medical practicioners in the identification and potential drug resistances of the pathogens. InfectoGnostics aims to develop rapid and highly efficient diagnostic methods which will play a major role in overcoming the menancing global threat of antimicrobial resistance.

The InfectoGnostics Research Campus Jena is conducting pioneering research in the field of infectious diseases diagnosis and infection research. It is providing an interacting platform for various research areas such as infection research, molecular biology and microfluidic, optics and photonics in order to rapidly translate such research into application-oriented, patient centered products and processes. Under this platform, the triad of invention, application and production is driving forth mature solutions for rapid and cost-effective point-of-care testing of infections for human and animal diseases.

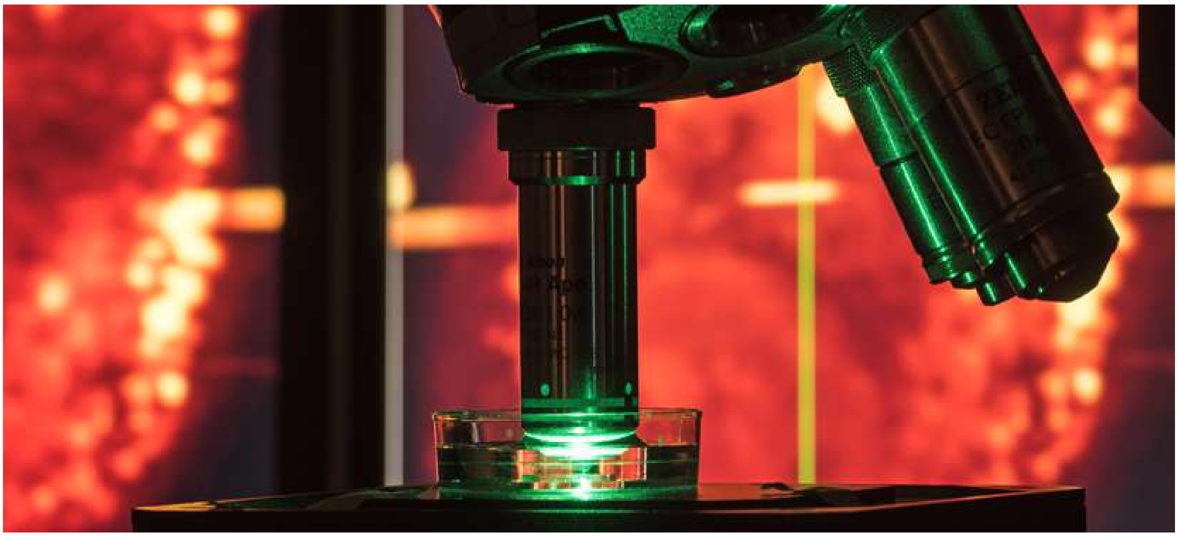


Figure 6: Confocal Raman microscopy is a high-resolution imaging technique: The combination of optical microscopy and Raman spectroscopy enables the examination of pathogens that cause infections of the upper respiratory tract.

Source: InfectoGnostics / European Commission

The InfectoGnostics research campus serves as an incubation platform for new ideas and methods where around 20 different partner institutions work together to develop mature products for patients. The Centre for Applied Research (ZAF) in Jena with over 1,000 square metres of laboratories and offices is the hub of this interdisciplinary cooperation where the researchers from different institutions work and collaborate on a regular basis. The partnership between science and industry is strategically aimed towards setting up a European centre for infection diagnostics which will conduct excellent research and provide advanced training for synergizing basic research, application and translation of technologies.

Scientific/Academic Partners

- Jena University of Applied Sciences (EAH)
- Friedrich Schiller University Jena
    - European Virus Bioinformatics Center (EVBC)
    - Institute of Physical Chemistry
    - Institute of Microbiology
    - Institute of Applied Physics
- Jena University Hospital
    - Center for Sepsis Control and Care (CSCC) Integrated Research and Treatment Center
    - Center for Infectious Diseases and Infection Control
    - Institute of Clinical Chemistry and Laboratory Diagnostics
    - Institute for Biochemistry I
    - Institute of Medical Microbiology
    - Institute of Virology and Antiviral Therapy
- Fraunhofer Institute for Ceramic Technologies and Systems IKTS
- Friedrich-Loeffler-Institut – Federal Research Institute for Animal Health

- Leibniz Institute of Photonic Technology (IPHT)
- Leibniz Institute for Natural Product Research and Infection Biology – Hans Knöll Institute

Industrial Partners

- Alere Technologies GmbH
- Analytik Jena AG
- Biophotonics Diagnostics GmbH
- Blink AG
- Cetoni GmbH
- CiS - Forschungsinstitut für Mikrosensorik GmbH
- GWA – Gesellschaft für Wasser- und Abwasserservice GmbH
- OncGnostics GmbH
- Q.Instruments GmbH
- R-Biopharm AG
- SmartDyeLivery GmbH
- Senova GmbH
- X-Case GmbH

v. M²OLIE

In cancer treatment there is a growing challenge due to the fact that about 20 percent of patients develop a number of metastatic tumors in another organ(s) of their body that are different from the primary tumor. Due to such differences each diffent tumours needs specific and customized treatment. The main aim of the M²OLIE Research Campus is to develop individualized cancer therapies based on innovations in process optimization and automation.

Under this Research Campus, a team involving various partners is developing a one-stop shop that will cover a patient's entire care process (admission, biopsies, diagnosis, treatment, discharge) during a single working day. M²OLIE aims to improve the prognosis of cancer patients through improved and innovative treatment methods.

All together 18 partners are working in the M²OLIE research campus based on multilateral partnership contracts. Out of these, five are from the academic sector and thirteen from the industry sector. The expertise of the industrial companies and the exposure to novel equipment and software benefits the academic partners. On the other hand, the industrial partners gets the opportunity to innovate, enhance, test and validate their products in the context of the research objectives that M²OLIE envisage. The research campus offers young researchers from different disciplines the opportunity to gain initial experience of cooperation with industry and cooperate in a joint research project.

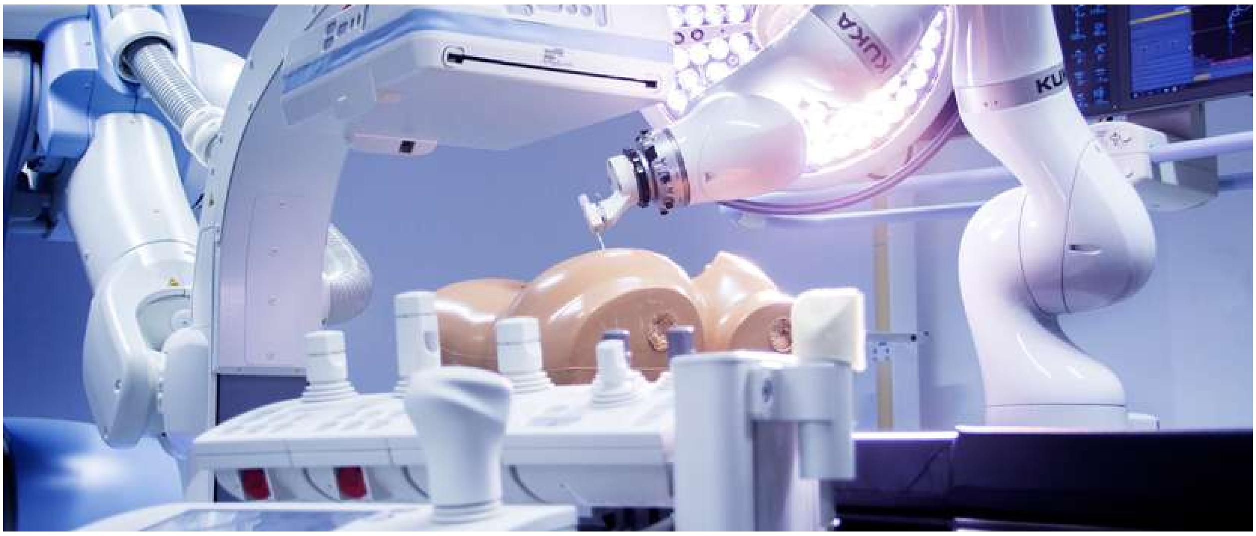


Figure 7: Robot-assisted needle positioning in the molecular intervention room

Source: Forschungscampus M²OLIE

The centrepiece of M²OLIE is the experimental intervention room in the heart of the CUBEX41 medical technology cluster on the site of Mannheim university hospital. This research campus provides an excellent platform for conducting pioneering research and facilitates knowledge transfer by incorporating clinical testing and evaluation in the R&D workflow. It is also working towards the establishment an "intervention room of the future" by involving partners from Germany and abroad.

Scientific/Academic Partners

- German Cancer Research Center (DKFZ)
- Fraunhofer Project Group for Automation in Medicine and Biotechnology (PAMB), Fraunhofer IPA

- Hochschule Mannheim University of Applied Sciences
- Heidelberg University
- University of Mannheim

Industrial Partners

- Bruker BioSpin MRI GmbH
- Carl Zeiss Meditec AG
- INFOMOTION GmbH
- KUKA Roboter GmbH
- Leica Biosystems Nussloch GmbH
- MAQUET GmbH
- Mint Medical GmbH
- Q-bios GmbH
- QIT Systeme GmbH & Co. KG
- RAPID Biomedical GmbH
- Siemens Healthcare GmbH
- ulrich GmbH & Co. KG
- University Medical Centre Mannheim

vi. Mobility2Grid

There is a need to transform the energy generation and transmission system in order to cater to the changing needs. The adoption of demand-based utilization strategies and public acceptance of new technologies are crucial features in the transformation of energy systems. The Mobility2Grid Research Campus is involving public institutions, networks and civil society in order to address the issues of integrating mobility and energy networks by studying the integration of grids, information and transport structures in urban areas.

The Mobility2Grid Research Campus is characterized by the large number of diverse partners from many disciplines. In this campus, 40 different institutions and companies are involved in the Mobility2Grid real-world laboratory on the EUREF site including five faculties of the TU Berlin which cooperate with other research organisations. The industry is also actively involved with large companies as well as SMEs and start-ups actively participating in the research activities. Public institutions including municipal utility companies and umbrella networks are equally involved.

This research campus is exploring technology options in various fields such as virtual power plants or vehicle-to-grid (V2G) energy storage systems for electric vehicles. It has been designed to provide infrastructure and manpower for testing mobility and innovative energy supply technologies. Mobility2Grid also provides a real-world laboratory in which novel energy and mobility systems are tested regarding their suitability for real life applications. The operational and supply safety aspects with regard to both societal processes and commercialization prospects plays an important role in the context of application. Mobility2Grid envisages to contribute towards the successful transformation of the energy system by providing enabling conditions for the use of electric vehicles in both commercial and private contexts by integrating on a grid.

Figure 8: Mobility2Grid's real-world laboratory: ZeeMo.Base innovative electric vehicle charging station.

Source: inno2grid

Scientific Partners

- Fraunhofer Institute for Solar Energy Systems ISE
- FZI Research Center for Information Technology, branch office Berlin
- HTW Berlin University of Applied Sciences
- Technische Universität Berlin

- TU-Campus EUREF gGmbH
- WZB Berlin Social Science Center

Industrial Partners

- BLS - Energieplan GmbH
- BMW Mobility Services
- Cisco Optical GmbH
- Constin GmbH
- DB Energie GmbH
- DB FuhrparkService GmbH
- EICT - European Center for Information and Communication Technologies GmbH
- EUREF Consulting (REM+tec mbH)
- GASAG Contracting
- German e-Cars GmbH
- inno2grid GmbH
- InnoZ - Innovation Centre for Mobility and Societal Change
- KKI - Kompetenzzentrum Kritische Infrastrukturen GmbH
- Lumenaza GmbH
- Messhelden (aventies GmbH)
- MMD Automobile GmbH (Mitsubishi Motors GmbH)
- Schneider Electric GmbH
- Siemens AG
- Stromnetz Berlin GmbH
- Velogikas UG

vii. Mathematical Optimization and Data Analysis Laboratories

The technical and economic processes in the area of energy, health and mobility are becoming more and more complex and thus harder to comprehend and manage. The societal change triggered by the use of novel technologies and services are global challenges and requires new and innovative solutions. The MODAL Research Campus uses mathematical models to address such challenge.

It conducts research on innovative mathematical solutions for devising information extraction processes from big data and to generate realistic models for complex processes. The overall vision is the development of new process optimization and decision support systems for industry and politics. It is laying the foundations for developing new kinds of services based on mathematical modelling.

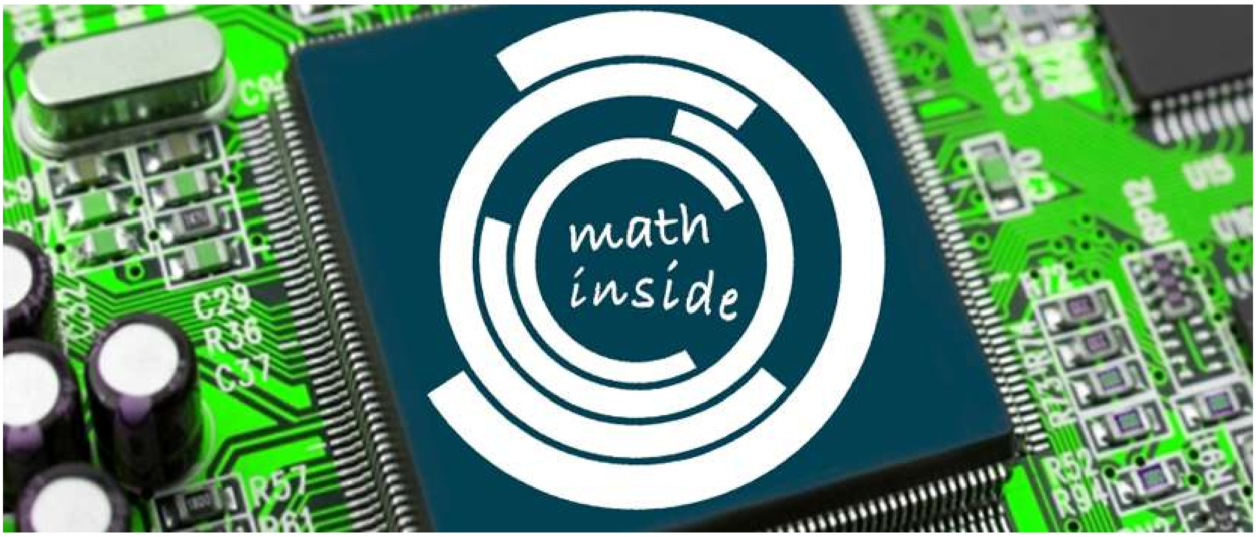


Figure 9:

Source: Zuse Institute Berlin / shutterstock.com

The research campus involves the academia industry partnership, the Zuse Institute Berlin (ZIB) and the Freie Universität Berlin (FUB) represents the academic partners and a broad range of industrial partners particularly many SMEs and some large companies covering various sectors represents the industrial sector. The research campus gives emphasis on providing a good mix of both experienced and early-career researchers and provides all staff the opportunity to learn through its initial and continual training about diverse career paths including academic career, industrial R&D or the establishment of a spin-off company through the entrepreneurial route. Gender equality and internationalization are also important characteristics of this Research Campus. The scientific/academic partners provide their expertise and infrastructure and the industrial partners offer their perspectives as end users of technology and presents genuine user problems and also contributes through data and software licences sharing.
The members from all the diverse partners work under one roof at the ZIB, located on the campus of the FUB in Berlin-Dahlem. The Research campus brings together different ways of thinking and working with the aim of creating an innovative

environment where researchers use the real data provided by the industrial partner and to test solutions through mathematical methods.

Scientific Partners

- FIZ Karlsruhe – Leibniz Institute for Information Infrastructure
- Freie Universität Berlin
- Zuse Institute Berlin (ZIB)

Industrial Partners

- 1000shapes GmbH
- DB Fernverkehr AG
- Dr. Michael Wulkow Computing in Technology GmbH
- Fair Isaac Germany GmbH (FICO)
- GAMS Software GmbH
- Gurobi Optimization GmbH
- inbion GmbH
- Dres. Löbel, Borndörfer & WeiderGbR
- MODAL Mathematische Optimierung und komplexe Datenanalyse AG
- Open Grid Europe GmbH
- SAP Deutschland SE & Co. KG
- Siemens AG
- Visage Imaging GmbH

viii. Open Hybrid LabFactory

The future car manufacturing platforms rests heavily on the lightweight construction model and it can solve many of the issues which are being encountered by the automotive industry. Digital transformation, e-mobility and energy and resource efficiency are some of the important aspects that are being considered crucial to the future automobile industry. The Open Hybrid LabFactory LightweightCampus works on developing novel and innovative lightweighting solutions for coming generations of cars though cooperative approach between various partners. The synchronisheddevelopment of both materials and production technologies for multiple material, for hybrid, lightweight components is the central focus of this research campus. It covers the entire innovation chain starting from conceptualization to the development and production of components to hybrid production processes and recycling technologies.

Figure 10: ENGEL v-duo 3600 injection moulding machine

Source: Volkswagen AG

The steps for production process are managed and coordinated by globally renowned technology companies which are applying their know-how into the research campus. The research conducted in the in the factory is cooperative and interdisciplinary, thereby creating synergies along the entire innovation chain leading to hybrid lightweight car manufacturing. It also provides an enabling atmosphere for academic and industrial research to cooperate on an equal footing under a single roof and thus enhances the overall efficiency to accelerate R&D processes. Young researchers are also provided with skill training and up-gradation through specific classes, internships along with the provision of earning their Bachelor's or Master's degree on the basis of such learning opportunities. The campus also has an internationalization strategy in order to enhance networking with other leading research institutions and industries.

The Open Hybrid LabFactory is situated in Wolfsburg which is the vicinity of Volkswagen's MobileLifeCampus. This Research Campus brings together many scientific and industrial partners as well as many SMEs including Volkswagen, the Automotive Research Centre Niedersachsen (NFF) at TU Braunschweig, BASF, DowAksa, Engel, IAV, Magna, Siempelkamp, ThyssenKrupp, ZwickRoell, various

Fraunhofer institutes, Clausthal University of Technology and Leibniz Universität Hannover.

Scientific Partners

- Cetex Institute
- German Aerospace Center (DLR)
- Fraunhofer Society for the Advancement of Applied Research
- Leibniz Universität Hannover
- Technische Universität Braunschweig
- Clausthal University of Technology

Industrial Partners

- BASF SE
- data M Sheet Metal Solutions GmbH
- DowAksa Advanced Composites Holdings B.V.
- DREISTERN GmbH & Co. KG
- EDAG Engineering GmbH
- Engel Deutschland GmbH
- IAV GmbH
- IFF GmbH
- ifu (Institut für Umweltinformatik) Hamburg GmbH
- INVENT GmbH
- iPoint-systems GmbH
- J. Schmalz GmbH
- KARL MAYER Technische Textilien GmbH
- KWD Automotive
- LSE - Lightweight Structures Engineering GmbH
- Magna International Europe GmbH
- Salzgitter Mannesmann Forschung GmbH
- Siempelkamp Maschinen- und Anlagenbau GmbH
- ThyssenKrupp Steel Europe AG
- Volkswagen AG
- Zwick GmbH & Co. KG

ix. STIMULATE

Presently, there is a huge increase in the prevalence of widespread diseases such as cancer, stroke and heart attack. The *STIMULATE* Research Campus is working on developing innovative image based, minimally invasive and gentle treatment processes and procedures for such diseases. It also aims to control the spirally cost involved in the healthcare system. The project is working on a PPP mode between the Otto-von-Guericke-University Magdeburg, Siemens Healthcare GmbH and the *STIMULATE* Association, which is a association of leading regional and international SMEs. The technologies that being developed in this specialist laboratories will be incorporated in the day-to-day medical and hospital care and eventually even in the patient's own home.

Figure 11: Siemens Artis zeego robot-mounted flat-panel C-arm X-ray system in *STIMULATE*'s angiography laboratory.

Source: Otto von Guericke University Magdeburg

The long-term cooperation between the scientific and industry partners supports broad activities along the entire innovation chain starting from the initial research finding up to the development of a commercial product. The industries benefit from the interactions with the universities, university hospital and the clinicians. It is very successful in the area of minimally invasive instruments, imaging and navigation technology. The pooling of expertise from various fields has a multiplier effect and fortifies the industry in general and SMEs in particular with opportunities to collaborate and penetrate potential markets. The academic/scientific partners in the project gains insights into the technological processes and developmental activities carried on by theindustries and enables them to expand and strengthen the expertise towards medical technology R&D.

Scientific Partners

- Otto von Guericke University Magdeburg
- Leibniz Institute for Neurobiology (LIN) Magdeburg
- Fraunhofer Institute for Factory Operation and Automation IFF
- Fraunhofer Institute for Medical Image Computing MEVIS
- Hannover Medical School (MHH)

Industrial Partners

- ab medica Deutschland GmbH & Co. KG
- ACANDIS GmbH & Co. KG
- ACES Ingenieurgesellschaft mbH
- AD MEDES Schuessler GmbH
- CAScination AG
- Deutsche Akademie für Mikrotherapie e.V.
- ESA Patentverwertungsagentur Sachsen-Anhalt GmbH
- IMTR GmbH
- KUKA Roboter GmbH
- MIPM – Mammendorfer Institut für Physik und Medizin GmbH
- METOP GmbH
- metraTec GmbH
- Metria Innovation, Inc.
- NORAS MRI products GmbH
- phenox GmbH
- Primed Halberstadt Medizintechnik GmbH
- Siemens Healthcare GmbH

2.2. Start-ups from Science - (Existengründungenaus der Wissenschaft – EXIST)

Background

EXIST ((http://www.exist.de/EN/Home/home_node.html)) has been designed to drive the research ecosystem of universities and research institutes towards entrepreneurial activity and to increase the number of knowledge based spin off companies. It is a programme funded by the Federal Ministry of Economics and Energy (BMWi). It was initially established by BMBF but BMWi took responsibility for the program in 2006. The public private collaboration is traditionally strong in Germany in the areas of chemistry and engineering. Many doctoral research in these areas are conducted in close association with industries or within industries. Special programmes to encourage exchange of sceintist between research institutions and industries at state level, with specific focus on SMEs are in place.

The program objectives are:

- Establishment of a lasting "culture of entrepreneurship" at universities and research establishments
- Support consistent transfer of scientific knowledge into commercial output
- Promotion of the enormous potential of business ideas and entrepreneurial personalities at universities and research institutions in a targeted manner
- Enhance the number and the chances of success of innovative business start-ups.

University-based start-ups has the inherent higher potential of creating jobs as compared to other types of business enterprises. In order to capitalize on this potential , EXIST supports the entrepreneurial activities of universities and research institutes. University based start-ups are also important channels for knowledge transfer from scienctific institutions to the industry. The EXIST programme is co- financed by the European Social Fund (ESF) and is a part of the German High-tech Strategy and.

Culture of Entrepreneurship, Business Start-Up Grants and Transfer of Research are the three program lines under the EXIST programmee:

Culture of Entrepreneurship program supports universities in their efforts to establish a start-up oriented and entrepreneurial ecosystem. The programme may be broken down into two phases. The university receives a grant up to €70,000 over a six months period in the first phase and the second project phase, funding can be up to €1m for a 5 years period.

Eligibility Criteria for receiving funding

- Academics and non-university researchers
- Graduates or former research assistants (up to five years after graduation/leaving the institutes)
- Students who have completed at least half of their study at the time of application
- Start-up teams of up to three people. One of the team members can be a person possessing a recognized vocational qualification or who completed university education more than five years ago.

Business Start-Up Grants is meant for supporting the formation of innovation based enterprises from research establishments and universities. The grant is designed to help scientists, university graduates and students develop their ideas into business plans and to further develop their ideas towards commercial products and services. Depending on the educational qualification, the incubatees selected in this scheme receive a grant between €1000 and €3000/month, for a maximum period of 1 year. They also receive funding for coaching worth €5,000, materials and equipment funding worth €10,000 for individual start-ups and €30,000 for group/team start-ups, and, if necessary, child care benefit of €150/month/child. During the pre-start-up period, the university or research institute provides infrastructure along with technical and start-up-related assistance.

Details of the EXIST funding:

Maximum period of funding: one year

Grant based on the highest education qualification obtained:

- Doctorate: € 3,000/month
- Graduates: € 2,500/month
- Non-graduate professionals with a recognized vocational qualification: € 2,000/month
- Undergraduates or students: € 1,000/month
- Extra support for parents: € 150/month/child

Transfer of Research is meant to support high end technology based enterprises in the pre-start-up and the start-up phase. This program is complementary to the broadly targeted EXIST "Business Start-Up Grants" with specific focus on high-tech start-ups. The first funding phase supports university or research institutes research groups which enables them to provide proof of concept and to prepare the start-up for commercial scale up. The funding includes expenses for for up to four members and €60,000 towards materials and equipment. Funding is available for another additional person with managerial skills to become a member of the start-up team after one year. In the pre-start up phase the maximum funding period is 18 months. In the next phase, the high tech companies may receive funding up to €150,000 to further work on the product and reach the prototype stage.

An important corresponding program is the High-tech Start-up fund which invests venture capital in young, high-opportunity technological companies with promising research results. The funding provides technologically oriented companies with start-up capital and ensures the necessary supervision and management support.

Figure 12: Some highlights of the High-Tech Start-Up fund since 2005
Source: https://high-tech-gruenderfonds.de/en/#facts-figures-2

The program targets spin-offs from universities, public research institutions and industry spin-offs. The funding is released through a combination of equity and loan. On an average, start-up projects receive funding of about €0.5m. During the first year, enterprises are exempted from paying interest.

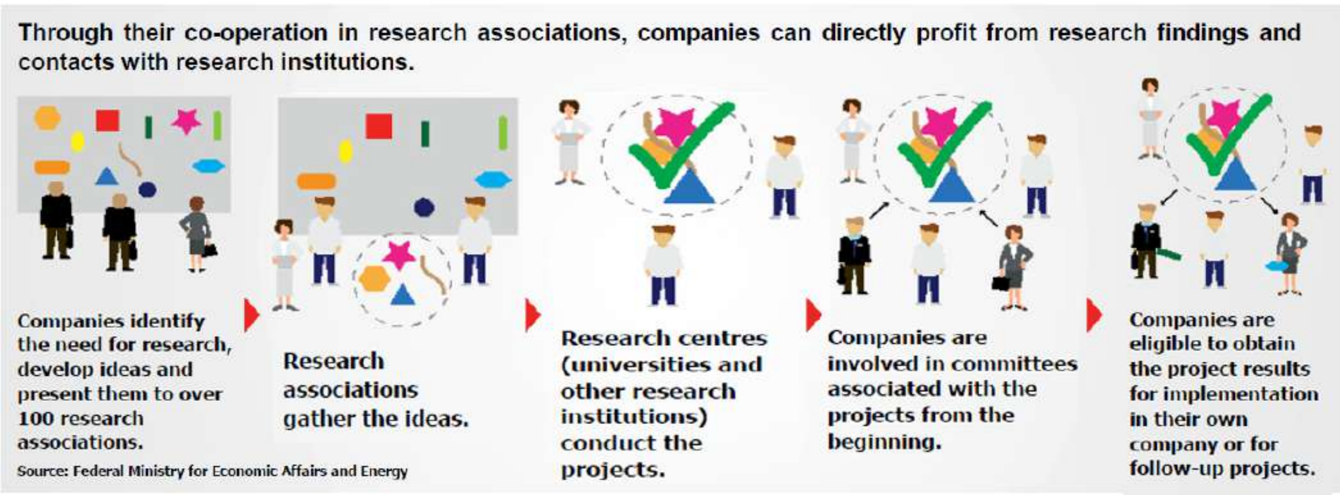
Every high-tech start-ups needs to engage an experienced entrepreneur in the role of coach, without which the equity investment from the fund is not released. The funding was initiated in 2005 and has a total volume of €272 million. The funding is financed from federal government sources and some large German corporates. During October

2011, the second High-Tech Start-Up Fund was introduced with an additional investment volume of €289m.

2.3. Industrial Collective Research for SMEs: Continuous access to new knowledge

The German Federation of Industrial Research (AiF)'s core activity is known as Industrial Collective Research (ICR) which was initiated during 1960. Industrial Collective Research is a mechanism enabling businesses to solve common problems through collective projects. The results emanating from such research are open for all the participating stakeholders and forms the foundation for adaptations based on firms individual needs. Such type of pre-competitive and collective research closes the gap between basic research and industrial application.

Research done prior to product development is essential for small and medium sized enterprises (SMEs) and their capability to deliver the latest state of the art. At the same time, many SMEs are not able to finance this research. This is where the Industrial Collective Research programme comes in.



The research associations under AiF supports the R&D activities of its constituent industries through a holistic approach and specifically assisting SMEs face the issues

arising out of the fast paced technological shifts.

A certain business sector forms a specific research association in the AiF where the industries mostly SMEs, from specific sectors of the economy join forces for collective research . SMEs can directly influence the association's research priorities and agenda through such research association. Industrial Collective Research which is funded by the Federal Ministry for Economic Affairs and Energy, provides SMEs uninterrupted access to new knowledge which can be further utilised for developing products, processes and services as well as opportunity to establish individual networks fro innovation. The funding is awarded in the form of non refundable grants. The funding amount is set at a maximum of 100% of expenses that are eligible for funding. Personnel costs, expenses for equipment and third party services that fulfil the purpose of the grant, etc., are eligible for funding. During 2015, the AiF managed an annual research budget of 525 million euros allocated from public funds for research projects on behalf of SMEs.

It aims to enhance the innovative activities of SMEs by addressing research needs and providing potential solutions on a common platform. Large industrial firms are also strongly involved and also benifit from the collective research of ICR. In the ICR model, public research institutons and universities conducts research on areas which are of direct relevance to the research associations. Individual industrial firms contribute towards such activities by bringing forward ideas, examining ongoing research projects. Further, they also benefit through harnessing the research outcomes towards commercial applications. The Research associations (RAs) undertakes research activities for specific sectors or cross-sectional technologies involving many sectors. The networks formed by such RAs are crucial to the innovation ecosystem of Germany, are deep rooted and effectively results in strong incremental innovation capacity of SMEs. Particularly, in the SME dominated sectors they have emerged as an important source of innovation in the German economy.

The main characteristic of ICR is that it integrates an autonomous, industry sponsored networking association with research funded predominantly by the Federal Government of Germany. This is part of the growing trend in developed market economies where the government emphasizes on fostering collaborations between industries and public research institutions/universities with a clear focus on technology development and innovations. *In the case of ICR, targeted government funds have supported an intermediate platform for supporting collective research at the interface of public research and private industrial firms in many manufacturing sectors, as well as some service sectors.*

Outcome of ICR

Over and above the contribution of ICR towards the development of new products and processes as a short term benefit, it also increased the technological knowledge base of the participating firms in the long term. However such qualitative outcomes cannot be easily assessed (Brooks, 1994; Salter and Martin, 2001; Scott et al., 2001). The long term effect of cumulative technological knowledge involving strategic technological fields cannot be readily assessed on a monetary basis. The table presented below compiles the various outcomes of ICR based on a questionnaire based survey conducted for the period 2003-2005. DOI: http://dx.doi.org/10.1080/13662716.2011.573957

Table 11: Utility of project results in individual firmsa

Aspect	Share in %
Knowledge about technological advances	62.7
Further development of products	59.1
Knowledge about relevant research questions	54.2
Improvement of product quality	47.4
Further development of an existing process	44.4
Knowledge about which paths should not be pursued further	32.7
Implementation of a new process	29.4
Development of a new product	26.6
Translation into standards/norms	18.8
Savings of material resources	16.9
Staff savings	3.6

Source: Business firm survey of RWI/WSF 2009. N = 608.
DOI: http://dx.doi.org/10.1080/13662716.2011.573957
[a] *Share of respondents indicating that one aspect applies (multiple responses possible).*

2.4. Central Innovation Programs for SMEs (ZIM)

Background

The Federal Ministry of Economic Affairs and Energy (BMWi) combined some of the previous programmes(PRO INNO II, NEMO and InnoNet) into a combined support measure: Zentrales Innovations program Mittelstand (ZIM) - the Central Innovation Programme for SMEs (http://www.zim-bmwi.de/zim-overview). The goal of the integration was to increase transparency and to minimise the costs incurred by SMEs in applying for federal funding. The Central Innovation Program was envisaged to support market oreinted technology solutions through R&D for German SMEs. It was also aimed to augment the firm’s innovative capacity and long-term competitiveness. In particular, cooperation between companies and research institutes is encouraged to assist the networking among academia and industrial partners. Such networks lead to effective transfer of know-how, which can subsequently be translated onto innovative products and processes.

ZIM is a funding programme targeted specifically towards SMEs with business activities in Germany, which are inclined to work towards developing novel or radically improve upon products, processes or services. The public and private non-profit research and technology organizations which are co-operation partner of a SME are also eligible for ZIM-funding.

Since 2008, ZIM has been providing reliable support for innovation efforts to SMEs with an overarching aim of increasing innovative capacity and competitiveness of SMEs. This programme also contributes greatly to the economic growth and generation of new jobs. All German SMEs with employee strength upto 499 employees are eligible for funding.

Table 12: Criteria for different types of Company

	Small companies	**Medium-sized Companies**	**Other Medium Sized Companies**
Employees	less than 50	Less than 250	Less than 500
Annual turnover	up to € 10 million	up to € 50 million	up to € 50 million
Annual Balance sheet total	€ 10 million	up to € 43 million	up to € 43 million

Under the ZIM program €380,000 per company is the maximum eligible amount, and in the case of research institute the maximum limit is €190,000 per research institute. The ZIM program has the option for grants to companies and research institutes for undertaking ambitious R&D projects. The funding is not constrained by the field of technology or area of application. However, the level of innovation involved in the application and the market potential of the projected product process or service is crucial for the grant approval.

The ZIM program comprises three schemes:

- ZIM-SOLO – This scheme ismeant for individual firms for thier in-house R&D activities. The funding is generally for the costs of the research projects which may also be extended for external consultation and support on innovation.

Individual projects
R&D projects in individual companies
R&D projects undertaken with the company's own staff, or with support from external service providers and / or external academic partners (R&D contract).
Optionally available for SMEs: services that support the market launch of the results of the funded R&D project

- ZIM-KOOP Scheme – This scheme is meant for the funding of R&D joint projects by two or more industrial firms, or by one industrial firm and one or more research institutes for the development of new products and processes. It needs to be ensured that the partners in this scheme contributes towards the innovations in the project in a balanced manner. Support and consultation services towards the valorization of the research outcomes is also eligible for funding underthis scheme.

Cooperation projects
R&D cooperation projects between at least two companies
R&D cooperation projects between at least one company and at least one research establishment
All of them undertaken with the company's own staff, or by relying on external service providers and /or external academic partners (R&D contract).
Optionally available for SMEs: services that support the market launch of the results of the funded R&D project.

- ZIM-KOOP networks - This program provides funding for R&D as well as for network management of networks that comprise at least six (6) SMEs which jointly develop a common innovation (predecessor programme: ZIM-NEMO).

Table 13: Characteristics of the three Schemes under ZIM

	Individual projects	Cooperation Projects	Cooperation Networks

R&D Funding Category	Funding provided for R&D projects undertaken by individual companies	Funding provided for R&D cooperation projects under taken by several companies or between companies and research institutes	Funding provided for cooperation networks • Network management • R&D cooperation projects • individual R&D projects
Market Launch	SMEs can claim additional funding for services that support the market launch of the project results.		
Application submission to	Project managementEuroNorm GmbH Stralauer Platz 34, 10243 Berlin EuroNorm	Project managementAiF Projekt GmbH Tschaikowskistr. 49 13156 Berlin	Project managementVDI/VDE Innovation + Technik GmbHSteinplatz 1 10623 Berlin

2.5. Validation of the technological and social innovative potential of Scientific research - Validierung des Innovations potenzial swissen schaftlicher Forschung – VIP+

With the new high-tech strategy, a broader concept of innovation has been applied to the promotion of R&D to include technological and social innovations equally. To encourage significant innovation, the bridge between research and the exploitation and application of research findings needs to be further strengthened. For this purpose the innovation potential of research findings needs to be checked at an early stage and if promising, lead to low-risk final development with third party financial participation.

This is the goal of the funding measure "validation of the technological and social innovation potential of scientific research - VIP +" (http://www.bmbf.de/de/2391.php). This program, which started in May 2010, was well received by Germany's research community. Currently, more than 50 projects are already being funded.

This funding measure invites scientists from all disciplines, to develop economic value or social application from their research. It is designed to assist scientists to examine the innovation potential of research findings and evidence as well as to open up potential applications, so creating the conditions for further development of research results into innovative products, processes or services.

The program targets researchers at universities, public research institutions, and federal institutions with R&D activities to test the technical feasibility and the commercial potential of research results, e.g. projects might focus on a proof of concept or proof of technology, on the analysis of the application potential, or opening up of new application areas. Applicants are eligible for up to €0.5 million per year for up to 3 years.

Core elements

- Funding should be oriented towards the early, high risk phase of validation projects.
- Funding is not confined to specific themes and topics should be cross disciplinary.
- Especially those projects should be encouraged that may cause so called jump innovations (excellence approach)

Project requirements

- Projects should build on present research results and develop them further in the direction of application, i.e. adjust or verify its feasibility.
- Projects can be applied alone or in collaboration with several research partners
- Industry collaborations are excluded, but openness in commercialization is required, i.e. projects should be funded in the early stage, in which there is no R&D cooperation with industry and firm formation is planned or implemented.
- The support by innovation mentors, i.e. experts who have experience in innovation processes, is mandatory for all projects.

- Funding is provided for a period of up to three years. The amount of funding per project does not exceed the sum of € 500,000 per project per year (i.e. a total of €1.5 million

The knowledge and technology transfer consists of three phases: (1) identification phase in which promising research results are identified that offer the promise of a significant innovation; (2) validation phase in which the technical feasibility and the commercial potential are identified and proved; the legal and ethical framework as well as the acceptance of the market and society are to be considered; (3) exploitation phase in which the results are transferred into marketable products, processes, or service, directly, or by licensing.

For the identification phase the BMBF relies on existing structures of universities and research institutions. For the exploitation phase federal and state funding programmes are available. The federal government focuses with this program on the validation phase. The programme is embedded in the High-Tech Strategy and supplement activities by thematic programmes.

Criteria for the evaluation of proposals are, among others, the quality of the project, uniqueness of the technology, the utilisation plan for intended results, necessity for the grant, and appropriateness of the financial planning. The funding decision is based on the evaluation of external experts.

Eligible costs include: equipment, labour costs (including overheads), training (including study trips), material costs, travel expenses, and in exceptional cases, project-specific investments. The funding can cover relevant training costs for participating young researchers. There are provisions to cover the costs for IPR protection during the funding period.

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United Kingdom

Contents

1. Introduction

The United Kingdom (UK) is an island nation comprising of the four provinces of England, Scotland, Northern Ireland and Wales. It is located in the northern Atlantic Ocean, and forms a part of the continent of Europe. The UK is a developed country and is primarily a capitalist economy. As per the latest Global Innovation Index (2017), the ranking of UK is 5 out of 137 nations. The major scientific agencies in UK are Innovate UK, Science and Engineering Research Council, Biotechnology and Biological Sciences Research Council, etc. The overall innovation is handled by the Department for Business, Innovation and Skills (BIS) of the UK government. The position of United Kingdom in terms of various global rankings is highlighted in the Table 1.

Table 1: Global rankings of U.K., based on S&T related indicators.

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php;

S. No.	Indicator	Global Rank
1.	Publications[a]	3
2.	H-Index[b]	1
3.	Intellectual Property Rights[c]	13
4.	Expenditure of Education[b]	25
5.	Gross Expenditure on R&D[b] (% of GDP)	21
6.	Research and Development[b]	10
7.	Global R&D Companies, avg. expend. Top 3, mn $US[b]	7
8.	QS University ranking, avg top 3[b]	2
9.	Availability of Scientists and Engineers[d]	17
10.	Capacity for Innovation[d](2017)	11
11.	Quality of scientific research institutions[d] (2017)	2
12.	Company spending on R&D[d]	14
13.	University-industry collaboration in R&D[d]	6
14.	PCT Patents[b]	18

[d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

2. Programs/ Schemes/Organizations

2.1. Catapults Program

Background

Until the beginning of 21st century, innovation in UK was primarily driven by a few public sector bodies, that worked independent of one another. These bodies were:

- **Research Councils** that primarily aimed at supporting academic research, generally with a requirement to address business and societal needs.
- **The Technology Strategy Board** to support technology development and innovation for the benefit of business.
- **Regional Development Agencies** that focused on driving regional economic growth through innovation
- **National Government/Devolved Administrations** that invested or co-invested in innovation to address market failure

- **RTO (Research and Technology Organizations)** that were independent bodies helping businesses to develop new products and processes.

However, there was a lack of mission driven organisations that would work towards the specific aim of bringing together industry and academia, for maximum utilization of the knowledge of the universities and expertise of the businesses.

In order to address this gap, UK government desired for recommendations to bring together the industry and academia (in UK). Consequently, in 2010, Dr.

Dr. Hermann Hauser is a science-based innovator and serial entrepreneur, who has successfully developed and financed over 100 high-tech companies whilst offering inspiration and mentorship to the next generation of entrepreneurs. He has founded and co-founded over 20 technology companies in a wide range of technology industries such as Amadeus Capital

Dr. Hermann Hauser

Partners, Acorn Computers – where he led the development of the BBC Microcomputor, Active Book Company, Virata, Net Products, NetChannel and Cambridge Network Limited. He was also theVice President of Research at Olivetti and during his tenure there, established aglobal network of research laboratories.

Hermann Hauser, an entrepreneur par excellence, submitted a report titled **"The Current and Future Role of Technology and Innovation Centres in the UK",** which identified best practices from around the world and made a robust case for long-term UK investment in a network of technology and innovation centers, which would 'deliver a step change in the UK's ability to commercialize its research'.

The report pointed out to a critical gap between research findings and their subsequent development into commercial propositions that could attract capital investment or be licensed. He also emphasized that making investments for supporting new technologies as well as aligning academia with industry could help diminish this gap.

The report mainly focused on assessing and making recommendations on the UK's approach to a specific component of its innovation system i.e. the role of business-focused Technology and Innovation Centres (TICs). According to the report, these centres could play a key role in enabling better transfer of knowledge, by acting as a bridge between the research base and industry. The report recommended the formation of the TICs (which were later re-named Catapults).

The report defined TICs as organizations focused on the exploiting new technologies, through an infrastructure, which bridges the spectrum of activities between research and technology commercialization. These could be in both established technology areas and in new, emerging technologies.

The report also mentioned about the Technology Readiness Levels (TRLs) - that indicate how ready an innovation is for market use, on a scale, as illustrated in the figure 1 below. The requirement of the TICs, as can be seen from the figure, is at an intermediate level to bridge the gap between university research and industry commercialization.

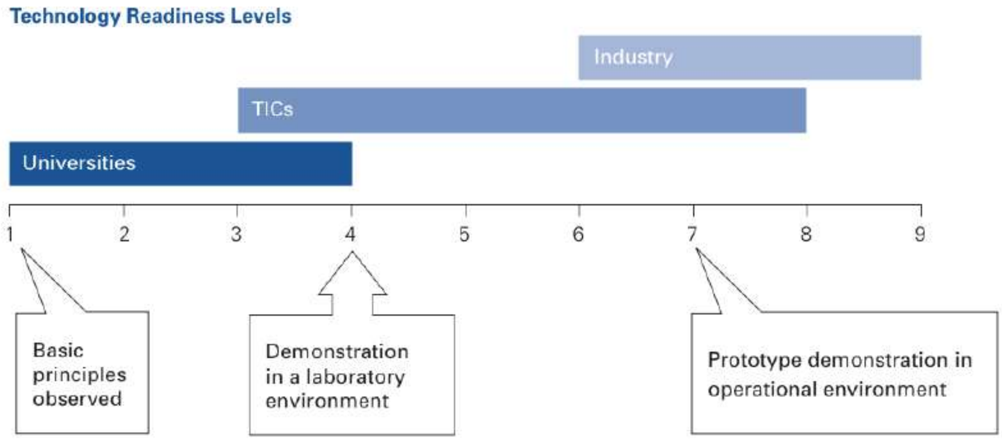

Fig 1: Technology Readiness Levels

Source:https://catapult.org.uk/wp-content/uploads/2016/04/Hauser-Report-of-Technology-and-Innovation-Centres-in-the-UK-2010.pdf

Important recommendations made by the report were:

- Government of UK and the Technology Strategy Board (which is now renamed as 'Innovate UK') should work with stakeholders across the private and public sector and come up with a national strategy for the TICs.
- When establishing new TICs, or enhancing and building upon existing TICs, while deciding their location, their national nature, track record, the location of UK research excellence (in universities and elsewhere), alongside industrial capability should be taken into consideration.
- Successful international PPP models should be well studied before designing a model for TICs in UK, like the Fraunhofer-Gesellschaft model, and the funding should be such that it should incentivize the TICs to link with and draw upon the outputs of the research base and other TICs.
- A business led steering group, comprising of industry and academic experts in the technology should monitor and oversee the activities in such TICs.
- The government, together with the Technology Strategy Board, should also create a web-based database of TICs and related organizations that offer services to industry. This could be available through websites that are easily accessible to all public sector and private sector industrial groups.

Based on the above recommendations, the Government of UK established the Catapult Centres, with the following objectives:

Objectives

- Main aim: To foster innovation and drive economic growth in UK
- To bridge the 'Valley of Death', which is commonly the name given to the gap between early stage publicly funded basic research and privately funded research at the latter end of commercialization.
- To harness British innovation and boost productivity, by commercializing research.
- To foster collaboration within and between organizations and sectors.
- To develop skills, help stimulate productivity, growth and jobs, and deliver economic value.
- To incentivize wider adpotion of enabling technologies such as Artificial Intelligence, biotechnology and robotics.

The establishment of Catapult Centres along with other programs such as Knowledge Transfer Partnerships, N8-Industry Innovation Forum, Higher Education Innovation Fund, etc. and a re-look at the S&T policies has placed UK as one of the leading R&D driven economies of the world (Table 1).

Funding Model

The source of funds is from both the companies and the government of UK. The UK government provides the core funds through 'Innovate UK'. There are variations in the model of funding throughout the life of any Catapult centre, but the general funding model is "the one-third, one-third, one-third model" (Fig 2), where the funds are contributed in a more-or-less equal proportion from three sources that are:

- business-funded R&D contracts, won competitively
- collaborative applied R&D projects, funded jointly by the public and private sectors, also won competitively
- core public funding for long-term investment in infrastructure, expertise and skills development.

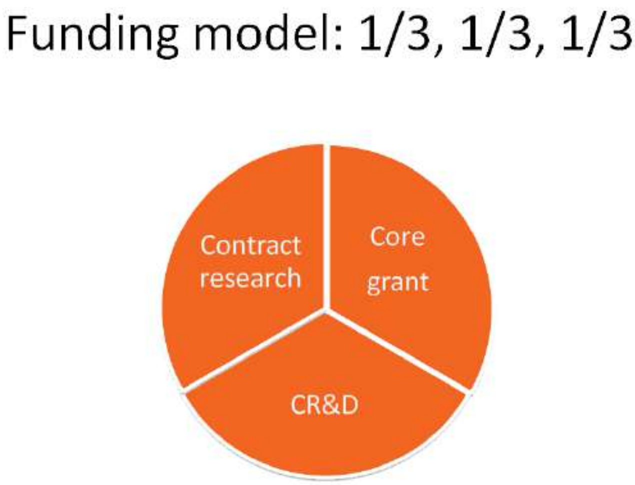

Figure 2: Funding model

Source: https://catapult.org.uk/wp-content/uploads/2016/03/Funding-model.jpg

<u>Types of Catapults</u>

Table 2: Catapult centres and their objectives

Type of Centre (No.)	**Established in**	**Objective**
High Value Manufacturing (7)	2011	To boost manufacturing capability of UK, by strengthening technology innovation
Cell & Gene Therapy (2)	2012	To improve the cell & gene therapy industry by closing the gap between scientific research and commercialization
Digital (1)	2013	To promote data sharing among organisations and on the internet sources in a secure and trusted manner and strengthening practical application of digital technology
Future Cities (1)	2013	To address the issues faced by the cities- (current and in the future), by promoting innovation and bringing companies, universities and city officers together
Offshore Renewable Energy (3)	2013	To meet around 35% of UK's electricity demand from offshore renewable energy by the year 2030
Satellite Applications (1)	2013	To speed up the growth of UK space sector by making space technology more accessible and relevant

Transport Systems (1)	2013	To deal with the emerging transport challenges by using new technologies and innovative solutions
Energy systems (1)	2015	To create a secure, affordable and sustainable energy system for the UK, by supporting research and testing of new energy products and processes
Medicines Discovery (1)	2016	To promote UK industries to develop their commercial medicines discovery capability and to improve productivity in drug development
Compound Semiconductor Applications (1)	2017	To support innovation in compound semiconductors and accelerate their use in healthcare, digital economy, energy, transport, defence and security
Precision Medicine (1)	2015	To identify and resolve barriers in building a leading UK precision medicine industry, by collaborating with national and global stakeholders

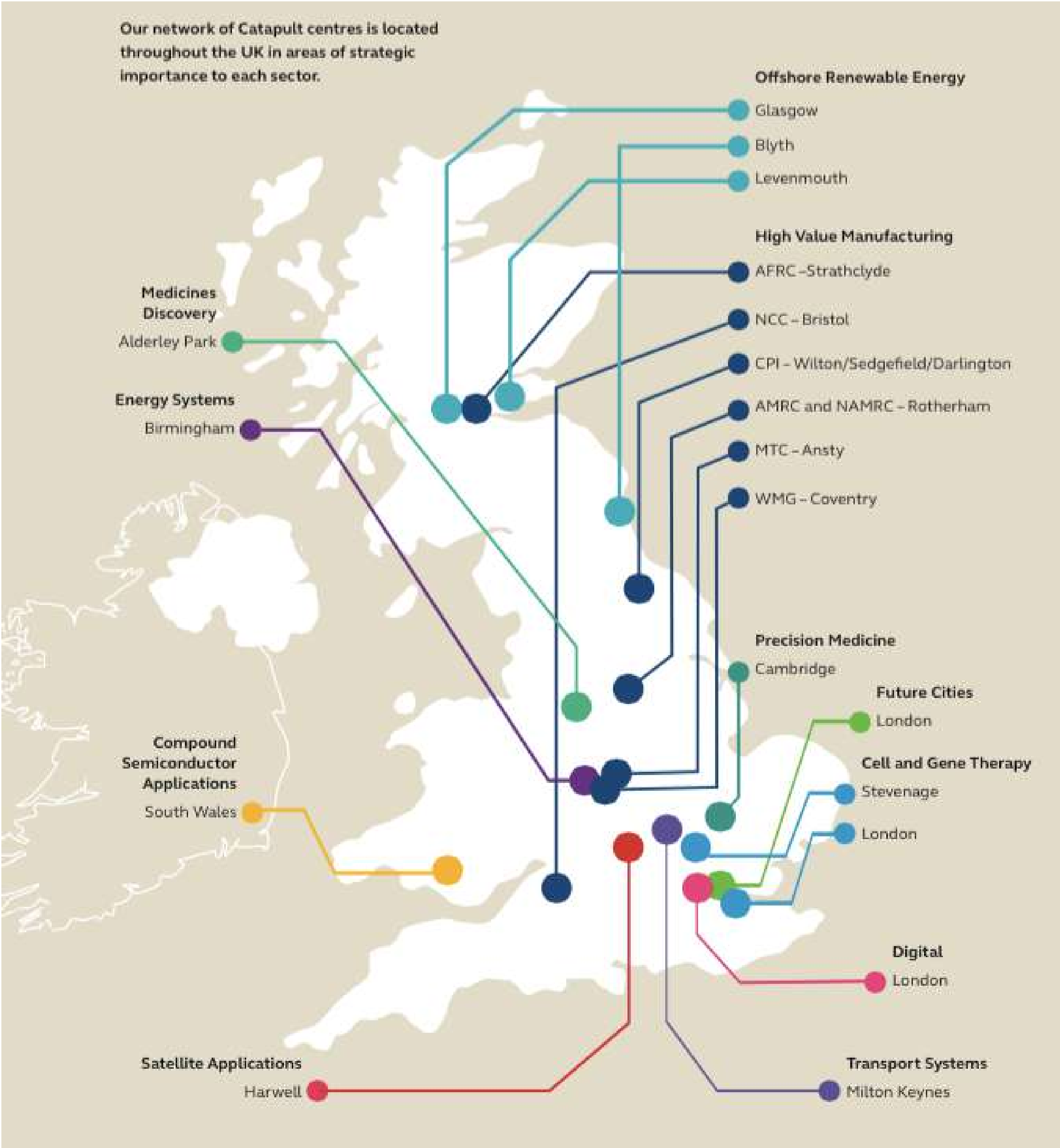

Figure 3: Catapult Centres across UK

Source: https://catapult.org.uk/wp-content/uploads/2016/04/How-Catapults-can-help-your-business-innovate-2016.pdf

Achievements (till 2015-16)

- Delivered 636 academic collaborations
- Supported 2851 Small and Medium Enterprises (SMEs)
- Delivered 2473 industry collaborations
- Worked across 24 countries around the world
- Operating 850 million pounds of open access research and demonstration facilities for the benefit of UK industry and academia

- Trained 900 apprentices in the year 2016
- Supported 1 billion pounds valuation of Virtual Reality(VR) companies
- Engaged with 4700 fast growing technology businesses in just 1 year

Intellectual Property (IP)

The management of the intellectual property (IP) by the Catapults is done in such a way that collaborations between the industry and academia are encouraged and at the same time, there is full utilization of the IP. The IP agreements are such that there is no deviation from the main aim of the Catapults. Also, there is enough room for flexibility and changes in the IP rules, depending on the requirements of the various partners and circumstances.

The following general rules are followed while dealing with the IP rights for various projects undertaken by the Catapults:

1. For work done exclusively under core funding by Innovate UK:
    - The Catapults will seek wherever possible to make Intellectual Property Rights (IPRs) available to business through appropriate licensing, spin out or other arrangements.
    - Centres will also adopt a transparent and open model to incorporate underpinning IP from the knowledge base promoting collaborative behaviours.

2. For jointly funded collaborative work (business and the public sector):
    - Centres will follow existing regimes for publicly funded collaborative research (for all partners to agree appropriate arrangements to share the rights to exploit IP created)
    - Centres will also safeguard any IP that customers bring into the centre as part of a project (customers background IP).

3. For R&D contracted with business(es):
    - The IP rights would be determined by the contract, and would depend on the contracting business to a large extent.
    - The Catapult must also protect any IP that customers bring into the centre as part of a project (customers background IP).
    - IP arrangements with the customer must not inhibit future use of the centre’s background IP (e.g. for other customers).

Governance

Each of the eleven Catapult centres is a company limited by guarantee (CLG), a separate legal entity from Innovate UK. They are controlled by their own Boards with an Executive Management team responsible for the day-to-day management of each Catapult.

i. High Value Manufacturing (HVM) Catapult

https://hvm.catapult.org.uk

The main aim of the HVM catapult is to bridge the gap between the basic experimental research taking place in universities and application of that research for commercial gains by the businesses. The vision of HVM Catapults, as presented in the HVM business plan for the coming years, in the short term as well as the long term is:

- *Economic development* of UK to be promoted by the activities of the HVM Catapults.
- HVM Catapults to boost *manufacturing* such that its contribution to the GDP of UK becomes 25 percent.
- Higher and greater focus on *skills and training* in the area of technology and engineering in the UK.
- Boost in the *employment levels* in the sector of manufacturing, by increasing the scale of manufacturing.
- Promote more and more *foreign investments* in the HVM Catapult.

Governance

- Supervisory Board: It comprises of leading academicians, industrialists and experts. The Board is the main oversight body that provides the strategic direction to the HVM Catapult and drafts the delivery plan.
- Management Board: It is responsible for the management and carrying out of the Delivery Plan along with reporting of deliverables and outputs to meet the requirements of HVM Catapult investments. The Management Board is chaired by the CEO of the HVM Catapult, and consists of the leaders from each of the Centres that are members of HVM Catapult. The management board also has a Finance Director and a Chief Technical Officer.

➢ Executive Team: It works with the individual Centres of Catapults to develop HVM Catapult's 'Strategy for Growth' and 'Delivery Plan'. It conducts stakeholder management, funding planning and communications for the Catapult, facilitates cross- centre collaborations and provides a first point of contact for those who want to understand more about HVM Catapult and what it might offer them.

Status of funding and finance

Table 3: Funding of HVMs over the years

Sources	**Targets**	**Actual funding**		
		2014-15	**2015-16**	**2016-17 (£218 m)**
Core Public Funding	33 %	£28.8 m (19%)	£55 m (30%)	£72.9 m (33%)
Competitively won collaborative R&D	33 %	£51.7 m (33%)	£57.7 m (31%)	£67.3 m (31%)
Commercial income	33 %	£75 m (48%)	£71.6 m (39%)	£77.6 m (36%)

Impacts and Achievements

According to Warwick Economics and Development (WECD) Report titled "*High Value Manufacturing Catapult- Pathways to Impact*" (2015) every £1 of core funding in HVM, generated around £15 of net benefits to the economy of UK. Other achievements are mentioned in Table 4.

Table 4: Achievements of HVM Catapult

Content	**2014-15**	**2015-16**	**2016-17**
Total value of assets	£ 474 m	£ 561 m	£ 617 m
Total number of employees	1577	1913	2114
Size of order book*	£ 183 m	£ 188 m	£ 205
Size of order book (for collaborative R&D)	66% of £ 183 m	£ 100 m	£ 137 m
Number of private sector clients	1514	3036	3387
Number of private sector SME clients	629	1701	1383

** - Order book is a book in which orders are entered as they are received by a business, hence it is regarded as a measure of the organization's success.*

- Number of private sector projects undertaken (2016-17) – 1730
- Total investment in large capital projects (2016-17) – £ 52 million
- Total numbers of projects undertaken (2015-16) – 1878
- Total investment in large capital projects (2014-15) - £ 69.4 million
- Total number of projects undertaken (2014-15) - 1259

Centres of HVM Catapults

There are 7 HVM Catapult Centres in UK, located at different places (Table 5).

Table 5: HVM Centres

HVM Centres	Location& year of launch	Objectives	Key competencies
1. Advanced Forming Research Centre (AFRC) (https://www.strath.ac.uk/research/advancedformingresearchcentre/)	University of Strathclyde, Glasgow (2009)	Metal formation and forging of technologies for designing and advanced manufacture of products	• Billet forging • Sheet forming • Precision forging
2. Advanced Manufacturing Research Centre (AMRC) (http://www.amrc.co.uk)	University of Sheffield, Catcliffe (2009)	Advanced machining and materials for manufacturing and other high value manufacturing sectors	• Machining • Materials and component testing • Assembly
3. Centre for Process Information (CPI) (https://www.uk-cpi.com)	Wilton Centre, Wilton, Redcar (2004)	Develop and commercialize next generation of products, processes and services	• Printable electronics • Chemical processing • Biotechnology
4. Manufacturing Technology Centre (MTC) (http://www.the-mtc.org)	Ansty Park, Coventry (2011)	To raise the UK's competitive advantage by validating and implementing concepts identified from primary research	• Intelligent automation • Electronics assembly • Joining • Process modelling
5. National Composites Centre (NCC) (http://nccuk.com)	Fenyman Way Central Bristol & Bath Science Park, Bristol (2009)	To evolve and mature emerging composite manufacturing technologies from the laboratory through to commercial maturity	• Composite design and manufacture

6. Nuclear Advanced Manufacturing Research Centre (NAMRC) (http://namrc.co.uk)	University of Sheffield, Catcliffe (2012)	To work with companies to ehance their abilities for manufacturing in nuclear and other innovative energy sectors	• Fabrication of civil nuclear components
7.WMG (https://www2.warwick.ac.uk/fac/sci/wmg/research/hvmcatapult/)	University of Warwick, Coventry (1980)	To work with businesses to overcome the challenges associated with low carbon mobility	• Energy storage and management • Digital verification and validation • Lightweight product systems optimization

Successful examples

a) **Advanced Forming Research Centre (AFRC) - Haven**

AFRC helped a private company based in Scotland-Haven(http://www.havenproducts.co.uk) to expand its business, by providing help based on advanced technology.

Haven is a social enterprise that provides employment opportunities to the disabled and deprived people. It is also a commercial business set up that provides various services ranging from making designs to textile manufacturing to printing and mailing solutions.

One of such services that Haven provided was the laser etching of wooden whiskey boxes for a spirits company based in Scotland. However, Haven did not have the technology for the same, and outsourced the work to China. This lead to delay in the service provided. That is where the AFRC steps in.

Fig 4: Epilog Laser Fusion Etcher

Source: http://www.engravingsolutions.com/epiloglaser/fusion-m2-40.html

AFRC used Epilog Laser Fusion Etcher to show how the laser etching could be performed on the wooden boxes. More than this, additional capabilities related to the field were developed by Haven that helped it expand its market and strengthen its capabilities.

b) Advanced Manufacturing Research Centre – Innovation in Orthopaedics

Scientists from the Medical AMRC have helped in the sector of orthopaedics by designing new types of surgical screws, that has proved to be of immense benefit to the patients, and also eased the procedure for the doctors.

Innovate Orthopaedics (IO) (http://www.innovateortho.co.uk/2/) – a medical device company based in UK came up with new designs for surgical screws. The designs were turned into tangible screws with the technical help from AMRC.

One of the examples of the utility of such screws (as also shown in the Fig) is for reconstruction of the knee's front cruciate tendon that can be torn during sports. The sound ligament is secured deep down to the bone with a screw over which the bone then develops.

 

Fig 5: Screw for surgical application
Source: http://www.amrc.co.uk/news/medical-amrc-helps-innovative-orthopaedic-company-launch-new-solution-for-sports-injuries/

c) **Centre for Process Innovation- Recycling of old tyres**

Recyclatech (http://recirclerubber.com) is a company based in UK that focuses in the area of renewable energy and environment friendly projects. It is an SME and its primary project is to recycle old tyres through the process of devulcanisation. However, the technology employed by the company was not viable on a large scale, and the purpose of Recyclatech as a commercial entity was defeated.

That is where CPI stepped in. The scientists at CPI and Recyclatech worked together to devise a methodology for large scale devulcanisation of rubber, and at a quick pace. As a result of the support from CPI, Recyclatech was then able to commercialize the environment friendly project that recycled rubber tyres in large numbers.

Fig 6: Waste tyres for recycling
Source: https://www.uk-cpi.com/login/resources/cpi-recyclatech-case-study.pdf

d) **Manufacturing Technology Centre –Sit Ski Technology**

The MTC, working with the HVM Catapult utilized great manufacturing technology advancements to enhance the design of a Paralympic Sit Ski by measuring the performance of the athletes on existing technology, before supporting with the design and structure of a bespoke, lightweight model.

For the Sit Ski venture, the MTC utilized cost-effective cell phone technology to build up an instrumentation, which could gauge accelerating velocities, lean edges and suspension redirection. This information was also linked to a PC amid an indoor testing session.

The result of this task was a lightweight Sit Ski that was fabricated such that there was 30 percent of reduced weight for every design. The new Sit Ski got extremely positive feedback from the ones who tried it. Utilizing the similar technologies as Sit Ski, many new spin-off projects were created with various UK fabricating organizations. They utilized the minimal effort instrumentation to gauge manufacturing and logistics processes, where current instrumentation would have been excessively delicate or costly. Numerous customers benefitted from this innovation.

Fig 7: Sit Ski Technology

Source: http://www.the-mtc.org/our-case-studies/sit-ski-technology-delivers-for-rolls-royce

e) National Composites Centre - Heraeus Noblelight

The company-Heraeus Noblelight (https://www.heraeus.com/en/hng/home_hng/home_noblelight.aspx) is a market pioneer in speciality lighting and warming applications, offering lights and complete frameworks with wavelengths from bright (UV) to infrared (IR).

Since 2012, Heraeus has worked with the National Composites Center (NCC) to explore the capability of the Xenon flashlamp framework in manufacturing of composites. Specifically, the flashlamp has been focused at Automated Fiber Placement (AFP), where it can possibly outperform the current heating solutions.

The coordinated effort united various specialists, in composites manufacture from the NCC and flashlamp frameworks from Heraeus, to fabricate a solid group that has quickly taken the innovation up the TRL (Technology Readiness Levels) scale, from introductory evidence of idea trials to a full demonstrator.

The NCC has helped Heraeus in finding collaborative R&D funds through the National Aerospace Technology Exploitation Program (NATEP), and has been important in helping structure a research consortium from its broad member base that has given fitting direction to the project.

A feature of the joint effort was a technology demonstrator event held at the NCC to exhibit the advantages of the flash-lamp framework to potential end clients of the innovation.

f) WMG –ULTRAN project

The Ultra Lightweight Transmission & driveline (ULTRAN) project, is a £5 million study co-funded by Innovate UK and led by Jaguar Land Rover (https://www.jaguarlandrover.com). It has developed cost-effective lightweight drive train technologies for power train weight reduction, vehicle performance and improvements in CO2 emissions. WMG's expertise in polymer composite performance, joining techniques, material and final component characterisation were key to the development of an innovative rear drive unit. The novel structural optimisation and design process led to a 25% (8.5kg) weight saving as well as CO2 reduction compared with the existing design. Other benefits realised throughout this project include: development of a cost-effective, high-strength gear steel material, with a 7% improvement in fatigue performance; enhanced understanding of gear failures, combining lubrication, materials and processing factors; selection and characterisation of a suitable lightweight material for the replacement of metallic structures for transmission and driveline units.

g) Increasing the scale and speed of commercialization

With the support of the AMRC, Yorkshire-based SME *Technicut* developed a cutting tool that speeds up the cutting of tough alloys such as titanium from nearly three minutes to five seconds. The *Technicut* tool was also one of the key innovations adopted by the combined team of AMRC and *Rolls-Royce* as they sought to reduce the time involved in machining Trent 900 fan discs, which had become uneconomic to manufacture in the UK. As a result, machine time was halved and productivity on engine discs doubled.

h) Needle free 'breathalyser' for daily diabetes testing

Applied Nanodetectors Ltd (located at Innova Science Park, Enfield EN3 7XU, United Kingdom) worked with Centre for Process Information (HVM-CPI) on developing a simple breathalyser test for daily monitoring of glucose levels in diabetics. A non-invasive handheld breath test device has the potential to replace the 'prick test' methods used today and would significantly improve patient monitoring and self-management. The collaboration is part of an Innovate UK project – 'Plasense' – which developed a low-cost and scalable method for printing sensors onto flexible plastic substrates. Further work will look at upscaling the sensor and integrating it into a point-of-care diagnostic device. The project is a key breakthrough for the monitoring of glycemic levels and the technology will revolutionize the way in which glucose is monitored.

ii. Cell and Gene Therapy Catapult

https://ct.catapult.org.uk

The Cell and Gene Therapy (CGT) Catapult is an independent Centre of Excellence that was established in 2012, for advancing the growth of cell and gene therapy industry in the UK, by bridging the gap between scientific research and full-scale commercialization. A key component of this is to ensure that UK has a strong and competitive manufacturing base for cell and gene therapies.

From the state-of-the-art laboratory and office space in London, to the manufacturing centre in Stevenage, the Cell and Gene Therapy Catapult has the capacity to support companies and researchers big and small, at all stages of therapy development. The central location of the Centres means that easy reach to the international community is available.

There is an industrialization team that is made up of early adopters of cell and gene therapies, who offer a diverse range of skills in cell and gene therapy and help in the practical application of the research in the area. The team has specialist knowledge in regulations across the entire value chain for cell and gene therapies, from procurement of blood, tissues and cells to specialist manufacture, clinical trials, release and supply. Also, there is combined scientific expertise with experience in clinical trial delivery specifically for cell and gene therapies. Large-scale manufacturing Centre under construction and industrialized laboratories in central London point towards state-of-the-art infrastructure available.

Governance

- **Advisory Panel** consists of academic and industry leaders that have expertise across science, medicine and technologies, and all come from a range of highly respected European academic organisations and the international pharmaceutical and biotechnology industry. Outcomes and recommendations from the panel feeds into the strategy, positioning and planning to ensure the continued growth of the Catapult and the success of the cell and gene therapy industry.
- **Executive Board** exists to oversee the activities of Cell and Gene Therapy catapult.
- **Management Team** manages the organization on a day-to-day basis.

Achievements and Progress made by the Catapult in 2015-16:

- More than 120 professionals are involved in the full spectrum of cell and gene therapy capabilities.
- 22 new projects were started in one year (2015-16).
- Partnerships in the three year period (2014 to 2016), on collaborative research and development grants totaled £27.3m.
- A total of 101 Business engagements started in one year.
- 7,200m^2large-scale Good Manufacturing Practice (GMP) manufacturing centre was established and is rapidly developing.
- Two new companies formed.
- 62 SMEs engagedwith the catapult.
- 13 Clinical trial sites set upacross the UK.
- £21.3m investedinto cell and gene therapy projects over three year period (2014 to 2016).
- 36 Research partners engagedwith the Catapult.

The funding from the three sources for the Cell and Gene Therapy Catapult is tabulated in Table 6, for the year 2015 and 2016.

Table 6: Finances-funding

Denomination	**2016 (million£)**	**2015(million£)**

Innovate UK core revenue grant funding	14.079	12.221
Innovate UK core capital grant funding	9.428	2.450
Collaborative R&D and other grant income	1.103	0.861

Successful examples

a) Creating a computer model for fluid movement inside a bioreactor

Bioreactors are devices used to address the manufacturing needs of cell therapy developers culturing cells in the large numbers. Stirred tank bioreactors (STRs) not only provide developers with the ability to alter environmental conditions such as pH or oxygen, but also contain an impeller that agitates the fluid environment to promote cell expansion.

In order to optimise a manufacturing process, the industrialization team at CGT Catapult compared repeated cultures to gain a statistical understanding of how cells grow in particular conditions.

CGT Catapult worked with Sartorius Stedim Biotech (Royston UK)- https://www.sartorius.com in order to evaluate the application of their new modular bioreactor system for the industrial scaling of cell therapy manufacturing processes and to identify opportunities for further optimization. The CGT Catapult team used *in silico* computational fluid dynamic (CFD) modelling to analyse the fluid within the bioreactor during cell culture.

To validate the model the team built a clear plastic replica of the STR, which allowed them to see inside the bioreactor.

The output of this project was a validated computer model of the internal environment of bioreactor system. This model was used to advise on operational and geometric changes to improve the bioreactors functionality with cell therapy processes, and can also be used to speed up and reduce the costs of process development.

b) Formation of Islexa

The CGT Catapult and University of Aberdeen, King's College, Aberdeen (https://www.abdn.ac.uk), formed a new company called Islexa, which aims to develop a novel technology to produce laboratory-grown islets. Islets represent the functional unit of the pancreas, responsible for the production of insulin in response to increasing blood sugar levels. The Islexa technology works by reprogramming donated exocrine pancreatic tissue into fully functional islets. The Islexa team will initially focus on further pre-clinical development of the protocol for reprogramming the pancreas tissue into functional islets. This will be followed by clinical trials in the next few years. An islet transplant can give patients effective, long-term glucose control without the need of insulin administration.

c) ReNeuron

ReNeuron, a leading UK-based cell therapy company andCGT Catapult started their business relationship in 2013 to develop CTX neuronal stem cell line to be used as therapeutic candidates for stroke and critical limb ischaemia. The collaboration intends to develop an automated robust manufacturing process and associated analytical tests for the proposed clinical and early commercial supply of this particular cell therapy cell line.

The partnership between ReNeuron, CGT Catapult and Loughborough University resulted in novel processing technologies from the biologics industry being applied to create a one-step stem cell therapy manufacturing process. Following the start of their collaboration with us to further develop their next generation manufacturing process, ReNeuron has successfully secured an initial £33m in financing and more recently was awarded a further £68m in financial backing from institutional investors.

iii. Digital Catapult

https://digital.catapult.org.uk

Digital Catapult is a market-led technology and innovation centre, helping businesses of all sizes to use digital technologies for growing, exporting and increasing the productivity.

CATAPULT Digital

The main aim is to drive the UK economy through the practical application of digital innovation and culture that would make UK businesses more competitive and productive. Digital Catapult works in wide range and layers of technology to increase the productivity and efficiency. Digital Catapult currently focuses on two sectors, digital manufacturing and creative industries. In addition it is exploring opportunities in digital health and care.

There is a wide range of technology layers where the Digital Catapult works. These are:

- **Data driven**: New ways to work with personal data with more control and trust, applications of blockchain and smart contracts, cyber-security particularly for emergent threats.
- **Internet**: The Internet of Things and associated enabling networking technologies such as Low-Powered Wide-Area networks and 5G.

- **Intelligence:** Artificial intelligence and machine learning in particular.

Achievements for 2014-15

- Engaged with 2229 SMEs
- 214 new business opportunities created for 7 SME case studies
- 45 showcase companies
- 1 million copyright images indexed by end of 2015
- 26 formal academic collaborations

Successful Examples

a) CreativeXR

The UK has a unique community with strengths in art, culture and technology, sparking trends and influencing creative practice. CreativeXR (http://creativexr.co.uk) unlocks the opportunity for this community to experiment with such content that inspires audiences.

Immersive technologies (including virtual and augmented reality) have significant potential to enable new formats of creative content for audiences and users. This emerging medium offers the arts and culture sector an unprecedented opportunity to create outstanding content that inspires the world around.

CreativeXR supports:

1. Compelling new creative content formats enabled by immersive technology.
2. The process of 'content-led R&D' whereby organisations are afforded space to develop riskier, content-focused projects that contributes to the development of new skills, tools and business opportunities.

CreativeXR help the UK to make the most of the wealth of talent it possesses in the creative industries. Working closely with current and future content commissioners the programme is designed to enable the UK's arts and cultural sector to lead the field in immersive content creation and digital innovation.

b) Immersive Lab

Digital Catapult's Immersive Lab gives organizations of all sizes the opportunity to get hands-on with the latest immersive technologies*.

(Immersive technology refers to technology that blurs the line between the physical world and digital or simulated world, thereby creating a sense of immersion.)

Access to the lab isn't limited to SMEs or corporates. Digital Catapult supports digital innovation more broadly fostering industry collaboration with academia and research.

The lab is available for hire to demonstrate, innovate, test and experience the latest immersive technology and content. The space is equipped with a range of the latest augmented and virtual reality hardware to encourage commercial innovation the UK's growing immersive community.

Different facilities that are available are:

3. Demo space: Companies, academics and researchers can book the lab to demonstrate their latest content, equipment or solutions.
4. Green screen mixed-reality: A comprehensive green screen mixed reality setup, including hardware and software, allows for the creation of mixed reality content that can showcase products or experiences.

iv. Future Cities Catapult

https://futurecities.catapult.org.uk

The main aim of the 'Future Cities Catapult' is to promote urban innovation, to develop UK companies, to make cities better. It seeks to bring together businesses, universities and governments so that they can work with each other to solve the problems that cities face. From the Urban Innovation Centre in Clerkenwell, London (http://futurecities.catapult.org.uk/about/urban-innovation-centre/), it provides world-class facilities and expertise to support the development of new products and services, as well as opportunities to collaborate with others, test ideas and develop business models.

The 'Future Cities Catapult' tests innovative ideas that could improve the lives of the city dwellers. These tests are carried out in real settings. Once the ideas are successfully tested, they are then spread to the different cities of the globe, to better the environment quality, increase the services and facilities for the residents and improve the economic parameters.

A lab of the Catapult, termed as the 'Cities Lab' helps in better understanding of the problems faced by the cities through modeling, analysis of data, and visualization techniques in a controlled environment. The same test is then carried out in real urban set-ups. Combining the two approaches, new ideas that can help solve the problems faced by the modern cities are discovered, tested and applied.

The activities of the Catapult brings together the UK's top architects, engineers, designers, academics and business professionals, and helps them transform cities on a large scale. It strengthens the UK's ability to turn excellent urban innovations into commercial reality in the form of cleaner and economically prosperous cities.

Successful Examples

a) Belo Horizonte

Many of the problems faced by the model cities can be solved by technology and intelligent infrastructure. The UK has found solutions for many of such problems like safe cycling, reliable broadband, etc with the deployment of intelligent infrastructure.

This Catapult wished to employ similar solutions in other cities of the world as well. However, just having the solution is not the answer, matching the demand and supply is of utmost importance as the right technology can only solve the right challenge.

A project by Future Cities Catapult, had identified key urban challenges in a major Brazilian metropolis that could benefit from UK-based knowledge and experience. The project was conducted in collaboration with Embarq Brazil (http://wricidades.org/sobre/embarq) that carried out itsown study alongside Future Cities Catapult's work.

The project included a series of workshops and discussions with institutions and businesses in Belo Horizonte, which is the sixth most populous city in Brazil. The Catapult identified four key problems in the city that can be matched with solutions already implemented in the UK:

5. Public transport being overburdened and overcrowded
6. Lack of supporting infrastructure for innovation
7. High number of road accidents
8. High number of vulnerable settlements in areas in the outskirts of the city prone to high geological and environmental risk

But the Catapult's study stresses that there is no one-size-fits-all approach to solutions in cities. The problems in different cities might seem alike, but require slightly different solutions to be addressed.

In Brazil, cities like Belo Horizonte face many diverse problems like improving the mobility in the cities, increasing the citizen safety in cities and better supporting local innovation.

One of the British innovations that Belo Horizonte could implement using pre-existing infrastructure is a public transport solutions developed in London. In order to address the problem of overcrowding in the public buses, the on-board CCTV cameras were used. The videos were analysed to study how crowdy it gets at different times of the day and at different routes. The information is also useful for transport operators to monitor user behaviour on board the buses and for future mobility service planning.

Another technology that UK uses to make the cities safe for cyclists was also tested for the Brazilian city. Sensor technology could be installed on cycle lanes to detect the volume of cyclists waiting to cross the road at traffic lights, for example. The technology was tested in London, where depending on the volume of cyclists the information was used to vary the green signal phase of the traffic lights to allow more cyclists through.

High-quality data was identified by the study as a key element in improving the safety of high environmental risk areas.

b) Capstone

Future Cities Catapult collaborated on a project with Intel Labs Europe (https://www.intel.com/content/www/us/en/research/intel-research.html), Imperial College and University College London to illustrate the ability of the Internet of Things (IoT) interventions to solve real urban challenges.

The project focused on the Queen Elizabeth Olympic Park (QEOP) in East London.

This final phase of a longer-term collaboration called "Capstone", included the goal to create an 'Urban Internet of Things Demonstrator' in the park to show the possibility of the IoT solutions to solve urban challenges. Individual partners deployed technology to test a research question specific to their areas of expertise, that includes:

9. Health and wellbeing demonstrations
10. Battery-less sensing to lower maintenance costs
11. The combination of static language making city-wide IoT easy to program
12. An adaptive radio that delivers data using a variety of methods dependent on the application demand
13. Prototypes and visualizations for soft sensing and sense-making
    Social media streams visualized on physical prototypes

c) Birmingham Eastern Corridor Smart Roadmap

Birmingham like other cities in the UK faces acute challenges brought about by the economic growth as well as the growing expectations of citizens. And despite so many interventions over the past decade, East Birmingham continues to have higher unemployment, lower skills and poorer health than other parts of the city. To accelerate the role of smart city technologies and data in improving the conditions for citizens, Birmingham City Council, established collaborations between the Future Cities catapult and Digital Birmingham program.

As per the research by the Future Cities catapult, a lot of stress has been laid on the technology for making cities smart. City Council Officers tend to look for uses for new technologies and creating city apps, rather than working closely with the beneficiaries to collaboratively combine the best that technology has to offer to solve the problems that matter the most.

Drawing on its extensive network, Future Cities Catapult organised a range of sessions and workshops with institutions and businesses in Birmingham, ranging from Aston University and British Gas to the University of Birmingham and the West Midlands Police. The resulting approach called for a bottom-up approach to improving health, mobility and 'quality of space' – ranging from leisure spaces to a perceived fear of crime – across East Birmingham.

To ensure that the collaborations strengthen the creation of marketable products and further innovations, Future Cities Catapult worked with various stakeholders to come up with a new methodology and outline for the city planners of Birmingham. In an approach that is more similar to how start-ups are run, the plan calls for a focus on first testing the technology solutions on a small group of people, and then rolling them out to the larger section of people.

With the help from Future Cities catapult, Birmingham made better use of the canals and river networks in the east, created an environment where there was greater engagement between the government and the citizens, and rolled out various initiatives that benefitted the people directly.

Data analytics was also used to better understand the problems and solutions for the city. It was useful in projects like establishing the relationship between intensity of streetlight and other factors.

v. Offshore Renewable Energy Catapult
https://ore.catapult.org.uk

It is UK’s flagship technology modernization and research centre for supporting wind, wave and tidal energy. The Offshore Renewable Energy Catapult is made up of 5 interdependent Directorates**:**

a) Testing & Validation Directorate**:** Leading the management of the greatest concentration of several offshore renewable energy technology experiment and exhibition facilities in the world. The facilities and highly practiced multi disciplinary team of experts and pioneer serve to demonstrate and de-risk promising modern technologies and fetch them to sell.
b) Research & Disruptive Innovation Directorate: Business, strategic, policy and research professionals tasked with industry interrelationship and decide and support the novelty and exploration strategies.
c) Marketing & Communications Directorate: Including public relations, digital supplies and strategic communications, the team encourage the business capabilities and the results of the Catapult’s activities to a broad stakeholder base.
d) Professional Services Directorate: involves the experts from Human Resources, Finance, Legal, Procurement, Information Technology and Administration who aid the smooth functioning of the organisation.
e) Operational Performance Directorate: Technical experts developing solutions that reform the functioning of offshore wind farms, building on the UK's solid track record in offshore renewables' operations and sustenance.

Successful examples

a) SPARTA (System Performance, Availability and Reliability Trend Analysis)

SPARTA is a new UK offshore wind performance data platform. It is a major collaboration scheme with the purpose of improving wind turbine functional activity by improving safety, reliability and accessibility. This is to bring down the lifetime price of electricity produced from offshore wind. The scheme is co-sponsored by Offshore Renewable Energy (ORE) Catapult and The Crown Estate (http://www.thecrownestate.co.uk) and supported by offshore wind farm owner/operators.

The project led to the formation of a data interchange model for sharing anonymous offshore wind farm performance and sustenance data. Owner/operator participants are provided with sound and dependable benchmarked data for the first time, serving to recognize functional improvements and price reduction opportunities at both company and sector-wide levels.

The SPARTA venture has created and presented a predictable reporting standard for a scope of measures covering resource accessibility, unwavering quality and execution. Expanded access to industry inferred information through SPARTA would permit owners/administrators to benchmark their execution, featuring regions where enhancements can be made. This drives activities intended to enhance execution, advancement and further financial improvement.

ORE Catapult and The Crown Estate have mutually dedicated to advancement financing in overabundance of £850,000 (till March 2015).

SPARTA has been created for UK-based undertakings yet the database is completely adaptable and takes into account the incorporation of international activities.

SPARTA works together with the German undertaking Offshore WMEP (http://windmonitor.iee.fraunhofer.de/windmonitor_en/6_Projekte/1_o~wmep/) led by the Fraunhofer IWES institute. The Fraunhofer venture works at a more point-by-point level, however the two are teaming up to guarantee that data capture is aligned. The Crown Estate, ORE Catapult and Fraunhofer IWES have signed a Memorandum of Understanding which records the joint wish to work cooperatively, and Fraunhofer IWES has gone to various SPARTA guiding gatherings and meetings.

b) WITT Ltd.

ORE Catapult supported the advancement of WITT Ltd's (https://www.witt-energy.com) creative gadget that converts motional energy into electric power, which could be an important achievement for large and small wave devices.

Utilizing the Catapult's Technology Assessment Process, WITT Ltd's innovation was benchmarked and an autonomous report gave on how risk could be lessened in future advancement stages, with ORE Catapult available to help manage WITT in future marine energy related exercises.

vi. Transport Systems Catapult

The Transport Systems Catapult was made to drive and advance Intelligent Mobility – utilizing new and rising technologies to transport individuals and products all the more astutely and proficiently.

It is helping UK companies make goods and services that address the issues of the world's automobile frameworks. With an unmistakable accentuation on coordinated effort, it is uniting various associations over various methods of transport, separating hindrances and giving a remarkable stage to meeting the world's most pressing transport challenges.

Successful examples

a) Self-driving pods

In October 2016, the Transport Systems Catapult was in charge of putting a self-driving vehicle on UK open lanes, for the first time. The demonstration of a UK created self-driving framework denoted the successful completion of the LUTZ Pathfinder Project (http://ori.ox.ac.uk/older-projects/lutz-self-driving-pods/), which started creating autonomous technology in 2014.

In the former months, LUTZ Pathfinder units had been driven in manual mode with a human driver in charge, while the venture group mapped the earth and tried the control framework's capacity to arrange its way along the assigned trial routes.

The project was carried out by the Transport Systems Catapult (TSC) on behalf of the UK Automotive Council and the Department for Business, Energy and Industrial Strategy (formerly the Department of Business Innovation and Skills).

Fig 8: Self-driving pod
Source: https://ts.catapult.org.uk/innovation-centre/cav/cav-projects-at-the-tsc/self-driving-pods/

b) Sentiment mapping

Teaming up with Nottingham University (https://www.nottingham.ac.uk) and Keolis (https://www.keolis.com/en), the TSC has been working on sentiment mapping to study and understand client experience and impact traveller behavior. The project likewise overlays 2 years of operational information and sentiment analysis to furnish travellers with certain indicators for their travel.

The project has made a device for travellers that prepares operators and controllers to give important advice regarding trip arrangement, safety information and traffic-related information. The instrument has additionally been created to take into consideration multi-modular development. The device is currently under testing.
Source: https://ts.catapult.org.uk/current-projects/sentiment-mapping/

vii. Energy Systems Catapult (ESC)
https://es.catapult.org.uk

The ESC is one of the top innovation and advancement centres set up by Innovate UK. The Catapult works with organizations that are centered on making best use of the opportunities created by the need to change worldwide energy systems. It additionally actively engages with government to address the market components and plans of action that will be required to achieve solutions to the energy problems.

The ESC makes a critical mass for business and research advancement, concentrating on power, heat and combustible gases. This centre is an imperative piece of the UK's development framework, making a noteworthy long-term commitment to UK monetary and economic development.

The information about the finances for the ESC is provided in the Table 7 below.

Table 7: Finances

Funding source	**2016 (million£)**
Innovative UK core grant funding	4.0
Collaborative and commercial funding	3.403
Fixed assets	1.069
Net current liabilities	0.782
Provisions for liabilities – deferred tax	0.054
Net assets	0.042
Capital and reserves	0.042

Successful examples

a) MC Power Innovations

MC Power Innovations (website not available) is an SME working on a ‘phase switch framework', using sharp sensors, correspondences and information preparing to balance local load between phases on the network. It can possibly significantly improve the limit of the system to convey electric vehicle charging, PV and heat pumps.

The Catapult gave specialized and business expertise to help create model plan and utilized its system of influencers and counselors to acquaint the organization with vital partners and potential end-clients.

MC Power Innovations and the Catapult had together applied into Innovate UK's 'Advancement in Infrastructure Systems' competition, with the goal of securing creative, innovative development funds to convey the collaborative model project and quicken the organization's specialized and business progress.

viii. Satellite Applications

https://sa.catapult.org.uk

The mission and vision of the Satellite Applications Catapult, that reflect the main aim of this Catapult are stated below:

CATAPULT Satellite Applications

Mission: "To innovate for a better world, empowered by satellites"

Vision: "To be a world-leading technology and innovation company, helping businesses of all sizes to realise the potential from space. By embracing a pioneering, agile, collaborative and entrepreneurial spirit, we create valued partnerships to deliver game-changing results."

Satellites technology is a technology of the future that has the tendency to explore beyond what we already know. Also, the challenges being faced by the world today can be solved by the power of the satellites. Hence, this cataput will have a global impact in the coming years.

Governance

The Satellite Applications Catapult, like the other catapults- is a private company limited by guarantee and controlled by its Board. It is a not-for-profit organisation and acts as an unbiased entry point for the overall network of UK expertise in development of application of satellite technology across the governments, universities and businesses. The company's primary purpose is to promote, develop and facilitate the increased market value and advancement of the satellite applications industry.

The Board and Management

The company is controlled by an independent Board comprising of the following:

- Chairperson
- Chief Executive Officer
- Chief Financial and Operating Officer, and

- Non-Executive Directors (NEDs)- six

There are representatives from the UK Space Agency and Innovate UK on the Board. The main function of the Board is to devise the strategy for the company, approving its annual budget, signing off the financial statements, making significant investment decisions, and setting the limits for expenditure.

Also, there is an **Advisory Group** whose purpose is to bring together industrial, government and universities' representatives to interact with the Board and provide advisory services.

Along with this, there is an **Executive Management Team** that comprises of the CEO and other senior personnel (CFO/COO, Chief Technical Officer, and Chief Innovation Officer). It is responsible for the day-to-day management of the Catapult.

There is also a subsidiary company of the Satellites Applications Catapult named Satellite Applications Catapult Services Ltd, which is a private limited company. This subsidiary makes sure that all the market services and contracts of the catapult are handled separately from its main services. Any trading surplus is re-invested in the main not-for-profit company.

Other initiatives:

a) Knowledge Exchange Fellowships

This is an initiative of the Satellites Applications Catapult to further strengthen the relationship with the universities. There are certain positions, termed as Knowledge Exchange Fellowships- that are jointly funded by the universities and the Catapult. The main aim of this program is to develop stronger engagement of the scientific community in UK towards the space sector.

The main job performed by the Knowledge Exchange fellows is to:

6. Identify intersections of existing or intended research strengths and un-met commercial need.
7. Strengthen the development of agreed inter-disciplinary research and exploitation themes that would appeal to the businesses and lead to commercialisation.

b) Secondments

The Satellite Applications Catapult actively supports secondments, and this is done by supporting the exchange of people, both in and out of Catapult activities. This includes Knowledge Transfer Partnership (KTP) schemes, undergraduate placements, sponsored PhDs and apprenticeships, as well as traditional secondments.

Secondments are generally for the people in academics, industry and also for the staff of Catapults.

The academic community benefits in the form of:

i. experience of working on market-focused projects
ii. career advancement in industry
iii. experience that can be taken back to the universities to support future research and teaching

The Catapult staff is generally offered short-term secondments as an opportunity to develop their profession. This means that the staff members are made to work at different places, exposing them to different work atmosphere, and finally they return to their original office after gaining experience.

The employees are also enabled to work on collaborative projects or support external companies where there is a requirement for resources that match their skills and experience. This further supports the transfer of industry-focused skills and expertise into the Space sector knowledge base.

c) Programmes

Most of the activities that the Satellite Applications Catapult does are within different programmes of work. By focusing on areas where it is believed that significant economic impact is possible, and where there are common needs and solutions, there most of the funding is made.

The United Nations in 2015 had agreed on 17 goals and 169 targets (termed as Sustainable Development Goals), to be completed till 2030. The satellites play a great role in the achievement and monitoring of these goals, directly or indirectly.

These Goals are intrinsic to the programmes of Satellites Application Catapult, and are a primary focus. The challenge for the achieving these goals is not primarily technology, but of establishing new types of economically sustainable partnerships between businesses and governments that enable the emergence of solutions based on technology.

The programmes are:

- Intelligent Transport Systems

The transport system relies on satellites in terms of locations and positioning. Intelligent transport is an advancement in the present dependence of the transport system on satellites for other many other purposes including inter-vehicle communications, judging exact location with greater precision. This could pave the way for the advancement towards autonomous vehicles.

- Blue Economy

The Blue Economy is the economy based on water resources like fishing, shipping, etc. The Catapult focuses on the maximum exploitation of the marine environment by making best use of the satellite technology.

- Sustainable Living

As per the Sustainable Development Goals of the UN, there is a great focus on sustainable solution for growing cities, power generation and cultivation. Then there is the need for studying the impact for various human activities on the environment and how that can be mitigated to ensure sustainability. Hence, this program aims at improving decision-making in agri-tech services by developing integrated satellite technologies to deliver cost reduction, increased yields and reduced pollution.

- Explore

This programme aims to include more space related technology into the wider economy and capturing the technology breakthroughs. The previous work within this programme was focused on assessing the market and spawning new programmes – currently concentrating on aspects of smart cities, food supply chains, health, security and energy – as well as an information campaign to promote awareness of satellite capabilities.

Achievements in the last 4 years (2013-2017):

- Carried out over 140 collaborative and commercial projects. These involved 94 UK companies, including 47 SMEs and 29 non-space companies, along with 25 universities.
- Worked with 17 businesses that have gone on to raise over £24.2 million of equity capital.
- Held 128 workshops, engaged with over 3,500 organisations.
- The facilities, such as cloud processing service, satcomms lab, operations centre, hot desking and Far Field Antenna Test Range, have been used by 169 businesses, including 86 SMEs.
- Opened five regional Centres of Excellence across the UK to extend its reach and encourage development of space activity in the regions: Scotland, East Midlands, North East, South Coast and South West.
- Increased the amount of funding available for satellite related companies, by being instrumental in the creation of the £50 million Seraphim Fund and supporting Satellite Finance Network activities.
- Worked on 38 international projects with partners from 22 countries.
- For every £1 of core grant invested, it has enabled £6 of investment and linked activity.

Successful examples

a) Space Placements in Industry (SPIN) scheme

The Space Placements in Industry (SPIN) scheme is supported by the Catapult, UK Space Agency and University of Reading, Whiteknights, Reading, Berkshire, UK (http://www.reading.ac.uk) to provide a paid 8 week summer placement opportunities in space-related organizations. SPIN students work on applied projects defined by space sector host organizations who can benefit from an injection of new ideas and approaches to problems, as well as having a chance to identify potential future employees for their businesses. SPIN has been running since 2013 and in 2017, 25 companies hosted 37 internships.

b) Remote sensing for organic food

In order to verify whether the food is organic, the method involves processes such as isotope testing, tracing pesticides in crops through extremely complex and expensive means. However, Sainsbury (http://www.sainsburys.co.uk)-a supermarket company, came up with a new technique based on the satellite applications for verifying organic food. The Catapult conducted a study to understand how effective such a technique could be. It was found out that on using a high-resolution satellite, it is actually possible to prove the evidence of organic farming.

ix. Medicines Discovery Catapult
(https://md.catapult.org.uk)

The Medicines Discovery Catapult is an independent company, set up by Innovate UK as part of the UK's industrial strategy to support and enable commercial drug discovery in the UK.
The Medicines Discovery Catapult is a national centre of applied R&D expertise to promote and support innovative, fast-to-patient drug discovery in the UK through collaborative projects across the community.

The Medicines Discovery Catapult provides an applied R&D platform that enables the broad community to:

- ✓ Build new collaborations between companies, academia, technology experts and medical research charities that pool expertise and address the system-wide problems that no one can solve alone
- ✓ Support disruptive medicines discovery programs focused on quick and efficient translation of promising drug candidates to clinical proof of concept stage
- ✓ Invest in new technologies and infrastructure to support SMEs and others to boost the UK's medicines pipeline over the medium and long term
- ✓ Develop new forms of financing to help stimulate collaborative activity and innovation in UK drug discovery
- ✓ Train and mentor a new generation of drug discovery leaders across key sectors

The Medicines Discovery Catapult undertakes work to support the discovery and early clinical development of stratified medicines.

Governance

- **The Board:** The Medicines Discovery Catapult is structured as a company limited by guarantee. The executive group manages the operations under the supervision and guidance of the board of directors.
  The CEO is accountable to the Catapult Board for successful operation of the Catapult**.**

- **The Management Team** runs the Catapult on day-to-day basis, and the members bring experience for achieving the overall vision, mission and objectives of the Catapult.

x. Compound Semiconductors Applications (CSA) Catapult
(https://csa.catapult.org.uk)

The Compound Semiconductor Applications Catapult is an open access R&D facility to help UK businesses exploit advances in compound semiconductor technologies across key application areas such as healthcare, the digital economy, energy, transport, defence and security, and space. The Catapult helps UK companies, particularly SMEs, to grow by exploiting advancements in compound semiconductor technologies which translate into opportunities for:

- Power electronics e.g. smart grid, electric vehicle powertrain
- RF/microwave e.g. RADAR, wi-fi and 5G
- Photonics e.g. security scanning, health diagnostics and high speed communications

The CSA Catapult provides world-class research facilities with access to independent, trusted expertise to develop capabilities in the above and accelerate the commercialisation of compound semiconductors in key application areas such as healthcare, the digital economy, energy, transport, defence and security, and space.

Summary

The Catapult network in UK is a successful example of an effort to bring together the public and private sector for economic growth. The model has drawn upon the international best models and adapted it to the UK scenario. The figures show that the government funding for the Catapults is gradually decreasing, as more and more funds are gained from the private sector and collaborative public-private. The independent governance of the Catapults further makes them more efficient due to minimum interference by the Government. Their presence in UK and other nations after a mere seven years of establishment is another evidence of their success

2.2. Knowledge Transfer Partnerships - UK

Background

Teaching Company Scheme (TCS), started in 1975, was replaced by Knowledge Transfer Partnerships (KTP; http://ktp.innovateuk.org) program in UK in 2003. Science and Engineering Research Council (SERC) enacted the Science and Technology Act to set up TCS in 1965. It was based on the concept of Teaching Hospital that means 'learning by doing'. The organisations which supported TCS financially were UK SERC, the Department of Trade and industry and many industries. The short term and long term multiple objectives of TCS were to prove beneficial to industry, to academic institutions by providing post graduate training and experience to develop a cadre of high quality and highly skilled professionals. To work principally in industry a scheme was evolved which set up the partnership between academic and industrial units, large or small. It was largely operated in engineering but was demonstrably applicable to other areas as well.

The Technology Strategy Board (now Innovate UK) started managing KTP in 2007.

Objectives

KTP's mission is "to strengthen the competitiveness, wealth creation and economic performance of the UK by the enhancement of knowledge and skills and the stimulation of innovation through collaborative projects between business and the knowledge base".
Its core aim is not only to translate academic knowledge to commercial output, but also to enhance the ability of businesses to benefit from the knowledge transferred on an ongoing basis. This differentiates KTP from other knowledge transfer activities where research is commissioned from outside.
The program aims to give priority to the needs of the business while promoting collaborations, even though it intends to benefit all the partners- academia, business and the associate.

Working

- An associate is placed in the business to mediate between the companies and Knowledge Based Institutions (KBI) and is hence able to transfer not only codified knowledge but also tacit knowledge that includes the knowledge of application of the solutions to real-world problems. This is a key aspect of KTP and hence makes it unique with respect to other schemes where the researcher works mainly from the research university.
- There is also a supporting infrastructure,to help businesses and academics to develop and implement projects that meet stringent programme objectives. This infrastructure comprises of KTP Advisers, KTP Programme Office and Managing Agent, and the KTP Officers.

Funding

The main funding body as well as the managing bodyfor KTP is Innovate UK. Other funding partners are the Research Councils, the Devolved Administrations, Department of Health, Department for Environment, Food and Rural Affairs as well as the Nuclear Decommissioning Authority.

The following figures provide an estimate of the funds received by the program.

- Over £648 million (£648,155,226) has been committed to the KTP programme over the last three decades, approximately.
- Since the establishment of TSB/Innovate UK in 2007, this funding stream's contribution to the programme has risen from 57% to 69% (till 2014)
- The share of 'Devolved Administrations' has also increased from 6% to 13% (from 2007 till 2014)
- The share of European funding such as ESF has declined (from 2007 till 2014)

Table 8: Funding partners for KTP over the years and their percentage contribution

Funding Stream	**Percentage funding (1987- 2007)**	**Percentage funding (2007-2014)**
Innovate UK/ Technology Strategy Board	57 %	69 %
Devolved Administrations	6%	13%
Research Councils	24%	15%
Government Departments	2%	2%
Europe (ESF and ERDF)	3%	1%

Non specified	8%	0
Total	100%	100%

Source: Innovate UK (https://www.gov.uk/government/organisations/innovate-uk)

Operating Structure/Governance of KTP

Each KTP is a 3-way partnership between:

- a UK-based business or a not-for-profit organization based in UK,
- an academic or research organization like a university, college or research and technology organisation in the UK
- a suitably-qualified graduate, who has the capability to lead a strategic business project

There are approximately 1,000 or more simultaneously running programmes at any one point in time.

Achievements

- For the year 2013-14, the KTPs helped the UK industries with a projected £211 million increase in their annual profit, creating over 450 new jobs and training 6,000 company staff.
- For every £1million of government money invested (in 2013-14):
  - 25 new jobs were created (including associates employed after their project completed)
  - 353 staff were trained
  - £2.2 million was invested in plant and machinery
  - £3.06 million was invested in R&D
- The academia stood to benefit from the KTPs, in the following ways:
  - develop business-related teaching materials
  - initiate new research projects and publish high-quality research papers
  - identify undergraduate or post-graduate projects
  - contribute to the Research Excellence Framework exercise (REF)
- The Associate too had a lot to gain from the KTP projects:
  - As one of the country's largest graduate recruitment schemes, KTP continues to enhance associate career prospects in the following ways:
  - it provides an opportunity to manage a challenging project that is core to the business's strategic development

- 58% of associates are offered employment by the host business on completion of their project

KTP is a recognised route for fast-track career development including training, coaching and mentoring support.

664 total classic* projects – 1 April 2013

Since then:

- 290 projects completed
- 317 offer letters issued
- 49 projects never established

642 total projects – March 2014

*classic projects are defined as projects of 12 months duration or longer

Success stories

a) YASA Motors Ltd.

YASA (http://www.yasa.com) is a British manufacturer of electric motors,which are used in automobiles and also have industrial applications. Before 2014, the motors built by YASA were handmade and hence, quite expensive to manufacture. This led to inefficiencies and a lot of time wastage. The requirement was to develop such a technology that could lead to mass manufacturing of the motors in an efficient manner. Under the aegis of KTP, YASA Motors partnered with Oxford Brooks University and the project for the development of low-cost, mass production of units emerged out to be a highly successful one. The result was that the company saved almost £100K in avoidance of motor durability failures, manufacturing time was reduced from 7 days to 2 days and the defect rate reduced by a factor of 100.

Fig 9: A product by YASA Motors Ltd

Source: http://www.yasa.com/products/

2.3. Higher Education Innovation Fund- Knowledge Exchange

Background

The Higher Education Innovation Fund (HEIF) programme (http://www.hefce.ac.uk/ke/heif/) provides funding to higher education institutions (HEIs) to build on the activity carried out under 'third stream' funding initiated by the Higher Education Reach-out to Business and the Community (HEROBC) fund. It forms the basis of the government's commitment for a permanent stream of funding to enhance the contribution of higher education to the economy and society.

It provides funding for *knowledge exchange (KE)* via Higher Education Innovation Funding (HEIF) to support and develop a broad range of knowledge-based interactions between universities and colleges and the wider world, which result in economic and social benefit to the UK.

HEIF's primary focus remains the support of KE activities with all forms of external partners – businesses, public and third sectors, local and community bodies and the wider public – to achieve the maximum economic and social impact for this country. Partnerships may be local, national or international.

Objectives

HEIF is designed to support a range of knowledge exchange activities that result in economic and social impact. The funding provides incentives for HEIs to work with businesses, public and third sector organisations, community bodies and the wider public. Activity that can help the country's economic growth and productivity is currently a high priority.

Funding

Higher Education Funding Council for England (HEFCE) provides funding for knowledge exchange (HEIF) to support and develop a broad range of knowledge-based interactions between universities and colleges and the wider world, which result in economic and social benefit to the UK. The latest round of funding was referred to HEIF 5+1+1 and till 31st July 2017. (2016 – 2017)

Funding is provided by formula. HEIs have flexibility to use funds to maximise societal and economic outcomes and impacts, responding to the needs of their external partners. The formula focuses on rewarding and incentivising performance. HEIF's success is judged in terms of the economic and social impact achieved.

Income remains the best proxy we have for the impact of KE activities on the economy and society; hence it is the best measure of performance and is used in the formula allocation of HEIF. The focus of HEIF is not on income generation for the HEI, though it is recognised that institutions must have a close eye on the sustainability of their activities. There are enhanced procedures put in place in the strategies process to ensure that the economic and societal outcomes and impacts delivered by HEIF are understood and evaluated, to guard against a focus on income achievement.

Knowledge exchange funding - HEIF for 2017 to 2018

Allocations for HEIF are performance-based, and institutions are eligible to receive an allocation if they exceed a £250,000 allocation threshold related to their external income earnings and performance of the sector overall.

For 2017 allocations, a new approach has been implemented for calculating annual allocations to higher education institutions (HEIs), based on latest data, to reward up-to-date performance.

This is coupled with an annual modifier to provide some stability in allocations. Ordinarily this is set at +/- 10 per cent year-on-year from the operation of the formula alone, but in 2017-18 the upward modifier has been relaxed to +30 per cent to allow a further £25 million of funding to be allocated in support of the 'Industrial Strategy'.

The SETsquared Partnership

The SETsquared Partnership is the enterprise collaboration between five leading research-intensive universities in UK: Bath, Bristol, Exeter, Southampton and Surrey.

Established in 2003 and funded by the HEIF, the partnership is a focus for enterprise activity and new business creation for the five university partners.

The region of SETsquared is home to many leading research-based technology corporates, universities, public-sector research establishments and successful entrepreneurs. It is also within easy reach of London. Despite this, when SETsquared was created, the region had a lower-than-expected technology start-up rate compared to other similar areas, such as Cambridge or Silicon Valley.

SETsquared's mission is to help turn an innovative spark into a thriving, commercial business, whether for an entrepreneur or a high-tech company.

SETsquared also has a role in embedding entrepreneurial thinking and behaviour within the universities that it supports. This is done at a number of levels - through a programme of student enterprise activity and also by supporting researchers and academics to realise the commercial and social impact of their research.

Successful Examples

a) **Bournemouth University: Northey Technologies**

With support from HEIF, one of the Bournemouth University's Business students (Product Design Engineer) worked with Northey Technologies Ltd (http://northey.net) to develop a new series of pumps and compressors. It was a two- year project as part of a KTP scheme that has enabled the company to develop and implement modern computer tool technologies such as Computer Aided Design (CAD) and Computational Fluid Dynamics (CFD).

This project led to the development and launch of a unique compressor with seal-less capability using advanced materials such as carbon graphite, and innovative technologies such as magnetic drives. The company expects a significant increase of its profit nationally and internationally, and has even got ISO certification and a European patent to protect the design of the new compressor. The company now sees research and development and partnership with higher education as long-term requirements that would offer them increased awareness of new technologies and opportunities.

b) **Institute of Cancer Research: Training of Institute Scientists**

HEIF-1 funding allowed the Institute of Cancer Research (ICR) (https://www.icr.ac.uk) to sponsor Institute scientists to attend courses on intellectual property rights (IPR) management and business skills. In developing a more entrepreneurial culture, scientists were able to meet and interact with colleagues from industry and increase their appreciation of commercial culture. The courses were oversubscribed and feedback was uniformly positive; some scientists decided to make a career change to technology transfer because of this training (as ICR had expected) while others found it enhanced their understanding of the technology transfer process, adding value to their academic discovery roles.

c) University of the West of England: Development of a Health Community

The University of the West of England (UWE) undertook a project across three faculties to review existing provision and develop new approaches for working with the health industry. Staff-exchange programmes supported further development of leadership programmes and the re-design of education modules. These programmes are now ‘fit for purpose’. UWE offers improved leadership studies in the Business School, and enhanced CPD in the Faculty of Health and Social Care, benefiting both commercial and not-for-profit partners.

This work was further developed under HEIF 2to develop science communities of practice in health. The initial analysis undertaken by UWE with HEIF-1 funds has resulted in significantly improved education and research for business and community partners. External relations have been strengthened, with benchmark study for customer relationship management, a network of community and business fellows, and the development of an effective interface with the health sector.

2.4. Industrial Partnership Award

Background

The Industrial Partnership Award (IPA) scheme is BBSRC’s (Biotechnology and Biological Sciences Research Council) principal mechanism for supporting collaborative research with industry within responsive mode. It was introduced in 2001 as a means of encouraging scientists to consider and seek industrial partnership in their research grant proposals, and to ensure that a route for knowledge transfer existed for BBSRC-supported research.

The IPA scheme provides funding for science-led grants where an industrial partner makes a significant contribution to the cost of the project. Responsive mode applications with a qualifying level of industry contribution are awarded IPA status and are considered more favorably during the assessment process (subject to meeting a quality threshold). Since the IPA scheme’s inception in 2001, 128 IPA projects have been funded with a total BBSRC investment of £57.2M.

The Biotechnology and Biological Sciences Research Council (BBSRC) is one of seven Research Councils sponsored through the Department for Business, Innovation and Skills (BIS) of the UK government. Its principal aim is to foster a world-class biological science community in the UK. The mission of the BBSRC is to fund internationally competitive research, to provide training in the biosciences, to encourage opportunities for knowledge exchange and economic impact, and to engage the public and other stakeholders in dialogue on issues of scientific interest.

Funding

The contribution of the industry towards funding of IPA projects is a minimum of 10%. Such a contribution is in form of cash. However, additional ‘in-kind' contributions too are encouraged.

Industrial Partnership Awards (IPAs) encourage and support collaboration between academic research groups and industry.

IPAs are academic-led, responsive mode grants that have significant industrial involvement and industry partner(s) contributes in cash at least equivalent to 10% of the full project costs. Additional in-kind contributions from industry are welcome but do not count against the industry contribution. Funding is only available for organisations eligible for BBSRC support.

Applications are assessed by the Research Committees, alongside standard applications, using the same criteria. IPA projects are normally funded in preference to standard grants of equivalent scientific merit.

The company partner should be registered in the UK or have a UK R&D or manufacturing site. Where a suitable company cannot be found in the UK, an overseas company may be used. However, such collaborations are judged on a case- by-case basis, and clear justification must be provided.

2.5. Stand-alone LINK scheme

Background

LINK is a government scheme (http://www.bbsrc.ac.uk/funding/filter/stand-alone-link/), in which the government provides support of up to 50% of the total costs of collaborative research between industry and the research base, the balance of funding being provided by industry. The scheme comprises a number of programmes in defined technology or market sectors that are sponsored by government departments and Research Councils, each programme being made up of collaborative research projects. Examples of LINK programmes where Biotechnology and Biological Sciences Research Council (BBSRC) has supported research grants include:

- Advanced Hygiene and Food Manufacturing LINK
- Applied Genomics LINK

- Bioremediation LINK
- Food LINK
- Food Quality and Innovation LINK

Funding

LINK supports collaborative research projects between at least one company and one academic partner. At least 50% of the full project cost comes from industry. Applications should be for pre-competitive research that would not be undertaken in this form without LINK support. Funding is only available for organisations eligible for BBSRC support.

The Research Committees assess the applications alongwith standard applications, using the same criteria. The funding is limited, hence very few extremely extraordinary applications are selected.

Partners must agree ownership and exploitation of intellectual property arising from the project at the outset. An appropriate management framework must be in place with defined scientific and commercial deliverables.

Benefits for company partners include:

- financial support for the project
- closer relationships with the science base possibility of recruiting appropriately trained staff at the end of the project.

Successful Examples

a) **QUOATS - Harnessing new technologies for sustainable oat production and utilization**

A five-year Sustainable Arable LINK project launched in September 2009, QUOATS (http://www.quoats.org) was led by Aberystwyth University's (http://www.aber.ac.uk/en/) Institute of Biological, Environmental and Rural Sciences (IBERS), and was jointly sponsored by:

- BBSRC
- DEFRA (Department for Environment, Food and Rural Affairs)
- Welsh Assembly Government's Academic Expertise for Business (A4B) programme with European Regional Development funding
- Scottish Government Contract Research Fund

- AHDB and industry partners

Oats are one of the most useful and nutritious cereal grains, that can help address the food security issues of the world. However, there are many emerging problems with cereal cultivation and at the same time it is an environmentally benign crop, which offers considerable health benefits for human and livestock consumption.

The QUOATS project combined the genetic engineering techniques of the scientists and the best agronomic practices of the farmers worldwide. It sought to develop oats with the best qualities, yield, economic competitiveness and quality that meet the need of growers and industrial end-users. It developed powerful enabling technologies for the identification of specific genes and molecular markers associated with key traits, in collaboration with academic partners and industrial end-users across the whole production chain.

The project capitalized on the value of oats as a profitable component of sustainable arable production for human and livestock consumption and for industrial end uses as proven by the earlier, and very successful, OatLINK project.

b) Conversion of high sugar grasses to alcohol based transport fuel (Grassohol)

A 3-year **Renewable Materials LINK** project launched in April, 2009 focusing on sugar-rich varieties of perennial ryegrass, developed at Aberystwyth University's Institute of Biological, Environmental and Rural Sciences (IBERS), as a raw material for producing bio-ethanol. The funding agencies were Department for Environment, Food and Rural Affairs (DEFRA), the Department of Energy and Climate Change (DECC) and the BBSRC, the project brings together the expertise of 8 partners from industry.

The team experimented with different soils, fertilizers and companion crops such as white clover, with the aim of reducing dependency on artificial oil-based fertilizers. The results were promising and indicated that up to 4,500 litres of ethanol per hectare of ryegrass could be produced every year, comparable with other energy crops but with the advantage of being environmentally friendly, capable of growing on poorer land and with cheaper management costs.

2.6. N8-Industry Innovation Forum

Background

The N8 Research Partnership (https://www.n8research.org.uk/partner-with-us/industry/) is a collaboration of the eight most research intensive Universities in the North of England created in 2007. The eight Universities are:

- Durham University, (https://www.dur.ac.uk)
- Lancaster University, (http://www.lancaster.ac.uk)
- University of Leeds, (https://www.leeds.ac.uk)
- University of Liverpool, (https://www.liverpool.ac.uk)
- University of Manchester, (http://www.manchester.ac.uk)
- Newcastle University, (http://www.ncl.ac.uk)
- University of Sheffield, (https://www.sheffield.ac.uk)
- University of York, (https://www.york.ac.uk)

N8 aims to create a positive impact of the research and its applications, by working closely with the universities, industries and the society in general. It aims to promote collaborations, float schemes in R&D to boost research capabilities of universities and industries and ultimately drive the economic growth of UK.

The Industry Innovation Forum is an initiative created by the N8 Research Partnership, the Higher Education Funding Council for England (HEFCE) and Innovate UK to bring together companies in UK and researchers from the universities and other key partners and networks involved in innovation.

History

The N8-IIF was launched in January 2012.

The initial partners of the N8-IIF were the N8 research-intensive universities and global firms involved with research and development, including AstraZeneca, Croda, National Nuclear Laboratory, Procter & Gamble, Reckitt Benckiser, Siemens, Smith & Nephew and Unilever.

Also, many SMEs participate in forums that lead to new collaborations with N8 academics.

Objectives

The N8 Industry Innovation Forum aims to strengthen the connection and market linkage between R&D sector, industrial and consumer needs and the research base in the UK.

The Forum aims to work as a stimulant for innovation by:

- Understanding the needs of the industry, to be met with solution oriented research by the Universities.
- Giving a boost to new ideas, innovations and business opportunities by combining talent of the researchers with experience of the businesses.

After interaction with the businesses, the N8-IIF has re-affirmed its objective to create new interactions between industry and the research base to drive innovation, competitive advantage and growth.

The N8-IIF also exemplifies the N8 Research Partnership's main focus and commitment to support industry for the commercialisation of science and research.

Working and achievements

The meetings of the forum are held on specific themes decided by the businesses in order to bring together industry challenges and ideas with new thoughts and solutions from the research base. For instance,

- It was found out that industry partners were looking for solutions and ideas in the arena of **Advanced Materials** from the research base across a range of sectors. The first N8-IIF event, held in February 2012, focused on this and through a series of industrial challenge led discussions, new industry to industry and industry to academic partnerships were created, to reach a solution.
- In the second N8-IIF meeting, that was held in November 2012, the focus was on **Active and Healthy Ageing**. More than 100 experts from the industry, charitable organisations and N8 group of universities had participated, and the event emphasized on digital innovation for health and wellbeing, ageing skin and food and nutrition.
- The third N8-IIF is met to deliberate on the theme of **Industrial Biotechnology**. The third N8-IIF was held in October 2013.

- The fourth N8-IIF meeting took place in October 2014 in York and focused on **Achieving a Sustainable Food System**.
- More recently, a forum held by N8 with CRODA scientists in 2015 identified **multiple collaborative opportunities**. The Forum facilitated partnering process is being utilised within the N8 Policing Research Partnership, and the N8 AgriFood Resilience Programme.

Subsequent to each forum meeting, the follow-up exercises expand the ideas with the greatest competence and interest in order to boost new research and development collaborations.

Industry partners benefit from utilising the combined proficiency and capabilities of the N8 Research Partnership, which provides an opportunity for efficient access to the N8 science base in a unique manner.

Successful examples

a) Setting up of a hub for development of anti-microbial surfaces

The hub, based in University of Liverpool was established to design such materials and surfaces that would inhibit the growth of microbes and infections. The main aim of setting up this hub is to rope in multinationals and the SMEs to understand the behaviour of bacteria and microbes and how disruptive innovation can be applied to prevent microbes from growing on surfaces.

2.7. Science Parks

A science park is a business support and technology transfer initiative, that:

- encourages and supports the start up and incubation of innovation-led, high-growth, knowledge-based businesses.
- provides an environment where larger and international businesses can develop specific and close interactions with a particular centre of knowledge creation for their mutual benefit.
- has formal and operational links with centres of knowledge creation such as universities, higher education institutes and research organisations.

United Kingdom Science Park Association (UKSPA)

The main objective of UKSPA is to be the authoritative body on the planning, development and the creation of Science Parks and other innovation locations that are facilitating the development and management of innovative, high growth, knowledge-based organisations.

Founded in 1984 by the managers of the eight Parks that then existed, UKSPA has gone from strength to strength. In the last thirty years the number of Science Parks has grown significantly (from two in 1982 to around 105 in 2014). There is still a strong regional, and local focus to their establishment. Over the years, the Science Parks have been encouraged in Universities because of the immense benefits that are provided to the industrial chain and the economy of the country in a broadbased manner.

As a result, over the last few years there has been continual growth in membership.

2.8. Technology Transfer Offices (TTO)

Background

The TTO is the part of a university that is responsible for protecting and commercialising intellectual property developed at the university for social and economic benefit around the world.

Objecives

The primary remit is to identify, protect and transfer knowledge created in the university out to businesses where it can be developed into products and services that benefit society and generate economic benefit for partners, universities, staff and students. TTOs seek a fair and equitable share of the financial benefits of success for the university to reinvest in university research, teaching and future commercialisation activity. Most universities set financial objectives for their TTO over varying timescales; with varying emphasis on generating income, making a profit, and promoting research impact.

TTO and Research Office

The Research Office (Research Support Services) of a university is also involved in intellectual property and negotiating arrangements for research funding involving industry, as well as charities, EU and government. In some universities the Research Office establishes ownership of university intellectual property, which is then passed on to the TTO for commercialisation. Each university will develop its own organisational structures for managing research funding, consulting, equipment services, material transfers and sales, and technology commercialisation. TTOs can be part of university administration, a wholly owned subsidiary company or rarely a contracted out service.

Who does TTO represent?

The TTO represents the interests of all those involved in transferring technology: the university, department, academic (who may or may not still be at the university), student inventors (many of whom are no longer students) and funders who have contributed to the research. Ultimately the TTO is responsible to the senior governing body of the university it represents.

Without a TTO, many of the jobs carried out by a TTO would still need to be done. For example, registering intellectual property (IP), checking freedom to operate, negotiating license agreements, spin out formation and investment, and collecting income and distributing it to beneficiaries. Whilst some academics have the experience to do this themselves, most do not and are often too busy. The TTO provides a central resource of trained and experienced professionals who can provide expert support to their academic partners. Without the TTO the same tasks would be carried out by people within the university for whom this is not their primary expertise or role; this would be less efficient, more expensive and less likely to have a successful outcome. The TTO fulfills obligations taken on by the university from research funding bodies and by the university's own objectives and policies on innovation.

The respective TTOs have amassed a great deal of expertise, contacts and knowledge on the process of commercialising technologies from universities. The staff is well qualified, trained and willing to engage in the process. Working with a TTO adds value and speeds up the commercialisation process. Many pitfalls are seen and the TTOs guide the academic researchers accordingly. In some cases it is clear that an academic entrepreneur is perfectly capable of undertaking the functions of a TTO. In most of the universities there are mechanisms to allow such that once the necessary revenue sharing agreements are in place the researcher can proceed independently of the TTO. University technology transfer is often described as a "contact sport" and it is important for university academics to have support from experienced people in 'their' university that are close, they know and trust.

Success stories

a) Simulect

In excess of half a million people have been treated with a monoclonal antibody developed at University College London (UCL) and marketed by Novartis as Simulect - an immune-suppressant agent used to prevent transplant rejection in people who are receiving kidney transplants.

b) Permasense Ltd

An Imperial team, in collaboration with British Petroleum (BP) developed a new pipe-wall thickness corrosion monitoring technology to improve safety in the oil and gas industry. Imperial Innovations patented the IP and formed a company, Permasense, to manufacture and market the technology. Permasense products are now used in the refineries of multiple customers around the world, including all BP oil refineries.

2.9. Industrial Strategy Challenge Fund

The Industrial Strategy Challenge Fund aims to bring together the UK's world-leading research with business to meet the major industrial and societal challenges of our time. The Industrial Strategy Challenge Fund provides funding and support to UK businesses and researchers. The fund is part of the government's £4.7 billion increase in research and development (R&D) over 4 years. The Fund is supported by Research Councils UK.

2.10. Industrial CASE

Background

The Science and Technology Facilities Council (STFC) Industrial CASE (Cooperative Awards in Science & Technology) studentship competition provides support for PhD students to work in collaboration with a non-academic partner on projects that fall within the STFC core science programme in astronomy, particle physics and nuclear physics; or that aim to apply technologies or techniques developed within the programme into other areas. Projects involve joint supervision of the student by a member of staff at an academic research organisation or related institution and an employee of a non-academic organisation, such as a UK industrial firm, public sector organisation or charity (the non-academic partner).

Organisations eligible to receive an STFC studentship quota (that is, universities, Research Council institutes and those independent research organisations approved as eligible to hold grants) may act as the academic partner, but not as the non-academic partner. Non-University academic-related partners would need to host the studentship in conjunction with the University where the student would be registered.

Other UK-based organisations (including UK subsidiaries of foreign firms) may act as the non-academic partner.

Industrial CASE awards are for a minimum of 3.5 years. During the period of the award, the student is required to spend a period on the premises of the co-operating body. For a 3.5 year award, the cumulative period should be no less than 9 months but this could be spread over the period of the studentship and would not normally exceed 18 months.

Non-academic partners are required to take part in recruitment and monitoring of the student and to maintain active contact with the student and academic supervisor throughout the period of the studentship. Research Organisations are encouraged to include an industrial external examiner for the PhD.

Industrial CASE Plus

Industrial CASE-Plus extends the Industrial CASE competition to help students become more effective in promoting technology transfer, should their chosen career path take them into either academic research or industry. For the first 3.5 years of the award, Industrial CASE-Plus operates in the same way as the Industrial CASE competition. The main difference is that the student spends one more year working full-time on the premises of the non-academic partner as an employee. During this additional year, the student is employed by the non-academic partner at a salary equivalent to that of a new STFC postdoctoral researcher.

STFC will contribute 50% of the salary costs incurred by the non-academic partner (up to a maximum STFC contribution of £14,250). Entry into the last year is dependent on the student demonstrating a level of achievement agreed in advance between the non-academic partner, the research organisation and the student. STFC will not commence funding for the additional year until the PhD thesis has been submitted.

Funding Contribution by non-academic partner

Non-academic partners (excluding small and medium enterprises) are required to make a financial contribution to both the student and the project. It must include:

- An annual contribution to the academic research organisation towards the cost of the project of £1,400.00.
- All additional expenses, such as the cost of travel and accommodation incurred as a direct result of attendance at the premises of the non-academic partner.

- A minimum annual contribution to the student of £2,760.

STFC funding contribution

Payments to the student include:

- Maintenance allowance 2017-18:
  - Industrial CASE outside London - £15,553 per annum
  - Industrial CASE within London - £17,553 per annum
- Industrial CASE and Industrial CASE-Plus awards addition:
  - £615 per annum

Payments to the research organisation:

- Tuition fees up to a maximum of £4,195 per annum in 2017/18
- Research Training Support Grant (RTSG), a contribution towards incidental costs of training research student - £1,000 per annum
- A contribution of £230 is paid towards the cost of conference fees and UK fieldwork

For Industrial CASE-Plus the non-academic partner will pay 50% of the student's salary in the additional year; STFC will contribute the remaining 50%, up to a maximum of £14,250.

2.11. Innovation Partnership Scheme

The Innovations Partnership Scheme (IPS) is designed to transfer technology and expertise developed through Science and Technologies Facilities Council (STFC) funding to the marketplace in partnership with industry and other academic disciplines. STFC technology or expertise must be integral to the project. The technology or expertise can be developed with STFC funding at UK higher education institutes, STFC laboratories, European Organisation for Nuclear Research (CERN), European Synchroton Radiation Facility (ESRF) and ESO (European Southern Observatory).

IPS projects can vary in length up to three years, with funding for a maximum project value of £150k per annum, over a period not exceeding three years.

IPS closing dates are every four months.

Success stories:

a) Technology that is used to study other planets' surface has been remodelled to be used as a diganostic technology in detection of various life threatening diseases. The participating organisation is University of Leicester's diagnostic development unit (DDU). The scientists in the University have secured the funding from Higher Education Funding Council for England and then from STFC's Innovation Partnership Scheme.

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France

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1. Introduction

France holds the position of one of the top five economies in the world, when measured in terms of GDP. The innovation ecosystem of France has also been ranked second largest in the continent of Europe, lead by Germany. It holds nearly 5% of OECD GERD, publications and patents [OECD (2016), "France", in OECD Science, Technology and Innovation Outlook 2016, OECD Publishing, Paris. http://dx.doi.org/10.1787/sti_in_outlook-2016-60-en]. It has been ranked 15th in the Global Innovation Index (GII). A few important indicators are listed below in Table 1.

Table1: Global ranking of France, as based on S&T related indicators.

S. No.	Indicators	Global Rank
1.	Expenditure on education, % GDP[a]	32
2.	Research & development (R&D) [a]	12
3.	Gross expenditure on R&D, % GDP[a]	12
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	8
5.	QS university ranking, average score top 3[a]	10
6.	University/industry research collaboration[a]	31
7.	Capacity for Innovation[b]	8
8.	Company Spending on R&D[b]	9
9.	Availability of Scientists and Engineers[b]	26
10.	Quality of Scientific Research Institutions[b]	9
11.	Publications[c]	6
12.	H-index[c]	4
13.	Intellectual Property Rights[d]	27
14.	PCT Patents[b]	15

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

Innovation persists to be at the heart of France's policy for advancement and growth. The government has keenly focussed its directives and strategies towards promoting business R&D and the evolution of novel firms. It has introduced new directives over time and has also increased its measure of funding in the said area, significantly. Variety of direct measures, like, innovation agency and indirect measures, such as, research tax credit, were introduced by the French government.

The major responsibility of R&D activities and innovation, in France, is borne by two ministries - Ministry of Research (MR) and Ministry of Industry (MI). However, for research activities that are domain specific such as defence, agriculture transportation, health and others, and the authority of research policy in that very domain is held with the parallel ministry.

The National Agency for Research [Agence Nationale de la Recherche; (ANR)], is the major agency in France that finances public research. The most fundamental goal of ANR is provide support for promoting and advancement of basic as well as applied R&D undertakings, innovative activities, and fostering collaborations amongst the private and public sectors. It also focuses over strengthening the technology transfer regime and translating the public sector research into commercially profitable entities.

The French public research system continues to evolve and several initiatives have been taken for strengthening the links between various research players and other stake holders. A recent Law on the missions and organization of higher education and research system encourages the public research institutes (PRIs) and higher education institutes to collaborate/merge for reaching upto critical mass in research and teaching. This law was also the basis of the National Research Strategy 2015-20. This strategy focuses on two main objectives, which are –

- Maintenance of competitiveness of France in scientific research in the global scenario
- Fostering research that answers scientific, societal, environmental and technological challenges of the 21st century.

The investment towards R&D by the public sector is above the OECD median and in comparison to the other countries in OECD area; the number of patents filed by the PRIs in France is relatively higher. For taking advantage of this encouraging position, the French government has oriented its policy towards reinforcing the translation of public sector research into commercial outputs for enhancing the competitiveness of the private sector to be able to address the needs of the common man and society.

Governance of a research and innovation system generally includes four levels, which are –

1. Level 1 is the highest level. It is where the general guidelines and priorities are defined for the entire national innovation system. It may entail providing advice to the government or more binding inputs, such as the decisions of an inter-ministerial committee. It must include not only government input, but also input by groups of key contributors, including businesses, researchers, etc.
2. Level 2 is co-ordination between government ministries, whose diverse portfolios incline them to pursue their own discrete policies. In practice, this co-ordination level may include both administrative and political elements. In some instances, an inter-ministerial group also functions as a level 1 co-ordination mechanism. In a number of countries, however, co-ordination at this level is complicated by inter-ministerial rivalries, especially over access to budgetary funds.
3. Level 3 is more operational and aims to ensure consistency among the measures taken by the various funding bodies. This level may involve co-ordinating funding activities, e.g. through joint programming. Effective co-ordination requires strategic intelligence and a degree of autonomy at this level – operators without a margin for manoeuvre cannot truly co-ordinate their actions. In some countries – the United Kingdom and the Nordic countries[3] – institutions known as Research Councils are responsible for programming and funding university research.
4. Level 4 is where co-ordination takes place between the operators responsible for executing research and innovation (companies, public researchorganizations [PROs]). At this level, co-ordination tends to be achieved through autonomous organization rather than formal mechanisms. This is often done through joint funding programmes and public-private partnerships.

In France the levels 1 and 2 on the one hand, and 3 and 4 on the other, are combined to a great extent. Indeed, ministries (level 2) play a key role in the defining the

[3] Nordic Countries – Denmark, Finland, Iceland, Norway and Sweden

general strategy (level 1), and PROs are both funding agencies (level 3) and implementing agencies (level 4) (Figure 1).

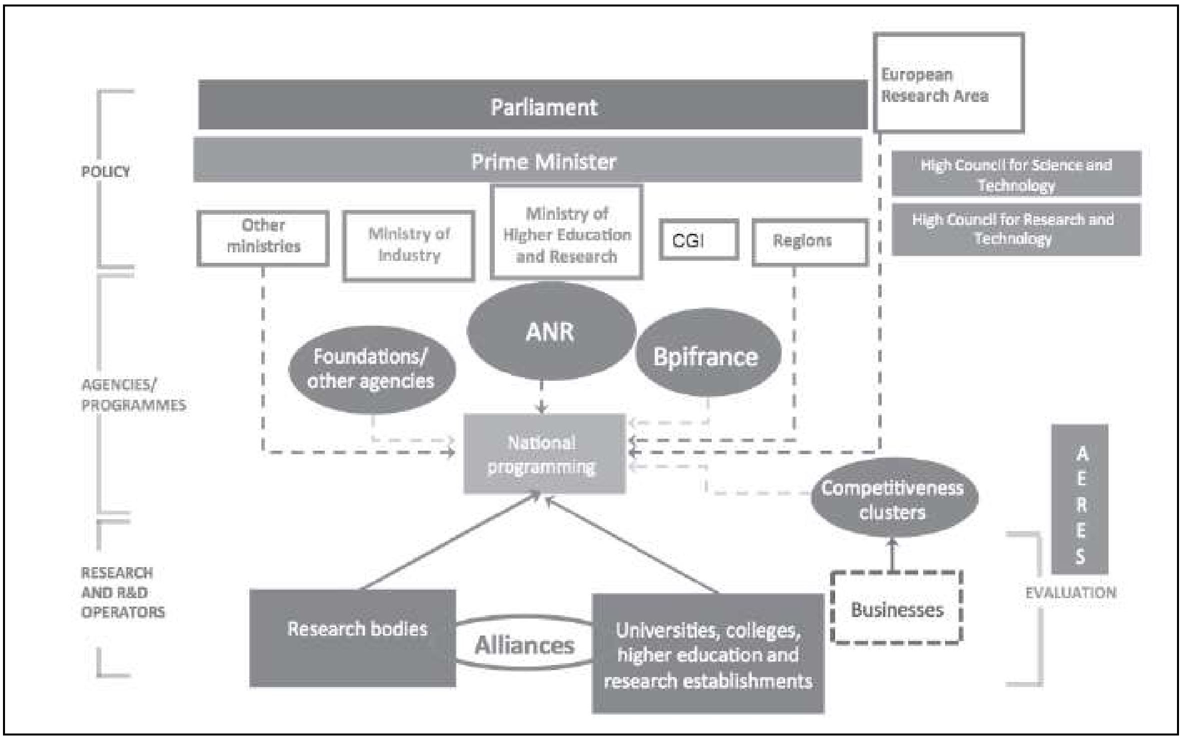


Figure 16: Framework of research and innovation in France
Source: OECD (2014), OECD Reviews of Innovation Policy: France 2014, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264214026-en

Even though nearly half of the public research was conducted by the public research institutes (PRI), in the recent times there has been a shift towards universities which have now been engaging strongly in the public research. In the previous decades the system of research and higher education has underwent certain alterations, together with re-organization at the ministerial level, creation of new agencies for research funding, such as National Research Agency (ANR) and French academic research evaluation agency (AERES), greater autonomy for universities (LRU Act), and introduction of contract-based relations between the state and research bodies etc.
The university system in France was fragmented and the introduction of recent laws and reforms has however strengthened it. These recent reforms in STI policy governance have resulted in a move towards more thematic research and competitive project-based funding and a larger role for universities. France has also invested highly for upgrading its research laboratories and facilities of excellence under the Future Investments

Program (*Programmed'Investissements d'Avenir*, PIA), which was founded in 2010. This program in itself aims at enhancing the competiveness of France by encouraging innovation.

The STI policy has sought to reinforce collaborative research and technology transfer. Under the PIA, interdisciplinary technological research institutes can be set up as public-private partnerships (USD 2.3 billion), with a view to becoming world-class campuses for technological innovation and enhancing cluster ecosystems. In addition to its funding for collaborative research, the ANR introduced in 2011 an Industrial Chairs programme to support collaborative research on strategic issues for French industry. The PIA has also funded the creation of a USD 1.2 billion National Fund for Research Promotion (2010) to support the deployment of accelerated technology transfer societies (SATT) and the professionalization of research promotion. France Brevets, an IP investment fund, was set up in 2011.

Business R&D is a key priority of the National Strategy for Research and Innovation (SNRI) and has drawn much policy attention in recent years. Government funding in this area has increased significantly. Indirect funding through the research tax credit (CIR) was reinforced by a major revision of the scheme in 2008 (at a budgetary cost of nearly USD 6 billion in 2010), while direct funding through the innovation agency (OSEO) and the ANR was maintained.

2. Schemes/ Programmes/ Organization

2.1 National Research Agency [Agence Nationale de la Recherche (ANR)]

Background

The National Research Agency (ANR) in France is the major player of research in terms of competitive funding. It was established in 2005 as a directing and funding agency for managing the resource allocation of competitive grants, which were aimed at promoting excellence and flexibility in research. The establishment of this agency was believed to promote competition which would lead to excellence and spark new research by means of allocating funds.

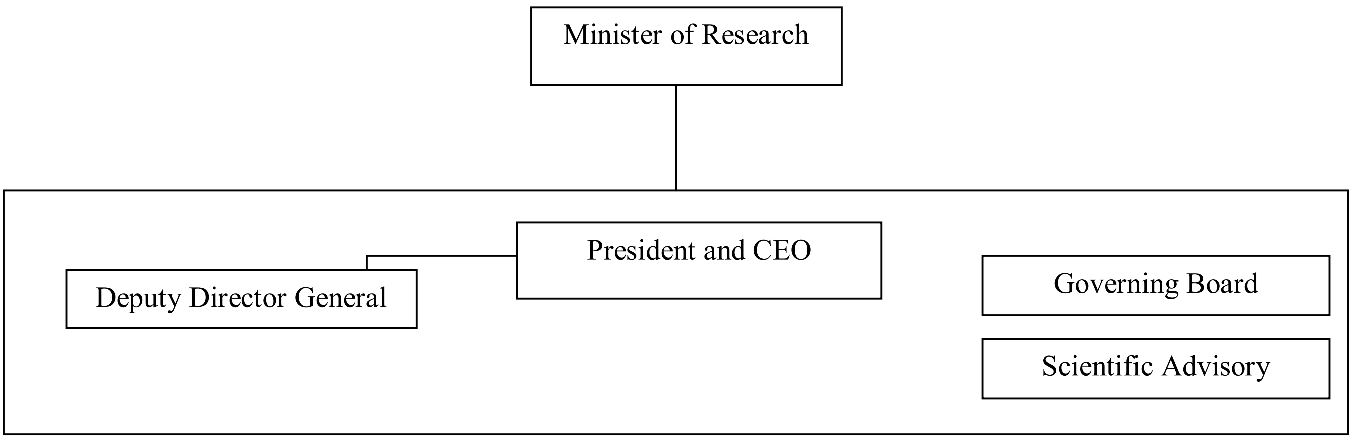
Since then the ANR has become a crucial agency for financing the universities, academic institutions and PROs.

Objectives:

The most fundamental objective of the agency is to advance and intensify partnerships amongst the public sector players (universities, PROs etc.) and the private sector (French companies, industries etc.) for research. The aim is to hasten the process of transferring technology and create economic worth from the outcomes of public sector research.
Thus, through its various undertakings and initiatives, the agency fosters transfer of technology, public-private partnerships and innovation along with augmenting scientific cooperation locally as well as internationally.

Organization:

The French ANR is a public administrative organization directly under the supervision and control of the Minister of Research. The main administrating body composes of a 'Governing Board', which is guided and directed by a President and CEO. One or more than one Deputy Directors assist the President along with a scientific advisory board, which also guides the President on strategies. The deputy directors are appointed for a fixed term, by the President.



Governing Board: The Governing Board of ANR comprises of delegates from various Ministries such as Higher Education, Research, Industry and Budget; representative from the French Strategic Research Council (CSR), and other proficient experts who represent the scientific and socio-economic fields broadly. The agency interacts and connects with other Ministries related to research, academic institutions, research organisations, research alliances (Aviesan, Ancre, Allistene, AllEnvi, and Athena), foundations/associations as well as competitiveness clusters.
Internationally, ANR interacts with project based funding agencies and organizations of other countries. ANR also performs activities with research organizations and agencies

in Europe or elsewhere, that work to support collaborative high end research (Science Europe, Global Research Council, etc.).
The annual work plan of the ANR is charted and implemented through the guidance of the Scientific Advisory Board. The board assists the President in various propositions including strategic work plan, assessment, modalities of scientific departments etc.

The Agency for the Evaluation of Higher Education and Research (AERES) is responsible for conducting evaluation studies on ANR.

In order to accomplish and satisfy the requirements of the research communities viz-a-viz project based funding needs, along with fulfilling its role as a public agency for promoting research, ANR has designed and put into place a variety of initiatives and funding instruments. These initiatives have been established for driving innovation and competitive research in France through apt funding and guidelines. Each of the deployed instruments satisfies a clearly defined goal and end purpose.

2.3 Joint laboratories between public research organisations and SMEs orintermediate-sized enterprises (LabCom)

Background:
A large number of players take part in the research activities and hence it is obvious that there is considerable scope of partnership amongst the players. Also the public research players, when subjected to an ordered and well-structured partnership will definitely produce more efficient and prudent solutions. However, establishing a successful bilateral partnership between the private sector (in particular SMEs and ETI[4]) and public sector players is a challenge that the ANR needed to focus on. The agency realized that efficiently created knowledge and know-how through joint efforts of the public sector organization and such enterprises would be a crucial factor for driving advanced research, competitiveness of the industries and hence economic growth. The formation of links and partnerships amongst the SMEs/ETIs and public research laboratories was

[4]Medium-sized enterprise (ETI): An ETI is a company that does not belong to the category of SMEs, and which:

- on the one hand occupies fewer than 5,000 people;
- on the other hand, has an annual turnover not exceeding EUR 1,500 million or a balance sheet total not exceeding EUR 2 000 million.

therefore recognized as a strategic element of the innovation chain. For drawing maximum benefits from the potential of such partnerships, the ANR, in 2013 put into motion the "LabCom" program. This initiative aimed at significantly boosting the formation and establishment of associated laboratories with SMEs, which shall offer flexible modes of operations and governance.

Objective:

The prime objective of this initiative was to support and encourage the players of academic research for partnering with industrial entities and engaging in efficient linkages with either SMEs or mid-caps. This program also demonstrated complementarily to the other programs of the ANR. The definitive purpose of this initiative is to therefore create novel structured partnerships by means of forming "Common Laboratories" between an SME or an ETI and a public sector research organization.

Establishment of a LabCom-

A Common Laboratory or Joint Laboratory initiative was launched for transferring potential commercially viable research into the market. As the partnership is defined by common roadmap therefore the partnering entities have a clear picture of the activities to be performed. The initiative has been designed in a manner so that it is easy to implement and allows for not only structures physically present but also virtual structures to apply and develop virtual laboratories.

The research partnership activities and undertakings are lead by a group or team from the public sector research organization/laboratory, which will essentially be the awarded the ANR grant. It is essential for the team to submit and produce a 'Letter of Commitment' from the industry as well as the research organization. The grant is provided to the research organization however there are no limitations on the research organization collaborating with other research groups for the activities of 'Common Laboratory'. ANR does not provide any subsidies for the partnering research group. It is mandatory for the collaborating industry to be a SME or an ETI in the European sense.

The program is mainly intended at creating novel Common Laboratories.

Characteristics of the Means Allocated

The ANR supports two phases for a combined duration of three years.

i. Assembly Phase: This is the phase that begins with the signing of the Common Laboratory Contract.
The desired duration of this phase is up to six months and a maximum assistance of € 50,000 is given by the ANR. This phase ends with a milestone of moving on to the second phase (operational phase) of the Joint Lab.

However, the transition to the operation phase is conditional and granted on certain terms:

- The transmission of the draft common laboratory contract at the latest within the 12 months from the start of ANR financing; and, if this first condition is fulfilled, to the favourable validation of the contract by the ANR.
- Non-transmission of the draft contract within the contractual deadlines or non-validation by the ANR of this contract will cause the project to stop.

ii. The second phase i.e. the operating phase of the LabCom initiates only after the contract is validated by ANR. This phase is financed for a maximum amount of 250 k €, for the remaining time period.
The total amount financed by ANR is in a form of the grant of a maximum total amount fixed at a flat rate of € 300,000 over a period of 3 years.

Characteristics of the Results and Impact

The setting up of *Laboratoires Communs* is expected to tender SMEs and mid-cap companies and public sector research organizations a prospect to work in concert for carrying out effective R&D innovative activities, over a destined time period. As stated by the ambition of the program, the common laboratories created represent all the actors of research. Gradually such relations can lead to rise in power for the SMEs/ETIs and the public sector stakeholders.

The program faces a two-fold economic challenge i.e.

- Development of technical innovations resulting from the exchange of knowledge between the industries and PROs
- Creation of conceivably profitable knowledge.

The program intents at generating value and knowledge for both private businesses as well as the research players.

Project Phasing

The grant provided by ANR is divided within two phases, which needs to be clearly stated in the proposal submitted with the application. The milestones have to be marked clearly. The planned initiation date also needs to be mentioned in the proposal.

- Assembly Phase: The time duration of this first phase of Joint Laboratory can vary from 6 months to 12 months depending upon the work required for the initiation and setting up of Common Laboratory.
- The second phase is the operation phase of the Joint Laboratory and entails proper functioning of the lab.

The proposal submitted should clearly mention the duration and modalities of both the phases and the following constraints should be kept into consideration -

- The first phase has to be a minimum of 6 months and a maximum of 12 months.
- The progression from the first phase to the second phase is based upon validation by ANR.

Nearly 100 ANR LabComs have been created under this program, as of the end of the year 2016, offering support to academic institutions for a time period of three consecutive years. One of the challenges faced by the structures as well as a benchmark of success is sustainability and therefore it is imperative that the newly formed LabComs must devise methods of self-financing rapidly. The private sector may wholly assume the responsibility of the LabCom after the three years of funding.

Even though the partnership between the academia and private industry is dedicated, however the industry does not always assign a specific number of its employees to the activities of the LabCom. This has been noted in approximately 54% of the cases. Notwithstanding is the fact that the steep and consistent involvement of the company into the management of a LabCom is the basic reason for success of these structures.

Starting 2017, the LabCom programme has also commenced a supplementary aspect containing a ‘consolidator grant’. This phase was specially developed in concern with the labs which were previously accredited with the status of LabCom. This grant was instituted to support these labs as the commercial gains and finances as a result of the exploitation of research results were just enough to incur the present standing expenses of the labs and not sufficient to support them further. In such a scenario, a lab possessing potential for future sustenance may apply for consolidator grant.

Success Stories –

a) SMILK, a LabCom between the Wimmics research team and Viseo

SMILK, which stands for Social Media Intelligence and Linked Knowledge, is a joint laboratory bringing together the Wimmics research team from INRIA's Sophia Antipolis – Méditerranée centre, and the Research and Innovation Unit at Viseo. SMILK sets out to make various types of data from social media more meaningful by developing research and technology, first to retrieve, analyse, link and reason on data from Web text resources, and second to use linked open data (LOD), taking into account social network structures and interactions, for improved analysis and understanding of text resources.

While the opening and release of large volumes of public data (open data) and the application of web principles to the networking of data sets via linked data has led to new research opportunities, it has also created new scientific obstacles owing to the heterogeneity of data and the ways in which different types of data can be related. The SMILK LabCom is at the crossroads of the Data Web, Social Web and Semantic Web. The laboratory divides its research activities into three very closely interwoven main topics:

- Natural Language Processing (NLP),
- Linked Open Data (LOD),
- and social networks, which are further broken down into three sub-topics.

SMILK investigates various methods to achieve this end, including closely coupled algorithms and linguistic and semantic models, extraction and disambiguation of knowledge guided by data web resources, and combining different types of reasoning (logical inference, approximations and similarities, etc.).

This LabCom gives Wimmics an on-the-ground view, allowing it to use real data and requirements to conduct its research. On the other hand, it allows Viseo to draw on Wimmics' scientific know-how in the semantic web field to build up its own NLP expertise. In this way, it can optimise its research and innovation costs and develop its business intelligence offering with the help of new ideas that may emerge from these two different approaches to web resources.

This collaborative effort with the Wimmics team will allow Viseo to add to its automatic language processing expertise through Semantic Web insights and methods. This will help it optimize R&D costs and develop its range of business intelligence products. Viseo would like to focus on software that bolsters a company's IS (usually an ERP) by interfacing with the Web. Through this joint laboratory, Wimmics will gain access to new real situations and data, and understanding needs in the field, to enhance and extend its research.

b) CardioXcomp, a LabCom between the Carmen and Réo research teams and NOTOCORD

CardioXcomp is a joint laboratory – or LabCom – that brings together NOTOCORD, a French software editor specialised in biomedical signal acquisition and processing, and two applied mathematics research teams from INRIA, Réo (the project leader) and Carmen. The laboratory is devoted to mathematical modelling for pharmaceutical research, with the aim of adding to and improving various devices for measuring the activity of heart cells.

While it is now thought that cardiac modelling and simulation will very likely revolutionise pharmaceutical research, these practices remain restricted to the academic world. INRIA research teams and NOTOCORD have joined up to address this issue: "We are convinced that the most effective way to transfer simulation tools to the pharmaceutical industry is to develop them as close to the experimental data as possible."

The main focus of this LabCom is a device known as a Multi-Electrode Array (or MEA), designed to study heart cell activity through the acquisition of a large number of simultaneous spatial and temporal measurements. CardioXcomp wishes to proceed to the next stage by allowing MEA users to add spatio-temporal signals to mathematical models. During simulation, the descriptive and predictive properties of these models can be used to validate or invalidate assumptions about the effect of a pharmaceutical compound on heart cells.

At the end of the first three years of research, the goal is to set up an innovative software offer targeting the pharmaceutical research sector and the stem cell industry. Patent applications could also be filed on the use of these techniques for predictive testing of the effects of drugs on heart cells.

c) **LabCom BRAIN e-NOVATION**

It is a joint laboratory between the Brain and Spine Institute (ICM) and GENIOUS Group. Competencies of the two structures (Health & Technologies) are really complementary. The laboratory has been set up following a seed investment provided by the French National Research Agency in 2013.

The main objective of this laboratory is to create innovative digital tools in the health domain, measure their clinical efficacy and bring them to the market. Our lab develops therapeutics videogames for physical and cognitive rehabilitation, with clinical tests integrated into the game. For example, X-TORP is a naval battle game created for Alzheimer's disease patients. This game was clinically tested for feasibility and acceptability in Nice hospital. Multiple neurophysiological tests were integrated into the game like Trail Making Test. The results show a really good acceptance with really promising results, reduction of apathy and cognitive and physical stimulation. The article about this study is available since August 2016 in Journal of Alzheimer's Disease (https://lc.cx/oEiT) TOAP run is the game created for gait and balance disorders in Parkinson's disease with a financial support from the World Innovation Competition 2014. This game was clinically tested for feasibility and acceptability in ICM. 10 patients participated in the study. Preliminary results show a really good acceptance and feasibility, as well as efficiency as a secondary outcome. Both game examples use Kinect TM motion capture system (Microsoft) for movement detection.

2.3. Industrial Chairs

Background:

The program of Industrial Chairs was initiated with an aim to support research, which is carried out by private companies and public research organizations as a joint effort i.e. in partnership. In this manner it fosters and encourages the integration of knowledge of the eminent academicians into the higher education system of France as well as reinforces the finest actions and initiatives that were taken for enhancing R&D and innovation.

This initiative lays down ground for long standing partnerships between private industries and academic/public institutions in domains of key priority. The institution of Chairs provides results of basic and high-end research as well as training to build manpower. Adhering to the intent of the program, this instrument obliges the creation of a Chair (research and higher education) within the public institute, which is financed partly by the industry.

Objectives:

The aim of this programme is threefold-

- To conduct research in strategic and priority areas via a strong and lasting partnership between public and private organizations.
- To provide quality-committed training by making the vision, methodologies and experience of private actors available to doctoral or post-doctoral researchers in high-level public research laboratories
- To allow prominent French and foreign researchers to develop and deepen their expertise and spearhead pioneering research.

Funding:

The finances for Industrial Chairs are provided for a term period of four years by the ANR. However, this time period may be extended or renewed. The maximum and minimum limit of funds provided by ANR is fixed and varies between EUR 600 thousand to EUR 2 million per chair. The expenses that can be covered include – salaries, equipment, facilities and other program expenditures, and are covered 50% by ANR and 50% by the private company.

2.4. Collaborative Research Projects involving Enterprise (PRCE)

Background:

Through the means of another instrument i.e. Collaborative Research Projects – PRC, ANR facilitates pooling of skills and resources from varied teams, which in an ordinary situation might not collaborate or pool their resources, thereby enabling them to score competitive results from research that differs from the conventional research systems and methods. Collaboration between the public entities in the international context are funded by International Collaborative Research projects (PRCI).

In order to fulfil one of the most primal objectives of ANR i.e. developing linkages between the public-private sectors, transferring technologies and promoting innovation, another funding instrument, the *Collaborative Research Projects involving Enterprise (PRCE)* was established.

The instrument PRCE concerns only effectual linkage between a French industry with R&D base and a French public research organization/institute. The project undertaken in collaboration must be a pursuit of common objective of both the public laboratory and the private enterprise. The collaborating parties define the scope of the project, contribute towards its execution, and distribute the technological & financial burden and results as well as risks. However, it is not mandatory. In certain cases one collaborating party may agree to bear the complete financial burden of the project. But all these conditions, rules of cost sharing, technological intervention, division of labour, allocation of IPR, access to knowledge generated etc. must be defined prior to the start of the project.

Certain protocols are not taken under the ambit of PRCE like a simple arrangement of providing research services or technical services does not constitute a PRCE project. A company merely giving technical service within an ongoing project is not identifiable under PRCE, but a third company or service provider may give services to one of the partners of PRCE. These companies may be labelled as potential service providers.

Other collaborations that are permissible but do not fulfill the criterion for PRCE include –

- Partners such as associations, foundations, industrial technology centres, regional centres of innovation and technology transfer (CRITT), chambers of commerce, cooperative societies, inter-branch associations, etc.
- Commercial companies not conducting research and development (SATT, etc.)

In case of a commercial company undertaking R&D work being absent, the linkages involving such partners are directed to choose PRC funding instrument. In cases of foreign/international partners taking part in PRCE, they are directed to engage with their own funds.

The amount of grant, for a 24 month – 48 month long period rages from €50 k to €900 k. The amount granted is also dependant on the type of R&D project, goals of the scientific research, the type of partnership/consortium, number of collaborators involved etc.

A few characteristics and summary of the funding instruments dedicated to collaborative research, initiated by ANR have been enlisted in Table 1.

Table 2: Few instruments initiated by the ANR

Instruments	Targeted Enterprises	Nature of Research Projects	Funding Procedures
PRCE instrument	All enterprises but not associations (industrial)	Collaborative research projects with results sharing, without perpetuation beyond the projects	ANR project partially funded by research organizations and enterprises
LabCom and LabCom Consolidation	VSE, SMB and mid-cap companies	Structure-giving research project carried out beyond ANR funding	ANR funding for research project only Mandatory contributions to project by enterprise
Industrial Chairs	Intermediate or large-sized enterprises, or a consortium of enterprises	A structure-giving academic research programme with support from enterprises, impacting higher education.	Partial funding from ANR of the research organisation alone, with funding matched by the enterprise allocated to the research organisation
Carnot	All enterprises	Research and findings benefiting companies	No project funding by ANR. The Carnot programme supports the scientific resourcing and professionalising of research organisations

Investments for the Future

In 2009 the French government floated the Investments for the Future programmes [*Programme d'Investissements d'Avenir*, (PIA)]. This initiative was a strategic one, which was aimed at boosting the competitiveness in the French S&T ecosystem. It pushed higher investments in higher education, research, professional training, in private sector research, SMEs and for sustainable development. The investments were also aimed at developing and expanding sectors like biotechnology, digital technology, nuclear energy etc.

The aspiration of the investment program was to provide funds in a huge amount for long-term ingenious S&T projects that shall eventually develop into a source of economic progress of France. In context with the global situation a strong investing initiative is a prerequisite for development, growth and progress. Along with various societal considerations a part of this investment initiative also targeted health and biotechnology issues. The focus in specific domains enhances the area specific knowledge, number of solutions for real life problems, novel approaches in agriculture, medicine, physiology etc.

The Investments for the Future programmes represent **47 billion euros** of which **26.6 billion euros** are allocated to higher education and research

2 programmes were launched so far: **€22.6 bn** in 2010 and **€4 bn** in 2014

3 types of action: Centres of excellence; Health and biotechnology; Technology transfer and valorisation

Objectives:

- Promoting excellence and the development of high-level projects and cluster
- Strengthening France's capacity for innovation
- Increasing the competitiveness and attractiveness of French research and higher education
- Generating growth

The PIA programme represents the adoption of funds allocated by the country in areas of higher education and training schemes, in R&D endeavours, big and small industries, in tenable development together with all domains that are key to strategic future development such as biotech, digital, and nuclear sectors.

This program has been allocated a total amount of 47 billion euros.

A. Centres of excellence

Initiatives	Characteristic
Initiatives of Excellence, IDEX	A flagship initiative of this programme, this instrument provides France with a number of world-class multidisciplinary universities in higher education and research, capable of rivalling with the world's top universities. The international dimension is a strong factor, both in the universities recruitment policy oriented towards top-level researchers, and in the training and courses provided. The global action of the IDEX follows a two-tier approach: forming international partnerships and setting up incoming and outgoing mobility scholarships; strengthening the global attractiveness of the universities for foreign students and researchers.
Equipment of excellence, EQUIPEX	Providing French research with very high quality scientific facilities, which comply with international standards and play a key developmental role at the national level.
Laboratories of Excellence, LABEX	Providing internationally visible labs the means to compete with their foreign counterparts on an equal footing, attract researchers and professors of international renown and build a high level research, training and value creation integrated policy
Initiatives of Excellence in Innovative Training, IDEFI	Promoting innovation in training by supporting ambitious initiatives, at international standard and representative of university courses of the future

B. Health and Biotechnology

Initiatives	Characteristic
Research Hospitals, IHU	Supporting centres of excellence in research, care, training and technology transfer in the health field. A specific initiative also aims at developing centres of excellence specialised in research, training and innovative treatments in oncology (PHUC).
Bioinformatics	Increasing knowledge of biological mechanisms using mathematical models, algorithms and software programmes, in order to remove the

	obstacles identified in multi-scale and multi-physics modelling and to develop software solutions for health, biology, agronomy and the environment.
Biotechnology and Bio resources	Towards a bio-economy based on knowledge of the living world and on new methods for recovering renewable biological resources
Nanobiotechnology	Exploring the potential of nanotechnologies to increase knowledge in the area of biology
Cohorts	Providing long-term funding for cohorts with underlying health issues, in both general population and patients
Preindustrial Biotechnology Demonstrators	Allowing faster achievement of the proof of commercial concept by developing products or processes for which the proof of scientific concept has already been established
National Infrastructures in Health and Biotechnology	Creating infrastructures suited to new needs relating to research on living matter, rapid growth in biotechnology and new approaches to medicine Promoting national infrastructures designed to serve ambitious and internationally competitive programmes, as well as European and global networks' French nodes

C. Technology Transfer and Valorisation

Initiatives	Characteristic
Carnot Institutes	Supporting the development of Carnot institutes with SMEs, and at an international level.
Technology Transfer Acceleration Companies, SATT	Improving the global efficiency of the French system of public research valorisation through the creation of local "one-stop services" allowing for the improvement of service provision to researchers and businesses. Optimising the social and economic impact of the outcomes from academic research and facilitating technology transfer from public research to industry.
Theme-based Technology Transfer Consortiums, CVT	Setting up thematic consortiums entirely dedicated to the national and international valorisation of academic research and to the promotion of technology.

Technological Research Institutes, IRT	Creating a limited number of technological innovation campuses with a global dimension.
Energy Transition Institutes, ITE	Setting up, in the energy and climate sectors, a limited number of technological innovation campuses with potential global dimensions.
Research on Nuclear Safety and Radioprotection	Funding of academic-industry partnership projects, research infrastructures and technological platforms in the field of nuclear safety and radioprotection, including the participation of foreign researchers, the cooperation of Japanese authorities, international missions and specific nuclear power site investigations.

Source: http://www.agence-nationale-recherche.fr/en/about-anr/investments-for-the-future/

Of the various initiatives of the PIA under different sub heads, the main commercialisation and technology transfer mechanisms of the PIA (2010) are discussed below –

2.5. The CARNOT Initiative

Background:

The French government, in 1999, executed the *Innovation and Research Act,* which brought into action the creation and development of novel innovative firms and translation of know-how/knowledge to the French industry from the public research labs and organizations. The enactment of this law brought about welcome changes such as introduction of fiscal incentives, streamlined the legal guidelines and framework for novel companies (R&D based), accredited the researchers working in government sector to set up and be involved with start-ups without giving up their status of civil service for a time duration of 6 years, along with grounding new mechanisms and protocols for fostering public-private research collaborations. Then, the Ministry of Industry in association with the Ministry of Research and Technology drew up the *Innovation Plan*, in 2003. This plan laid down a series of recommended endorsements and touchstones for providing innovation support in the country. Furthermore, this plan was strengthened and reinforced by the *Pact for Research*; by the Ministry of Research and Technology in 2005. The pact set forth propositions, which provided as a base for the *Law for Research*, which came into force in 2006. The *Law for Research* aimed at supporting greater coalition amongst diversified actors within the research community, for networking public and private R&D activities, for contributing towards upgraded circumstances and surroundings for scientific careers, and finally for encouraging the amalgamation of the system of French research with the *European Research Area* (ERA).

The fundamental basis of the Carnot Initiative (http://www.agence-nationale-recherche.fr/carnot) arose from the efforts that were initiated in the early 2000s for reforming the country's innovation ecosystem and modify the relations between the research base and private industry, particularly SMEs. However, it was not until 2006 that the Carnot Initiative was officially launched. The launch of this initiative urged the public research organizations to requisite for gaining identification as a "Carnot Institute". This identification represented a seal of excellence, which was named in the commemoration of Nicolas Leonard Sadi Carnot[5]. The *Pact for Research,* which aimed at reinforcing the undertakings of the PRIs associated with or partnering with other public or private entities, gave birth to the Carnot Initiative. This program aimed at labeling the best amongst those institutes as Carnot Institutes and then makes them deserving of special grants from the government through ANR, which are linked with the amount of funds that the institute generates through contract research from the private sector.

The seal of excellence obtained not only benefits the reputation of the institution but also makes them worthy of government funding. This initiative also derived inspiration from the Fraunhofer-Gesellschaft of Germany, a hugely successful public research organization and therefore is at times ascribed to as "Fraunhofer Lite". The design aims to pick up the best features and methods of the latter without replicating it in its entirety — an acknowledgment that took nearly 60 years to constitute the Fraunhofer system and also part of the aspects of the German innovation structure that contribute towards Fraunhofer's success are not present, to the same degree, in France.

Objectives

"Foster stronger links and partnerships between public and private research in France".

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[5]Nicolas Léonard Sadi Carnot was a French military engineer and physicist, often described as the "father of thermodynamics".

The aim of paramount significance is transfer of knowledge from the public domain into other sectors mainly the private companies by means of licensing, contractual services, IPR assignments/transfers etc. The Carnot Institutes spur stronger relationships between the industries and public research entities, with an aim to achieve steady transitioning of R&D outputs to commercial and profitable outcomes.

Carnot Institute

A PRO/institute may appeal for the recognition as a Carnot if certain criteria are met, such as -

- Distinctly construed research strategy
  (technological claims and challenges, competitive stance, markets and partnership policy)
- Efficient and organized governance system
  (appropriation of funds, cardinal structures and orientations, contracting, human resource management)
- Preserves and maintains all its research undertakings so as to enrich the in-house applied research
- Engages in contract research and research collaboration substantially
- Strong environment of IPR protection, both own and that of the partnering entities

The esteemed 'Carnot' label is conferred by the Ministry of Higher Education and Research.

The first Carnot designations, in 2006 and 2007, were for a renewable 4-year period. Subsequent designations run for 5 years.

By 2016, 38 Carnot institutes [including 29 Carnot institutes plus 9 Carnot Springboards (Table 1)] had been designated, distributed widely across France and involving about 25,000 researchers.

Table 3: List of Carnot Institutes

S. No.	Institute	Core Domain	Annual budget (million €)	Contractual Revenue (million €)	Number of Researchers
1.	3BCAR	Chemistry	46.2	5	836
2.	AgriFood Transition*	Agriculture, Food and Nutrition	41	10	708

3.	ARTS	Materials, mechanics, processes	82.0	13	1,260
4.	BRGM	Energy, environment, earth sciences	108.0	8	989
5.	CALYM	Life sciences	14.6		301
6.	Cerema Effi-sciences*	Environment Construction, civil engineering, landscape planning	29	22.5	245
7.	Cetim	Materials, mechanics, processes	39.0	10	223
8.	Chimie Balard Cirimat	Materials Environment, natural resources, chemistry Chemistry Health	33.8	7.3	630
9.	Cognition*	Information and Communication Technologies Soft sciences	47.9	5.2	962
10.	Curie Cancer	Life sciences, health	22	2	247
11.	Energies de futur	Energy, environment	131.0	42	1,555
12.	ESP	Energy, environment	25.3	5	310
13.	France Futur Elevage	Agriculture Health Food / Nutrition	94.7	13.9	1078
14.	ICEEL	Energy, environment, earth sciences, materials, mechanics, processes	74	8	1424
15.	ICM	Life sciences, health	30	7	397
16.	IFPEN Transports Energie	Energy Transport	38.7	13.9	300
17.	Imagine	Health Technologies for health	51	5.3	438
18.	Ingénierie@Lyon	Materials Mechanics and processes Energy Transport Technologies for health	95.8	33.9	1325
19.	Innovation Chimie Carnot (I2C)*	Chemistry	29.3	3.1	386

20.	INRIA	Information and Communication Technologies	165	26	1608
21.	Interfaces*	Information and Communication Technologies Health Technologies for health	41.7	6.5	612
22.	IPGG Microfluidique*	Micro and nano technologies / systems Chemistry Health Technologies for health	13.6	3.1	176
23.	Irstea	Agriculture Energy Environment Natural resources	86	14	1100
24.	ISIFoR	Energy, environment	31	3	474
25.	LETI	Microelectronics, nanotechnology	225.0	70	1335
26.	LSI	ICT, life sciences	17	2	510
27.	M.I.N.E.S	ICT, energy, materials, mechanics, processes, earth sciences	80.5	24	1820
28.	MECD*	Materials Construction, civil engineering, landscape planning		20	404
29.	MICA	Chemistry, energy, micro- and nanotechnology, materials, mechanics, processes	65	7	879
30.	PASTEUR MI	Life sciences, health	72	14	772
31.	Plant2Pro	Agriculture Food / Nutrition	169.7	33.1	1264
32.	PolyNat	Chemistry, materials, mechanics, processes	16	3	273
33.	Qualiment	Life sciences, health	43	6	516
34.	Smiles*	Information and Communication	18.5	1.6	304

		Technologies			
35.	STAR	Chemistry, energy, environment, materials, mechanics, processes, ICT, microelectronics	29.4	3	650
36.	Telecom & Societe Numerique	ICT	71.7	14	2,200
37.	TN@UPSaclay (List)	Information and Communication Technologies	76.7	42.5	768
38.	Voir et Entendre	Life sciences, health	14	2	234

**Springboard Carnot*
Source: http://www.instituts-carnot.eu/en/38-carnot-en

Governance & Funding:

The Carnot system is governed and steered by the Ministry for Higher Education and Research. The system of Carnot institutes i.e. the financial and the structural is managed by the ANR.

All the institutes given the label of Carnot Institutes are affiliated with the "Association des instituts Carnot", which is responsible for directing and leading the network.

ANR is also responsible for the selection of the institutes for accreditation of the label and then monitoring them further. A call of proposals is opened periodically, which invites the institutes to seek the title of a Carnot, by showcasing their interactions and linkages with the industries.

The support provided to the institutes by ANR is based on an incentive formula. This incentive formula takes into consideration the revenues generated from research partnerships, contract research services for public or private organizations, income as a result of ownership of IP, and other funds generated from SMEs. The funding is directly proportional to the revenue stream and grows with it.

Contracts with Industry:

Different institutes have different and varied partnerships with the companies i.e. the type of association of every institute with the industries varies significantly. However, these collaborations may vary from a definitive research project for which the entire costs shall be borne by the company to joint laboratories where the cost is shared, to consortia, joint supervision of PhD students, collaborative projects in response to the calls of other funding agencies such as ANR etc. Most of the associations seek the involvement of the representatives from both the organizations i.e. the Carnot institute as well as the industry. A Carnot institute may also offer short term courses/projects for SMEs, which act as a base for longer partnerships in the future.

Example: CEA LETI (microelectronics and nanotechnology), a Carnot Institute, offers a program termed PEPITE. This program provides project engineering course of 6-12 months for SMEs, which are seeking to make use of mature technologies available with CEA LETI.

AiCarnot:

The Association des Instituts Carnot (AiCarnot) is a network of Carnot Institutes and works for coordinating the institutes for developing a well organized structure. The association works for securing public funding support for each Carnot institute, defines strategies and objectives alongwith forming directive for IP usage and IPR policies. AiCarnot with time has formed long standing alliances with domain specific and thematic bodies providing knowledge assistance to industries, including OSEO, the French competitive clusters, research clusters, professional organizations, and the French Chamber of Commerce.

Evaluations:

In France all the PRIs including the Carnots are subjected to evaluation and monitoring regularly. These external evaluations are directed by and supervised by the government aided Agency for the Evaluation of Research and Higher Education (AERES). The assessments are undertaken by independent professionals (Visiting Committees) who are not related or associated with the institute in any sense and in some cases may not even be French nationals.

Intellectual Property:

The AiCarnot has postulated the "Carnot institutes' Code of Best Practices for Intellectual Property and Knowledge & Technology Transfers". This code charters rules with respect to the proprietary rights regarding the research carried out and the results generated during partnership between a Carnot institute and other socio-economic players. R&D results as generated through combined R&D efforts are owned jointly by the parties within the conditions related to exercising IP rights "defined according to specified and negotiated terms, for example, in proportion with their contributions in terms of inventing and funding." However, in subsequent research work that succeeding the research undertaken in partnership; the Carnot Institute holds the sole right of that research and its results. IPR transfers/licensing etc. is performed by Carnot institutes on a case to case basis after determining the apt compensation value for the same. The rights to IPR, which the parties own before the collaboration, cannot be altered without bringing it into the notice of the partners or until negotiated prudently. The partners may or may not provide free access to their rights for the purpose of collaborative research. The licenses for the developed technology during partnership "will be limited to a definite period and to specific fields and territories."

Spin-offs:

Most of the institutions that had been conferred the Carnot label had pre-existing relations with the industries and had worked closely with the private sector. A large number of institutions were also parents to spin-off companies, a practice that is given much importance and encouraged under the label. Example: INRIA, an information technology institute, largest Carnot by budget and headcount, has created 106 spin-off companies. These include Esterel Technologies, an innovative software SME which certifies and verifies "critical codes;" Trusted Logic, a developer of smart cards; and the high-performance computing firms Activeon, Kerlabs, and Sysfera. The Carnot Institute Telecom & Societe Numerique averages 25 spin-offs per year.

Carnot spin-offs are privy to a large number of benefits as a result of the measures that were brought into action by the government in the last decade for encouraging PRIs to create start-ups. One such initiative was the creation of incubators near to the PRIs by the funds provided by the Ministry for Higher Education and Research. The Finance Law of 2004, authorized the small firms to be exempted from a number of taxes and payments related to social security under the Jeune Entreprise Innovante status. Through PIA, an incentive program, the government provided funds for the institution of 2 special venture funds for assistance to start-ups - the National Fund for Digital Society (2010) and the National Seed Fund (2011).https://www.nap.edu/read/18448/chapter/16 - fn59

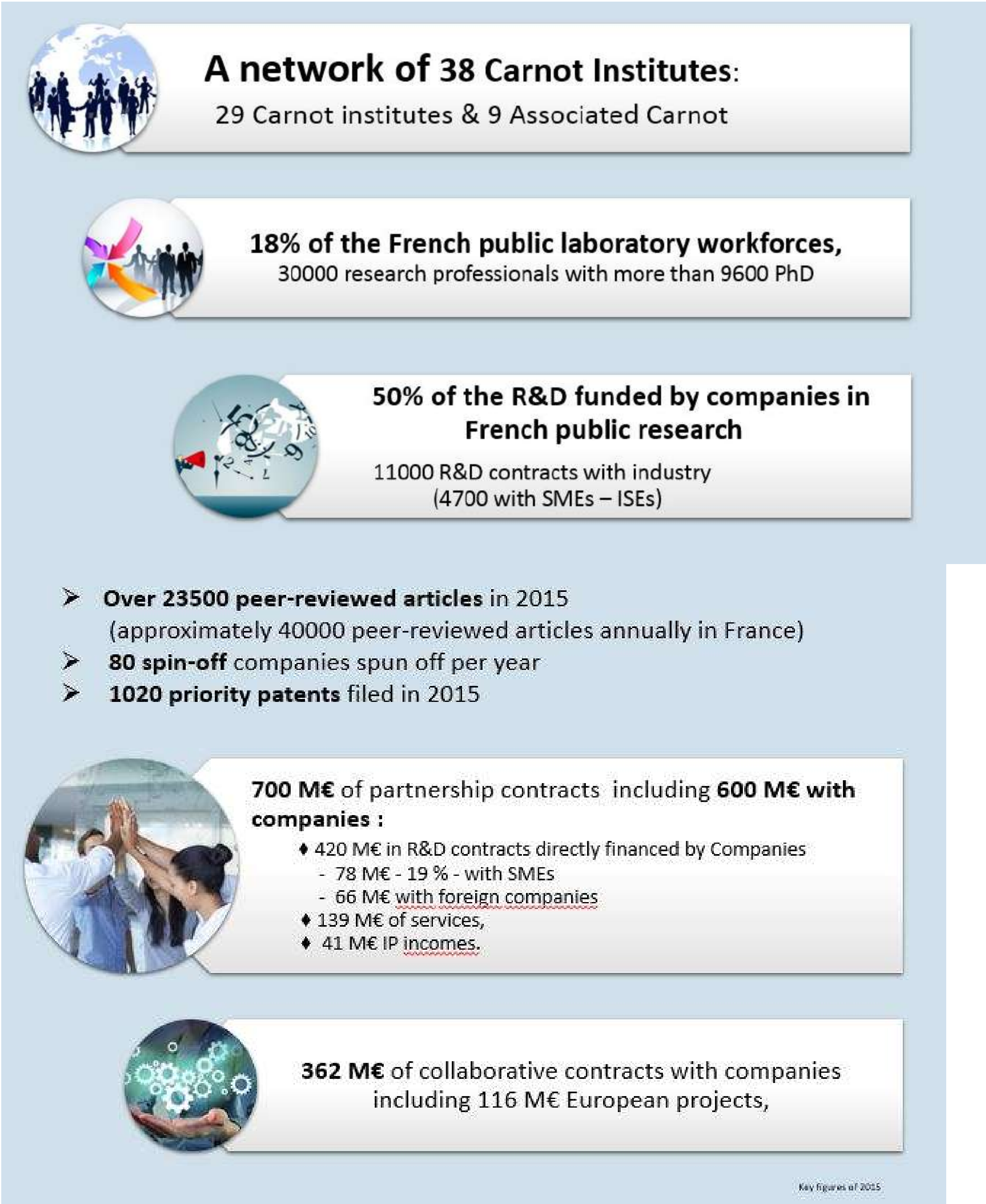


Figure 2: Characteristics of Carnot Program

Source: http://www.instituts-carnot.eu/en/key-figures

Success Stories:

a) The TOAP Run therapeutic game:

With an ageing population and a growing incidence of chronic diseases, society currently needs clinically validated solutions for physical rehabilitation and cognitive training of patients with neurological disorders (Parkinson's disease, Alzheimer's disease, stroke, brain injuries, etc.). In this context, the ICM Carnot Institute and the GENIOUS Group, an SME with 200 staff, created a joint laboratory, BRAIN e-NOVATION, the first serious gaming structure in France to have substantial experience in the health field, with solid clinical validation. This laboratory has produced TOAP Run, a serious game for people with walking and balance problems. The solutions developed will enable a reduction in health costs for the society. On the other hand, the technique's versatility allows it to be adapted to more than one pathology, in areas other than neurology.

b) RSV-NanoViaSkin, an innovative vaccine for infant bronchiolitis

Respiratory syncytial virus (RSV) is the main causative agent of bronchiolitis in infants and of pneumonia in calves. There is currently no vaccine for human use, and those for cattle are not very effective. The partnership between the France Futur Elevage Carnot Institute and DBV Technologies (the first French biotechnology company to be listed on the New York Stock Exchange in October 2014), which specialises in epicutaneous immunotherapy, has resulted in the development of a first paediatric vaccine for bronchiolitis, which is non-invasive and adjuvant-free, and most importantly, effective when administered cutaneously.

c) ATIS, an artificial retina and biomimetic camera

The ATIS system, a product of research carried out at the Voir et Entendre (Seeing and Hearing) Carnot Institute, and developed in partnership with Chronocam—a startupand spin-off company from the Vision Institute— works in a very similar way to a natural retina. Contrary to other systems, which work with images acquired bytraditional cameras at regular intervals, its biomimetic camera uses a new asynchronous sensor, in which each detector is sensitive to variations in light and not its absoluteintensity. The camera's temporal resolution and sensitivity, together with its asynchronous operating principle, give the developed prototype a clear competitiveadvantage over anything available on the market. Data processing actually requires very little computational power, and the camera can operate in highly variable environments and be used in many domains: health, imaging, cars, aircraft, telephones, meteorology, video games, etc.

2.6. Technology Transfer Acceleration Company *[Société d'accélération du transfert de technologie* (SATT)]

Background:

The efficient evaluation of results and outcomes of research and technology transfer are key influencing factors in the growth and progress of any region. Future skill and competitiveness is bestowed upon the companies through novel R&D. In spite of being a hub of high-quality research, France has not been able to capitalize much on its research potential. Strong relations between the private and public sector is a key for effective research result translation and conception of 'Technology Transfer acceleration Company; SATT' (www.satt.fr) was a response to this very challenge.

Simplified Joint Stock Companies that have been institutionalised by several PRIs within the "Valorisation" action are known as SATT. Conceived under the PIA, the SATTs intend to collectively promote university sites and terminate the system of structure fragmentation. The SATTs, which are in close contact with the PRIs, dedicatedly work for transferring technologies and drive the inventions to the maturation stage from the PRIs.

For this a generous budget of € 856 million to be spent over a time period of 10 years has been provided by the French government. A large portion of this budget has been allocated for the technical growth and economic advancement of projects that were a result of academic research. Transferring the know-how, translating the result into an offer that will be taken by the private industry is the primary aim of a SATT and thereby its intent is to enhance the skill and competiveness of the French industry.

As of now there are a total number of 14 SATTs that are responsible for the entire territory. Nearly 160 PRIs have entrusted the evaluation, transfer and valorisation of their research results into the kitty of these 14 SATTS. This offers the researcher with a simplified and single contact point for transferring their research without having to put in too much effort into other details like evaluation of product, market analysis, pricing etc. The companies also find it easier to contact one single point for novel technologies, know-how etc.

The SATTs are the very first leads of closeness and certitude, backed by the support and assurance of the shareholders (PRIs), who have the connection with and avenues to the know-how developed and inventions of the researchers in that area. The SATTS have dedicated teams and personnel for undertaking various processes of technology transfer and valorisation. These teams aptly evaluate a research outcome, develop it into an offer (license, technology brick, service etc.) and be an adjunct to them until they are transferred to a company.

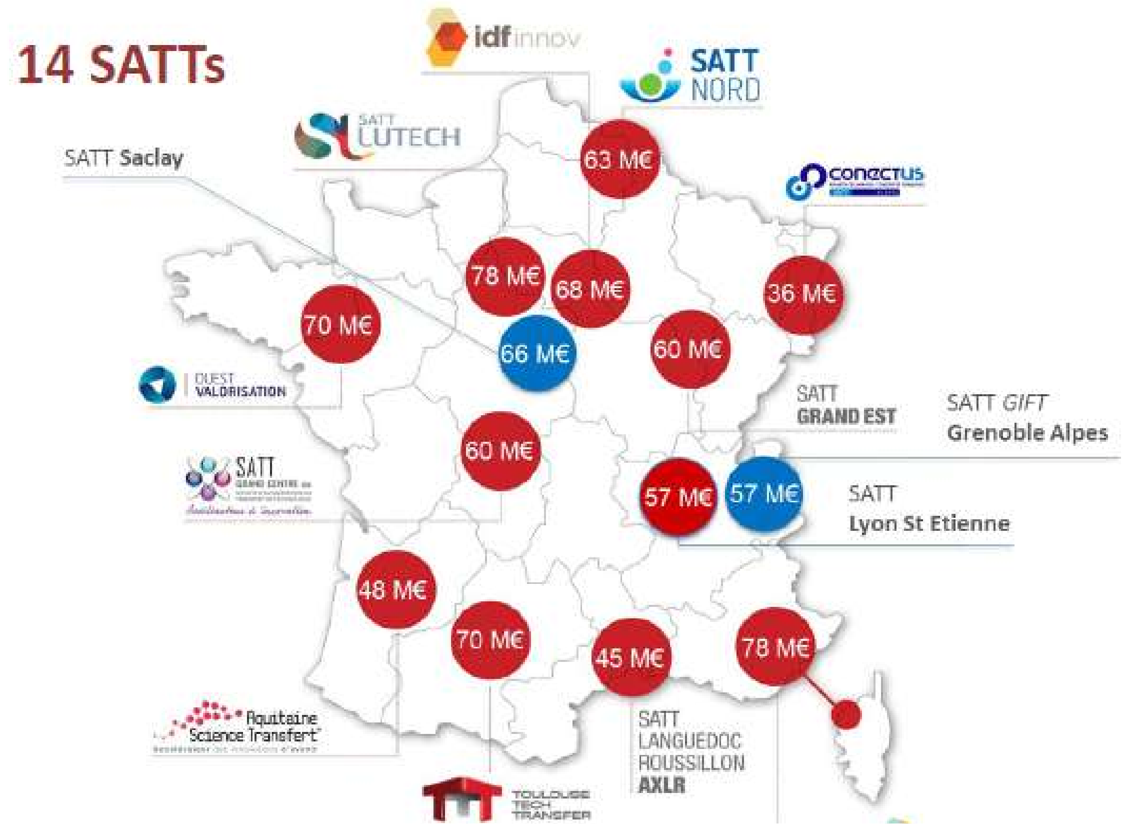


Figure 3: A National Network of SATTs

Source: http://www.nce-rce.gc.ca/AnnualMeeting-ReunionAnnuelle/2014/Presentations-Presentations/CECRBLNCE-CECRRCEE/05-04-FrancoisDupoteau.pdf

The SATT Network, an association, brings together the 14 SATTs are brought together (Figure 2). The mission of the SATT Network is to professionalize and make easier the process of transferring innovations from French PRIs to companies.

Constituted in 2014, the SATT Network aims at accomplishing shared activities for increasing the productivity, skilfulness and visibility of the 14 SATTs.

Through its various activities, the SATT Network allows for:

- A common portfolio for the technologies to be transferred
- Seal partnerships
- Outlook shared values
- Undertake joint communications

The SATT acts as –

i. **Actor in Economic Development** – The SATT, a model for bridging academic research and the markets, aspires to take advantage of the socio-economic significance that the results of academic research shall compel and also to uphold creation of new jobs in the country by easing, accelerating and expediting the process of knowledge and technology transfer from PRIs to businesses of all capacities. Alongside the provision of a unique 'maturation fund' in France, the SATTs protect the inventions of researchers and accompany them from the level of nascence to full maturation, until they are adopted by the companies. The instrument of SATT bears all the technical and financial risks intrinsic to these projects.

ii. **Unique Window** – The main intent of SATTs is to expedite and streamline the technology transfer process. They act as an exclusive window for the various processes of the entire value transfer chain, which include -
    a. Recognition of pioneering projects and identifying their positioning with regard to the needs of the market and the competition.
    b. Protection of research results by applying for protection, and then maintaining the intellectual as well as industrial property rights.
    c. Implementation and supervision of validated projects
    d. Marketing the technology in the form of licenses and/or start-ups

A few SATTs also undertake secondary activity of providing services to the stakeholders i.e. various research units. The scope of such an activity is varied according to the region.

a. Identification of novel research results and innovations with a potential for commercialization
b. Managing the IPR portfolios of research units

c. Providing enabling support services such as negotiating research project contracts with the private sector.
d. Undertakings for generation of IPR, innovation and creation of awareness amongst the researchers, scientific staff, students etc.
e. Detecting research areas and then mapping ideal partners to accomplish the research work in the identified domain.
f. Scrutinizing research and delineating research themes, markets, IP etc.
g. Providing finances and incubation support to novel innovative companies.

iii. **Private structures with public capital** – SATTs hold the standing of simplified joint-stock company (SAS), and encompass a capital of nearly 1 million euros dispersed - 67% for PRIs in the adjoining regions and 33% for the Maturation Fund. The SATTs cover a quasi-equity payment over a time period of 10 years, waged in 3 fractions that are conditioned according to the accomplishment evaluation steps. The research results are licensed to SATT for valuation however, the ownership is retained by the research unit and hold all the intellectual as well as industrial property rights.

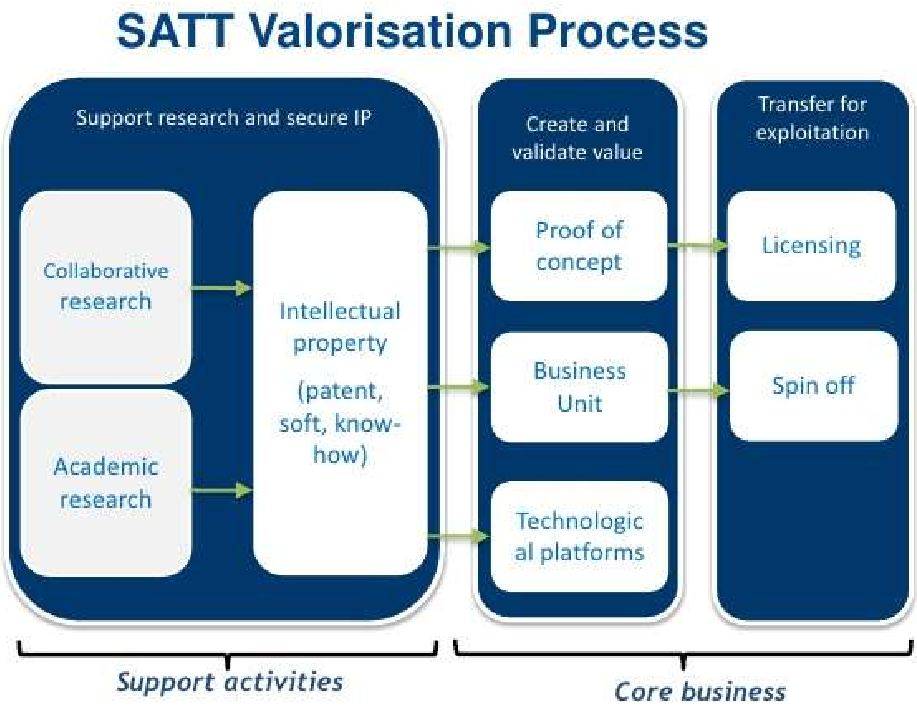
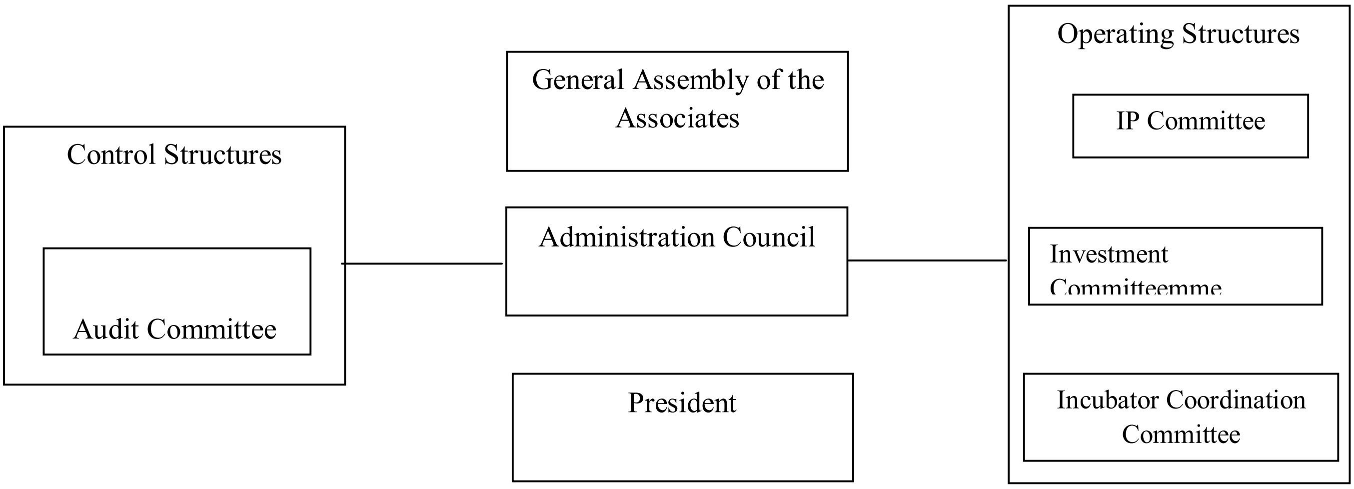


Figure 4: Valorisation process of SATT
Source: https://www.slideshare.net/met3project/tech-transfer-current-reforms-in-france-satt-tech-transfer-accelerating-companies

Governance: The governance structure of SATT is as follows -



The main task of the SATTs is to make the most of the IP assigned to them by the affiliates – universities and PROs. Their capacity is fundamentally geographical. The SATTs have been given the extremely ambitious target of balancing their operating accounts by 2020. A variety of ideas led to their creation: the aim was to make commercialisation more professional in terms of competences (by entrusting it to operational experts rather than the administrative services of universities or other organisations) and to provide appropriate, performance-based incentives for those in charge of commercialisation. In addition, to achieve that aim, the emphasis (and probably the principal function) was placed on developing the research results to facilitate their transfer to industry. The SATTs have been highly impactful as is illustrated in figure 4.

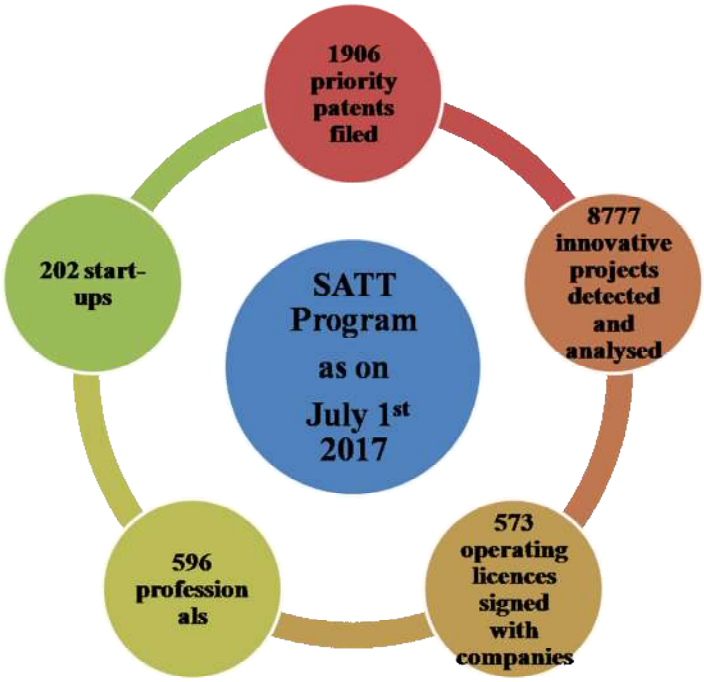


Figure 5: Key figures of SATTs

Example: **SATT Nord**

SATT Nord, a structuring instrument, devised on the scale of three provincial regions (Hauts-de-France and Champagne-Ardenne) originated in July, 2012. This instrument has been at the service of the research units of the above mentioned three regions in regard to valorisation of the public research and technology transfer.

Ascribed to the cross-disciplinary approach followed and the efforts of the team of professionals (thematic specialists, IP proficiencies, business developers, legal experts etc.), SATT Nord ensures the identification of projects, their advancement and their protection, awaiting their commercialization through transfers/ licenses or creation of start-ups etc.

Key Figures related to SATT Nord:

Date of Creation	July 26th 2012
Personnel	73
Innovative projects detected and analysed	449
Priority patents filed	81
Licences granted	17
Business created	3

2.7. Theme-based Technology Transfer Consortiums, CVT

Background:

The International Cooperation Center of Agricultural Research for Development (CIRAD), the Institut Pasteur, the French Research Institute for Development (IRD) and four foreign universities (Reunion, French West Indies-Guiana, New Caledonia and French Polynesia) have collaborated for promoting research in France and have devised the Theme-based Technology Transfer Consortium (CVT) "Valorisation Sud" (http://www.cvt-sud.fr/index.php).

The "Valorisation Sud" Consortium (CVT) is a multi-institutional establishment sanctioned within the framework of PIA. With an endowment fund of €9 million for 10 years, the CVT Valorisation Sud is the French national reference organization for transfers of technology and know-how adapted to tropical and equatorial regions and developing countries.

Aim

To boost transfers of technologies and know-how adapted to the Global South (tropical and equatorial regions, developing and emerging countries) to the economic world.

Mission

To promote and transfer technologies of socioeconomic interest developed by French public research laboratories to markets in the Global South.

Services

- Backing and support for IP management;
- Creation of a portfolio of technologies with an aim of promoting transfer and translation.
- Marketing and promotion of technologies in markets in the Global South;
- Pre-industrial maturation, project management, licensing agreements;
- Establishment of novel innovation oriented companies.

2.8. Technological Research Institute [*Institut de recherche technologique* (IRT)]

Background:

The Institutes for Technology Research (IRT) represent technological innovation institutes of global repute, which work in the field of key priority areas and cutting edge sectors, identified for strengthening the cluster environment (http://competitivite.gouv.fr/les-investissements-d-avenir-une-opportunite-pour-les-poles-de-competitivite/les-instituts-de-recherche-technologique-irt-campus-d-innovation-654.html).

The IRTs are an instrument implemented under the PIA programme and have materialized as a promising mode of PPP for training manpower, research activities and innovation. The IRTs have also had a positively inducing and structural effect on the instrument of 'Industrial Chairs'.

An IRT is defined as an instrument of excellence, institutionalised mainly for the purpose of developing the industrial capabilities by pooling together public and private capacities. It takes into account the skills and resources of a region. An IRT covers the complete innovation process, demonstration, prototype building etc.

The fundamental role of IRT is to merge the equipment, expertise, facilities of the public and private sector together.

The primary role of the IRTs is to pool public and private research equipment, facilities, and expertise, preferably under a single roof. The goal is to achieve the "critical mass" necessary to drive the entire innovation process, from concept to demonstrators and prototypes. The research and development carried out at the IRTs is market-driven and interdisciplinary, and calls upon know-how from both academia and industry. The innovations developed must contribute to economically-competitive technological solutions addressing markets deemed strategic to France's economy.

Each IRT brings together at a single location state-of-the-art expertise, equipment, and facilities, conducting applied research through to the demonstrator/industrial prototype stage. The IRTs maintain a special focus on transferring the technologies they develop to industry for integration into economically-viable products and services, thereby helping get innovations "made in France" onto international markets. The IRT must ensure the international visibility of themes of excellence and position itself in new markets.

The IRT's international development is based on four dimensions:

1. Collaboration with international industry partners that contribute to the funding of their projects, their first partners being US corporations;

2. Partnerships with foreign institutes with similar missions;
3. European-wide projects with European Commission funding (Horizon 2020);
4. Presentations at international conferences and exhibitions (Las VegasConsumer Electronics Show, etc.)

The IRTs are run by the French National Research Agency (ANR).

Funding:
The envelope dedicated to IRT is € 2 billion, of which: 25% is consumable and 75% is non-expendable. Government funding must be less than 50% of the total funding over 10 years.

Eight IRT projects have been selected in the following fields:

- IRT Nanoelectronics in Grenoble, which concerns nano-electronics (with the Minalogic cluster, ST-microelectronics, Soitec, etc.)
- IRT AESE in Toulouse, on aeronautics, space and embedded systems (with Aerospace Valley, Airbus, Safran, Latecoere, etc.)
- IRT Bioaster in Lyon and Paris, on infectiology (with Lyonbiopole, Biomérieux, Sanofi, Danone, Institut Pasteur, etc.)
- IRT M2P in Metz, Belfort-Montbéliard, Troyes, on materials, metallurgy and processes (with competitiveness clusters Matéralia, Vehicle of the future, Microtechniques, Fibers, Saint-Gobain, Arcelor-Mittal, etc.)
- IRT Railenium in Valenciennes, Villeneuve d'Ascq on rail infrastructure (with I-Trans, RFF, Alstom, SNCF, etc.)
- IRT Jules Verne in Nantes, on composite materials (with the EMC2 pole, Airbus, STX, DCNS, Alstom, Segula, etc.).
- SystemX at Saclay on Digital Systems Engineering (Systematic pole)
- IRT B-COM in Rennes on networks and digital infrastructures (Images and networks cluster)

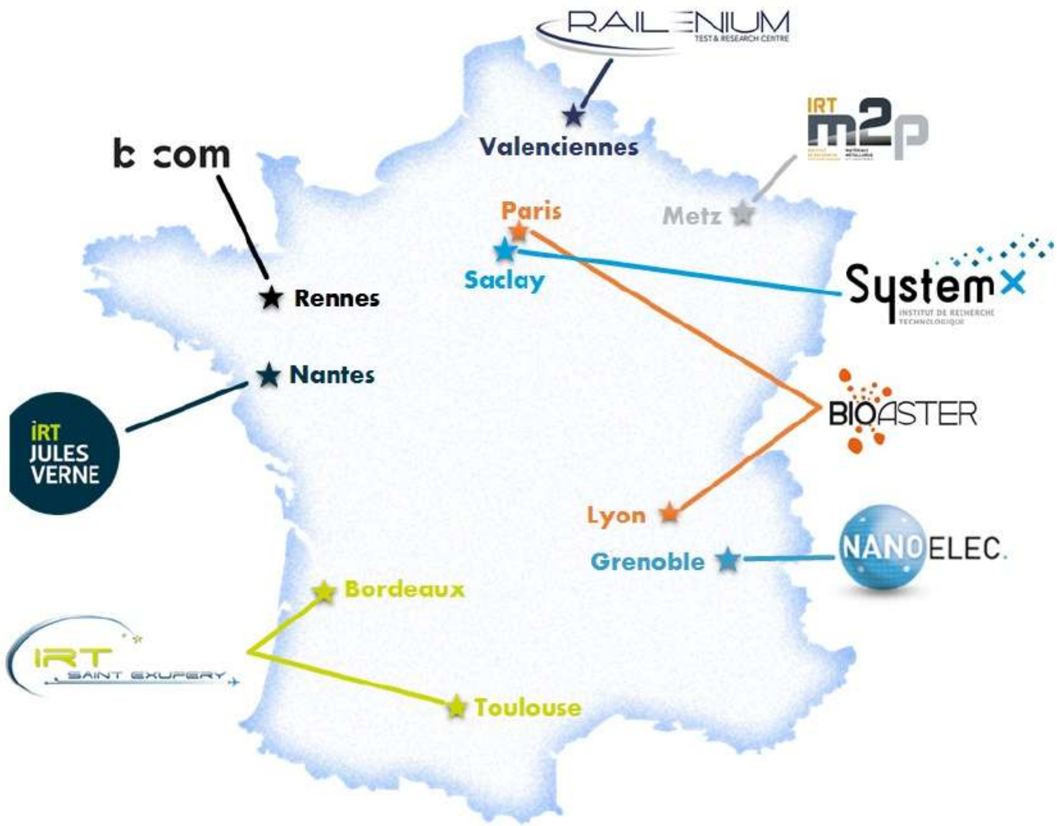


Figure 6: Eight IRTs in France

Source*: http://competitivite.gouv.fr/les-investissements-d-avenir-une-opportunite-pour-les-poles-de-competitivite/les-instituts-de-recherche-technologique-irt-campus-d-innovation-654.html*

An IRT:

- Is a physical research centre focused on a specialised scientific or technological topic;
- concentrates at a single site highly skilled technical personnel, state-of-the-art equipment, and facilities at the forefront of technology**;**
- focuses on the development of activities at the TRLs range from 3 to 6, includingapplied/technological research and production of demonstrators/industrial prototypes.

Facts and Figures

- 50-50 public-private partnership between the French government, higher education and public research organisations and key industrial partners;
- initial public investment of €2bn;
- nearly 400 members:

75% market-leading businesses of all sizes;

25% top-tier academic research organisations.

French Institutes of Technology Association

In order to step up, gain visibility and become key partners for both businesses and public technological research organisations internationally, the IRTs launched the "French Institutes of Technology "(FIT) Association. FIT's other missions are to facilitate the development of best practices and to act as a single voice in interactions with the European Commission and French funders.

Example:

IRT SystemX: SystemX is one of eight institutes for technological research that have been established by the Government to enhance the country's attractiveness. The IRT SystemX was officially created on February 1st, 2012 as part of the "Investment for the Future" program put in place to support innovation in France. Unique IRT in Ile-de-France in the field of digital engineering of complex systems, SystemX meets today's technological challenges through flexible, open, and collective innovation.

The functioning of the Institute is based on two fundamental aspects:

- the co-localization of its talents: the Institute brings together in one place all the project partners, thus creating a melting pot of interaction between stakeholders of public and industrial research;
- the pooling of skills and platforms: by reaching a critical mass, SystemX will be able to provide a platform through the pooling of many skills and technological bricks.

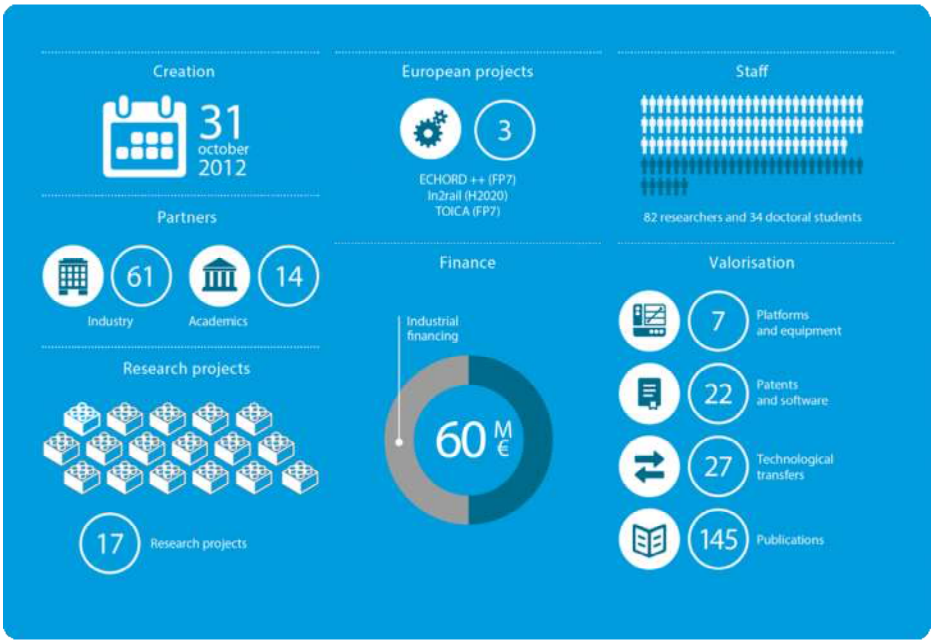


Figure 7: Figures related to IRT SystemX
Source*: http://www.irt-systemx.fr/en/comprendre-systemx/lirt-systemx/*

2.9. Industrial Training Convention by Research/*Conventions Industrielles de Formation par la REcherche (CIFRE)]*

The CIFRE - Industrial Convention Training by Research (http://www.anrt.asso.fr/fr/cifre-7843) is an initiative that has been designed for helping companies and industries. The industries and companies regularly need to hire new engineers and scientists for their research undertakings, which is where the CIFRE initiative aids them. The initiative helps an industry hire a young professional at a starting R&D position. Then contract of CIFRE provides them with a doctoral student who shall work in collaboration with a public laboratory.

Objective:

"Promote the development of public-private partnership research and to place PhD students in employment conditions"

- CIFRE associates 4 partners for a period of 3 years:

  - A graduate student desirous of undertaking training through research, which shall lead to a doctorate. The student is stipulated to dedicate his/her complete time to research, which can be divided between the company and academic institute. Both industrial and academic training is provided to the student through this association. It is necessary for the graduate student to have a basic degree and should be eligible for doctoral degree.

- A company which wishes to carry out an R&D project. The research work has to become the subject of the doctoral thesis of the employee/student.   wishing to carry out a research and development project
- An external academic research laboratory (French or non-French) that shall supervise the research activities of the employee/student. It is mandatory for the employee/student to be enrolled with the academic research laboratory.
- The subsidy to the hiring industry is paid by ANRT on the basis of the Industrial Research Training Agreement (CIFRE).

The *Ministry for Higher Education and Research* finances the said contracts and the system of contracting and hiring is implemented by the *National Association for Research and Technology (ANRT).*

In the early 1980s, for increasing the R&D activities of the private businesses and industries, CIFRE was brought into action. This initiative for the French enterprises, launched in 1981, aimed at enhancing the mobility of the researchers between the private and the public sector. This initiative also aimed at training the individuals in an aspect that they become desirable for hiring in both the public and private sector.

This effort greatly reinforced the technological research pursuits of the industries, expedited avenues to trained and skilled workforce and also ensured that the doctoral student, in future respond to the innovation requirements of that very firm.

The students working under CIFRE contracts receive superior supervision from the academic laboratory and working alongside other researchers in a professional environment trains them to emerge as fine and skilled at art scientists. The time spent in the industry by the students sensitizes them to the details of industrial and societal modalities of their research work. This results in their rapid absorption in the real world upon completion of their degree. The industrial firm involved can also explore the scope of extending the research work beyond the doctoral thesis and carry out further collaborative activities.

The company and public laboratory are provided with a time period of six months from the initiation of CIFRE for stipulating a contract that includes the terms and guidelines of the collaboration. This conditions of partnership as stated by the contract also include the research methodology to be employed, places of practice of doctorant, issues of intellectual property, confidential questions etc.

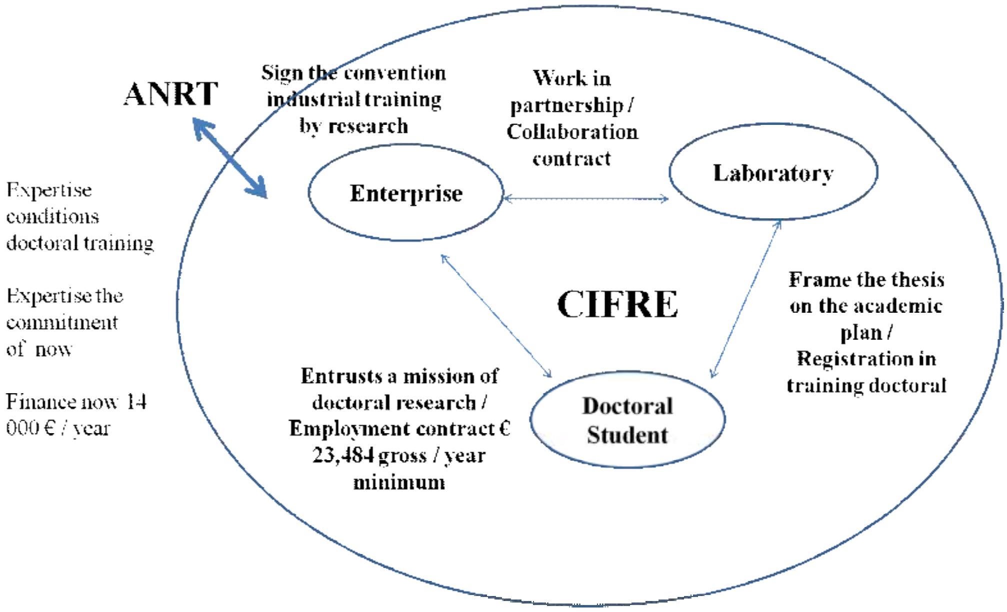


Figure 8: Working of the CIFRE Model

IMPACT of the CIFRE Initiative

The ANRT and the French Ministry for Higher Education and Research undertakes a survey of graduated CIFRE doctors regularly. The statistics presented below are a result of the survey conducted in the early 2016:

- Since 1981, CIFRE has brought together 9,000 companies, more than 4,000 laboratories and 25,400 PhD students around research projects.
- The triple supervision of ANRT-company and academic laboratory proves to be crucial for the thesis completion of the doctoral students. The rate has been particularly high and in the above mentioned survey it was 98%.

  The students receive support and guidance for not only the scientific aspect but they also understand the strategies of business, which brings responsibility and quality to their research.

- The median salary offered to former CIFREs is 23% greater than average salary of doctors hired by companies

- 2/3rd former CIFREs build their careers in private sector whereas in general only 1/3rd of the doctorate holders do the same. It is mainly the large companies and the SMEs that employ former CIFREs. The companies majorly recruit them over permanent contracts. The latter has also enhanced due to the combination of 'Research Tax Credit[6]'.
- In companies, 64% of those who terminated CIFRE in 2010 were still working on R&D in a company in 2016. Former CIFREs are usually hired and granted work on R&D missions, as their previous research calibre is valued and recognized by the industries.
- 1,377 new agreements were accepted in 2016.

2.10. Competitiveness Cluster

Background:

In France cluster initiatives are quite popular amongst the policy makers at all the levels i.e. national, regional and local levels. Such initiatives encompass various dimension of the policy – industrial, R&D, strategic, business, regional innovation etc., stressing on the fact that for economic growth to be apparent it is necessary to foster wealth creation and development at local levels.

A competitiveness cluster in its true sense is the conglomeration of both small and large industries, research organizations/laboratories and academic institutions, working collectively in a definitive area for developing synergies. A competitive cluster is defined as a geographical concentration of businesses, training centres and public and private research units working in partnership on innovative projects.

More partners can be brought in the cluster, such as public agencies, local/national authorities, and business providers etc. for developing innovative projects and providing the member companies/organizations to demonstrate their capabilities and reach at a global platform.

Realizing the importance and pressing nature of R&D/innovation in intelligence based economy several discussions have been made over cluster-confirming approaches in France. In 2004, 'Inter-ministerial Committee for Spatial Planning and Development'

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[6]In France, the research tax credit represents a reliable element of an innovative company's financial plan, and is particularly well adapted to the needs of SMEs. This tax incentive enables companies to increase their competitiveness by supporting their Research & Development efforts.

(CIADT)[7] announced the creation of Competitiveness Clusters. The policy was introduced for strengthening industrial and technological partnerships.
The aim of the initiative was clearly fostering encouragement of and giving support to the projects that were initiated by local academic or economic agents and to cultivate strong public-private collaborations. This initiative received a funding of USD 575 million as a component of the PIA inclusive of the initial bequest of USD 1.7 billion. The second phase of the cluster policy greatly focused on inter-cluster cooperation and enhanced visibility on the international scale.

Objectives:
Strengthening the capabilities of the French economy and advancing growth and jobs in the markets, by -

- Increasing innovative activity
- Supporting and reassuring creative and high-value technological activities, majorly industry oriented, at a provincial level
- Enhancing visibility at the global level and attracting businesses to France

Competitiveness Clusters Strategy
According to the strategy a five-year plan needs to be drawn for each competitiveness cluster, which is based on outlook of the stakeholders of that cluster. Within the scope of this plan the cluster can:

- Foster collaborations with stakeholders from different domains, on basis of the complementary skills of the partners.
- Develop and construct projects that can benefit from public funding, such as the Inter-ministerial Fund (FUI)
- Promote an environment conducive to innovation activities of the cluster. Knowledge sharing, support amongst stakeholders, presentations, human resource training, management of IP, private-sector financing etc. are the activities that come under the ambit of a promotional environment.

[7]CIADT: Comité Interministériel d’Aménagement et de Développement du Territoire. The CIADT, chaired by the Prime Minister, sets the government’s guidelines for spatial planning and development.

Public Support for Clusters

In its endeavour to promote an environment conducive for innovation, the government of France is increasingly interested in supporting the R&D efforts of the players by forming clusters. It encourages and fosters development of competitive clusters both at a local and national level. Thus, it is evident that France is committed towards developing a conducive environment for innovation.

The main instrument of the French government for providing assistance and support to cluster based research activities is by means of Single Interministerial Fund (FUI). This fund specifically supports the policy of cluster formation and allows forward looking investments. The assistance at regional and national levels is secured by -

- by allocating financial aid to the best R&D projects and innovation platforms, through calls for projects from the Single Inter-ministerial Fund and the Investments for the Future Programme
- through partial financing of cluster governance structures, alongside local authorities and firms
- by providing financial aid for theme-based collective actions, through the intermediary of decentralized government departments. These actions, initiated by the competitiveness clusters in a wide range of areas, involve cluster members, particularly SMEs, with the aim to promote innovation and improve their competitiveness.
- by bringing additional partners on board : the French National Research Agency and OSEO provide financing for R&D projects carried out by cluster members; the Caisse des Dépôts et Consignations (CDC) supports innovation platform projects;
- by relying on local authorities, who may also provide financial support for cluster projects (both R&D and innovation platforms)
- by helping competitiveness clusters and their member firms find the best international partners and set up technological partnerships with them focused on value creation
- finally, by bringing to bear new resources from the Investments for the Future Programme earmarked for competitiveness clusters.

The Competitive clusters are capable of taking different legal forms, such as:

- an association under the association act of 1901,
- economic interest grouping (EIG)
- scientific interest grouping (SIG).

The government provides three public structures to underpin the competitive cluster policy. These structures are designed to step up:

The involvement of public research in programmes that foster partnerships between public laboratories and corporate laboratories and hence contribute to technological transfers of the results of public research to the business world: the National Research Agency.

The development of R&D with projects implementing major development programmes alongside private financing: the Agency for Industrial Innovation Support to SMEs: the OSEO group.

Ireland

Contents

1. Introduction

Ireland is a prosperous economy located in the northern Atlantic Ocean. It is a developed economy, and strives towards further economic development by expanding its R&D and innovation ecosystem. The Global Innovation Index ranking of Ireland is 10/127 (GII Report-2017). In Global Competitiveness index, the rank of Ireland is 24/137 (GCI Report- 2017).

The main institutions in Ireland that take care of the scientific and industrial development and their collaborations are the Enterprise Ireland, Department of Jobs, Enterprise and Innovation, Industry Research and Development Group. These organisations run various programs for the promotion of collaborative research, some of which are Industrial Promotion Partnership, Knowledge Transfer Ireland, etc.

The other innovation indicators and Ireland's rank in those are tabulated below.

Sr. no.	Indicator (year)	Global Ranking
1.	Publications[a] (2016)	42
2.	H-Index[b] (2017)	28
3.	Intellectual Property Rights[c](2017)	17
4.	Expenditure of Education[b]	36
5.	Gross Expenditure on R&D[b] (% of GDP) (2017)	23
6.	Research and Development[b](2015)	19
7.	Global R&D Companies, avg. expend. Top 3, mn $US[b]	12
8.	QS University ranking, avg top 3[b]	19
9.	Availability of Scientists and Engineers[d]	21
10.	Capacity for Innovation[d](2017)	19
11.	Quality of scientific research institutions[d] (2017)	19
12.	Company spending on R&D[d] (2017)	20
13.	University-industry collaboration in R&D[d](2017)	13
14.	PCT Patents[d]	19

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

2. Schemes/ Programmes/ Organization

2.1. Knowledge Transfer Ireland

Background:

Knowledge Transfer Ireland (KTI; http://www.knowledgetransferireland.com) is the national office thatbrings together the industry and academia in Ireland, in order to generate economic and societal benefits to the nation. KTImakes it easy for the businesses to get in touch with the research groups in Ireland. KTI was set up in late 2013 as a partnership between Enterprise Ireland and the Irish Universities Association, emerging from a suggestion from a Government-driven team that audited the condition of business-research base engagement in 2012. Prior to that, the State supported collaborative R&D through the Enterprise Ireland Technology Transfer Strengthening Initiative (TTSI1).

In 2012 the Irish Government published 'Putting Public Research to Work for Ireland – revised guidelines, policies and procedures' to additionally energize industry, from new businesses to small and medium enterprises (SMEs) to multinational enterprises, to team up with Ireland's public research performing associations. A key proposal in the report was the foundation of a national capacity (around then alluded to as the Central Technology Transfer Office (cTTO)) with the aim to help business and the research base to boost development from State supported research for the advantage of the general population and the economy. This prompted the formation of Knowledge Transfer Ireland (KTI).

Knowledge Working with Ireland's State-funded research associations, for example, colleges, institutes of innovation and technology and other R&D centres of excellence can enhance business profitability, sales and performance by improving quality of items, services and procedures. Organizations and business visionaries are advantaged through the sharing of knowledge and ideas and getting access to innovation and intellectual property, which can build business competitiveness.

Hence, in a nutshell, KTI is an office, an asset and a facilitator.

Aim:

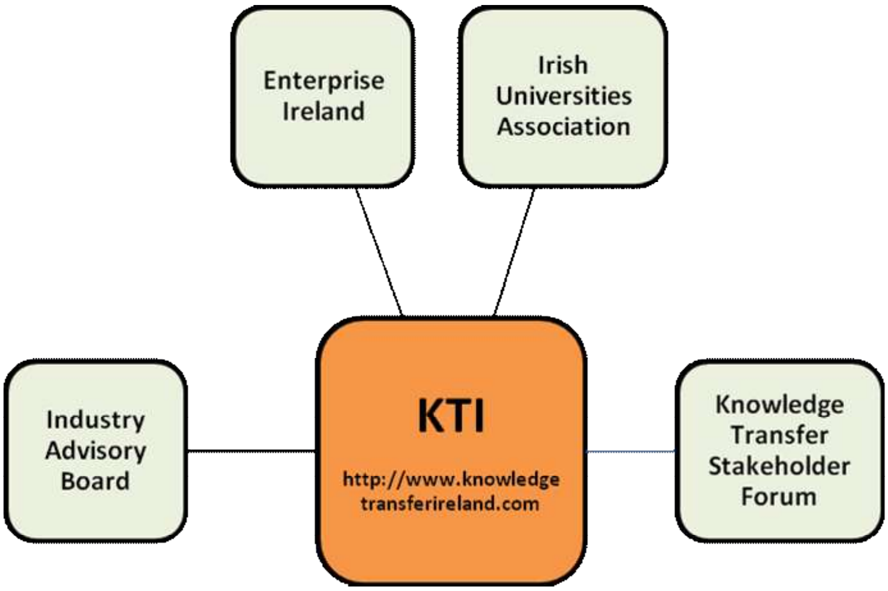
The main aim of Knowledge Transfer Ireland is to support business and the research base to maximise innovation from State funded research by getting technology, ideas and expertise into the hands of business, swiftly and easily for the benefit of the public and the economy.

KTI takes the guesswork out of knowledge transfer through providing a predictable knowledge transfer system for Ireland. It works with businesses, investors, research funders and TTOs to review, recommend and implement changes to the way in which Ireland approaches managing IP and contracting.

Governance:

KTI is accountable to the Department of Jobs, Enterprise and Innovation (DJEI) through Enterprise Ireland (https://www.enterprise-ireland.com/en/). KTI is advised by:

- a group of commercially experienced people drawn from industry (SME and multi-national, Irish and overseas) and the investment community,
- KT Stakeholder Forum of representatives Irish HEIs, TTOs, research funders and government agencies.



Technology Transfer Offices (TTOs)

Ireland's universities, institutes of technology (IoT) and research organisations have a professional technology transfer infrastructure in place to work with existing companies and to support new enterprises to leverage the value in this investment.

The technology transfer offices (TTOs) and industrial liaison offices in Ireland's HEIs and research organisations help companies and investors to:

- Access new knowledge and expertise to drive innovation through research collaboration, contracted services and consultancy.
- Identify and license new technologies and intellectual property (IP) relevant to their business.
- Make use of state-of-the-art facilities and equipment.

The majority of people working in technology transfer in Ireland has a background working in companies, from multi-nationals to start-ups, and understand the issues that businesses face when seeking to innovate. Technology transfer teams have scientifically trained business managers and act as sector experts, able to translate the needs of business and to identify exciting new commercial propositions.

Production of National IP Protocol

The new Protocol entitled "*Inspiring Partnership - national IP Protocol 2016*" is an update on the national Protocol published in 2012. As such, it continues the State's aim of making the process of engagement between business and the research base in Ireland more straightforward.

This latest version of the Protocol was produced by Knowledge Transfer Ireland through a process of consultation and on behalf of the Department of Jobs, Enterprise and Innovation (DJEI) and published in January, 2017.

The suite of KTI Model Agreements and accompanying KTI Practical Guide are designed to be suitable for transactions between commercial companies and Irish research performing organisations (RPOs). The Guides explain common terms in the Agreements and considerations that might apply. Each Guide contains annotated Model Agreements with commentaries on key drafting points to help in drafting and negotiation.

Produced four volumes of Annual Knowledge Transfer Survey (AKTS) in conjunction with the Higher Education Authority (HEA) with data collected from the Research Performing Organisations (RPOs). The AKTS covers the range of Knowledge Transfer (KT) activities that include licensing, spin-out company creation, intellectual property commercialisation and business engagement such as collaborative research, consultancy services and use of facilities and equipment.

Successful examples

a) **Orbsen Therapeutics**

Orbsen Therapeutics is a spin-out company of NUIG University (http://www.nuigalway.ie) which was supported by the Technology Transfer Office (TTO)-Ignite West TTO at the NUIG University to develop special stem cells. These stem are more effective than already existing in market as they are more highly purified. Also, the company has been linked with the best companies to partner with. The TTO has provided support to Orbsen Therapeutics to in terms of patenting and protecting its intellectual property.

b) **Ceramicx- Trinity**

Cermicx (www.ceramicx.com/) is a heat processing company based in Cork, Ireland. It developed a product named Herschel- an infrared energy mapping machine- with support from Trinity's School of Engineering, Ireland. The support was in terms of licenced software and know-how required for the development of Herschel. The licence was a result of the research project funded from Innovation Partnership funding by Enterprise Ireland. Cermicx association with at TTO at Trinity School of Engineering has led to an increased turnover of 15 percent per year (on an average) from the year 2010 to 2015.

c) **Alimentary Health- UCC**

The company Alimentary Health (https://www.alimentaryhealth.ie) was supported by the Industry Liaison Office based in University College Cork (UCC), specifically for the launch of a new product- Alflorex in 2014. Alflorex is a precision biotic product, that is based on the probiotic cultureBifidobacterium infantis 35624 (B. infantis 35624). Along with this, the TTO at UCC has helped Alimentary Health to explore further licencing opportunities for other products.

d) **ESBI- WIT**

ESB International (https://www.esbinternational.ie) is a global energy consultancy company. Its association with Waterford University of Technology (WIT) (https://www.wit.ie) through the South Eastern Applied Materials (SEAM) research centre has benefitted the company by enhancing its experience of designing of conductor and its installation. There was a direct funding from ESBI for a research project in 2012 that led to bettering the design of conductors through finite element analysis.

e) **Dairymaster - IT Tralee**

Dairymaster is a company located in Kerry, Ireland that manufactures milking equipments by use of madern technology so that the dairy business is made a more profitable venture. The company has been supported by the Technology Gateway situated at Institute of Technology, Tralee for development of:

i) An auto-washer for the cleaning and sanitization of milking machines.
ii) A device that detects the level of progesterone in the milk, for determining when the cow is ready to breed

f) Molloy Environmental Systems - NUI Galway

Molloy Environmental Systems(http://molloyprecast.com) is a company that treats wastewater by developing novel technology. In 2013, it employed a patented technology from the NUI Galway (http://www.nuigalway.ie) in a collaborative research project. As a result, the company was able to set up a Pumped Flow Biofilm Reactor (PFBR) plant to treat wastewater for upto 750 people. A number of contracts have been won by Molloy using PFBR.

g) EirGen Pharma – WIT

EirGen Pharma (http://www.eirgen.com) is a company based in Waterford, Ireland. It develops and manufactures cancer therpay products for global pharma market.The Pharmaceutical and Molecular Biotechnology Research Centre (PMBRC) at Waterford Institute of Technology (WIT) supported the company in solving problems related to the characterization and formulation of the drug, drug delivery, biomedical research and biotechnology.

h) Sonex Metrology – DCU

Sonex Metrology is a spin-out company from Dublin City University (http://www.dcu.ie). The research on Photo-acoustic technology in a lab in DCU led to its patenting and hence a business opportunity. This has enabled the company, which was established in December 2011, to build on its DCU research foundations through further R&D and to embark on production of the technology. As a result Sonex has developed its own IP around the commercial product embodiments.

Status of Research Collaborations in Ireland

KTI collects and analyses data from Ireland's universities, Institutes of Technology and other state-funded research organizations, together termed Research Performing Organizations (RPOs).

Data related to industry collaborations of the various RPOs in Ireland is presented below.

RPO (year of formation)	Total number of collaborations with industry in 2016
Dublin City University, Glasnevin, Dublin (2007) (http://www.dcu.ie)	105
Maynooth University, Maynooth (2005) (https://www.maynoothuniversity.ie)	72
NUI Galway (2005) (http://www.nuigalway.ie)	71
Trinity College Dublin, Dublin (1987) (https://www.tcd.ie)	151
University College Cork (1982) (https://www.ucc.ie/en/)	65
University College Dublin (http://www.ucd.ie)	152
University of Limerick (https://www.ul.ie)	83
National College of Art and Design, Dublin (http://www.ncad.ie)	19
National College of Ireland, Dublin (https://www.ncirl.ie)	11
Royal College of Surgeons in Ireland, Dublin (http://www.rcsi.ie)	21
Marine Institute, Galway (https://www.marine.ie/)	0
Teagasc, Carlow (https://www.teagasc.ie)	196
Athlone Institute of Technology, Athlone (https://www.ait.ie)	191
Cork Institute of Technology, Cork (http://www.cit.ie)	173
Dublin Institute of Technology, Dublin (http://www.dit.ie)	86
Dundalk Institute of Technology, County Louth (https://www.dkit.ie)	28

Galway-Mayo Institute of Technology, Galway (https://www.gmit.ie)	23
Institute of Technology Blanchardstown, Dublin (http://www.itb.ie)	6
Institute of Technology Carlow, Carlow (http://www.itcarlow.ie)	79
Institute of Technology Tralee (http://www.ittralee.ie/en/)	22
Institute of TechnologyTallaght (http://www.it-tallaght.ie)	40
Limerick Institute of Technology (http://www.lit.ie/)	35
Letterkenny Institute of Technology (https://www.lyit.ie)	27
Waterford Institute of Technology (https://www.wit.ie)	328

2.2. Technology Gateway Network

The Technology Gateway Network (https://www.technologygateway.ie) delivers development ability to industry all over Ireland. It functions under Enterprise Ireland alongwith the Institutes of Technology.

There are 15 Technology Gateways in total, arranged in 11 Institutes of Technology in Ireland which,

➢Deliver innovativesolutions for Irish industry for their market needs.

➢Are open access points for industry of all sizes.

➢Act as local access points to the more extensive assets in the Irish research foundation.

➢Have a demonstrated reputation of delivering to industry.

TGNs concentrate on key innovation zones which are adjusted to industry needs in regions, for example, polymers, photonics, portable, coatings, modern plan, mechatronics, biotechnology, pharmaceuticals, remote advancements and exactness building. Each centre works in conjunction with industry to help the innovative work of newproducts and services through a devoted group of specialized engineers.

Aim:

The objective of the Enterprise Ireland Technology Gateway Network is to deliver near to market technology solutions to companies based inIreland to help them develop new products, processess and services.

Governance:

Inside every Gateway, a devoted Gateway Manager and a group of sector specific business advancement staff go about as the key contact points for industry and deal with the effective conveyance of tasks on time and spending plan.

Achievements:

Since 2013, more than 900 Irish based organizations have utilized Technology Gateways to finish more than 2,000 development based tasks at an aggregate estimation of 19.4 M, 48% of which has come straightforwardly from industry. A Review by Frontline Consultants in 2016 on the effect of the Technology Gateway Network for partner organizations found that:

• 63% of organizations revealed the development of new items

• Improved technological knowledge (88%) and increment in the general estimation of the organization (46%) were the best two advantages refered to

• 71% of organizations refered to the advancement of a culture of development inside the organization because of the Gateway collaboration

• 19% of organizations report that they couldn't have developed or would not have made it without the help of the Technology Gateway .

Additionally, effective collaborations result in the Gateway turning into an extension of the organization's R&D office after some time, as it partners with the business along the innovation journey towards expanded development, supportability and intensity.

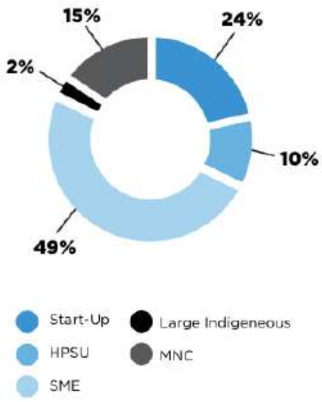
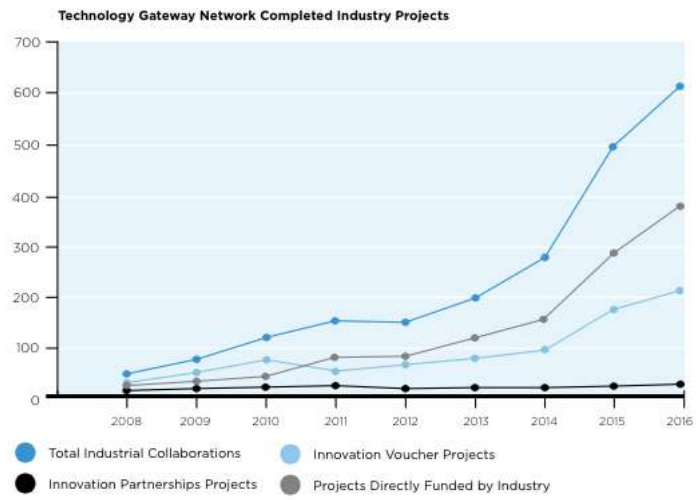


Figure 1: Profile of Technology Gateway Industry collaborations

Source: Technology-Gateway-A-Guide-for-Companies



Project Type	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Industrial Collaborations	36	69	117	150	150	208	279	476	618
Innovation Voucher Projects	20	55	75	52	64	71	107	166	212
Innovation Partnership Projects	2	5	8	18	11	19	18	21	34
Projects Directly Funded by Industry	14	9	34	80	75	118	154	289	372

Figure 2: Increased levels of Industry collaboration from 2008 to 2016

Different gateways are:

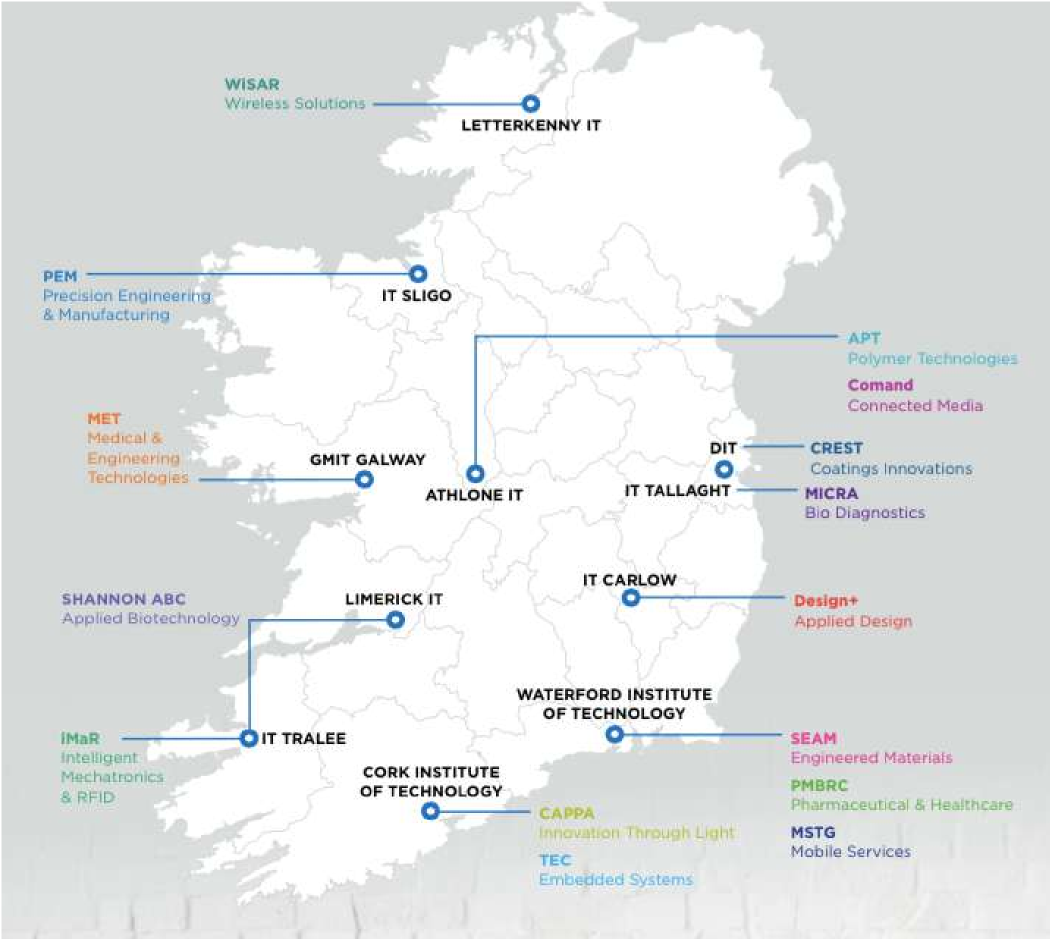


Figure 3 : Location of the different gateways across Ireland

1. **Applied Polymer Technologies Gateway- APT**

   The APT Gateway is based in the Athlone Institute of Technology. APT provides polymer technology solutions for businesses in the medical, composite, recycling and pharmaceutical sectors. APT has a core focus on three applied technology areas it aims to transfer to industry: biomedical polymers, polymer recycling and composites. It is a dedicated resource for the Irish polymer manufacturing industry and regularly provides training and information dissemination.

Case Study- Athlone Extrusions

Athlone Extrusions (http://www.athloneextrusions.ie) is a company based in Westmeath. It is a thermoplastic sheet extruder and compounder. Athlone Extrusions have a long working relationship with the APT Gateway in AIT. APT provides material analysis support for production, optimisation and new product development activities within the company. In the last number of years, the Labs at Athlone Extrusions have been expanded, adding advanced material testing capabilities through numerous collaborations with Athlone IT.

2. **Centre for Advanced Photonics and Process Analysis- CAPPA Gateway**

The CAPPA Gateway is based in Cork Institute of Technology (CIT). It applies light-based photonic technologies to solve market problems for industrial partners.

CAPPA applies photonics solutions to industry in a wide range of sectors, including medical devices and technologies, pharmaceutical manufacturing, food & beverage technologies and electronics and telecommunications.

***Case Study*- Enterasense**

Enterasense (http://www.enterasense.com) is a Start-up company based in Galway, Ireland that has developed an ingestible biosensor that detects bleeding in the gastrointestinal tract in real time without requiring a complicated intervention. CAPPA has supported Enterasense in developing the optical elements of this swallowable pill to be used for the detection on intestinal bleeding post-surgery. CAPPA also partnered with its sister Gateway in CIT, TEC to assist in the development of the driving, measurement and output electronics required for the unit.

3. **Connected Media Application Design And Delivery Gateway (COMAND)**

The COMAND Gateway, based in Athlone Institute of Technology, aims to deliver industry-focused technology solutions for the programming industry across multiple platforms.

The COMAND Technology Gateway focuses on the research and development of interactive media technologies focused on: cross-platform applications, mobile media cloud, 3D sensing, and the interoperability for the Internet of Things. These innovations combine to create the opportunity for new and innovative forms of "connected media" – personalised, real-time, interactive applications – in a wide range of commercial fields including telecoms, gaming, TV, e-health, e-learning, e-tourism, e-retailing, entertainment and digital marketing. COMAND's goal is to transfer these technologies to industry to maximize commercial benefit.

Case Study: Visual ID

Visual ID (http://visualid.com) is an SME based in Dublin, that provides virtual content production systems for print and digital outputs for the fast-moving grocery market. The COMAND Technology Gateway in association with Visual ID, designed a cloud based smart image recognition processing solution for the Visual ID digital asset management system.

4. **Centre For Research In Engineering Surface Technology Gateway- CREST**

The CREST Gateway, based in Dublin Institute of Technology, delivers coatings innovation solutions for industry in the engineering, construction, healthcare and biomedical industries. CREST Technology Gateway is addressing the needs of the Irish engineering, aerospace, automotive, architectural, electronics, biomedical and healthcare sectors in the area of surface coatings.

Case Study- ESB International (ESBI)

ESB International (ESBI) is a leading global engineering consultancy specialising in the utility sector.Since 2005 ESBI has been regular clients of CREST with particular needs in the area of corrosion prevention.

5. **Design+ Applied Design Technology Gateway (Design+)**

The Design+ Gateway, based in Institute of Technology Carlow, applies industrial design capabilities for companies from the engineering, ICT & software and bio lifescience sectors nationally.

***Case Study-* NJ Doherty Solutions**

NJ Doherty Solutions is an Enterprise Ireland Start Up based in Kilkenny, Ireland. The company's product is The Hamstring Solo, a fitness and testing apparatus for professional sports teams. Design+ engaged with NJD Solutions at the early stage of design and prototype development through an Enterprise Ireland Innovation Voucher.

6. **Intelligent Mechatronics and RFID Gateway (IMaR)**

The IMaR Gateway is an applied research provider delivering technology solutions for industry. IMaR offers a range of services to industry such as project development and specification, prototype/proof of concept development, consultancy and industry collaborations, as well as assistance in sourcing funding for research and development projects.

Case study: Internet Of Things Energy Sensor For Injection Moulding Machines

7. **Medical and Engineering Technology Gateway (MET)**

The Medical and Engineering Technologies Gateway is based in GMIT's Galway campus. It offers a range of applied technologies relevant to companies in the product engineering and design application phase. MET has immense expertise in data analytics and the visualisation of clinical data to inform the design of the next generation of medical device prototypes.

Case Study- Capsos Medical

Capsos Medical (http://www.capsosmedical.com) is a High Potential Start-Up medical device company based in Galway that design & develop medical devices to penetrate total occlusion of blood vessels. MET Technology Gateway and Capsos Medical collaborated on an Enterprise Ireland innovation partnership project to address the technology gap for the treatment of chronic total occlusions (CTO) by developing an in vitro simulation system for testing the performance of the product developed by Capsos Medical.

8. **Microsensors For Clinical Research & Analysis Gateway (MiCRA)**

The MiCRA Gateway, based in Institute of Technology Tallaght, delivers solutions for companies in the in vitro diagnostics, environmental, food and pharmaceutical sectors.

The MiCRA Gateway focuses on the advancement of biosensor technologies, using materials such as enzymes and advanced polymers.

Case Study-Advance Science

Advance Science is a company based in Connemara in the West Ireland, that aims to safely improve bee health worldwide and to make new technologies available to beekeepers.Advance Science worked on a project- Bee Hive Health Project, in which it drew on the expertise of MiCRA Biodiagnostics in the R&D of bio- and electro-chemical sensors.

9. Mobile Services Technology Gateway- MSTG

The MSTG Gateway is based in Waterford Institute of Technology. It is a centre for the industry to access knowledge and solutions in advanced mobiles services and service enablers.

Case Study- Waterford Technologies

Waterford Technologies is a client company of Enterprise Ireland with offices in the UK, US, Ireland and the Middle East. The company provides Data Management solutions for Email and File Archiving and Fax Solutions for a wide range of customers across many sectors including Legal, Financial, Health, Education and Government. MSTG and Waterford Technologies worked together to understand in detail the existing business and ideas for creative innovation and developed a comprehensive file archiving and analysing solution to fit their vision and requirements.

10. Precision Engineering & Manufacturing Gateway (PEM)

The PEM Gateway is based in Institute of Technology Sligo. It offers technology solutions for industry in precision engineering, manufacturing and materials targeted at companies based in Ireland and abroad.

Case Study- Northwest Aluminium

Northwest Aluminium is an SME based in Donegal, Ireland that manufactures and distributes Roofing and Ventilation Products. The company worked with the PEM Gateway in IT Sligo through an Enterprise Ireland Innovation Voucher to further develop their dry ridge roofing system for a range of roof types including plain tile and slate mediums.

11. Pharmaceutical & Molecular Biotechnology Research Centre Gateway (PMBRC)

The PMBRC Gateway is based in Waterford Institute of Technology. It provides technological solutions for the pharmaceutical and healthcare sectors in such areas as drug delivery, process technology, biotechnology, biomedical and separation science.

Case Study- TopChem Pharmaceuticals

TopChem Pharmaceuticals is an Enterprise Ireland client company based in Sligo.It is a supplier of active pharmaceutical ingredients (APIs) worldwide. The company is supported by PMBRC gateway for analytical characterization of APIs. Some of the technologies and facilities provided by PMBRC are solid-state NMR, modulated Differential Scanning Calorimetry (mDSC), thermogravimetric analysis (TGA), dynamic vapour sorption (DVS), laser diffraction particle size analysis, and a range of chromatography and associated analytical equipment.

12. **South Eastern Applied Materials Gateway- SEAM**

    The SEAM Gateway is based in Waterford Institute of Technology. It provides engineering material solutions for industry in sectors such as biomedical devices, pharmaceuticals, micro-electronics, precision engineering & construction.

    Case Study-Sulzer Pumps Ireland

    Sulzer Pumps Ireland is a pump manufacturing company based in Wexford, Ireland. It has a broad range of pump manufacturing capabilities that includes machining, assembly, motor winding, packaging and shipping of submersible pumps.The SEAM Gateway collaborated with the company to analyse and redesign the various shaft components as far as the main bearing section using Finite Element Analysis (FEA).

13. **Shannon Applied Biotechnology Centre Gateway- Shannon ABC**

    The Shannon ABC Gateway is based on the Institute of Technology Tralee and Limerick Institute of Technology campuses. It develops novel processes and new products from bio-resources, transferring these solutions to biotech, food and life science industries.

    Case study- Irish Atlantic Sea Salt

    IASS (Irish Atlantic Sea Salt) is an SME based on the Beara Peninsula producing the only Irish made, gourmet sea salt. The company collaborated with Shannon ABC to identify opportunities for the by-products and the Gateway identified a potential opportunity to develop a sea mineral drink product.

14. **Technologies For Embedded Computing Gateway- TEC**

    The TEC Gateway is based in Cork Institute of Technology. The Gateway develops Internet of Things (IoT) and Cyber Physical System prototypes for a broad range of companies, connecting everyday objects and systems and making them *smart*, for example: smart buildings & cities, eHealth, eLearning and location-based services.

    Case Study- SR Technics Airfoil Services

    SR Technics Airfoil Services is a multinational company based in Cork which provides turbine engine hot section component repair services • for blades and vanes on GE, CFMI, Snecma, Pratt & Whitney and Rolls Royce large commercial airline engines. With the company, TEC Gateway created a solution for a smart shelf where RF antennas are placed.

15. Wireless Sensor Applied Research Laboratory Gateway- Wisar

The WiSAR Gateway is based in Letterkenny Institute of Technology. It delivers solutions to Irish industry for the Internet of Things (IoT) using expertise in wireless, embedded systems and power electronics.

Case Study- LC Seating

LC Seating is a medical supplier company specialising in the provision of all types of rehabilitation and seating products. LC Seating and the WiSAR Gateway in through an Enterprise Ireland Innovation Partnership Project worked on a project to prevent pressure sores on the people who sit or lie down continuously due to some disability. They developed a ‘ prototype smart cushion’ that can detect and monitor the pressure build up and then send wireless alerts to a monitor giving a local reminder to a paralysed person or helper when it is time for their position to change.

S.No	Name of Gateway	Location	Research Domain
1.	APT	Athlone Institute of Technology campus.	Providing polymer technology solutions for companies in the medical, composite, recycling and pharmaceutical sectors.
2.	CAPPA	Cork Institute of Technology	Light-based photonic technologies for near-to-market problems for industrial partners.
3.	COMAND Gateway	Athlone Institute of Technology,	Delivering industry-focused technology solutions for the software industry across multiple media platforms.
4.	CREST Gateway,	Dublin Institute of Technology	Delivers coatings innovation solutions for industry in the engineering, construction, healthcare and biomedical

			industries.
5.	Design+ Gateway,	Institute of Technology Carlow	Applies industrial design capabilities for companies from the engineering, ICT & software and bio lifescience sectors.
6.	IMaR Gateway	Institute of Technology Tralee,	Applying its core expertise in providing electronic and mechanical hardware, software, IoT and data analytics innovation for increased productivity in the manufacturing, agriculture and process sectors.
7.	T Gateway	lway-Mayo Institute of Technology,	Offers technology solutions targeted at medical device and engineering companies.
8	MiCRA Gateway	Institute of Technology Tallaght	Delivers solutions for companies in the in vitro diagnostics, environmental, food and pharmaceutical sectors.
9	MSTG Gateway	Waterford Institute of Technology	Provides knowledge and solutions in advanced mobiles services and service enablers.
10	PEM Gateway	Institute of Technology Sligo,	Provides innovation-services to industry in precision engineering, manufacturing and materials.
11	PMBRC Gateway,	Waterford Institute of Technology,	Delivers industry solutions for the pharmaceutical and healthcare sectors in areas such as drug delivery, process technology, biotechnology, biomedical and separation science.
12	SEAM Gateway	Waterford Institute of	Provides engineering material

		Technology,	solutions for industry in sectors such as biomedical devices, pharmaceuticals, micro-electronics, precision engineering & construction.
13	Shannon ABC Gateway	a) Institute of Technology Tralee b) Limerick Institute of Technology	Develops new processes and novel products from bio-resources, transferring these solutions to biotech, food and life science industries.
14	TEC Gateway	Cork Institute of Technology	The Gateway develops Internet of Things (IoT) and Cyber Physical System prototypes for a broad range of companies, connecting everyday objects and systems and making them *smart*.
15	WiSAR Gateway	Letterkenny Institute of Technology,	Provides solutions to Irish industry for the Internet of Things (IoT) using expertise in wireless, embedded systems and power electronics.

2.3. Innovation Partnership Program

ENTERPRISE IRELAND
where innovation means business

IPP | INNOVATION PARTNERSHIP PROGRAM

Background:

Enterprise Ireland is the government association in charge of the development of Irish companies in world markets. It works in association with Irish undertakings to enable them to begin, develop, improve and win export sales in worldwide markets. Thus, it underpins sustainable financial development, regional advancement and secure employment (https://www.enterprise-ireland.com/en/Funding-Supports/Researcher/Funding-toCollaborate-with-Industry-in-Ireland/Innovation-Partnerships.shortcut.html).

The Innovation Partnership Program finances Irish-based organizations to work with Irish research establishments bringing about mutually gainful co-operation and association. Organizations can get access to skill and assets to develop new items, procedures, benefits, and create new learning and know-how. The participating organization benefits in terms of its development, the advancement of its vital innovative work and the making of new information that it can use to create business profits. The research institute benefits in terms ofdeveloping skill sets, intellectual property and publications.

The organization must be an enlisted customer of one of the accompanying state advancement offices: Enterprise Ireland, IDA Ireland, Local Enterprise Office (LEO).

There are two phases associated with an Innovation Partnership application.

- In Phase 1, there are two options:

- Option 1 is to submit an Innovation Partnership Outline Proposal.

- Option 2 is to apply for an Innovation Partnership Feasibility Study.

Phase 2 is a Full Innovation Partnership Proposal Application.

Funding Levels & Criteria

Funding Levels

Under the state aid guidelines, funding rates can vary from 40% to 80% depending on the size of company and the type of research.

	Company Size		
Type of Research	**Small company**	**Medium company**	**Large company**
Industrial Collaborative Research	**80%**	**75%**	**65%**
Experimental Collaborative Development	***60%***	***50%***	***40%***

Funding Criteria - Company Size

It depends on the size of the company, details of which are mentioned below.

Company Size	No. of Employees	Annual Turn Over	Annual Balance Sheet
SMALL	1-49	<€10M	<€10M
MEDIUM	50-249	<€50M	<€43M
LARGE	More than 250	>€50M	>€43M

Funding Criteria - Type of research

Project types can be grouped as subsets of either Industrial Research or Experimental Development. The 'Full Grant Rate' CANNOT exceed 80% for Industrial Collaborative Research and 60% for Experimental Collaborative Development.

Industrial Research

- The main aim of Industrial Research is bringing together new ideas and expertise for developing innovative products, processes or services or bringing about a significant improvement in existing products, processes or services.
- However, Industrial research does not include the development of prototypes.

Industrial Collaborative Research

- This is a research project that involves significant input on behalf of both partners in designing and undertaking the projects.
- The company is dependent on the college know-how and the background IP to deliver the project.

Experimental Development

- Experimental Development focuses on bringing together already existing knowledge and skills to produce plans designs for new improved products, processes or services.
- This could also include producing prototypes, blueprints, plans and other documentation. However, care needs to be taken that they are not intended for commercial use.
- The research leads to development of a product, which a company could expect to commercialize.
- Experimental development projects are to be funded at a lower rate.

Experimental Collaborative Development

- This research leads to a product that the company could expect to commercialise without significant additional development.
- There are inputs on behalf of both partners in designing and undertaking the work plan and the company is dependent on the college know-how and /or background IP to deliver the project.
- Both parties share risk and the college partner will own the foreground intellectual property.

Payments

Enterprise Ireland Payments

If and when the proposal is approved by the Industry Research and Commercialisation Committee, a payment schedule is agreed between Enterprise Ireland and the research institute.

The grant payment will be in three installments, the second and third installment will be based on a review of eligible expenditure:

- 20% of the grant upon acceptance and receipt of the project contract.
- Reported eligible grant expenditure alongwith 20%, upon receipt and approval of the mid-term (interim) report.
- Final payment up to the amount of the approved grant, upon receipt and approval of the final report. Payments may only be issued pending submission of reports, which are satisfactory to Enterprise Ireland.

Eligible Costs

Stipends / Salaries

- The stipends / salaries of persons employed to work directly on the project are supported from the grant fund.
- The technical staff appointed under a grant may, with the permission of the director of the research project, engage in teaching (up to 4 hours) or

demonstrating (up to 6 hours) each during normal working hours, related to the work on which they are engaged.

- The salaries of the permanent academic staff are not eligible for financial support from the grant.

Equipment

- The process for buying, installing and maintaining items of equipment shall be the responsibility of the research institute.
- All the itemsbought under a grant shall, during the duration of the project become the property of Enterprise Ireland.
- When the project terminates, such items of equipment (and any unused materials) shall become the property of the research institute.
- **Project Duration** The normal duration of a project is to be from **six months** up to a maximum of **two years**.

2.4. Industry Research and Development Group (IRDG)

http://www.irdg.ie

The IRDG is an industry-driven group for manufacturing and services organizations associated with Research, Development and Innovation (RD&I).

Set up by industry in 1992, the Group is an autonomous, non-profit body, serving the necessities of individuals on all issues identifying with RD&I.IRDG participation is generally equally divided between Irish-possessed and foreign organizations, who range in size from new companies to the biggest organizations in Ireland.The Group is financed by members' yearly subscriptions.

Today, the IRDG is the representative of all segments of industry including electronics, programming and broadcast communications (ICT), money related administrations, nourishment, designing, medicinal services and life sciences, plastics and utilities.

IRDG activity is organized around the 5 pillars of:

- ✓ Representation
- ✓ Funding & Support
- ✓ Innovation Networking
- ✓ Collaboration
- ✓ Learning

Representation

IRDG is the leading industry representative voice on RD&I in Ireland. It is quite a successful organisation that provides a respected input on R&D policy and represents members' views on RD&I issues to government departments, bodies and development agencies. IRDG is recognized as being constructive and representative of the voices of R&D performing companies in Ireland.

Key aspects of IRDG representation include:

- Open relationship and ongoing dialogue with government departments, bodies and agencies on behalf of the membership (includes Enterprise Ireland, IDA, SFI, Dept. of Finance, Office of Science & Technology etc…)
- Direct input to R&D policy through member workshops on specific issues, e.g. collaboration, R&D tax credit audits
- Consultation on nominations to research, technology and innovation bodies
- Input to government on topics such as the funding of R&D, interactions with colleges, R&D tax credits, patent royalty scheme, intangible assets etc.
- Input to government task forces, e.g. Innovation Task Force

IRDG representations were instrumental in the establishment of the RD&I Tax Credit Scheme.

Funding and support: IRDG member companies maximise funding for their Innovation and R&D through Grants and Tax Credits with full support, advice and assistance.

IRDG experience of funding

IRDG has experience over 20 years of supporting member companies to identify and secure the most appropriate grant funding for their initiatives. Member companies have received between €175m – €200m grant funding since we were set up in 1992. Member companies are also maximizing their tax incentives through our involvement and support on R&D Tax Credits and Intangible Assets.

Innovation Networking

IRDG membership covers a broad range of manufacturing and service companies, ranging in size from 2 to 2,500 employees. It is also relatively evenly split between indigenous and multi-national operations.

IRDG operates a nationwide Innovation Network providing a networking forum for R&D practicing companies to meet and discuss issues of common interest.

IRDG has links and networks across all research institutes and services and advises and supports companies to choose and engage with the most suitable partner depending upon the nature of the project and expertise required.

2.5. Innovation Vouchers by Enterprise Ireland

The Innovation Voucher initiative was developed to build links between Ireland's public knowledge providers (i.e. higher education institutes, public research bodies) and small businesses. Innovation Vouchers worth €5,000 are available to assist a company or companies to explore a business opportunity or problem with a registered knowledge provider (https://www.enterprise-ireland.com/en/research-innovation/companies/collaborate-with-companies-research-institutes/innovation-voucher.shortcut.html).

The Innovation Vouchers initiative is open to all small and medium-sized limited companies registered in Ireland. Applications are not restricted to clients of Enterprise Ireland only.

Exclusions: Small and medium-sized enterprises in the agricultural sector are excluded in line with State aid guidelines.

Companies with charitable status, commercial semi-state companies, “not for profit” organisations, trade associations, company representation bodies such as Chambers of Commerce, Sports Bodies & Associations, Sports Clubs and other non-commercial bodies or associations are not eligible to participate in the innovation voucher initiative.

Eligibility Criteria and Conditions of Use

Small and medium-sized companies may make use of a maximum of three vouchers, one of which must be a 50-50 co-funded Fast Track voucher.

Companies that have been approved in excess of €300,000 (includes funding under the Enterprise Ireland Innovation Partnership programme) funding from Enterprise Ireland in the previous 5 years are not eligible to apply for a fully funded 5k Standard Innovation Voucher, but are eligible to apply for a Co-Funded Innovation Voucher provided they satisfy all other eligibility criteria.

A company may have one 'active' voucher at any point in time. Companies should ensure that the voucher has been redeemed by the knowledge provider before applying for a subsequent voucher.

Companies will not be eligible for further vouchers until their accounts with the knowledge providers are settled in full (including the payment of VAT).

The voucher will also be accepted by registered knowledge providers in Northern Ireland (UK) as part of Enterprise Ireland's arrangement with Invest Northern Ireland.

Available Voucher Types

- Standard Voucher: Standard €5k vouchers are available to assist a company explore a business opportunity or problem with a registered knowledge provider. You can only apply for one of these standard €5,000 vouchers during one of our open calls.
- Co-funded Fast Track Application: The value of the voucher is €5,000 and the company contributes 50% of the project costs in cash. Therefore, a company may use a Fast Track voucher to cover project costs up to €10,000 on a 50-50 co-funded basis. The company and the knowledge provider jointly agree on the work programme for the project in advance of submitting an application.

Permitted uses for a Voucher

Innovation Vouchers can be used for any kind of innovation such as:

- new product/process development
- new business model development

- new service delivery and customer interface
- new service development
- tailored training in innovation management
- innovation/technology audit

Vouchers can be exchanged for knowledge transfer projects from the knowledge provider.

Ineligible activities

The Innovation Voucher may not be used to cover the costs of:

- achieving compliance with statutory regulations or legislation
- standard training courses
- software purchases and software development
- aid that would promote/subsidise the cost of exports
- internships for students of knowledge institutions
- design and production of advertising material
- branding
- sales activities
- business plans, business strategies, economic appraisals, costs analysis, general business consultancy
- standard website development and online optimization
- standard mobile applications development
- activities such as market research and market surveys that may be readily provided by the private sector
- calorie& nutritional analysis, recipe development etc for all Food Service Outlet menus
- activities supported by the mainstream funding mechanisms available from other Development Agencies such as the Local Enterprise Offices
- activities unlikely to result in commercial enterprise or business capable of generating jobs and/or exports
- advice or assistance with the following areas
    - Legal

- Commercial law
- Patents
- Taxation
- Training and mentoring;

Marketing activities, digital marketing activities, marketing plans & strategies

If potential solutions to the knowledge question already exist in the marketplace, then Enterprise Ireland is likely to reject the application on the basis that the proposed activity may be undertaken by the private sector.

2.6. SFI Industry Fellowship Programme

About SFI

The Irish Government initiated the Technology Foresight Fund and allocated a budget of €646 million. SFI was established in 2000, to administer Ireland's Technology Foresight Fund (http://www.sciencecouncil.ie/Publications/1999/Technology-Foresight-Ireland-an-ICSTI-Overview.pdf).Science Foundation Ireland has a vision to progress Ireland's society and economy by supporting the best scientific and engineering research while building an awareness of the role, impact and opportunities science creates.

Aim

- to enhance industry-academia collaborations through the funding of collaborative industry-academia research projects.
- to stimulate excellence through knowledge exchange and training of researchers.

Structure

The fellowship is cateogarized into two types:

- — "Academia to Industry" Fellowships : The staff and postdoctoral academic researchers ("Academic Fellows") spend time in industry.
- — "Industry to Academia" Fellowships: In this, individuals from industry anywhere in the world, including Ireland, ("Industry Fellows") spend time in an eligible Irish academic or research institution.

Duration

- — Full time: 1 -12 months
- — Part-time: 2 - 24 months
-

Funding of up to €100,000 per Fellowship

Intellectual Property (IP) agreements entered into between the Industry Partner and the Academic Partner's Research Body, as named on the Letter of Offer, are the responsibility of the Research Body and should comply with the National IP Protocol, 'Inspiring Partnership – the national IP Protocol 2016.' For the purpose of the Industry Fellowship Programme, the IP arrangements are the responsibility of the Research Body and shall reflect the collaborative nature of the project, the level of commitment of the Industry Partner and compliance with State Aid Regulations.

3. References:

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European Union

Contents

1. Introduction

The European Union (EU) is an economic and political collection of 28 countries, which are located primarily in Europe. The population of the EU constitutes about 7% of the world population. The EU is a distinctive and complex entity that is guided by constantly modifying and evolving governance structures and hence is a great challenge for policy makers. The research and innovation activities undertaken in the EU have a global impact not only owing to the fact that the expenditure on research incurred by EU accounts for 24% of the world's total but also because the union directs various strategies in response to the economic changes. Ingenious activities and innovation have always been placed at the heart of the union for generating resources and creating more jobs.

Even though the EU accounts for 32% of high impact publications and worlds patent applications, the member countries of the EU have been encouraged to reach up to the level of 3% GERD by 2020 (1% public funds and 2% private sector funds).

Various initiatives have been put into place by the Union for focusing its efforts on better science and finding solutions for global challenges like food security, climate change, energy etc. the initiatives use the intervention of the public sector for enhancing the private sector to invest in R&D thereby removing the bottlenecks that prevent novel ideas from translating into effective solutions. These bottlenecks include factors such as, fragmented research structures, lack of funds, low procurement of public sector research, slow level of standard setting and more.

A few of the innovation bodies that are responsible for directing policy guidelines and research and innovation in EU have been listed in the table below:

Table 1: Agencies and their primary focus areas

Name of the Agency/Body	Main Focus Area
Joint Research Centre (JRC)	Commission's in-house service providing independent, evidence-based scientific and technical support for EU policies.
European Research Council (ERC)	Supports ambitious and novel research.
Research Executive Agency (REA)	Manages about half of all EU-funded research grants.
Executive Agency for Small and Medium-sized Enterprises (EASME)	Manages several EU programmes to help businesses.
Innovation & Networks Executive Agency (INEA)	Manages the implementation of the EU's trans-European transport networks.
European Institute of Innovation & Technology	Sets up partnerships of higher education institutions and research/innovation bodies: 'Knowledge and Innovation Communities'.

Since the year 1984 EU has run its research and innovation policy and funding programmes on the basis of multiannual framework programmes. Seven framework programmes have run between the years 1984-2013. Discussed below in an abstract manner are the framework programmes (FP1 to FP7) and the current framework programme 'Horizon2020', which was established in 2014.

2. Schemes/Programmes/ Organization

2.1. The Framework Program- European Union

Background:

The Europeans Union's (European Commission's) funding programs for research and technological development are known as the 'Framework Programmes' – FP1 to FP8. These programmes were initiated for supporting and fostering research in the European Research Area (ERA). These programmes for funding brought the researchers/scientists and the industries together within the Union as well as from around the world to work for generating solutions to a wide array of challenges. For excellence driven research continued funding is imperative and often plays as a fundamental founding element for technological advancement. Therefore the FP was established for ensuring continued investments into research and innovation activities of EU.

All the programmes (FP1 to FP7) were characterized by different time frames, budget allocations and different objectives. The time frame of the programmes until FP6 was five years and since then has been increased to seven years. The previous programmes focused on technological research, whereas the current programme, FP8, which is called 'Horizon 2020' focuses on innovation and research, heightening the economic growth rapidly and delivering solutions at a faster pace.

Objectives

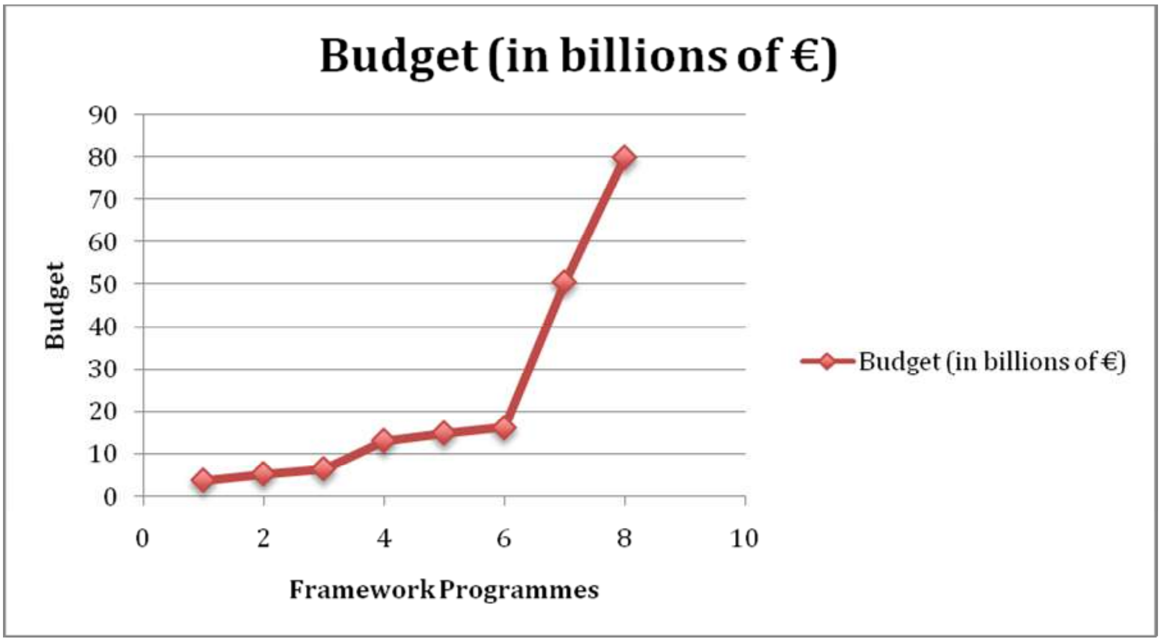
- Strengthening the scientific and technological base of European industry;
- Encouraging international competitiveness, while promoting research that supports EU policies.

Budget

The first FP ever was brought into action in 1984 for a time period of three years. The successive 30 years saw the implementation of subsequent FPs with an aim of executing the directives set by the European research and innovation policies. The table below enlists the various FPs with their designated time periods and allocated budgets in billion Euros.

Table 2: Various Framework Programmes till date

Framework Programme	Time Period	Budget (in billions of €)
First	1984–1987	3.8
Second	1987–1991	5.4
Third	1990–1994	6.6
Fourth	1994–1998	13.2
Fifth	1998–2002	15.0
Sixth	2002–2006	16.3
Seventh	2007–2013	50.5
Horizon 2020(Eighth)	2014–2020	80 (estimated)



Framework Program 7

The Framework Programme 7 (FP7), a program that spanned from 2007 until 2013, was a key tool for Europe's growth and competitiveness. The budget allocated by the EC for FP7 was € 50.5 billion, which represented a 41% increase from the budget of the sixth FP.

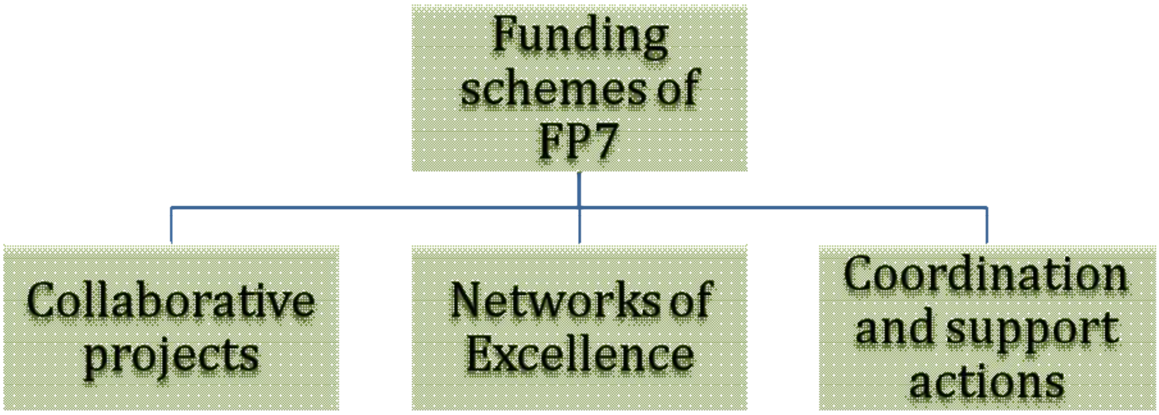
The allocated budget was spent on research grants that were provided to research players all over Europe for financing research and development activities as well as demonstration of projects. The grants were awarded on the basis of 'Call for Proposals' and a 'Peer Review Process', which were highly aggressive.

The FP7 was required to be a programme whose activities were presumed to possess 'European Added Value'. One key part of the European added value is the transnationality of many activities: research ventures are taken up by consortia, which incorporate members from various European (and other) nations; scholarships in FP7 require portability over national borders. Undoubtedly, many research challenges (e.g. fusion research, and so on), are complex to the point that they must be tended to at European level.

Be that as it may, in FP7 there was additionally another activity for "individual groups" with no commitment for trans-national collaboration as well.

Funding schemes of FP7

The way in which the different projects under FP7 are implemented, are through the 'funding schemes', which are illustrated below:



- **Collaborative projects**

Collaborative undertakings are focused research ventures with plainly characterized logical and mechanical objectives and particular expected outcomes, (for example, developing new innovation to enhance European competitiveness). They are done by group of members from various nations, and from industry and the academic world.

- **Networks of excellence**

The Networks of Excellence are intended for research organizations willing to consolidate and practically incorporate a considerable part of their exercises in a given field, so as to make an European "virtual research centre" in this area.

This is accomplished through a "Joint Program of Activities" in light of the coordinated and correlative utilization of assets from whole research units, offices, labs or extensive groups. The execution of this Joint Program of Activities will require a formal responsibility from the associations incorporating some portion of their assets and their exercises.

- **Coordination and support actions**

These are activities that cover not simply the research, but rather the coordination and systems administration of undertakings, projects and approaches.

This incorporates, for instance: coordination and systems administration exercises, dispersal and utilization of information studies helping the usage of the FP bolster for transnational access to real research foundations; activities to invigorate the investment of SMEs, common society and their systems; bolster for collaboration with other European research plans.

Joint Technology Initiatives

In FP7, it was for the first time that public-private partnerships in R&D were started. These were carried out through Joint Technology Initiatives (JTIs), in which the EU and the industrial sector jointly funded the various aspects of FP7. The legal entities that actually implement the JTI are the Joint Undertakings.

Under FP7, five JTIs have been set up, in the field of:

- Nano-electronics
- Aeronautics
- Pharmaceutical research
- Embedded systems
- Fuel cells and hydrogen

When an evaluation was carried out of the JTIs, it was found that they were a successful and novel way for the implementation of the R&D policy of the European Union. They unite the leaders as far as research and advancement in the modern areas concerned and enable them to center and adjust their endeavors around key research and development plans.

The dispatch of JTIs was very much supported based on recognized market disappointments, the long haul nature of the required exercises and the size of the dedication expected to accomplish the fundamental achievements.

In FP7, the total contribution by JTIs to the EU was EUR 3.12 billion, with an industry venture of EUR 4.66 billion. JTIs have turned out to be fruitful in drawing in large number of industries, including SMEs who make up around 28% of the members.

Furthermore, and despite the fact that the JTIs have just been completely operational since a short period, the various assessments have recognized the development made and the main indications of effect. The Fuel Cells and Hydrogen JTI, for example, has set up a critical venture arrangement of vital significance and some early market applications. The assessment of the Aeronautics JTI affirmed that it is effectively empowering advancements towards its vital natural focuses by concentrating on profoundly new mechanical ideas. It was firmly recommended to proceed with similar activities of JTIs under Horizon 2020, considering that no single association or Member State could address every one of the difficulties of the segments in Europe.

The reports and assessments additionally pointed towards a few shortcomings in the JTIs of FP7. The main concern was the requirement for more commitments and responsibilities from industry, with clear estimation of these duties. There was likewise a need to gain greater clarity on how JTIs were built up, to furnish them with clearer goals and to guarantee more prominent receptiveness towards new members. One of such evaluation reports-the report of the JTI Sherpa Group, gave some recommendations to disentangle and streamline the running of JTIs, including through a particular monetary structure suitable to their necessities. Partners have additionally raised concerns about the diverse rules and regulations that apply for each JTI and which may change amongst JTIs and with those pertinent under FP7. These worries have been tended to in the JTIs under Horizon 2020.

2.2. Horizon 2020

Horizon 2020 (https://ec.europa.eu/programmes/horizon2020) is the greatest EU research and advancement program. Nearly €80 billion of finances are accessible for more than 7 years (2014 to 2020) – notwithstanding the private and national finances that this cash will pull in.

Horizon 2020 has the political support of Europe's pioneers and the Members of the European Parliament. They concurred that involvement and contribution in research and development is basic for Europe's future. Hence, R&D was put at the core of the Europe 2020 procedure for brilliant, practical and comprehensive development. Horizon 2020 is accomplishing this by coupling research to technology and concentrating on three key fields: brilliant science, business leadership and societal difficulties. The objective is to guarantee Europe produces world-class science and innovation that drives monetary development.

EU research funds under past FPs has united researchers and industry both inside Europe and from around the globe to find out answers for an immense range of difficulties. Their developments have enhanced lives, and made European industry more competitive and sustainable.

Specific Objectives and Pillars

Horizon 2020 is developed around three main pillars and two specific objectives.

- <u>Specific Objective 1: Increasing participation and enhancing technological development</u>

The first specific objective in Horizon 2020, 'Increasing participation and enhancing technological development ', provides various ways to fully take advantage the talents and capabilities of Europe's research and technological base and to help decrease the technology gap between different regions of the European Union. The various elements developed under this objective are:

- Associating ('joining') main research establishments with their partners in less-performing innovation areas, to make new 'centres of excellence' in these regions;
- Establishing European Research Area (ERA) Chairs in new establishments to build their potential for innovation by pulling in leading researchers;
- Improving the outline, execution, and assessment of national and local research and development approaches, through expert ideas from a Policy Support Facility;
- Promoting scientists' intellectual investment in global networks;

The operational budget for this specific objective is €785 million, managed by DG-RTD (Directorate General of Research and Innovation).

- <u>Specific Objective 2: Science with and for society</u>

'Science with and for Society' is the second specific objective under Horizon 2020. It covers building compelling collaboration amongst science and society, enlisting new ability for science, and matching logical excellence with social mindfulness and obligation. In the year 2014-15 work-programme, the calls for recommendations under this goal tended to the accompanying issues:

- making science instruction and professions appealing to youngsters;
- promoting gender equality in research and development;
- integrating society in science and advancement;
- setting up governance for mindful research and advancement.

The operational spending plan for this ‘specific objective’ is €424 million, which is overseen by REA (Research Executive Agency) under the supervision of DG-RTD (Research and Innovation).

Pillar 1: Excellent Science

The motivation behind the first pillar of the Horizon 2020 program is to make best use of the EU potential in crucial research. The goal of these projects is to help the research framework in the long haul through generation of new information and the improvement of human resources. These projects are centered around what is normally alluded to as exploratory, blue-sky or key research exercises.

Pillar 2: Industrial Leadership

Pillar 2 of Horizon2020 should accelerate the R&D activities that would support tomorrow's organizations and help upcoming European SMEs to develop into world-class organizations. The Pillar concentrates on three particular targets, which are, to create Key Enabling Technologies and space research; to give financing instruments for R&D exercises, particularly in the private sector; and to help the formation of innovative SMEs.

Pillar 3: Societal Challenges

The third pillar of Horizon 2020 focuses on seven societal challenges (SC). While the points are like those characterized under 'Participation' in Framework Program 7 (FP7), the way to deal with getting ready calls for proposition is entirely different. Every point concentrates on policy priorities and incorporates financing for basic research, applied research, information exchange and innovation in order to cover the full cycle of research and development. The objective is to unite a minimum amount of assets and information over various fields, advancements and research foundations so as to address each of these particular difficulties.

The seven societal challenges are:

- Health, demographic change and well-being
- Food security
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Climate action, environment, resource efficiency and raw materials
- Inclusive societies
- Secure societies

Joint Technology Initiatives (JTIs) under Horizon 2020 - Key features

The Commission proposals represent significantly more ambitious partnerships than the JTIs of FP7. Horizon 2020- JTIs have better clarity, contributing specifically EU strategic objectives. Each JTI has set quantifiable targets and key execution markers, which will permit closer and better assessment. The objectives are better designed than in FP7. The targets lay greater stress on development, enabling innovation to close the gap between research and technological application. For instance, the aim of the new Fuel Cell and Hydrogen JTI is to address the cost and execution hindrances that should be overcome for the innovation to be commercially viable. Besides, a large number of the targets specifically give a boost to EU strategy objectives. For instance, the Bio-based Industry JTI will create advances that will permit the generation of bio-powers from non-food crops, in this manner enabling agriculturists and industry to meet EU renewables targets.

Activities

There are different types of indirect actions under Horizon 2020. Funding is provided to participants through different types of actions:

- Research and Innovation Actions (RIA) fund collaborative research projects that aim to develop new ideas and technologies.
- Innovation Actions (IA) promote activities for market directed products or

services.

- Coordination and Support Actions (CSA) fund partnerships and networking of research and development projects, programmes and policies.
- Pre-Commercial Procurements enable the public sector, as an innovation demanding customer, to encourage research, development and validation of breakthrough solutions in areas of public and social interest.
- Public Procurement of Innovative Solutions allow international buyers to share the risks.
- Prizes.

Governance

The budget of Horizon 2020 is managed by nine different Directorates-General (DGs) within the European Commission:

- DG Research and Innovation (DG-RTD)
- DG Communications Networks, Content and Technology (DG-CNECT)
- DG Education and Culture (DG-EAC)
- DG Energy (DG-ENER)
- DG Internal Markets, Industry, Entrepreneurship and SMEs (DG-GROWTH)
- DG Mobility and Transport (DG-MOVE)
- DG Migration and Home Affairs (DG-HOME)
- DG Agriculture and Rural Development (DG-AGRI)
- the Joint Research Centre (JRC)

After an agreement of the Commission in 2011, the implementation of Horizon 2020 is mostly executed outside the Directorates General (DG). Estimates indicate that 75% of the Horizon 2020 operational budget will be implemented by bodies other than the Commission DGs. This exceeds the target set in 2011 by the Commission that two-thirds of the Horizon 2020 budget be implemented by bodies outside the DGs.

Overall, 22 different bodies implement different parts of the Horizon 2020 budget:

- five Commission DGs

- four executive agencies
- four public-public partnerships (P2Ps)
- seven public-private partnerships (PPPs)
- the European Institute of Innovation and Technology (EIT)
- the European Investment Bank (EIB)

➢ The Commission Directorates-General

About 25% of the budget of Horizon 2020 will be implemented directly by four DGs:

- DG RTD (Research and Innovation),
- DG CNECT (Communications Networks, Content and Technology),
- DG HOME (Migration and Home Affairs) and
- DG GROWTH (Internal Markets, Industry, Entrepreneurship and SMEs).

➢ Executive Agencies

Four executive agencies are involved in the implementation of Horizon 2020:

- the Research Executive Agency (REA)
- the Executive Agency for Small and Medium-sized Enterprises (EASME)
- the Innovation & Networks Executive Agency (INEA)
- the European Research Council Executive Agency (ERCEA)

The REA was set up in 2008 to actualize FP7 and it now oversees usage of around 20% of the Horizon 2020 budget. It includes the Future and Emerging Technologies (FET) Open calls, the Marie Sklodowska Curie Actions supporting portability, an offer of the calls for recommendations for space inquire about and an offer of the financial plan of three of the societal difficulties (to be specific 'Sustenance', 'Comprehensive society' and 'Secured social orders'). It likewise actualizes the particular goals 'Spreading Excellence and Widening Participation' and 'Science with and for Society'. As the Research Executive Agency (REA) is the fundamental official organization actualizing Horizon 2020, its command has been mandated to incorporate administration support for the entire program: assessment support, member approval, administration of the help for master evaluators and the Horizon 2020 Helpdesk.

EASME was set up toward the end of 2013 (with help from the European Parliament) as the successor to the Executive Agency for Competitiveness and Innovation. It concentrates on help for SMEs, energy, environment and maritime issues. Under Horizon2020, EASME deals with the implementation of Innovation in SMEs, the SME Instrument, the Fast track to Innovation pilot, and an offer of the calls for recommendations under two societal difficulties ('Energy' and 'Condition'). Outside Horizon 2020, EASME deals with the implementation of the COSME program.

INEA was set up towards the end of 2013 as the successor to the Trans-European Transport Network Executive Agency. For Horizon 2020, INEA is responsible for the usage of part of the budget of two societal difficulties ('Energy' and 'Transport'). Outside Horizon 2020, INEA deals with the execution of the Connecting Europe Facility.

The ERCEA is the official organization setup in 2007 to actualize the European Research Council (ERC) work program, which includes an extraordinary position inside Horizon 2020 as a semi-independent program.

- Public-Public Partnerships

As indicated by Article 185 of the Treaty on the Functioning of the European Union (TFEU), the European Union can participate monetarily in research projects together with the Member States (for the most part up to half). Monetary arrangements for these public-public partnerships (P2P) can be made by the EU through the Framework Program. Rules for setting up these P2Ps are decided by the European Parliament and the Council following the standard administrative technique.

- Public-Private Partnerships

Public-private partnerships supported under the Framework Program are known as Joint Technology Initiatives (JTIs). The Council arranges for the setting up of JTIs after counseling the European Parliament.

Joint Technology Initiatives were started as a part of Framework Program Seven (FP7). JTIs for the most part start in European Technology Platforms (ETPs), i.e. industry-driven discussions that create basic strategies in particular fields. The extent of the research objective and the size of the assets required for a few themes led to the setting up of long term public private partnerships as JTIs. Joint Technology Initiatives consolidate private ventures with European public funding. The private sector will undoubtedly give an in-kind budgetary commitment to the JTI that is at par with the monetary commitment of the public partners.

Though JTIs are a special financing plan made under FP7, the legitimate entity used to actualize JTIs is characterized under Article 187 TFEU and is known as a Joint Undertaking (JU). Joint Undertakings can likewise be set up to actualize other financing plans.

- European Institute of Innovation and Technology

The European Institute of Innovation and Technology (EIT) was made to enhance the associations and cooperation between higher education, research and development in Europe. The EIT was set up in 2008 by a direction of the Council and the European Parliament, in view of Article 157 of the Treaty of the European Community with respect to industry. It started functioning in 2010 and is directed by DG Education and Culture. Till 2013, the EIT was separate from the Framework Program. In 2013, it was incorporated into Horizon 2020 and its direction was aligned with the goal of Horizon 2020.

- European Investment Bank

The European Investment Bank (EIB), with the European Investment Fund (EIF), executes the InnovFin program, which supports private research and development ventures.

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Switzerland

Contents

1. Introduction

As per the Global Competitiveness Index, 2017, Switzerland tops the index, showing the excellent R&D ecosystem in the country. The budgetary allocation for Research and Development in Switzerland is one of the largest in the world- around 3 percent of GDP.

The other innovation indicators and Switzerland's rank in those are tabulated below.

Table 1: Innovation indicators for Switzerland

Sr. no.	Indicator (year)	Global Ranking
1.	Publications[c]	18
2.	H-Index[b]	9
3.	Intellectual Property Rights[d]	4
4.	Expenditure on Education [a]	46
5.	Gross Expenditure on R&D [a] (% of GDP) (2017)	7
6.	Research and Development [a] (2015)	6
7.	Global R&D Companies, avg. expend. Top 3, mn $US [a]	3
8.	QS University ranking, avg top 3[a]	3
9.	Availability of Scientists and Engineersd[b]	12
10.	Capacity for Innovation[b] (2017)	1
11.	Quality of scientific research institutions[b] (2017)	1
12.	Company spending on R&D[b] (2017)	1
13.	University-industry collaboration in R&D[b](2017)	1

14.	PCT Patents[b]	3

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

2. Schemes/Programmes/Organizations

2.1. Innosuisse/ Commission for Technology and Innovation (CTI)

The CTI is a statutory, federal body in Switzerland that aims to boost the innovation ecosystem in the nation by linking the basic research institutes with the businesses to promote the commercialization of the technology. It has been formed as per Article 64 of the Constitution of Switzerland, which states that "The Confederation shall promote scientific research and innovation".

CTI provides support to boost the research and development in Switzerland by providing advisory services and targeted funding and bringing together the knowledge providers and technology generators.

From January 2018, CTI functions with the name of Innosuisse.

Vision

To be the world's best innovation funding agency.

Mission

The untapped scientific and research potential of the Universities of Switzerland to be converted into commercial and economic value for the nation.

Activities

The funding areas of CTI are the following three cateogaries:

1. R&D funding
2. Start-up and Entrepreneurship
3. Knowledge and Technology Transfer (KTT) support

However, there are different ways in which funding and other services can be sought from the CTI. The main aim of these services is to make sure that the different companies, that lack in innovation are provided access to R&D resources from the universities, and funds to convert such resources into viable commercial products.

The various ways in which this can be achieved are:

1. Collaborative innovation projects between an R&D establishment and a private company

In this case, the company and the university, after deciding to work together on a project, approach the CTI with a joint application, for funding their commercially viable R&D project. If the application is accepted, the funding is provided by CTI to the university only, not the company. The company should cover 50 percent of the costs of the project on its own.

2. CTI- Innovation Cheques

   This program was started in 2009 and since then, around 120 cheques have been awarded per year. This provision is for those companies which are new in the area of innovation and research products. These companies are provided R&D services from the research universities (to the maximum amount of CHF 7500). The innovation cheques encourage the companies to start working with the research institutes from the very starting stages in order to plan, develop and commercialize any new technology.

3. CTI Vouchers

   The CTI vouchers are availed by companies by applying to the CTI, without already deciding on the research partner to work with. In case the company's application is approved by CTI, it receives funding in the form of vouchers to cover the basic costs related to the project. After selecting the research institute, they can together apply for other regular funding from CTI.

4. Project solely by the research university

   Funding is provided to such higher education institutes that show innovative capacity, without collaborating with an industrial partner. Support by CTI to such projects is usually for 18 months.

5. Assisted patent searches

   For those companies and start-ups who wish to apply for CTI funding, it is required for them to understand the current trends in the technology in which they wish to apply. For that, the CTI provides help in searching the patents in the relevant technology.

Management and Governance

- Board

The Board is the vital part of Innosuisse. It includes seven individuals and oversees Innosuisse in accordance with the Federal Council's key ambitions and with an eye on what's to come. It chooses the individuals from the Board for a period of four years and furthermore settles on the president.

- Innovation Council

The Innovation Council is the expert body of Innosuisse. It decides on the financing applications and helps in the execution of the supported exercises in aninnovative and creative sense. It additionally creates proposals for the funding methodology and instruments to be endorsed by the Board. To complete its work, the Innovation Council uses a pool of specialists.

- Management team

The main operational body of Innosuisse is its Management team. It coordinates Innosuisse's various activities and deals with the Secretariat. The teamcomprises of six individuals and is overseen by the Director.

- Auditing body

The Swiss Federal Audit Office SFAO is the auditing body of Innosuisse. It surveys the yearly financial articulations and the execution of a suitable risk management and reports its discoveries to the Board and the Federal Council.

2.1.1. Bridge program

A special program Bridge has been started jointly by the CTI and the Swiss National Science Foundation (SNSF). The main aim is to promote and support application based research by bringing together the Swiss industry and the academia partner.

BRIDGE comprises of two funding schemes with different target groups. These are:

- Proof of Concept
- Discovery

A budget of CHF 70 million has been set apart for these schemes.

'Bridge' depends on an integrative and iterative vision of development which expects that science and advancement collaborate in a wide range of ways. Research and technology partners are expected to counsel each other from the very beginning of any project. Bridge also expects to encourage coordinated effort between various research foundations, especially the colleges, ETHs and the colleges of applied sciences. The point is to improve utilization of the monetary and societal capability of research discoveries.

The program plans to help scientists who see an application potential in their research, yet need to accomplish more work to achieve their vision and show convincingly that the true potential is there.

Bridge- Proof of Concept

BRIDGE Proof of Concept helps young researchers to apply their research results and gain the confidence needed to make a market entry. The projects may target innovations of all kinds from all research areas. Support provided by Bridge includes:

- Salaries and costs related directly with the project are covered, to a maximum amount of 1,30,000 CHF per year.
- Funding for the project is provided for one year period, which can be extended once for a six month duration.

Bridge- Discovery

BRIDGE Discovery scheme is for experienced researchers for basic as well as applied research in order to realise the innovation potential of research findings. It allows the researchers to move ahead with their vision during the critical precompetitive phase of the research project. The support provided by Discovery is in the following form:

- Salaries of the staff and direct project costs are covered upto four years.

Organisation of Bridge

For implementation of the Bridge program, the researchers, industrialists and the administrators- all have a role to play. The Steering committee comprises of elected members from the above group of people and the voters are the presiding boards of the two funding organisations- CTI and SNSF.

The funding schemes have their own evaluation panels, whose members comprise of experts from the fields of science, business and industry. The panel members are appointed by the Steering Committee.

2.1.2. KTT (Knowledge and Technology Transfer) program

As indicated by the name of the program, the CTI-KTT program facilitates the exchange of ideas and expertise between industry and higher education institutes. It promotes the conversion of newly-formed knowledge in the universities into technology in the market. Also the basic research of the universities is aligned with the market needs and the needs of the economy.

Innovation mentors (IMs)

Three out of the nine IMs are the head IMs. These nine IMs started their work in 2013, and in 2014, another four IMs joined them. The IMs excel both in the field of business and research. They provide guidance in terms of the funding schemes of the CTI, catering specifically to the needs of the SMEs. Alongwith that, the IMs provide detailed information of the various funding opportunities that can be made available to the companies from within Switzerland as well as the entire European Union. The companies are supported to establish contacts with the organisations that are sources of funding. They hence help to set up organizations in science-based development undertakings of national importance amongst organizations. In the initial two years of the program, IMs supported around 80 demands for R&D ventures at the CTI all things considered every year. Around 66% of the organizations whose applications were affirmed had at no other time made an application to the CTI.

National Thematic Networks (NTNs)

NTNs were set up for the first time in 2013 by CTI, after an evaluation program was carried out. There were a total of eight NTNs initially set up. The different NTNs focus on different innovation topics.The NTNs are the affiliations which get a yearly stipend for their exercises from the CTI. The sum is set independently and is between CHF 200,000 and CHF 400,000 a year. It consists of a basic commitment (60%) and an result related commitment (40%). In 2014 the NTNs played a major rolein around 100 CTI financing applications, the nature of which was impressively higher than in whatever remains of the R&D Funding area: 64 percent of the appli-cations were endorsed, contrasted with the overall average of 55 for percent.

Thematic platforms

Thematic platforms are fundamentally chosen trade events in plainly recognized themes, which will be of impressive relevance in the SME inventive business condition in coming years. The important features of these platforms are that they provide an opportunity for face-to-face discussions about the various innovations. This helps in developing contacts and SMEs can talk about their principle innovative and administrative difficulties. The CTI does not itself coordinatestrade events, however it takes care ofupto 50 percent of the expenses.

Achievements

- Projects assessed and approved- 11,000 and 5,000 (from 2002 till 2017)
- Created 1350 full-time jobs (as a result of coaching program between 2005 and 2009)
- CHF 200 million per year invested by CTI in funding activities
- Around 10,000 SMEs have been identified as potential economy booster for Switzerland, that would be supported by CTI

Success stories

a. Development of Elios- collision tolerant drone.

Elios is the name given to the drone that was designed and manufactured by a start-up company Flyability and Swiss Federal Institute of Technology Lausanne (EPFL). A commercial drone is used primarily in oil and gas industry for inspections, however on hitting various objects, the drones crash, defeating the purpose for which they were made. Hence, Elios- collision tolerant drone, that has a protective cage around it to protect it when it hits obstacles.

In 2015, Flyability had won the 'Drone for Good' award in a competition in Dubai. In 2016, Flyability had received the CTI Start-up Label. Elios now serves energy production companies and the oil and gas industry by carrying out visual inspections of the tanks and pressure vessels where gases and liquids are stored under high pressure.

b. Enhancing security to deal better with cyber crimes

A security solution for increasing cybercrimes was developed by the company Securosys and the Institute of Microelectronics and Embedded Systems (IMES). The CTI Innovation Mentor helped the partners successfully draft a CTI project application. The first cyber-security services by Securosys were delivered in 2016.

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Sweden

Contents

1. Introduction

In 21st century, Sweden, in the 21st century has made a position for itself as one of the most innovative nations of the world. Sweden is the 7th richest and competitive country in the world with high GDP per capita ratio as per World Economic Forum. It is ranked very highly in the indictors of higher education, research and innovation (Table 1). It is ranked 2nd (out of 127 countries) in Global Innovation Index 2017 Report published by Cornell University and World Intellectual Property Organization, and 7th (out of 137 countries) in Global Competitiveness Index 2017-18 Report published the World Economic Forum.

Table 1: Global ranking of Sweden in S&T indicators

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	7
2.	Research & Development (R&D)[a]	5
3.	Gross expenditure on R&D, % GDP[a]	4
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	11
5.	QS university ranking, average score top 3[a]	14
6.	University/industry research collaboration[a]	12
7.	Capacity for Innovation[b]	4
8.	Company Spending on R&D[b]	6
9.	Availability of Scientists and Engineers[b]	20
10.	Quality of Scientific Research Institution[b]	13
11.	Publications#	18
12.	H-index[a]	11
13.	Intellectual Property Rights[d]	5
14.	PCT Patents[b]	2

Source: *[a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php ; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)*

The major ministries and government agencies associated with formulating science and technology policy and initiatives for promoting research and innovation in Sweden are as follows:

i. **Ministry of Education and Research** (http://www.government.se/government-of-sweden/ministry-of-education-and-research/): Under this ministry number of government agencies, government foundations and public enterprises have been set up to promote research and innovation in Sweden. The ministry has dedicated 'Division for Research Policy (http://www.government.se/government-of-sweden/ministry-of-education-and-research/organisation/)' for implementing Swedish research policy and research cooperation with European Union and other global countries. The major government agencies under Ministry of Education and Research are listed in table 2.

Table 2: Government agencies under Ministry of Education and Research for promoting research ecosystem

S. No.	Government agency	Brief details
1.	**The Swedish Research Council** https://www.vr.se/inenglish	Impersonates critical role in funding as well as supporting research at universities, research institutions and within the private sector. The main objective of this agency is to bring Sweden to the top position in scientific research and aims at doing so by 3 major functions – • Allocate government funds for supporting basic research • Provide recommendations to the government on issues regarding scientific research • Educate the public about research in science. The funds are made available for research infrastructures, Medicine, Clinical Therapy Research, Humanities And Social Science, Natural and Engineering Sciences, Development Research, Educational Sciences and Artistic Research.
2.	**Swedish National Space Board** http://www.rymdstyrelsen.se/en/Home/Home/	Dedicated towards the development of Swedish Space Industry by promoting research and innovation through national and international collaborations. Presently, ~34 companies are registered in the board and are eligible for research funding through government for promoting space industry.

3.	**The Swedish Knowledge Foundation** http://ju.se/en/collaboration/collaborate-with-our-researchers/spark/the-swedish-knowledge-foundation.html	Aims at funding research projects in order to develop competency of Swedish universities by building international tie-ups, cooperation between universities and companies along with long term based strategic profiling. The foundation funds and supports research at the universities on a condition that the industry supports it with a matching grant and also participates actively through the development of the research project.

ii. **Ministry of Enterprise and Innovation** (http://www.government.se/government-of-sweden/ministry-of-enterprise-and-innovation/): The ministry is responsible for the development of state-owned and private enterprises in order to promote regional growth in infrastructure, industry and research policy. The ministry is also responsible various government agencies including Swedish Agency for Innovation Systems (VINNOVA), Swedish Patent and Registration Office (PRV), Swedish Agency for Economic and Regional Growth etc.

The major agencies under the ministry to support industrial growth and encourage collaborations amongst the universities and industries have been listed in table 3.

Table 3: Government agencies for promoting university-industry research linkages under Ministry of Enterprise and Innovation

S. No.	Government agency	Brief details
1.	**VINNOVA** https://www.vinnova.se/en/	VINNOVA is the Swedish agency for promoting innovation in the country. The agency widely promotes active collaborations between companies, higher educational institutes, public service agencies, civil society and various other stakeholders. On annual basis, VINNOVA invests SEK 3 billion in promoting innovation activities in the country.
2.	**Swedish Agency for Economic and Regional Growth** https://tillvaxtverket.se/english.html	This agency has been tasked to foster entrepreneurship and growth. The agency promotes overall growth of Swedish companies by providing them financial support to enhance and boost their competitiveness.

3.	**Swedish Agency for Growth Policy Analysis** http://www.tillvaxtanalys.se/in-english.html	This agency deals with the task of identifying, recognizing and analyzing the areas, which are most critical for growth of the country. The main objective is to enhance the competitive capacity of businesses in Sweden by evaluating the growth policy. The agency focuses on how can the country promote its 'Innovation Capacity', strengthen its 'Investments' and its capacity of 'Structural Transformation', all the factors that are crucial for development in a knowledge-based economy.
4.	**Swedish Competition Authority** http://www.konkurrensverket.se/en	The authority supports competition growth in public and private firms to excel in overall growth of the enterprises and consumer benefits. The authority supports the enterprises in terms of law applications, improvement measures, knowledge research development and international cooperation. The authority along with council of research issues works for qualitative and quantitative development of the Swedish companies through funding support for various research projects.
5.	**Swedfund International** https://www.swedfund.se/en/investments/	Swedfund is the state owned company that provides financial support to the corporate sector in Sweden through development of venture capital and start-up funding support targeting development of low and middle income economies of the world.
6.	**Research Institutes of Sweden (RISE)** https://www.ri.se/en	The main mission of RISE is to develop coordination amongst the research institutes in Sweden and thereby reinforce their part in the innovation ecosystem of Sweden. It ensures that effective mechanisms of governance, performance, funding are put in place. Hence, it works for the overall growth and strengthening of Swedish institutes.
7.	**Inlandsinnovation** http://www.government.se/government-agencies/inlandsinnovation-ab-	A government owned venture capital based company having an equity base of SEK 2 billion. The company, which was initiated in 2011, aims at increasing the availability of venture capital, which can be utilized for enhancing

	inlandsinnovation/	competiveness and development of innovative enterprises.

The roadmap for R&D and innovative activities in Sweden is laid down by the 'Research and Innovation Bill', which is released by the government of Sweden for a time period of 4-5 years. The bill of time period: 2012-16, identified three broad areas (medicine, climate and technology) where research and innovation need to be strengthened to advance Sweden innovation ecosystem. The bill highlighted the importance of basic and applied research and took steps to stimulate business sector's investments in R&D. The bill specifies that highly specific research should be undertaken to match the international quality and deliver human well-being along with industrial competitiveness.

The Swedish government has also developed 'Swedish Research Institutes' to promote international tie-ups for promoting culture, research and innovation. Moreover, under the ministry of foreign affairs, dedicated agency 'Business Sweden' was created to support innovation and economic growth ecosystem for Swedish enterprises by setting up a national network of government agencies, companies and industry associations to showcase growth in international markets. Business Sweden is the joint undertaking of the Swedish government and business houses of Sweden to promote the international growth of Swedish companies globally.

2. Programs/Schemes/Organizations

The major programmes and initiatives undertaken by the Swedish government for promoting public-private partnerships for research and innovation in Sweden are presented in sections ahead.

One of the major agencies in Sweden – VINNOVA, the Innovation agency, funds innovative research projects and gives support in form of network. It aims at building bridges between industry and science by creating conducive research environments, which encourage the participation of industries/companies and delivers long standing gains.

The prime mission of the agency is to strengthen the National innovation System by strengthening the links between its main components i.e. academic research groups, public sector and industrial R&D players.

2.1. Centre of Excellence (CoE) Initiative

Background

VINNOVA, the government agency for innovation, is one of the agencies, which in alliance with industries and academic circle, funds VINN Excellence Centres at a selected number of universities. These milieus have been established with an aim of building globally competitive research environments for need-oriented cross-disciplinary research.

Contemporary knowledge, new processes and innovative technology(ies) rising from the Centres leads to the development of new services & products, through a close collaboration between academia, industry and the public sector.

The first generation of competence centres were established in the universities in Sweden in the early 90s by National Board for Technical and industrial Development (NUTEK), VINNOVA's predecessor. These competence centres were aimed at creating research environments within the academia where the industry can partake and deliver long term benefits. In 2005, VINNOVA initiated the VINN Excellence Centre (VINN Ex Centre) programme. The VINN Ex Centres don not focus on performing research in specific/key areas however; they focus on strategic aim of obtaining sustainable growth through R&D. These centres perform applied as well as basic research and partner with all the players of the innovation system.

Objectives

These centres of excellence are working with following mandate:

- Long-term based cooperative relationship between industry-university-public sector
- Transfer of ideas and technologies between various sectors
- Development of new products
- Creation of research based firms

Currently, VINNOVA has funded 19 R&D centres for promoting high technology-oriented research in the field of biotechnology, information and communication technology and informatics in 9 different educational institutes with hundreds of companies associated with these centres.

Organization and Funding

The proposal for creation of a VINN Ex Centre can be initiated by either an industry or a public sector organization however; it can only be formally located at a university. The activities and performance of the VINN Ex Centres are overseen by a 'Board', which consists of participants from both public and private sector. The Board holds the majority to decide the direction of work undertaken by the Centre and to ensure that the centre undertakes need-oriented research. Along with the host university, a number of research institutions, industries and/or public services constitute as the participants of the Centre.

The parties are required to contribute jointly to the R&D programme of the Centre. the collaborations and financial contributions are embodied in a 'Contract', which is formulated before the actual execution of the research programme.

The funding support pattern executed for each centre is described below:

Funding support agency	**Percentage of support**
VINNOVA	30-40%
Host university	30%
Industry partner/public sector partner	30%

Most of the excellence centres are currently delivering a total turnover of ~EUR 21 million for 10 year period since the inception. VINNOVA invests roughly around EUR 7 million in each centre and roughly around EUR 7-10 million has to contribute together by industry and host university. VINN excellence centres jointly promoted by VINNOVA and industry in various universities are listed in table 5.

Table 5: List of VINN Excellence Centres

Field	CoE	Host institute
Biotechnology & Better Health	AlbaNova Center for Protein Technology	KTH Royal Institute of Technology, Stockholm
	Antidiabetic Food Centre	Lund University, Lund
	BIOMATCELL – Biomaterials and Cell Therapy	University of Gothenburg, Gothenburg
	Supramolecular Biomaterials Structure Dynamics and Properties	Chalmers University of Technology, Gothenberg
Telecommunications & Innovative Services	Centre for Sustainable Communications	KTH Royal Institute of Technology, Stockholm
	CHASE – Chalmers Antenna Systems Excellence Center	Chalmers University of Technology, Gothenberg
	GigaHertz Centre	Chalmers University of Technology, Gothenberg
	Mobile Life Centre	Stockholm University, Stockholm
	iPack Center – Ubiquitous Intelligence in Paper and Packaging	KTH Royal Institute of Technology, Stockholm
	WISENET – Uppsala Center for Wireless Sensor Networks	Uppsala University, Uppsala
New Materials & Production Methods	BiMaC-Innovation	KTH Royal Institute of Technology, Stockholm
	Faste Laboratory – Centre for Functional Product Innovation	Luleå University of Technology, Luleå
	FunMat – Functional Nanoscale Materials	Linköping University, Linköping
	HERO-M – Hierarchic Engineering of Industrial Materials	KTH Royal Institute of Technology, Stockholm

	Wingquist Laboratory Excellence Centre for	Chalmers University of Technology, Gothenberg
Modern Working Life & Sustainable Transport	Centre for ECO2 Vehicle Design	KTH Royal Institute of Technology, Stockholm
	HELIX – Managing Mobility for Learning, Health and Innovation	Linköping University, Linköping
	SAMOT – The Service and Market Oriented Transport Research Group	Karlstad University, Karlstad

Source: https://www.vinnova.se/contentassets/ff790c3ad6f94667b65391dc19dda0a4/vi-11-05.pdf

Impact of VINN Excellence Centres

VINN excellence centres have impacted the economic growth along with improvement in research ecosystem in Swedish environment which are as follows:

- Enhancement in research capacities, training and higher education
- Improvement of research publications and citations on global level
- Technical based cooperation between universities and industry
- Transfer of ideas from university to industry
- Development of innovation based firms
- Employment of university students in industries
- Creation of common infrastructure sharing between universities and industries
- Skill enhancement as per industrial needs
- International networking of academic co-operation

The VINN excellence centres are regularly evaluated and reviewed. The second evaluation of excellence centres was carried out and published in 2013. The major outcomes of these centres were as:

- 4 centres have led to generation of 8 companies
- Collaborative R&D has generated 158 products/services/processes
- 3 of the products are licensed in the market
- 9 centres have filed and granted 32 patents
- Research collaborations have led to 748 publications, out of which 133 joint publications of university and industry have been published

- Leadership capacity of 75 individuals from business sector was enhanced
- 12 projects have been completely funded by industry
- 24 European Union projects have been undertaken by these centres

Other CoEs, funded under other government schemes, established in Sweden to promote research and innovation by building structural capital for industry and academia are presented in table 4.

Table 4: Major funding agencies for establishing CoE

S. No.	Funding agency	Theme
1.	Swedish Research Council (VR; https://www.vr.se/inenglish.4.12fff4451215cbd83e4800015152.html)	Scientific research and basic science
2.	Berzelii Centres (VR and VINNOVA)	Perform & excel in basic research, but aim at developing co-operation with industry
3.	Foundation for Strategic Research (SSF; https://strategiska.se/en/)	Advancing basic and strategic scientific research for high technology applications

Source: *https://www.oecd.org/sti/Center%20of%20Excellence%20-%20Sweden.pdf*

2. 2. Swedish Knowledge Foundation (http://www.kks.se/om-oss/)

The foundation was independently set up in 1994 with an initial founding capital of SEK 9.3 million. Till date, the foundation has invested up to SEK 9 billion over 2500 collaborated projects. The foundation specifically finances R&D activities of universities which are carried out in conjugation with industrial units. Under this programme research financing services is provided to specific colleges, research institutes and universities in order to strengthen and align research in accordance with industrial needs. The foundation supports the research activities jointly undertaken by industry (at least two companies should be associated) and university. The foundation has provided financial support in subject domains as digitalization, software development, production technology, health, steel production, radar technology, wood construction, waste management, automation, 3D printing, big data analysis etc. The foundation also supports the promotion of business research of industrial units via following funding programmes as depicted in table 6.

Table 6: Swedish Knowledge Foundation programmes to promote university-industry linkages

S. No.	Programme	Aim of the programme
1.	Expert Competency program	Tailor-made research and skill training based on the needs of companies
2.	Business Research Schools program	Building networks to address industrial needs
3.	High Program	Researchers and companies jointly address to the research problems
4.	Synergy program	Industry and universities come together to address common core research issues
5.	Research Profiles program	Universities are promoted to adopt the industry and promote new collaborations to enhance particular venture
6.	Recruitment program	Industry and university together recruit professors, lecturers and research staff as per the strategic requirements of both industry and universities.

Source: http://www.kks.se/vart-erbjudande/for-dig-som-jobbar-i-naringslivet/

The most impactful collaborations resultant from the financial support under Swedish Knowledge Foundation was reported between Telenor Sweden, largest mobile operating company of the world with the Blekinge University of Technology, Sweden that strongly contributed to the production in the company to the product development. The collaboration has resulted in enhancement of skills of current employees and access to R&D activities.

Establishment of Industrial Research Institutes

Swedish government in partnership with the private players and industry associations have established Industrial Research Institutes with employee strength of ~2100 employees. These institutes are jointly owned by the government (31% funding); industry (60% funding) and European Union (9% funding). Major research institutes have been set under collaborative mode which is as follows:

- INNVENTIA (Subject domain: paper, pulp, packaging and biofuel)
- SP Technical Research Institute of Sweden (Subject Domain: chemistry, material sciences etc.)
  - ✓ CBI, Swedish Cement and Concrete Research Institute
  - ✓ Glafo, Glass Research Institute
  - ✓ JTI, Swedish Institute of Agricultural and Environmental Engineering
  - ✓ SIK, Swedish Institute for Food and Biotechnology
  - ✓ SMP, Swedish Machinery Testing Institute
  - ✓ YKI, Institute for Surface Chemistry
- Swedish ICT (Subject area: information and communications technology)
  - ✓ Acreo Swedish ICT
  - ✓ Interactive Institute Swedish ICT
  - ✓ SICS Swedish ICT
  - ✓ Viktoria Swedish ICT
- Swerea (subject domain: materials technology)
  - ✓ Swerea IVF
  - ✓ Swerea KIMAB
  - ✓ Swerea MEFOS
  - ✓ Swerea SICOMP
  - ✓ Swerea SWECAS

INNVENTIA AB, SP and Swedish ICT have merged to form RISE institutes (https://www.ri.se/en) in order to accelerate innovation in the country. The RISE institutes have evolved as a strong research and innovation partner and have been strongly promoting international collaborative programmes with industry, academia and other public sector agencies. These institutes together have created 100 test beds and various demonstration facilities to support innovation ecosystem in Sweden. The RISE institutes provide following services:

- Enterprise Europe network to support companies in Sweden
- Start-up cooperation between small and large companies in Sweden and in other countries
- Market access to companies
- Testbeds and demonstrators open to industry, SMEs and academic units
- Services such as technical evaluation, verification, prototype and pilot production specifically for industrial units
- Expert consultation for finding innovative solutions to the societal challenges
- Creation of business and innovation areas in collaboration with small and large companies. The innovation areas have access to researchers in academic and research institute and the large network of industries and academic institutes both nationally and internationally have been created to solve the problems in key innovation areas. Five major sectors addressed are as
  - ✓ Digitalization
  - ✓ Energy & bioeconomy
  - ✓ Health and life science
  - ✓ Sustainable cities & communities
  - ✓ Mobility

2. 3. Start-Up Sweden Programme (https://tillvaxtverket.se/english/startup-sweden.html)

This programme was started as a boot camp under the aegis of Swedish Agency for Economic and Regional Growth (https://tillvaxtverket.se/english.html). The boot camp created composes of 10 companies that provide networking support to upcoming start-ups in the field of ICT, Informatics and life science. Through boot camp participants, the start-ups can avail various services including Financial advice, Business development support, Venture capital and Work expertise.

The major portfolio companies which were set up in other countries under Start-Up Sweden Fund are listed in the table below.

Table 7: Major portfolio companies under Swed-Fund

S. No.	Portfolio company	Subject Domain	Country where the company is established	Year of establishment

1.	Gamma Knife Centre	Healthcare	Egypt	2000
2.	Pieno Zvaigzdes	Agriculture	Lithuania	2001
3.	Karlsson Spools	Industrials	China	2005
4.	Addis Cardiac Hospital	Healthcare	Ethiopia	2006
5.	Engro Energy	Energy	Pakistan	2007
6.	Athi River Steel Plant	Industrials	Kenya	2009
7.	Eskaro	Industrials	Ukraine	2010
8.	Jacobi Carbons Lanka	Chemical Industry	Sri Lanka	2010
9.	Vireo	Energy	Belarus	2012
10.	AAR	Healthcare	Kenya	2013
11.	Frontier Energy	Energy	Africa	2016
12.	DBL Industries	Consumer good	Ethiopia	2017

2. 4. Coaching Programme for Small and Medium Size Companies

(https://tillvaxtverket.se/english/digitalization.html)

The programme was launched by the Swedish Agency for Economic and Regional Growth to establish coaching and network building for small and medium sized companies. Initially, the agency provided coaching and mentoring support to around 350 companies and covered ~10 industrial sectors. Under 'Digilift initiative', 10 projects have been selected to mentor small and medium-sized companies by the consortium of local and regional partners.

2. 5. Demo Environment Programme funds

(http://swedishcleantech.se/english/demoenvironment.4.2089ae6e15244fe02f31c1d.html
)

This programme is launched by Swedish Agency for Economic and Regional Growth to finance technology for newer markets. The focus area for generation of technology is from the domain: cleantech products, processes and services involving in the subject area of renewable energy, climate change, ecosystem services, urban development and water and sanitation. The programme funds international technology transfer from

Sweden to 14 countries in Africa (Kenya, Mozambique, Tanzania, Zambia), Asia (Bangladesh, Cambodia), Latin America (Bolivia, Colombia, Guatemala), Western Balkans (Bosnia and Hercegovina, Serbia) and Eastern Europe (Georgia, Moldova, Ukraine)

2. 6. The Knowledge Triangle

The government of Sweden under administrative control of VINNOVA initiated a programme, called 'The Knowledge Triangle'. This initiative, aimed at creating an interactive ecosystem for education, innovation and research within the universities and the industries. This programme focused on enhancing the mobility between the academia and industries.

Under this initiative various steps were undertaken for strengthening industry-academia partnerships for research. The following steps were conducted:

- VINN Verification: to analyse the commercial potential of the research work undertaken in universities
- Key Actor Programme: design an expertise, processes and structured framework for supporting research activities of companies, universities and individual researches. Through this programme, call for higher education infrastructure for collaborations for growth was called through which universities were funded to self evaluated their collaborative work in various domains.
- Individuals and innovation Milieus: it promoted developing strong research collaborations between universities, companies and research institutes targeting specific sectors. Under this initiative VINNOVA supported creation of 18 VINN Excellence centres

Several other programmes and initiatives undertaken in Sweden to promote research collaborations between public and private sector for enhancing innovation ecosystem of Sweden are presented in table 8.

Table 8: Initiatives undertaken to promote PPP for R&D in Sweden

S. No.	Programme	Brief Details
1.	**Innovation Partnership Programmes** http://www.government.se/articl	Under this programme, partnerships with public and private sector are promoted to address challenges through innovative

	es/2017/09/innovation-partnership-programmes-impact-swedish-innovative-environments/	solutions. Five major innovation tasks are in the domains of Next generation's travel and transport, Smart cities, Circular and bio-based economy, Life sciences and connected industry, and New materials
2.	**Treesearch** http://www.treesearch.se/en/home/	It is Sweden's one of the largest open research platforms composed of public (government, academia) and private (industries) sectors leaders. This scheme funds research in field of new materials and speciality chemicals from forest raw materials. Treesearch was jointly started by academy, industry, Knut and Alice Wallenberg Foundation (KAW) and Swedish government.
3.	**Strategic Innovation Areas** http://www.formas.se/en/International/Strategic-innovation-areas-/	This initiative was jointly started by VINNOVA, Swedish Energy Agency and Swedish Research Councils (Formas) where funding for research work in strategic areas for enhancing Sweden economy was provided. Initial funding of SEK 145 million was arranged in 2013 where private industry contributed SEK 20 million. It was proposed that the financial grant will be enhanced to SEK 1.25 billion where industry will be contributing around 50% for the year 2016-17.
4.	**Innovation Bridge Program** https://www.rieti.go.jp/en/events/bbl/06090501.pdf	The programme was initiated by VINNOVA to support commercialization of university research to the market by promoting collaborations and interactions with various industrial partners. Through this initiative VINNOA provides financial support for verification research and industry collaborative research.

5.	**Innovation Office Programme**	Under Research and Innovation Bill, 2008 and 2012, 11 universities have been selected and provided with SEK 10 million on annual basis funding support from the government to set up innovation offices to support commercialization, patenting, technology transfer and contract research with industrial units. 11 universities having innovation offices are as: Uppsala University, Lund University, Umeå University, Linköping University, Karolinska Institute, KTH Royal Institute of Technology Stockholm, and Chalmers University of Technology Gothenburg, University of Gothenburg, Stockholm University, Luleå University of Technology, and the Swedish University for Agricultural Sciences. Many prominent companies have emerged from these universities in effect of innovation offices located in these universities. Few examples are as Ericsson, Gambro and Alfa Laval emerged from Lund University

Netherlands

Contents

1. Introduction

The nation of Netherlands for many years fraught over something known as the "European paradox*":high-quality scientific research coupled with trailing application of public knowledge in actual innovations, despite the existence of a relatively large applied research infrastructure.*

A few of the challenges that the Dutch government faced in the research and innovation ecosystem of Netherlands included:

- The need for growing incentives and refining the framework of institutions for fostering co-operation between public and private stakeholders.
- The need for improving and streamlining the public R&D funding initiatives
- Enhancing the coordination amongst different departments.
- The requirement of bolstering the position of Netherlands as an attractive location for research and innovation undertakings.

A lot has transformed in the recent times and Netherlands now scores high in various indicators of skills, overall framework and innovation. In some indicators, such as, investment of private sector in R&D and innovation it has reached the level of OECD median. Other S&T indicators that explain the position of Netherlands as an S&T advanced nation have been listed in the table below.

Table1: Global ranking of Australia, as based on S&T related indicators.

S. No	**Indicators (2017-18)**	**Global Rank**
1.	Expenditure on education, % GDP[a]	28
2.	Research & development (R&D) [a]	14
3.	Gross expenditure on R&D, % GDP[a]	18
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	10
5.	QS university ranking, average score top 3[a]	13
6.	University/industry research collaboration[a]	5

7.	Capacity for Innovation[b]	6
8.	Company Spending on R&D[b]	8
9.	Availability of Scientists and Engineers[b]	19
10.	Quality of Scientific Research Institutions[b]	4
11.	Publications[c]	14
12.	H-index[c]	8
13.	Intellectual Property Rights[d]	9
14.	PCT Patents[b]	9

*Source: [a]GII 2017-18; [b]GCI 2017-18; ** IPRI 2017-18;*
[c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report 2017-18

The government has also established objectives for reducing the administrative liabilities and compliance expenditures for enterprises and develops transparency within the public services.

2. Schemes/Programmes/Organizations

2.1 Political/ Governmental authorities and Advisory Bodies

In Netherlands, the various commissions on education, S&T policy and culture deliberate over the fundamental subjects and matters of the innovation policy, drafts laws/acts and motions in these domains. The accountability towards research and innovation policy, in the Dutch parliament, is held with two ministries. Education and scientific research are focussed upon by the Ministry of Education, Culture and Science, which provides funds for research infrastructure and fundamental research. All the agencies and other research institutions that fall under the remit of this Ministry implement the policies. The second ministry responsible for innovation policy is the Ministry of Economic Affairs, which works towards strengthening the potential and competitiveness of the country's economy.

As an element of the previously mentioned mission, the ministry's *Directorate General for Enterprise and Innovation* contemplates over the enhancement of innovation surroundings, the encouragement of innovative activities of the enterprises, the propagation of partnership between knowledge institutions and businesses etc. The Ministry of Economic Affairs enforces its programmes also through different agencies. In addition, other ministries with sectoral responsibilities (e.g. the Ministry of Agriculture, Nature and Nutrition or the Ministry of Health, Welfare and Sports) actualize and establish detailed research policies for their respective sectors. The Ministry of Finance holds the responsibility of providing funds for research and for the relevant fiscal framework.

The innovation system of the Dutch is rather fragmented in terms of support, with majority of the instruments being under the Ministry of Economic Affairs. Various executive agencies and organizations, like the, Netherlands Organization for Scientific Research (NWO), also deliver programmes and initiatives at a national level. An expansion in the range and number of actors i.e. more ministries, more agencies, etc., that support innovation has been witnessed in the research performance ecosystem of Netherlands. However, the overall system is fragmented with more of the public research organizations and agencies performing R&D.

Organization of Research

The Netherlands has three main financial support instruments for funding public sector research: direct funds through the Ministry of Education, Culture and Science to the academic institutions/universities and knowledge institutions; indirect funds through means of intermediate organizations such as NL Agency, the Netherlands Organization for Scientific Research (NWO) and the Foundation for Fundamental Research on Matter (FOM); and other sources including private organizations and other government ministries (Figure 1).

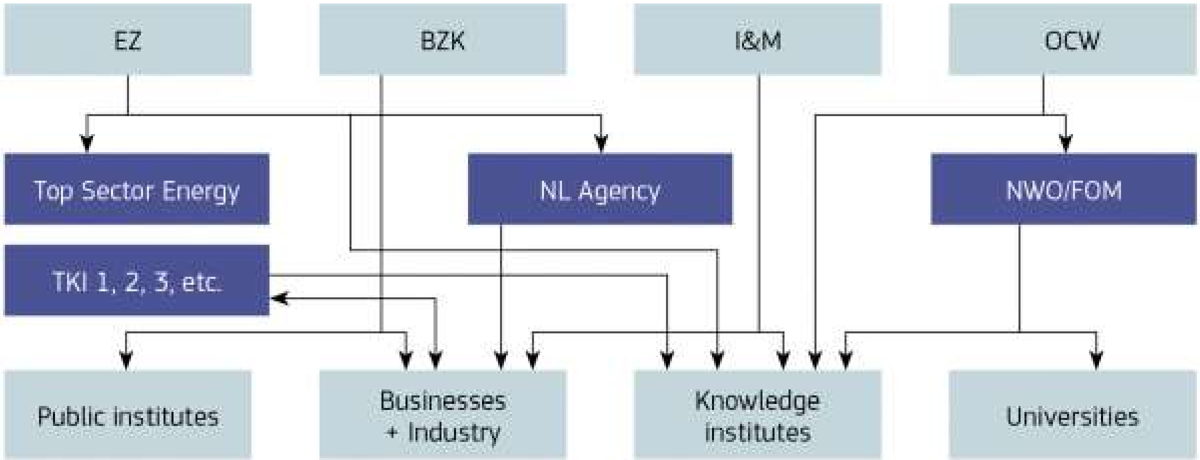


Figure 17 Direct and indirect funding of publicly financed research in Netherlands

Based on Figure S.2 in 'Monitor publiek gefinancierd energieonderzoek 2011', November 2012, p. III, published by Decisio.
EZ = Ministry of Economic Affairs; BZK = Ministry of the Interior and Kingdom Relations; I&M = Ministry of Infrastructure and the Environment;
OCW = Ministry of Education, Culture and Science; TKI = Top Consortia for Knowledge and Innovation;
NWO = Netherlands Organisation for Scientific Research; FOM = Foundation for Fundamental Research on Matter

The main funding organizations for R&D and innovation in the Netherlands are the Netherlands Organization for Scientific Research (NWO), the Royal Academy of Arts and Sciences (KNAW) and the Netherlands Enterprise Agency (RVO).

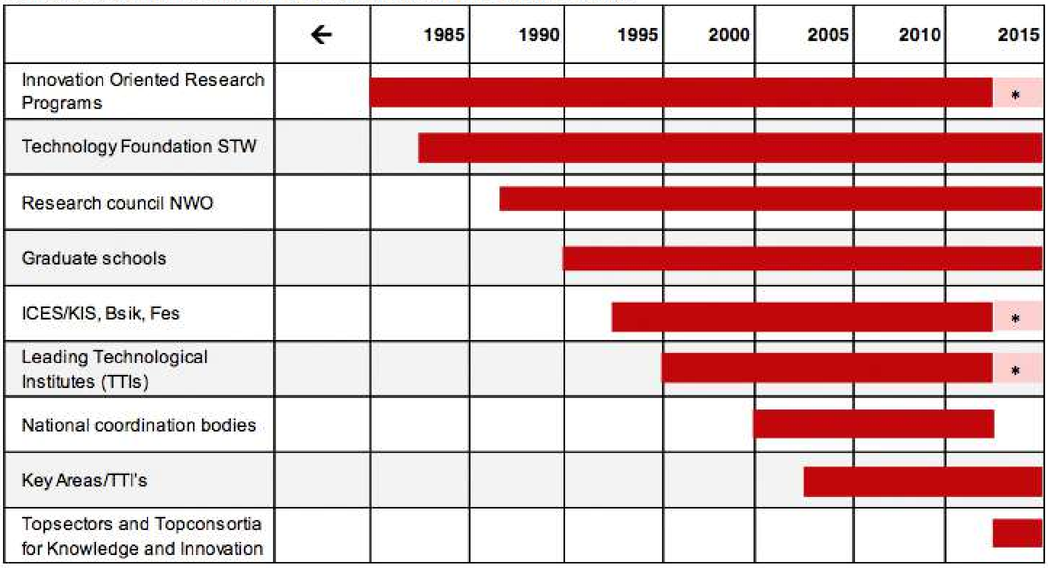
The Netherlands Organization for Scientific Research (NWO) backs and supports a robust system of S&T in Netherlands by boosting the quality of research and innovation. It is established on the fundamental basis of the fact that high quality research provides for the well being and prosperity of the nation. NWO receives public money for science from the Ministry of Education, Culture and Science and from almost all the other government ministries, which is then distributed by means of competition to the universities and national research institutes. NWO manages this competitive research funding and ensures that the money reaches the best scientific talent and the best research proposals. Business and civil society organizations also provide financial support for research in their sphere of activity through NWO, typically in the form of jointly funded themed programmes.

Variant	Approach	Role of partners	Partners' contribution	NWO budget (2015) million EUR
Variant 1: Scientists take the initiative for a joint research proposal with opportunities for companies/organisations	Scientists submit a research proposal with the support of partners in broad calls/tenders (all top sectors)	Follow the research and actively participate in it when tangible results are on the horizon	Make a limited contribution at project level: 1-20%, mostly in-kind	15-20
Variant 2: Scientists and partners jointly formulate a knowledge question related to a top sector or several roadmaps	Together with NWO, scientists and partners draw up programmes with a thematic focus (top sector or roadmap)	Actively participate in the research	Make a considerable contribution at project level: 10-40%, mix of in-cash and in-kind contributions	80-105
Variant 3: A company or consortium of companies has a specific knowledge question and initiates research together with scientists	Company or consortium takes the initiative for a programme (related to a roadmap) and together with NWO invests in research	Enter into a long-term partnership with researchers; are highly involved in the research throughout the duration of the programme; and are closely involved in formulating the research questions and monitoring the projects	Make a substantial contribution of 30-50% or more at the programme level which, in principle, is entirely in cash	

Figure 18 Three variants of public-private partnerships involving NOW
Source: based on the information obtained from NOW website (www.nwo.nl)

Like other countries, Netherlands too has introduced several coordination structures and has supported PPP in research through various initiatives like 'Innovation Oriented Research Programmes', 'Leading Technological Institutes' and interdisciplinary multi-actor programmes funded from national gas revenues (the so-called BSIK and FES investment impulses). Most of these initiatives were temporary entities, which were often in their virtual form. However, the propensity of working with temporary arrangements has lead to a governance landscape of research, which is complex and intricate (figure 2).

Figure 1. Overview of the most important intermediary organizations and policy initiatives concerned with research coordination in the Netherlands



* The programs marked with an asterisk will run for another couple of years based on existing funding commitments, without new subsidies becoming available.

2.2 Technological Top Institutes (TTIs)

The Technological Top Institutes (TTIs) signify one of the chaste forms of PPP, both in their foundation and structure. The LTIs have proven to be a fine practice involving mobilization of public and private research for mutually agreeable objectives, critical for the society and economics of the nation. This initiative was launched in 1996 with the mandate of 'strengthening the innovation potential and competitive position of Dutch Industry'. An TTI or Leading Technological Institute (LTI) is basically an exceptional category of research establishment at a Dutch research university, which undertakes research in areas that -

- Designated as areas of key importance to the nation by the Dutch government; and that
- Subject to such an interest to the Dutch industries in order for it to be considered prudent for funding through PPP mode.

This initiative was launched based on the concept laid down the Ministry of Economic Affairs for identifying critical areas of national and economic interest, and bring into place funding programs for stimulating research in these very areas. Although the instrument of LTI does not have in place a definite legal document describing its modalities and objectives but the memorandum of the Dutch government issued in 1996 entitled 'Towards Leading Technology Institutes' enlists the prime features an LTI:

- A recognizable institute led from one position and, if required, physically concentrated;
- The LTI focuses on one coherent scientific area of fundamental-strategic research
- This area is chosen in close consultation with knowledge intensive enterprises;
- The LTI harbors researchers and equipment of global excellence;
- This excellence forms an attraction for knowledge intensive firms and international top-talent;
- The LTI has a training component through PhD and designer courses;
- Enterprises should have a strong commitment to the LTI.

The LTIs have been able to fill gaps in the Dutch NIS, which was broadening as a result of the development of research plans of large firms, lack of receptiveness of public sector research to the growing prospects, and lack of focused industry-relevant research activities in most PRIs. In Netherlands, the responsibility of LTIs was seen as undertaking 'strategic-fundamental research' placed amid academic research (basic research being performed by universities) and applied research, which was being undertaken by contract research organizations such as TNO (Figure).

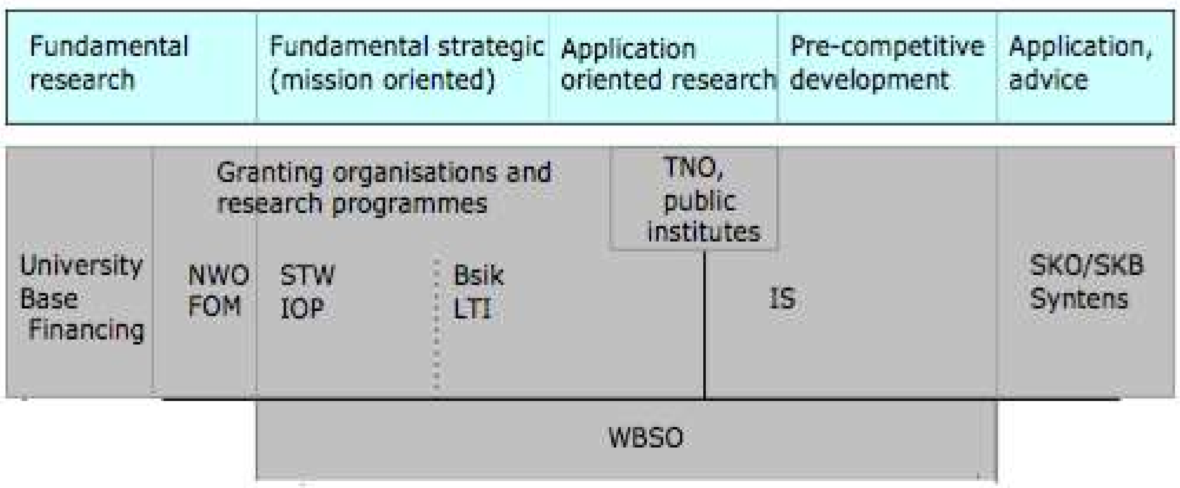


Figure 19 Positioning of the LTI in Netherlands Innovation System

They function at the interface of university research and private sector. The private sector plays a vital role in defining the research goals and ensuring that the research program is in accordance with the long-standing needs of the industry. The involvement also ensures that the outcomes will be prudent for transferring knowledge from the academia to the industry in a more favorable manner. The dedicated participation of the industries entails that the information and knowledge available in the consortia is also diffused within a wide diaspora and the data is available to all of the competing industries. For inducing intense PPP research collaborations of international competence, initially four TTIs were established since 1997: Telematica Institute (situated at the Twente University campus), Wageningen Centre of Food Sciences (WCFS; situated near Wageningen Agricultural University Research Centre), Netherlands Institute for Metals Research (NIMR; situated at Delft Technical University) and Dutch Polymer Institute (DPI; situated at Eindhoven Technical University). A total of 19 proposals were screened for establishing these initial four LTIs. Consortia of researchers led by the industry, keeping into mind all the scientific and economic criteria, submitted the proposals for the creation of the initial LTIs. They were established with the objective of maximizing the long-term social and economic benefits of the research conducted. The LTIs pool together the fortes of PRIs and industrial partners for collaborative research for innovation and technological advancement, possessing high commercial application and significance. The private sector partners lead the research programs by defining the needs and plan of action for the same. The results are then distributed amongst the diverse partners both academic and commercial.

Organization, governance and management

Although the Dutch government actively participated while establishing the LTIs however it provided them absolute freedom for deciding their organizational set up. It did however postulate pre-requisites for setting up of LTIs i.e. scientific expertise and industrial pertinence. The organization and structure of each of the LTI is absolutely specific and distinct. For example, the Dutch Polymer Institute (DPI) and the Wageningen Centre for Food Sciences (WCFS) are virtual organizations consisting of a core lean organization and research performing institutes. The others such as

Netherlands Institute for Metals Research (NIMR) undertake research activities at the core as well making its structure more central. A few characteristics of each of the structure have been enlisted in the table below -

Table 5 Organizational set up of LTIs

	Central Institute	**Virtual Institute**
Advantages	• Easy integration • More corporate culture	• Researchers can work in their natural habitat • Flexible personnel policy
Disadvantages	• Pulls out researchers from universities • Can become isolated	• Difficult to organize • Double loyalty of researchers

Funding Structure

Since the inception of the LTIs, the Dutch government strictly imposed the regulations regarding sharing of costs amongst the participants. The government imparts a maximum of 50% of the total costs. This amount is also subject to the consideration that the amount provided by the government should not exceed two times the least contribution made by either of the partnering organizations (either institute or industry). PRIs and the private entities have to mandatorily pay at least 20% of the total costs. The size of the contribution of the industry to a particular LTI plus the modalities of the industry varies according to each LTI. In DPI, there is presence of a ticket system i.e. an industry can buy a ticket for a specific amount to ensure its position and vote in the program committee. Firms can buy as many tickets as they wish to, for strengthening their hold and have greater influence. A different system known as the four-year rolling system is followed by WCFS. Each firm can pay for a time period of four years, ensuring its influence and capacity in the research domain for a long period.

Example: Dutch Polymer Institute (DPI)

DPI has been set up as a public-private partnership to promote advanced polymer research. Because of its narrow focus it works with a light governance structure consisting of small executive and supervisory boards.

DPI has been established as a virtual, flexible research network with a small core organization, and broad participation from the polymer industry (producers and users) and knowledge organizations (Technical Universities and TNO) with significant financial support from the Netherlands' Ministry of Economic Affairs. DPI uses an innovative ticket system to make research demand driven. Tickets are bought by companies at € 50,000 each per year for a minimum of four years. A ticket corresponds to one vote in the program committee of one of the technology areas (e.g. rubber technology) Firms can buy more than one ticket per technology area in order to have more influence. Contributions from companies are matched by the knowledge institutions (i.e. universities and TNO) mostly through in-kind contributions (research work), but also equipment. The combined industry-knowledge institution investment is doubled again by the Ministry of Economic Affairs. The research agenda is set by the companies and €1 of their contribution results in €4 worth of research work.

At DPI the research agenda is driven by the polymer industry. This means that program priorities are determined by the participating companies, while research work is done by the knowledge institutes and funding is shared between industry, knowledge institutes and government through the formula discussed above.

DPI uses a broad stakeholder consultation process (through a survey and a workshop) to obtain feedback from its users, financiers and others on organizational relevance and performance and the needs for adjustment to changing dynamics in the environment.

In the last few years DPI has transformed itself into an International Centre of Excellence in Polymers. To achieve that goal, the institute has expanded its pre-competitive research programmes with projects focusing on pre-commercial and societal themes. The following figure represents a summary of the financial data of the year 2014

Income	(x EUR million)	%
Contributions from industrial partners	3.85	33.4
In-kind contributions from industrial partners	0.26	2.3
Revenue Patents	0.03	0.3
Revenue DPI Value Centre	0.50	4.3
Contributions from knowledge institutes	1.36	11.8
Contributions from Ministry of EA	0.00	0.0
Revenue TKI SPM	0.29	2.5
EU FP7 projects	5.14	44.7
Industrial pre-commercial research programme Value Chain	0.08	0.7
Solving societal themes and challenges	0.00	0.0
Total income	**11.51**	**100**

Figure 20 Financial Summary of DPI (2014) (Annual Report, DPI, 2014)

Key Performance Indicators:

	2013	2014
No. of industrial partners	38	37
European governmental funding (% of total funding)	7%	45%
Number of partner knowledge institutes (Universities, etc.)	45	45
Participation of foreign knowledge institutes as % of total expenditure	12%	18%
Industrial contribution (cash and in-kind) as % of total income	46%	35%
Expenditure for knowledge transfer (x EUR million)	0.53	0.16
Scientific Publication	170	111
Number of patents filed by DPI	8	2
Number of patents/reported inventions licensed or transferred to industrial partners, universities and DPI Value Centre[8]	0	6
No. of start-ups supported by DPI Value Centre		42

2.3 Top Consortia for Knowledge and Innovation Scheme

In accordance with the new approach towards its innovation policy – 'Topsectoran' the Dutch government brought into action a new initiative termed as Top Consortia for Knowledge and Innovation Scheme (TKI). This initiative was implemented in line with the objective of creation and utilization of knowledge for innovation as laid down by the Topsectoren policy approach (https://www.nwo.nl/en/policies/top+sectors). The nine 'Top Sectors' as identified by the government, which aspire at increasing the aggressiveness of the economy by motivating advancement in the nine sectors: agriculture and food; creative industries; energy; horticulture; life sciences and health; water, high-tech systems and materials; logistics; and chemistry.

[8] DPI Value Center helps entrepreneurs with innovation in the field of polymers (http://www.dpivaluecentre.nl/).

Each of the sectors is governed by a Top Team, which comprises of two representatives from the industrial sector (large companies as well as SMEs), one delegate from a knowledge (research) institute and one representative from the Netherland government. The R&D priorities and fund requirements of each sector are decided upon by these Top Teams.

Under the sector – Energy, there are seven Top Consortia for Knowledge and Innovation (TKIs). These TKIs are public-private partnerships between industry and research institute, which cater to that specific domain.

The plans and strategies are defined by the TKIs under Innovation Contracts and a Human Capital Agenda.

The Top Consortia for Knowledge and Innovation (TKI), are basically consortia, with an aim at performing research which is user oriented. As of 2016, a total number of 19 TKIs have been created in Netherlands under the sub heads of 9 top sectors as identified by the policy.

Sector/Domain	TKI
Agri & Food	TKI Agri & Food
Chemicals	TKI Chemicals
Creative Industries	TKI CLICKNL
Energy	TKI Energy
High Tech Systems and Materials	TKI HTSM
Life Sciences & Health	TKI Life Sciences & Health
Logistics	TKI Logistics
Horticulture and Propagation Materials	TKI Horticulture & Propagation Materials
Water	TKI Maritime Engineering; TKI Delta Engineering; TKI Hydraulic Engineering
Cross-cutting	TKI Biobased Economy

In a TKI, players throughout the knowledge chain join hands for consolidating outstanding public-private partnerships for R&D. The TKIs are funded by the NWO and therefore as the main research funding body it plays a critical role in the functioning and operation of TKIs. However, the exact part played by NWO in each of the TKI is dependent on the involvement of NWO, domain wise as well as financially.

The established TKIs, are asked to develop innovation contracts, which lay out the R&D design for the upcoming years starting from the stage of fundamental research up to commercialization, through valorization.

'Topconsortia for Knowledge and Innovation' play a leading role in coordinating research. Their governmental funding depends directly on the contributions made by industry and knowledge institutions.

2.3 ACTS

ACTS is a public private partnership between Dutch government, universities, research institutes and industry in the field of sustainable chemical technologies. Its mission is to initiate and support the development of innovative technologies for the sustainable production of materials and energy carriers. ACTS realises this mission by establishing and coordinating challenging public private research programmes. These programmes consist of a coherent cluster of projects, executed by universities and research institutes in close cooperation with industrial partners' (www.nwo.nl/acts, 29 December 2011).

Objective: The mission statement indicates that ACTS intends to fulfill a boundary role between different institutional and epistemic cultures. Its aim is to establish intensive collaboration between research activities of public research organizations, on the one hand, and industry, on the other. Moreover, it strives for coherent clusters of projects, implying alignment of the work of researchers with different disciplinary backgrounds.

Governance: ACTS is a relatively autonomous organization, but it is organizationally associated with NWO (Nederlandse Organisatie voor Wetenschappelijk Onderzoek), the general Dutch research council. This special status implies a possibility to develop a tailor-made approach to coordination, but it also implies a need to maintain relationships with established parties. ACTS was established in 2002 as part of a shift towards consortia-based funding in the Dutch science system (Hessels, 2013).
Programmes: The first cohort of research programmes (Table 2) in different domains was in operation from the time period of 2002-2012.

Programme	Duration	Budget (M€)
ASPECT (Advanced sustainable processes by engaging catalytic	2004–12	12.5

technologies)		
IBOS (Integration of biosynthesis and organic synthesis)	2003–12	13.6
PoaC (Process on a chip)	2004–13	8
Sustainable hydrogen	2002–12	18.2

Each of the above-mentioned programmes focussed on research themes to achieve goals for short, to medium to long term periods. With different programme committee for each of the sub programme, the strategies and work focus was accordingly planned. The committee consisted of a Chair, a Programme Manager and representatives from the knowledge institutions as well as industries.

Output of the programmes

Programme	No. of Projects	Scientific Papers	Patent Applications	Industrial Partners
ASPECT (Advanced sustainable processes by engaging catalytic technologies)	32	110	3	8
IBOS (Integration of biosynthesis and organic synthesis)	24	164	3	19
PoaC (Process on a chip)	11	46		12
Sustainable hydrogen	34	225	5	5

The new set of programmes that ACTS is currently implementing under the heading of Technology Areas for Sustainable Chemistry (TASC). The TASC innovation programme focuses on the development of innovative technologies for new process routes aimed at minimizing energy consumption, emissions and waste and reducing the use of fossil raw materials. TASC is the follow-up programme to ACTS.

Programmes

- TASC - Eco-efficient Use of Biomass for Bulk and Fine Chemicals Production (Biomass)
- Comprehensive Analytical Science and Technology (COAST)
- TASC - Low Energy Routes to Bulk Chemicals (Low Energy Routes)

– TASC - Syngas, a Switch to Flexible New Feedstock for the Chemical Industry (Syngas)

TASC focuses on Technology Areas (TA's) in smaller programmes (3 to 7 million euros). This approach aims at a more application-oriented research and more direct involvement.

The programme budget of the first call of each of the programme is 3 million euros o which 1 million euro is co-funded in cash and in-kind by private partners (industry, research institutes, SME's).

2.4 TechnoPartner Programme

'The Techno Partner Programme is designed to improve the business climate for high-tech start-ups by providing them with access to money , knowledge , experience and equipment , by giving them a forum for their questions , ideas and comments and by encouraging academic institutions and commercial investors to back them .' (Source: EIM & Ministry of Economic Affairs, 2006)

The TechnoPartner Programme is a special programme that has been developed for high growing innovative enterprises. This programme finds its origin in the ambition of the Dutch government to be amongst the most knowledge-based economies of Europe. The Netherlands recently experienced some problems with knowledge exploitation: results of scientific research were too less used by businesses. Although the quality of scientific research was high, the link with practice was often lacking. This phenomenon was referred to as the 'European Paradox' (Ministry of Economic Affairs, 2004).

Techno-starters play an important role in levelling this paradox. This was mainly acknowledged because they link scientific research to business: newly developed technologies are often being commercialised by new firm formation (e.g. spin-offs). This made techno-starters creative innovators that boost job creation.

As the government became more and more aware of the strength and potential of this group of entrepreneurs, an action plan was developed for them by the Ministry of Economic Affairs, together with the Ministry of Education, Culture and Science.

In the TechnoPartner Programme, all former initiatives regarding technostarters have been incorporated and levelled. Furthermore, it contains proposals for improvements in the institutional environment of knowledge institutions. A revision of the initiatives and the institutional environment was necessary, because techno-starters experience specific, typical bottlenecks:

- Lack of entrepreneurial skills - Due to the fact that most techno-starters have a technical or scientific background, in which entrepreneurship lacks, this group does not (or hardly) have entrepreneurial skills. Therefore, they experience problems when writing a business plan, attracting customers or with regard to product development.
- Entrepreneurial culture - The Dutch entrepreneurial culture is rather weak, as Dutch society is somewhat risk-averse. This has resulted in a relatively low number of new firms, compared to other European countries. As a consequence, there are relatively still less new technology-based firms, as this form of entrepreneurship is seen as more risky.
- Risk capital - Attracting risk-capital often appears to be difficult for a technology-based start-up. This is mainly due to the uncertain market prospects together with high risks. Therefore, they receive limited investment in the seed stage, the stage before the actual launch of the company.

The government developed the TechnoPartner Programme while accounting for above mentioned bottlenecks. This programme brought back the numerous former instruments and schemes to one initiative, consisting of the following pillars:

- TechnoPartner Seed Facility (RSCT) - As mentioned before, especially new and (potential rapidly) growing firms are having difficulties with obtaining capital. This will be made easier by implementing a Seed Facility, which makes it more attractive for venture capitalists to invest in technostarters, as their risk decreases. Technological start-ups that are financed by venture capitalists get 50% more funding by lending from the Seed Facility. In practice, this means that these start-ups have to obtain ‘only’ 50% of their required risk capital, as the other 50% is funded by the Seed Facility. Venture capitalists will perceive a decreased risk of investing in techno-starters.

- TechnoPartner Subsidy Regulation Knowledge Exploitation (SKE) - This regulation has been developed in such a way that scientific knowledge will be exploited easier by techno-starters. It is both meant for spin-offs and new independent start-ups. A pre-seed facility provides the opportunity to techno-starters to spend more time and effort in the stage before the actual start. A patent facility makes it possible for the knowledge institution to professionalize the internal patent policy. Large companies and knowledge institutes can, together as a consortium, get 50% funding for initiatives that create technological start-ups based on these research programmes.
- TechnoPartner Platform - This platform is aimed at increasing the group of potential innovative technological entrepreneurs. This will be done mainly by information provision and exchange of information. The platform will also follow techno-starters for feedback.
- TechnoPartner Label - Another financial facility provided by TechnoPartner, is the TechnoPartner Label. This label is actually an extension of the regular guarantee facility of the Ministry of Economic Affairs for all start-ups. TechnoPartner Label provides an extra facility to technological, high potential start-ups, because the Ministry puts itself for 80% guarantor for the financing of high potentials through a loan. The risk for the loan providing bank will be reduced, but the bank will have to pay a risk premium.
- Business Angel Network Programme - This programme consists of information provision to both innovative entrepreneurs and business angels to achieve a better match. Business angels are informal investors that provide next to capital, also knowledge, management experience and coaching to (starting) entrepreneurs.

Promoting innovation and cooperation between the private and public sector has always been the priority of the Dutch Innovation Policy therefore other few programs were also initiated over time (Table).

Table: Public-private partnership programs in the Netherlands

Initiative	Characteristics
STW Technology Foundation	The Ministry of Economic Affairs via the STW Technology Foundation aims at stimulating and promoting the

	development of highly competitive Dutch University Research Centers. The main aspects of the initiative are: the involvement of user, utilization and outcomes of research.
Innovation-Oriented Research Programs (IOPs)	IOP aims at strengthening tactical research at universities of Netherlands and PRIs in response to the demand of the private sector, their issues, innovation requirements etc.
Technological Partnership (TS) Scheme	The TS scheme offers subventions and sponsorships for technological projects devised by corporate coalitions or alliances between the research institutes and companies.
Economy, Ecology and Technology (EET) Program	This program offers subsidies for critical research projects undertaken by corporate coalitions or alliances between the research institutes and companies, which ultimately lead to suitable improvements through technological both in ecological and economic scenario.

2.5 Technology Foundation STW

Technology Foundation STW was founded in 1981 as an organization for serving the complete diaspora of technical sciences. This foundation since its inception has been working for realizing the transfer of knowledge from competitive research being performed in the Netherlands i.e. between technical studies and its users. Technology Foundation STW has been incorporated into the new NWO Domain Applied and Engineering Sciences (TTW), since January 1st 2017. The foundation in its effort to fulfill the objective of facilitating knowledge transfer has realized the need for a accountable methodology with respect to the results of research in a general form and with respect to patents and other IP in particular. In its approach TTW intents at exploiting and publishing the results of research for maximum public outreach along with safeguarding intellectual property rights. These rights are subsequently commercialized for profit making. The set of regulations regarding IP are into place and are strictly adhered to by TTW. These regulations are in accordance with the IP policy espoused by Netherlands Organization for Scientific Research, NWO and also in tune with the '*Rules of Play for public-private collaboration*' as offered to the Lower House of Dutch Parliament dated 25 June 2013.

However, TTW also provides the freedom to the knowledge institutions for postulating their own publication and IP rules/measures with the collaborating partners. This provides for better response to the needs and requirements of the researchers, co-funders and the other stakeholders. This arrangement is allowed only if prior intimation along with the consent of the partners is provided to TTW i.e. duly stated at the time of application. The institution is supposed to take the lead in making the above stated arrangements, which are then reviewed by TTW. This evaluation ensures their compatibility with the pre-requisites of the funding program.

2.6 Innovation-Oriented Research Program

The Ministry of Economic Affairs in the 1980s initiated the Innovation-Oriented Research Programs (IOPs). The management and administration of the program was delegated to an agency of the Ministry - SenterNovem (later called NL Agency). This program was later shifted and made a part of the 'programmatic approach' of the Ministry of Economic Affairs (Van *et al.,* 1998). The prime goal of the IOP initiative was to intensify calculated pre-competitive basic research at the Dutch universities and PRIs, in alignment with the requirements of the private sector. Allocation and knowledge transfer, employment of research outcomes, encouraging of long-periodassociations and creation of strong networks were amongst the other targets of the IOP program.

2.7 National Genomics Initiative (NGI)

The initiative on National Genomic was brought into force in 2002 as an independent yet temporary task force, affiliated to Dutch Organization for Scientific Research (NOW) for bringing together collaboratively the efforts and proficiencies of various ministries, organizations, agencies, private entities and other players, in the specific domain of genomics. The initiative aimed at developing high-class infrastructure, continuous knowledge transmission and capacity building for genomics research and promotion of innovation in the field. Through the initiative a national strategy was put into place, which had its fundamentals in three main elements – world class international research, industrially relevant innovations and relevant for the society. The preparations and ideas for launching this initiative had started as early as 1998 and were undertaken with the involvement of various stakeholders – ministries, private sector players, agencies, research society and few other teams of the Dutch Community for harboring a strong political backing and sustainable associations resulting in mutual benefits. These entire group stakeholders were given the priority of defining the matters and significances of the prophesied investments.

A crucial realization factor in this blend of bottom-up and top-down essentials is to preserve the vital stability amid involvement of investors in a partaking role in the progress of a needs-driven policy, and the policy element not to be directed by petitioners.

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Finland

Contents

1. Introduction

Finland is a small knowledge-intensive Northern European Country. The Finnish economy is characterized by medium to high technology and the sectors of importance are ICT, wood and paper industries, metal-machinery and basic metals (Innovation Policy Platform). It invested around 2.9%of its GDP for R&D (GERD) activities during 2015 (World Bank data).The involvement of private sector in R&D activities is strong with the public private GERD ratio (%) at 30/70.

Table1: Global ranking of Finland, as based on S&T related indicators.

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	13
2.	Research & development (R&D) [a]	9
3.	Gross expenditure on R&D, % GDP[a]	8
4.	Global R&D companies, avg. expend. Top 3, mn $US[a]	15
5.	QS university ranking, average score top 3[a]	17
6.	University/industry research collaboration[a]	2
7.	Capacity for Innovation[b]	7
8.	Company Spending on R&D[b]	7
9.	Availability of Scientists and Engineers[b]	1
10.	Quality of Scientific Research Institutions[b]	8
11.	Publications[c]	26
12.	H-index[b]	19
13.	International Property Rights Index [d]	2

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

The various agencies and institutions that contribute to the research and development in Finland and run programs for the promotion of public–private partnership are illustrated in the schematic diagram below:

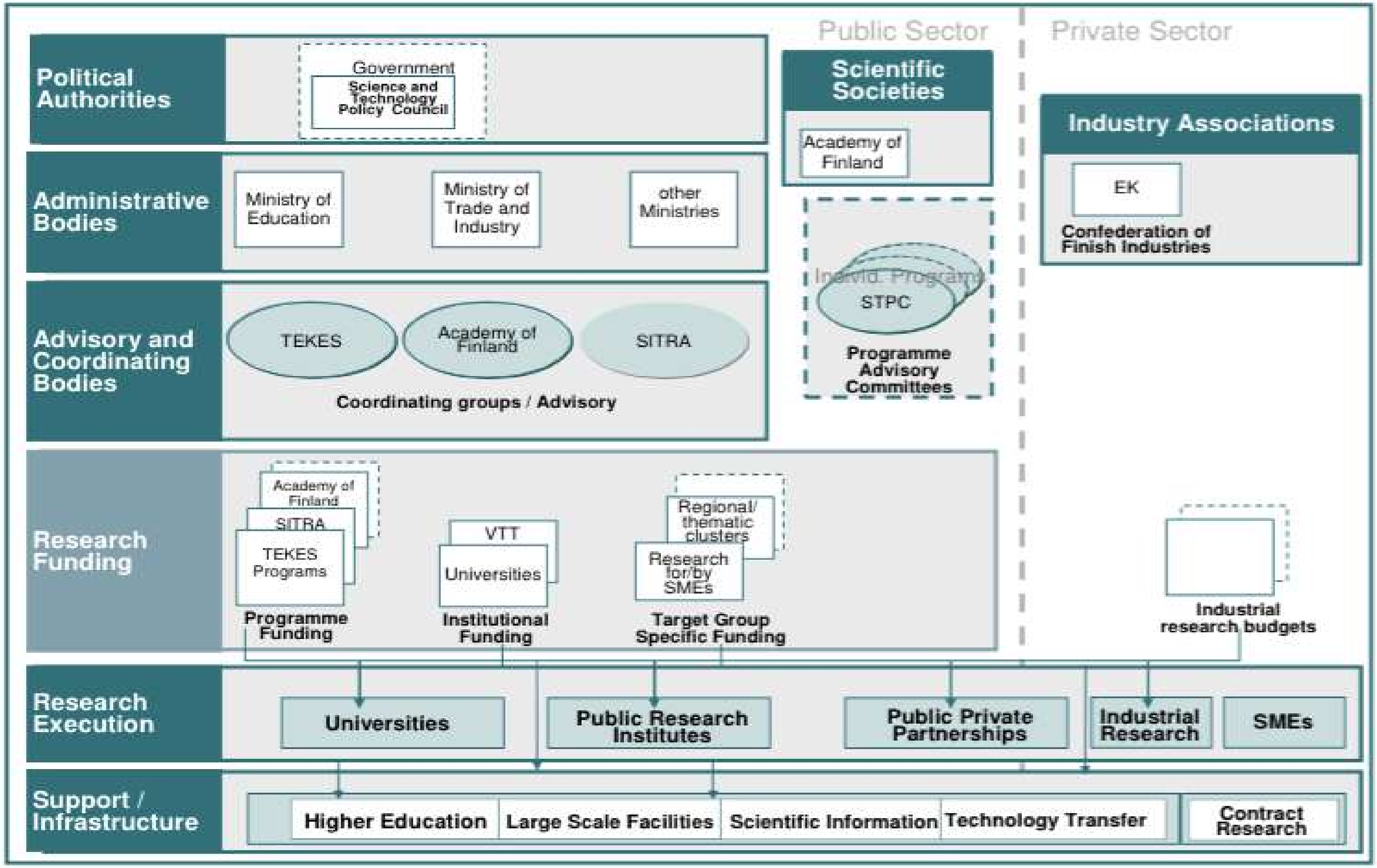

Fig 1: Relevant decision structures of the Finnish Innovation System

2. Schemes/ Programmes/ Organisations

Science and Technology Policy Council (STPC)

The Science and Technology Policy Council of Finland (STPC) is the primary agency that takes care of the development and co-ordination of S&T policy and of the National Science and Innovation System as a whole in Finland. STPC's chairperson is the Prime Minister of Finland, and other members are from the Government as well as important organisations dealing with science and research, that include the National Technology Agency (TEKES) (now Business Finland), the Academy of Finland, and the research universities.

STPC gives advice on S&T strategy, plans policy recommendations and proposals for the Government and its Ministries and screens the improvement of R&D-based exercises, the advancement and use of S&T and application-based and scholastic research needs. STCP reports straightforwardly to the prime minister and the legislature. STCP's operational staff comprises of one part from the Ministry of Industry and Trade and one from the Ministry of Education.

The Ministry of Trade and Industry's main focus is on modern and innovative strategies. The Ministry of Education is accountable for issues identifying with instruction and preparing, science arrangement, foundations of advanced education and the Academy of Finland and other essential research issues.

Different ministries, for example, the Ministry of Energy, the Ministry of Defense and the Ministry of Agriculture and Forestry assume little parts in S&T arrangement. These ministeries generally fund open R&D establishments which work inside their administrative/regulatory area. Such ministeries dispatch likewise research projects and undertakings, which go for delivering new information in light of a legitimate concern for their individual strategy domains.

a. TEKES

The Finnish Funding Agency for Technology and Innovation (TEKES) is one of the key players in the domain of Science, Technology and Innovation in Finland.

TEKES **mission** statement strategy is: *"TEKES boosts the development of Finnish industry and the service sector by technological means and through innovation. This will renew the economy and increase added-value, productivity and exports, thereby creating employment and enhancing wellbeing."*

The **vision** is that: *TEKES is a leader in boosting innovation.*

The key **objectives** of TEKES are:

- Develop a concrete information base for vital areas of R&D advancement, i.e. to improve capacities in development exercises. The most important issue is that of internationality of development exercises and solid and organized Strategic Centers.
- Enhance efficiency and re-establishment of ventures, with a stress on youthful creative organizations and development organizations.
- Combine financial development with the prosperity of individuals and nature, with an attention on feasible vitality financial matters and condition, an amazing social and human services benefit framework and administrations.

Table 2: TEKES programs overview

Program	**Years of Operation**	**Objective**
5th Gear	2014-19	To solve the problems related to the wireless communications of the next generation, and making Finland an attractive destination for foreign investments.
Arctic Seas	2014-17	To convert Finland into a knowledge hub of the Arctic areas.
BEAM – Business with impact	2015-19	It is the joint program of TEKES and Ministry for Foreign Affairs of Finland. The aim is to support sustainable growth in Finland and the developing world by promoting innovation through the development of industry in Finland.
Bits of Health	2014-18	The program is predominantly planned for organizations that use digitalisation and make progress toward global development and that create items and services advancing wellbeing, the early determination of ailments, health monitoring and customized treatment.
EVE – Electrical Vehicle Systems	2011-15	The aim of the Electric Vehicle Systems program is to create a community of electric vehicle and support system developers in order to develop advanced technologies, businesses and service competence.
Feelings – Intangible Value Creation	2012-18	The program aims to raise client experience, feelings and implications as key business drivers other than innovation and aptitude. Notwithstanding feelings and client encounter, the program urges organizations to utilize the greater part of their intangible resources better, including brands, reputation and learning capital.

Green Growth	2011-15	The objective of the Green Growth program is to help promote the advancements empowering noteworthy jumps in vitality and material proficiency and to make establishment for the improvement of new esteemed systems in view of green development.
Green Mining	2011-16	The main objective of the Green Mining program is to make Finland a global leader of sustainable mineral industry by 2020
Industrial Internet	2014-19	The program expects to re-vitalize the business activities of organizations through the Industrial Internet and empower organizations from various fields to participate in new sorts of collaboration.
Innovation in Social and Healthcare Services	2008-15	Based on its vision, the program will renew health and social services and increase business opportunities through innovative activities.
Innovative Cities	2014-20	The aim of the program is to create internationally attractive innovation clusters in Finland based on top-notch talent. Innovation clusters include companies aiming for growth that are capable of creating brand-new products and services for the international market.
Learning Solutions	2011-15	The objective of the program is to develop internationally important learning solutions in cooperation with participants in the sector, to develop new operating approaches, create new skills and develop products, services and comprehensive packages for international markets.
LIIderj – Business, Productivity and Joy at Work	2012-18	The vision of the program is that in 2020 Finland will have Europe’s best workplaces. Making this vision a reality will require radical changes to management methods and new forms of work organisation and working.
Skene – Games Refueled	2012-15	The aim of the program is to make Finland a gaming and entertainment industry centre of international importance.
Smart Procurement	2013-16	The program will speed up the introduction of innovations through procurement excellence and the development of markets.
Witty City	2013-17	The aim of the Smart City program is to provide people with better living and working environments and companies with opportunities to bring new products and services on the market.

Some of the prominent TEKES schemes/Programmes supporting Public Private Partnership for R&D are listed below:

2.2.1. BEAM Program (Business With Impact)

BEAM – Business with Impact, produces new, feasible business in creating nations by helping Finnish ventures and different performers to utilize their advancements to address worldwide developmental challenges. Along these lines Finnish advancements are changed over into effective and maintainable business in both Finland and creating nations. BEAM is a joint program of TEKES (now Business Finland) and the Ministry for Foreign Affairs.

BEAM program bolsters Finnish organizations, NGOs, research associations, colleges and others in creating, guiding and exhibiting advancements that enhance prosperity in poorer nations, while offering support to global businesses to support Finnish organizations.

BEAM is a five-year program (2015-2019) with a total budget of EUR 50 million, equally financed by Business Finland and the Ministry for Foreign Affairs.

The program is not restricted to any particular sectors and the target countries can be any of the developing countries (listed as eligible for official development assistance (ODA))by the OECD/DAC (Development Assistance Committee), except China.

Advancements are the essential drivers of monetary improvement, producing new and changing existing financial action while creating new occupations, opening doors for business and monetary resources, and expanding long-term potential of exports. Along these lines, advancements empower needy individuals in creating nations to expand their utilization of ordinary products. Developments can likewise enhance individuals' chances to take an interest in and affect the economy and society on the larger scale. Developments incorporate new items, sevices, types of business and participation, advancements, arrangements and social advancements.

The companies that the BEAM program supports are the ones which have:

- Any business based on products or services,
- a plan to expand their businesses and to increase cooperation in emerging markets,
- enough resources (approximately 50% self-financing rate required to be eligible for Business Finlandfunding).

- Alongwith companies, non-governmental organisations, research organisations, universities, universities of applied sciences, and other organisations are also encouraged to participate.

The BEAM program was launched in 2015 and a brief outline of its journey is illustrated below:

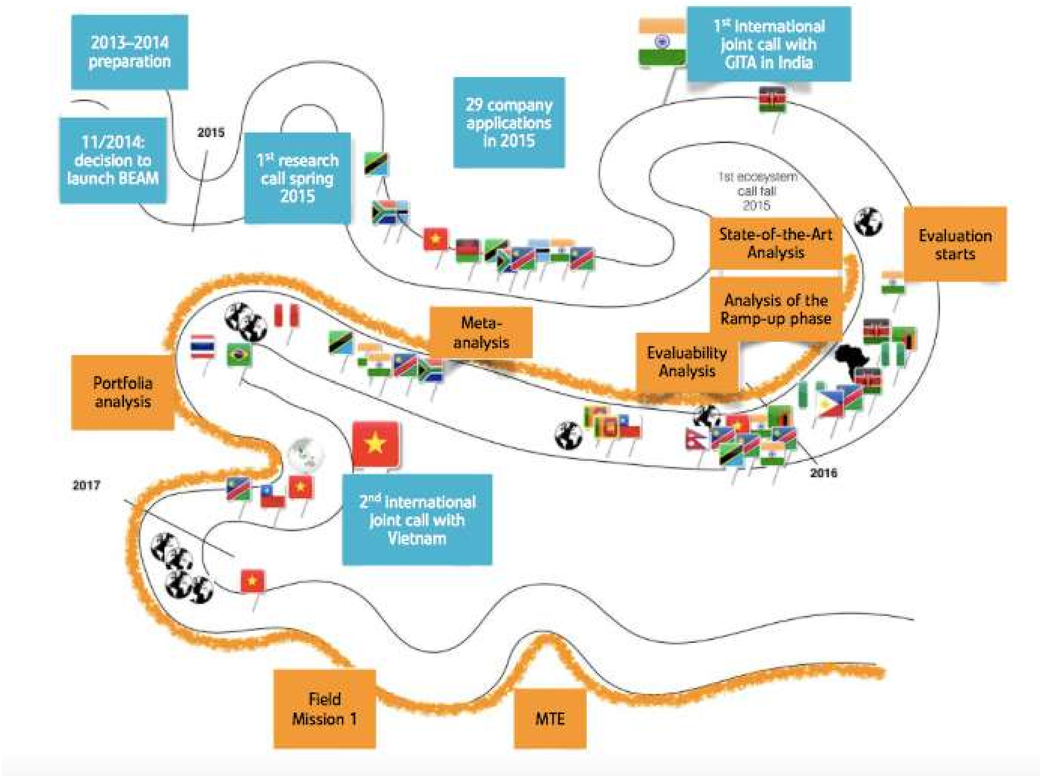

Figure: Progress of BEAM

Funding for BEAM

The program is funded jointly by TEKES and Ministry of Foreign Affairs, through the various grants, as is shown in the figure provided below.

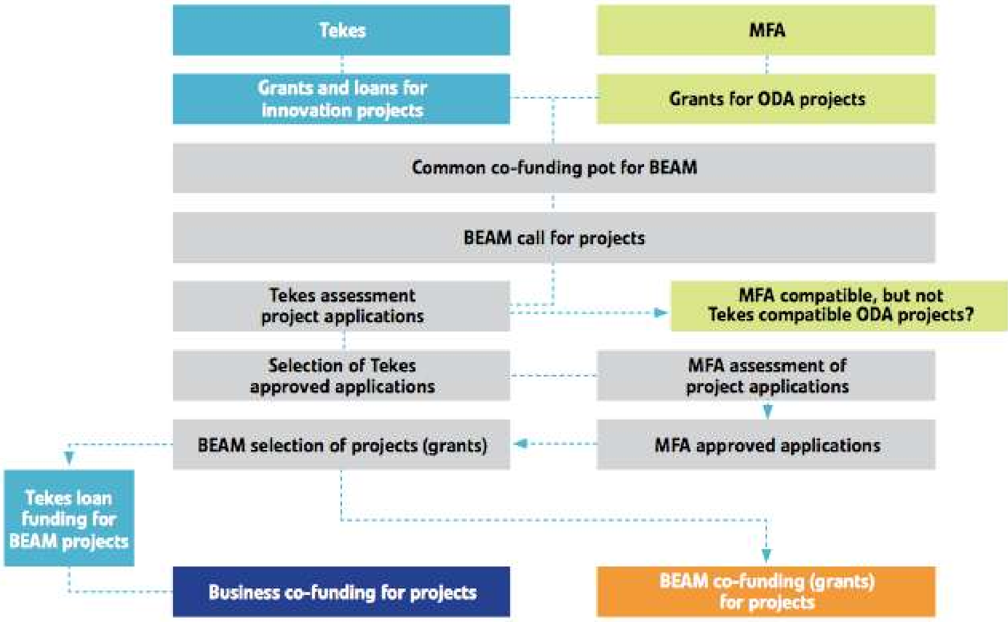

Figure: Funding structure for BEAM

2.2.2. SHOKs Programme

SHOKs stands for Strategic Centres for Science, Technology and Innovation. Itwasinitially a Public- Private- Partnership (PPP) program which was started in 2008.Under this program Universities and Private companies collaborated with the purpose of boosting innovations. SHOKs had a wide sectoral coverage and was multidisciplinary in its approach. The development of radical innovations through renewal of the industrial systems was the main aim of SHOKs. It supported cutting edge research projects for a span of 8 years. These projects were selected based on their potential utility for the Finnish industry and society.

There were six operational SHOKs Centers, each SHOKs focus was established as a not-revenue driven organization which was jointly possessed by a virtual research association and different partners from important organizations, colleges and research foundations. Public funding of these SHOKs were the obligation of TEKES.

The six SHOKs Centres were as follows:

1) Energy and the Environment (CLEEN Ltd.)
2) Metal Products and Mechanical Engineering (FIMECC Ltd.)
3) Forest Industries (Forest Cluster Ltd.)
4) Built Environment (RYM Ltd.)
5) Health and Wellbeing (SalWe Ltd.)

6) ICT industry and Services (TIVIT Oy)

The SHOK program came to an end in 2016.

2.2.3. Aid for Young Innovative Companies (YIC)

TEKES provites grants and funds for Young Innovative Companies (YICs) to boost quick international growth. Qualified organizations are the ones that have a international development model and have items, arrangements or services with sustainable competitive advantage and high market potential. They ought to likewise have a credible growth plan and a submitted and experienced administration team. They should not be establishedfor more than six years, small in size and put altogether in R&D – the R&D speculations ought to be at least 15% of its turnover. Tekes specialists and a board comprising of third-party specialists survey the organizations.

The funding is phased as follows:

- The aim of the first phase of funding is to get the company on a growth path andto demonstrate the company's competitiveness on the international market. Companies approved for the first phase have often been operating for a few years and have demonstrated their business concept by already attracting customers. Funding is typically around €250,000.
- The aim of the second phase of funding is to accelerate and enhance the growth and internationalisation of the company's operations. The total funding for the first and second phase is maximum €1 million per company (in areas eligible for regional aid max. €1.25 million). Funding covers a max. 75% of all operating costs.

Funding for YICs was introduced in 2008. At the end of 2010, the number of companies covered by this type of funding was 71, with a total of €33 million allocated to them. The majority of these companies operated in the ICT sector but companies in the energy and environment sector and the field of biomedicine were also funded. No sector was ineligible for funding.

In addition to funding YICs, Tekes promotes the development of potential growth companies through the Vigo Start-up Accelerator programme that was launched together with the Ministry of Employment and the Economy. Tekes and Finnvera's Seed Fund Vera are investing a total of around €45 million in the three- year programme. In 2010, six accelerators were involved in the Vigo programme. Of the companies the Vigo accelerators worked with, 22 had received Tekes funding.

2.2.4. De minimis grant

The De minimis grant provides flexible financing for SMEs for starting up systematic RDI activity. SMEs can receive 50% of the eligible costs, up to €100,000 per project. In 2010 Tekes spent €14.5 million for 203 projects.

2.2.5. SUUNTA strategy

In 2013, the fundamental research and innovation organizations of Finland (Academy of Finland, Tekes, Sitra, Finpro, Finnvera) chose to unite and build up another procedure (SUUNTA technique) with plan to move focal point of support for research, improvement and development past individual ventures, organizations and parts towards more extensive business ecosystems in zones of key significance to Finland. The BioNets program is a test case program that is a part of the SUUNTA procedure work. It was propelled in 2016 to encourage the rise of new organizations and ecosystems to grow new higher quality biomass-based items.

Achievements:

For the year 2016, following figures illustrate the results:

- 467 million Euros were invested in R&D and innovation projects in companies and research organisations.
- Completed projects resulted in 1000 patents or patent applications.
- Completed projects generated 2250 products, services and other innovations.
- In SMEs funded by TEKES, the increase in jobs was 16% in the period 2012-15.
- Almost half of the Tekes customers are from Uusimaa region (Helsinki and surroundings). Three other regions – Pirkanmaa (with Tampere), Pohjois-Pohjanmaa (Oulu) and Varsinais- Suomi (Turku) – had a relatively strong representation (with more than 6%).

Table 3: Distribution of TEKES customers by region

Region	Number of customers (between brackets: excl. universities and research organisations)	Share
Uusimaa	2429 (2,392)	45%
Pirkanmaa	519 (514)	10%
Pohjois-Pohjanmaa	389 (386)	7%
Varsinais-Suomi	386 (382)	7%
Pohjois-Savo	214 (209)	4%
Keski-Suomi	200 (198)	4%
Päijät-Häme	153 (152)	3%
Satakunta	150 (149)	3%
Etelä-Pohjanmaa	144 (143)	3%
Pohjois-Karjala	119 (117)	2%
Häme	113 (110)	2%
Pohjanmaa	112 (107)	2%
Etelä-Savo	104 (102)	2%
Lappi	98 (95)	2%
Kymenlaakso	84 (83)	2%
Etelä-Karjala	77 (74)	1%
Itä-Uusimaa	59 (59)	1%
Kainuu	52 (52)	1%
Keski-Pohjanmaa	47 (46)	1%
Ahvenanmaa	1 (1)	0%
Kanta-Häme	0	0%
Åland	0	0%

2.2 Business Finland

Business Finland is a agent of worldwide development. It supports new developments by helping organizations go worldwide and by supporting and financing advancements and innovations. The best specialists and the most recent research data empower organizations to seize market opportunities and transform them into examples of overcoming challenges.

Business Finland was made on first January 2018 by the merger of two associations: Finpro, which offered services for internationalization, ventures and tourism advancement, and Tekes, which offered funding for innovation exercises.

There is two-fold technique for the arrangement of Business Finland: empowering organizations to develop globally and furthermore make world-class business communities and a focused business condition for Finland.

Business Finland employs 600 experts in 40 offices overseas and in 20 regional offices around Finland. Business Finland is part of the Team Finland network.

Funding Information

Consistently, many organizations and research bunches work with Business Finland and get funding for research, innovation and advancement activities. In 2017, Business Finland (in the past Tekes) allowed a sum of €450 million financing for R&D activities.

When settling on a funding choice, Business Finland embraces financing of an exploration, improvement, or development venture with the sum allowed. Business Finland pays out the funding as per the progress of the project.

2.3. Academy of Finland

The Academy of Finland is the focal point of financing and planning for essential basic research in Finland. The Academy fundamentally funds astounding researchcarried out through individual projects and ventures, centres of excellence, research posts and research training. The Academy of Finland assumes an imperative part in long termstrategy formulation for fundamental research and research training. The close collaboration amongst TEKES and the Academy of Finland in science and innovation approach plan guarantees that the necessities of various parts are dissolved into one consistent research and advancement procedure.

2.4. SITRA

The Finnish National Fund for Research and Development (SITRA) is another independent organisation that functions under the Finnish Parliament.It works in close cooperation with TEKES and is responsible for financing technical research and development.It covers multiple technical research, educational and venture capital activities, including technology transfer and seed finance, the financing of growth companies, investments in venture capital funds and strengthening the links between research and societal decision-making through research and training.

3.6. Finnerva

Finnerva is a state-owned financing company that specializes in high-risk financing, specifically for SMEs and regional research policy measures.

3.7. Finpro

Finpro is an organisation established by Finnish endeavors to give counseling services to organizations and to help outline and execution of national research and development strategy. As a counseling association, Finpro centers around quickening the internationalization of Finnish organizations while keeping in mind the risks included. Finpro brings out this national undertaking through a customer-oriented approach in coordination with other administration associations, working towards similar objectives. Finpro works through a worldwide system with 50 Finland Trade Centers in 40 nations and in addition two Trade Centers in Finland.

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Israel

Contents

1. Introduction

The R&D ecosystem of Israel is founded on three pillars: basic scientific research conducted in universities, research undertaken in government institutions and research undertaken by the industrial-civil collaborations. The private sector of Israel performs intensive R&D. The investments of the private sector towards R&D have been increasing since 2000 thereby leading to decreased burden on the government.

Israel is ranked seventeenth according to the Global Innovation Index and sixteenth according to the Global Competitiveness Report 2017-18, published by the World Economic Forum (WEF). Israel keeps its 1st place in researchers, venture capital deals, GERD performed by business, and research talent in business enterprise. It also gains top 3 positions in gross expenditure on R&D (1st), university/industry research collaboration (3rd), ICT services export (1st). A few of the other indicators have been enlisted in the table below:

Table 1: Global ranking of Israel, as based on S&T related indicators.

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	24
2.	Research & development (R&D) [a]	2
3.	Gross expenditure on R&D, % GDP[a]	1
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	18
5.	QS university ranking, average score top 3[a]	22
6.	University/industry research collaboration[a]	3
7.	Capacity for Innovation[b]	3
8.	Company Spending on R&D[b]	3
9.	Availability of Scientists and Engineers[b]	6
10.	Quality of Scientific Research Institutions[b]	3
11.	Publications[c]	25
12.	H-index[a]	16
13.	Intellectual Property Rights[d]	10

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

The Office of Chief Scientist (OCS) has initiated a variety of incentive and support programs, a few of which have beendiscussed below:

2. Schemes/Programmes/Organization

2.1. MAGNET(http://www.matimop.org.il/)

The MAGNET (Generic Pre-Competitive Technological R&D) program incentivizes the creation of consortiums of research institutes and industries, that wish to collaborate for developing new and innovative technologies. This program was established with an aim at promoting innovation and R&D along with preserving the strength of Israeli industry as an international competitor. It was established in 1994 and since then has been providing support for industry-oriented R&D, capacity building, innovation etc.

Thus, the main objectives can be summarized as –

- Enhancing the competitiveness of Israeli industry
- Broadening the technological infrastructure of Israel
- Encouraging and fostering entrepreneurship
- Encourage national and international collaborations in R&D

The following characteristics define the Magnet program –

- It functions and performs under an impartial and ambitious basis and no efforts are made to promote any specific scientific fields or sectors of the industry.
- The program aims at supporting generic technology development while the responsibility of developing a product lies in the hands of the partnering/associated industries.
- The consortia and partnerships developed through the program are aimed at combining the prowess, proficiencies and resources along with sharing the costs and risks.
- The program encourages participation of both small and large scale industries as well as academic institutions.

- The program budget represents nearly 1/4th to 1/5th of the OCS budget for industrial R&D.

Governance: The program is run by the OCS of the Ministry of Industry, Trade & Labour, and is carried out under an executive head known as the 'Director of the MAGNET Program'. The Director General, Ministry of Industry, Trade & Labour appoints a 'Committee' for carrying out the activities of the program. This committee is chaired by the Chief Scientist.

The program encourages partnerships and associations amongst researchers from academic institutes and industrial companies through a wide range of instruments, such as – MAGNET Consortia, MAGNETON, NOFAR and KAMIN.

i. MAGNET Consortia (http://www.matimop.org.il/MAGNET_Consortiums.html)

Background: The instrument of MAGNET Consortia supports the creation of consortia involving companies and academic research institutions, working together/collaboratively for developing novel technologies. These consortia facilitate long-standing R&D and construct encouraging work surroundings. Collaboration with industry facilitated through consortiums also fosters strengthening of the commercialization capacity of research institutes and aids them in deciphering the needs of the industry as well as market.

Objectives:

To assist in the development of generic technologies in important fields in the global market, in which Israeli industry has a competitive advantage.

The amount of the support provided through the consortium is up to 100% of the approved budget for a research institution and 66% of the approved budget for an industry for three to five years. In this program the companies are exempted from paying royalties for repayment of grant funds received by them.

ii. Kamin Program (http://www.matimop.org.il/KAMIN.html)

Background:

This program is designed to address preferred application-oriented research. It aims at fostering the functional research being performed in the research institutions (RI), which is anextension of the precedingfundamental research, and then taking it to ajuncture where businessesand industries can take it to a stage of commercialization or make a decision to enter into an agreement of commercialization with the specific RI. Thus, the aforementioned program is intendedto bridge the basic and applied research for improved research outputs and innovations.

Objectives:

The rationale of the program is to mine scientific expertise available in the public research institutions and universities in Israel for the assistance of the Israeli industry. The program, therefore, aims at all fields, which possess the capability to be implemented commercially by the industry.

Funding:

The Kamin fundis intended for academic research which is carried out within an academic institution. The end goals of the study being undertaken should aid a business to invest, promote and commercialize the research. A qualified grant of 85%-90% of the requested research budget, up to a maximum amount of NIS 400,000 is provided through the program. The period of research is 24 months and should be specified within the proposal as the amount of grant is dependent on the same. An extension period of 12 months is permissible. The amounts of maximum grant for different study periods are as follows:

- 360,000 NIS for 12 months or 90% of requested research budget
- 680,000 NIS for 24 months or 85% of requested research budget
- Extension period of 12 months shall qualify for 66% of requested research budget

Grant for joint research involving two institutions will be 50% higher than that mentioned above. The remaining costs of the research projects are to be borne by the academic institution. The grant can be utilized for paying the costs of materials, personnel, equipment etc.

This grant is not for a researcher or institution that intends to undertake the process of commercialization on their own i.e. they wish to set up a company. The grant is only for academic research. The recipients of grant are not liable to paying royalties and are absolved from the same. However it is imperative for them to conserve and protect the knowledge within the country vide the 'Law for the Encouragement of Industrial Research and Development'.

Governance:

The Ministry of Trade and Industry supports and looks after the Kamin program in association with the Israel Innovation Authority (formerly Office of the Chief Scientist).

iii. Magneton Program

The Magneton program of Israel exemplifies a generous support of direct nature for translating research. Magneton awards sustenance to collaborative exploration assignments concerning both the private sector and universities. The program entails management of the project by the industrial partner, who is also the recipient of the program and recompense the research team of the university. This program is implemented and managed by the OCS, encourages direct transfer of research work to the industry through this collaboration. Magneton program targets at maximizing the capacity of commercialization of the technical capability of the universities, thereby advantaging the Israeli industry.

As this program funds for collaborative R&D projects only, a part of the research is carried out by the university/research institute and the other part by the private sector. It is expected of the industrial partner, that once the project is complete, they move forward with the development of the product with the help of the technology devised through the project.

The applications for the grant of funding are carefully scrutinized and there are certain pre-requisites to be followed by the applicants to qualify for the funding, which are -

- The university or PRI must possess the capability and technical know-how of the technology to be transferred.
- The industrial partner should possess relevant and appropriate personnel.
- The industry should also possess the capability and resources for realizing the

commercial prospective of the technology.

- The technology or product should be novel and should never have been developed by a different company in the country.

Funding grants of up to 66% of the total approved costs can be provided to the eligible project applications. The funding is available for a period of 12 months to 24 months. Industries are not allowed to fund more than 1/3rd of their R&D through this program. The private sector partner managing the grant of the project reimbursesthe team conducting research at the university. Also the private sector partner is not liable to pay any royalties on the IP generated through the project.

The Magneton program has been known to support various projects from different fields including, communications, electronics, life sciences etc. and an evaluation revealed that nearly 80% of the projects supported through Magneton have lead to high innovations and technological breakthroughs.

Background

The "Magneton" program is dedicated to encourage Technology Transfer from the research establishments to industries using channels of "dual cooperation”.

Purpose

Increase the access of the Israeli industry to the scientific technologies which have commercial potential to industrial corporations in Israel.

Performing initial research and development to proof the conceptstage and then transferring the scientific invention which originated at the research institution into a commercial product.

The objective of the "Magneton" is to encourage research that is not carried out in other set ups and to maximize the technology commercialisation potential of the Israeli academic research institutions for the benefit of Israeli industry.

Principles

- Magneton is a collaborative project, one part of which will be carried out in research institute and other part of which will be performed by the industrial corporation. After the project completion, the industry ought to absorb the technology developed within the project.In other words, the industrial corporation should have the system and the professional expertise which can lead to product development based on the technology.

- Project contents of the industrial corporation can solely be needed for the absorption of technology from the academic institutions.
- The main aims of Magneton project are to strengthen the company's technology set-up and to advance the product development activities of the company. Importantly, company can give in no more than one-third of its R&D activity to the Magnet framework.
- An eligible project would receive a grant of up to 66% of the approved budget for the industry and academia.
- Selected recipients would be exempted from paying royalties in respect thereof.
- The research institute is a full partner in implementing the project, but for the purposes of administrative ease, the project grant request will be submitted by the industry which also will serve as the means for the transfer of the academic grants.
- A contract is signed before receiving funding between the industrial corporation and the research institution that regulates the association between the two bodies and their privileges and obligations and in particular the issue of addressing the right to the use of the knowledge.
- The project timeline of one to two years.
- The project budget up to 3,400,000 NIS for the two organizations and for the entire period

Fundamental condition for the project "Magneton"

- The basic technology which already exists at the institution lab before submitting the application to Magneton, or alternatively, the subject should benovel and original which requires proof of technological likelihood. The academic research should have a significant contribution but not exclusively in achieving the project objectives and the research teamshould haveexpertise in the field.
- The research institution will be the sole owner of technological knowledge to be transferred, and no other entity can claim any property rights on this knowledge.

Success Story

Success Story - InSightec

InSightec

InSightec
Bringing therapy into focus

Primary Activity: Non-invasive destruction of growths by means of ultrasonic energy

Established: 1999

Currently Em ploys: 125

No. of Employees When First Created Ties with the OCS: 3

Affiliation with The OCS: 1999-present

OCS Program Participation: R&D Fund, MAGNETON, Global Enterprise R&D Cooperation Framework

Strategic Partners: GE Healthcare, Mayo Clinic, Brigha m and Women's Hospital of Harvard Med ical School, The Johns Hopkins Hospital.

Website: www.insightec.com

Operating Rooms without Scalpels

InSightec has developed a Magnetic Resonance guided Focused Ultrasound Surgery (MRgFUS) that has potential to replace invasive procedures and the use of scalpels. OCS support has accompanied the company from proof of concept through to its first clinical application – ultrasonic destruction of uterine fibroids. The procedure's lack of collateral damage and obviation of the need for hysterectomy made it a life-changing procedure for many women. Applications were subsequently developed for bone metastases and adenomyosis.

InSightec has cooperated with The Hebrew University in the framework of OCS' MAGNETON program to develop a solution for delayed, pinpointed release of toxic medications – such as chemotherapy – using ultrasound beams, thus minimizing the adverse effects of the toxins. Another OCS program partnered the company with GE Healthcare for the development of a treatment for liver growths.

Over 10 years after its invention, InSightec's system for uterine fibroids is approved in almost all countries around the world. Other clinical applications are in various stages of regulatory approval and clinical investigation.

OCS-Office of the Chief Scientist

iv. NOFAR

Background: The NOFAR program deals with selected applications oriented research in designated sectors of Energy, Biotechnology, Nanotechnology, Medical devices, Water Technology& other Multi-disciplinary technologies. NOFAR is formulated to cultivate applied research in institutions in Israel, which is in continuity of the previous basic research.

Purpose: Objective of the NOFAR is to address another gap between basic research and applied research. In other words, allowing the research team to continue the basic research which is no longer adequate to get support from competitive research funds such as the National Science Foundation, towards applied research and bringing it to the stage where industrial corporations show interest and invest in it for further development.

The other main purpose of the program is a broad and deep mining of scientific ability in the academic research institutions of Israel for the benefit of the industry. As in the MAGNET program continued support can be provided for technology transfer of the invention into a commercial product, or in a technology incubator, or setting up a new venture (a start-up), or in an existing company, provided that the technology should be useful to the Israeli industry.

NOFAR program is open to the following fields of science and technology:

Energy related technologies – "Studies on storage of energy and diffusion of energy by radiation".

Biotechnology - "Industrial use of living cells or organisms or industrial application of biological processes."

Nanotechnology - "Creating materials or devices or systems or components (other than chemical or biochemical reactions) in dimensions not exceeding tens of nanometers."

Medical Devices – "Research on technologies and equipments used for the treatment and / or diagnosis of diseases."

Water Technology – "Biological, physical and / or chemical technologies used for treatment of water to improve its quality."

Technologies used by the water sector in general for safety, security, management, control and so on are not eligible for this program.

Multidisciplinary research - Research that brings together numerous disciplines of science and innovations including pharmaceutical, science and different engineering fields.

The method: Financing the higher phases of the research, which is preparatory directed by an research group in a scholarly research organization in Israel, when there is an Israeli industrial enterprise willing to co-support no less than 10% of the researchas a feature of the commercialization of basic academic knowledge and research. Consequently, toward the completion of the project time frame, the company will have the Right of "first observation" on the results of the study and the Right of "first negotiations" for a predefined period.

Principles

- In general, the research time frame is up to a year and ought to be resolved at the season of presenting the application. The execution time frame might be set to 15 months, to oblige for set-up time. Augmentation and/or endorsement for look into for over 15 months, as an exemption, to be talked about and affirmed exclusively.
- Research that qualifies for help, will get a concede at a rate up to 90% of the approved spending plan.
- The grant will be utilized to fund costs for researchers, materials and subcontracting in Israel.
- Grant beneficiaries will be absolved from payment of royalties, but are required to preserve the knowledge in the nation as per the "Law for the Encouragement of Industrial Research and Development" (The R&D Law).
- The business organization is to fund no less than 10% of the research program.
- The business enterprise giving the additional financing has the expert capacity to manage and direct the research towards commercial applications.
- This motivating program concentrates on innovatively plausible thoughts, which are not developed enough for the supportfrom the MAGNETON incentive program, however require funding in the initial applied research phase at colleges keeping in mind the end goal to coordinate them with the suitable industry.
- The research result is utilized for commercial application in Israel, and is of high increased the value to the Israeli business.
- The research permits the transfer of the information to the business for improvement of the innovation coefficient.
- A mutually agreed arrangement before getting the funds, between the industrial enterprise and the research organization, which decides the rights and commitments of each side, the willingness of the company to back no less than 10% of the cost of the research. The industry shall not be granted any right to knowledge but priority in negotiations "from the end of the study period”.
- The maximum of the NOFAR venture-spending plan is 500,000 NIS. The grant of the Ministry of Industry will be up to 90% of the research-spending

plan, and the rest will be completed by the industry.

The NOFAR incentive program is limited to the fields of biotechnology and nanotechnology only, for a period of one year.

Goal of the incentive program:

The research foundation upheld by the NOFAR incentive program is eligible for a grant of up to 90% of the affirmed spending plan with a maximum of NIS 550,000 for a year, with a choice to extend it up to 15 months. The supporting organization fills in as an accomplice in professional guidance and in defining of research objectives, and in addition partakes in the financing of 10% of the venture cost. On completion of the research project, the supporting organization gets the first right to arrange a commercialization concurrence with the researchorganization. NOFAR researchin a joint effort with two unique organizations qualifies for finances of up to NIS 660,000.The grant beneficiaries are absolved from reimbursement of royalties.

Success Story:

The MAGNET Program has lead to a large number of success stories and ventures in the Israeli ecosystem, some of which are:

SolarOr(https://www.enfsolar.com/directory/panel/13966/solaror) (Solar Buildings)- SolarOr's development launches an era of renewable energy in which skyscrapers produce their own energy. The invention by SolarOr, which develops panels for building facades, was developed within the framework of the MAGNET program through the Office of the Chief Scientist.

After development of the product, SolarOr's representatives were invited to join a delegation to China, organized by MATIMOP (http://www.matimop.org.il). With the assistance of the Office of the Chief Scientist, the companies worked on transforming the technological development into a commercial product.

2.2. Technological Incubators Program

Background: The program of Technological Incubators in Israel was set up in 1991. This program of Technological Incubators includes four classes of support i.e. direct finances, fiscal, consultation and infrastructure-relatedsupport and consequently, is an integral program, which gives benefits by channeling the public and private funds into research projects and commercialization.

Technological Incubator: A technological incubator is an organization, which aims at supporting research in its early stage, highly-innovative projects, that are too risky for the private sector investments.

The technological incubator program coordinates monetary, advising and infrastructure services. The incubators furnish the initiator with area, monetary help, business and advertising ideas, proficient direction, and managerial help – all of which help the initiator to transform his underlying thoughts into a new product, while checking on its financial viability, its uniqueness, focal points, and the expected demand for the item in the market.

Objectives:

The main objective of the program is to convert innovative ideas that might be risky for private ventures, into feasible new businesses that after the incubator term having raised money from the private segment, should be able to work and operate on their own.Secondary goals of the program are as follows:

1. Promote R&D activity in peripheral and minority areas.
2. Create investment opportunities to the private sector, including venture capitalists.
3. Transfer technologies from research institutes to the industry.
4. Create an entrepreneurship culture in Israel.

An incubator is a private legal entity, for profit, that supplies its portfolio companies with the following:

1. Work environment.
2. Administrative services.
3. Technological & Business guidance.
4. Legal & Regulatory assistance.

Determination of an incubator licensee is done through a competitive procedure in which the victor gets a permit of 8 years to set up an incubator in Israel and to submit the grant applications for new innovative ventures, keeping in mind the end goal to set up new businesses. The competitive procedure is open for everybody.

Amongst shareholders of current incubator licensees there are Venture Capitalists, Private equity groups, Super Angels, local and Multi-National Corporations.

There are 24 incubators in Israel as of now, out of which 22 are innovative incubators, 1 is an innovation based business incubator and 1 is an assigned biotech incubator. The incubators are spread the whole way across Israel including 8 that are situated in fringe regions. There are around 180 organizations in different phases of R&D that work in the incubators at any given time.

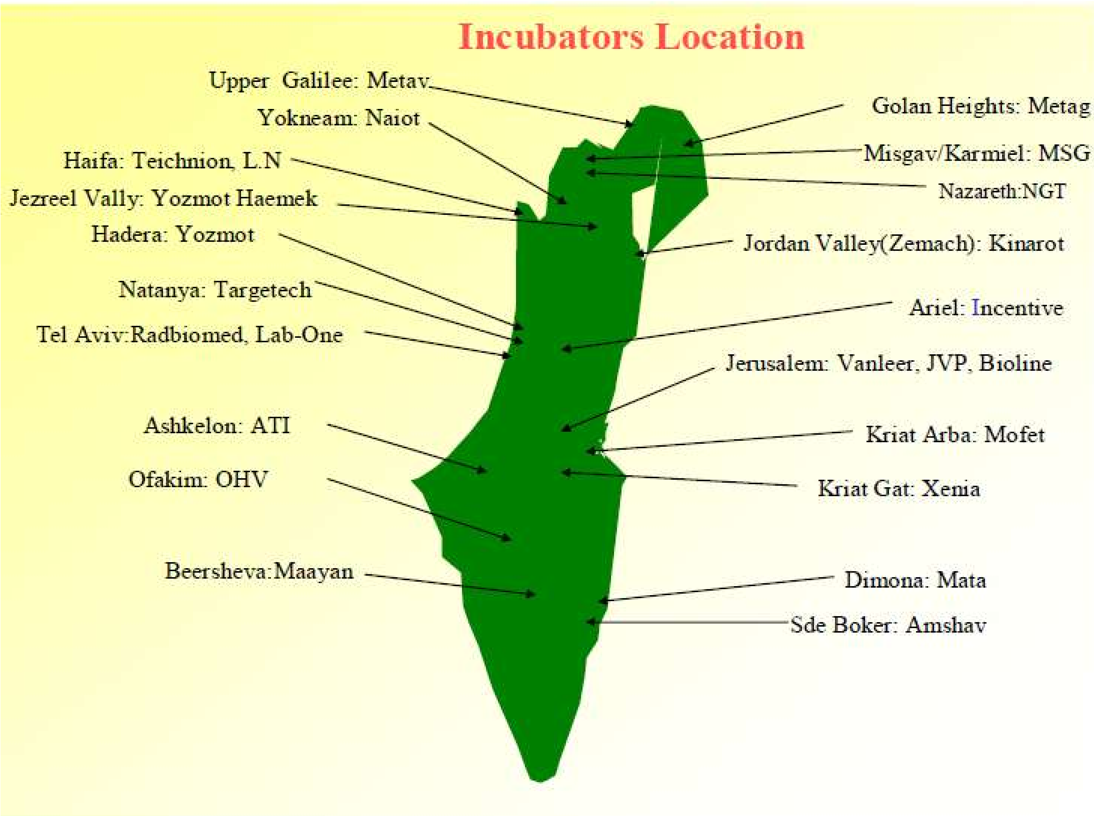

Figure 21 Location of Technological Incubators in Israel

Organization of Technological Incubators:

- Independent legal entity

- Skilled and experienced general manager
- Board of directors - from industry, business sector, research institutes
- Suitable facilities for R&D activity
- Technological, financial, administrative and
- Logistic support to projects.

The Israeli Technological Incubators Program is administrated by the Office of the Chief Scientist, Ministry of Industry, Trade & Labor.

Innovative incubators are somewhat supported and administrated by the Office of the Chief Scientist (OCS) of the Ministry of Industry, Trade and Labor. The program was set up in 1991 to help advancement of creative technological ideas into feasible new businesses following a two year time frame at an "incubator".

Financial Support:

- Average budget of project: $500K
- Government grant: 85% of budget
- Incubator's investment: 15% of budget • Payback: 3% royalties from revenue
- Support duration: 2 years
- Extended support to Biotech/Pharma & Clean-Tech projects
- Annual Government Budget to the Program: ~$50M

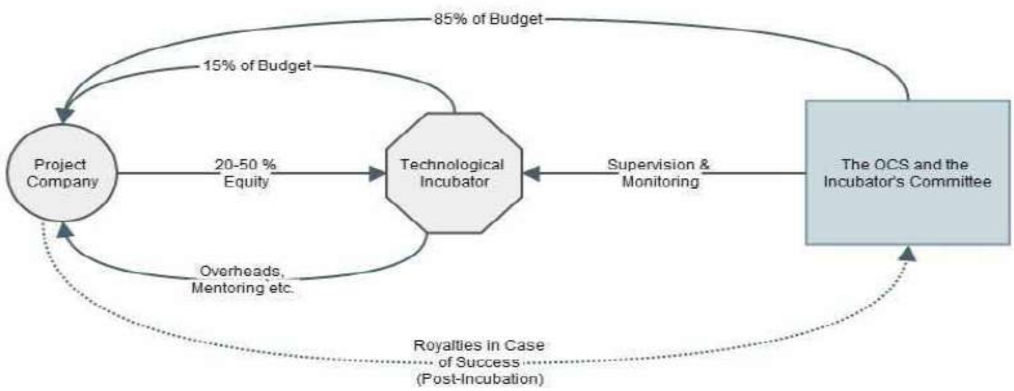

Figure 22 Funding Mechanism of Incubators in Israel

Source: TIP case study for Israel (OECD, 2013).

Privatization of the Technological Incubators Program:

Ten years after the foundation of the program it was found that the incubators are fit for developing their financial plan and budget from non-administrative sources – for the most part royalties, profits and dividends, and vital partnerships. These new fundspointed towards the fact that the largeamount of government finances in the earlier stages could be diminished after some time i.e. once the outside private financing sources mature to a level.

The accomplishment of the Technological Incubator Program in Israel of pulling in seed cash from private sources was a great advancement in the program and provided for privatization of the program.

The entrance of private cash-flow to new financial exercises is a part of the privatization procedure guided by the justification that there is no requirement for government mediation where the private sector operates. Privatization implies a decrease in the State's part in creating products and services, and restricting its control and direction of the economy. The privatization method utilized as a part of the Technological Incubator Program is to make a joint organization of general society and the private division. The incubator does not trade its shares but rather builds the capital of the organization. Alongwith the privatization procedure, which a portion of the State's incubators experienced, private industrial incubators likewise began showing up in the Israeli system because of the private business visionary activities.

One reason behind the foundation of this program was the need to alleviation the issue of financing during the initial phases of new activities. Since an expansive, private VC market began working in Israel, it was then important to check whether the VC funds could fill in as a substitute forthe funds allowed by the CSO. The best favorable position of the Private Technological Incubator Program (PTIP) lies in its capacity to support high-risk tasks, those that are seen as non-appealing ventures during their beginning stages.

The Involvement of Academia and Industry:

Some of the incubators are situated close to the national colleges, where scientists work as an inseparable unit with the growing businesses at the incubators and the college graduates are usually the ones that patent their technologies there. The vast majority of the colleges in Israel have created or are accomplices in innovative incubators.

Israel's cutting edge industry has likewise been quite supportive of the program. The *Rad-Ramot Incubator* is owned partly by the Rad Data Communications Company, while the *ELTAM - Technology Incubator* was set up and is partly possessed by Elron Industries, Israel's biggest high-tech holding organization, which owns Elbit and Elscint, makers of driving edge medicinal hardware gear.

Israel's only non-OCS hatchery, the *HiTEC-Technology Entrepreneurship Center* at Har Hotzvim in Jerusalem, was set-up in 1992 by Intel Israel and Teva Pharmaceuticals. Eleven more neighborhood organizations, and additionally the Hadassah Medical Organization, have likewise loaned their help.

Up until this point, more than 300 ventures have left the OCS incubators. Of these graduates, 165 (56%) have proceeded under their own particular stream. More than seventy five percent of these fruitful activities have pulled in outside funds from both Israel and abroad, running in measure from \$100,000 to \$8 million. Approximately, ventures draw in speculations of \$500,000. The aggregate interest in ventures that have left the incubators today remain at more than \$80 million. Besides, almost 800 experts serve on the various teams at the incubators. The greater part of them are migrants with scholastic skills, usually masters and doctoral degrees. Moreover, somewhere in the range of 700 new outsiders including many postgraduates, are utilized by those venture organizations that have left the incubators.

Examples of Technological Incubators in Israel:

Meytav Technological Incubator

The company looks to make investment in the life science segment with an emphasis on biotechnology, biopharmaceuticals and restorative gadgets. The firm looks for a board seat in the organizations.

Meytav Technological Incubator was established in 1991 is situated in Tel Hai, Israel with an extra office in Hertzelia, Israel.

Successful Spin off -Protalix

- Proprietary technology based on plant cell culture and bioreactor system which provides an effective and scalable cell system for industrial production of recombinant biopharmaceuticals.
- Developed Enzyme therapy for Gaucher Disease
    - First commercially available plant cell culture produced protein product, taliglucerase alpha (Elelyso®), approved by the FDA in May 2012 for long-term enzyme replacement therapy (ERT) for patients with a confirmed diagnosis of type 1 Gaucher disease.
- Year graduated from incubator: 1996
- Partnerships with Teva, Wiezmann institute, Hebrew University and Boyce Thompson institute for plant research

Incentive Incubator

Incentive Incubator is the first privatized incubator in Israel, which has an excellent reputation of providing support to the start-up companies and contributing to their success. It is owned by Peregrine Ventures (www.peregrinevc.com)- a venture capital fund, with high experience in the field. Incentive puts resources into therapeutic and medicinal gadget organizations, with an emphasis on Single-Patient-Use-Devices (SPUD), and in software organizations.

Successful Spin off –D-Pharm

- Developed lipid-like therapeutics and has generated a rich product pipeline from its drug targeting and discovery technologies.
- Several drugs for Stroke & Alzheimer's disease.
- Early stage of developing a drug for pancreatic cancer.
- Year graduated from incubator: 1994

<table>
<tr><th>Successful Spin-off</th><th>Technological Incubator</th></tr>
<tr><td>Aeronautics</td><td>Incentive Incubator</td></tr>
<tr><td>Compugen</td><td rowspan="2">Iris Incubator</td></tr>
<tr><td>Imagine</td></tr>
<tr><td>Sightline</td><td>Eltam Incubator</td></tr>
<tr><td>Remon Medical</td><td>Naiot Incubator</td></tr>
<tr><td>Mazor</td><td>Technion Incubator</td></tr>
<tr><td>Contipi</td><td>L.N. Incubator</td></tr>
</table>

Zoomix	JVP Incubator
Double Fusion	
Lucid	Ma’ayan Incubator

2.3. Industrial Research Institutes

Background:

This program helps the scientific organizations in Israel that focus on applied research for commercialization of technology. Thissupport is given by means of two incentive programs:

1. the budgetary support program for R&D in collaboration with anindustrial partner, and
2. the support program for the buying of research facility and scientific hardware.

Objectives:

To provide assistance and support to research institutes that conduct applied research whose goal is the further development of Israeli industry.

For the two programs of R&D incentive program and the equipment purchase incentive program, the grant funds are to be used. Such benefit can be availed for one year, however it can be extended for a period of one more year. For the third year, the research institutes committee can approve a request for grant, depending on the prioritized sectors of industry.

Academia Driven Initiatives

2.4. Israel Tech Transfer Organization (ITTN):

Background:

The IITTN serves as the umbrella organization for Israel’s technology transfer companies. These companies are affiliated with the country’s world-renowned universities and research institutions.

Currently, the 12 partnering organizations comprise the shareholders. ITTN intends to add more members from Israel’s government-owned medical centers and research institutions.

ITTN is a private non-profit organization.

Objectives of the Organization:

- Representing the enthusiasm of its member associations before the Knesset, government specialists, services, offices, and boards of trustees
- Advancing synergistic endeavors between the technology transfer group in Israel and its partners the world over
- Improving the availability to the general population of new research discoveries and inventions performed at Israel's colleges and research establishments

The Partnering Organizations

ITTN's partners are affiliated with some of the world's leading educational and research institutions.

- BGN Technologies (Ben-Gurion University of the Negev)
- BioRap Technologies Ltd. (Rappaport Research Institute of the Technion-Israel Institute of Technology)
- BIRAD – Research & Development Co. Ltd (Bar Ilan Uiversity)
- Carmel-Haifa University Economic Corp. Ltd. (University of Haifa)
- Gavish Galilee Bioapplications Ltd. (MIGAL Galilee Technology Center)
- Hadasit Ltd. (Hadassah Medical Organization)
- Mor Research Applications (Clalit Health Services)
- Ramot at Tel Aviv University Ltd.
- T3 – Technion Technology Transfer (Technion Research & Development Foundation Ltd.)
- Tel Aviv Medical Center
- Yeda Research & Development Company Ltd. (Weizmann Institute of Science)
- Yissum Ltd. (Hebrew University of Jerusalem)

Success Stories:

PERIOCHIP

PerioChip is a little, orange dark colored, rectangular chip (round towards one side) for addition into periodontal pocket.

The dynamic element of PerioChip is Chlorhexidine, a best quality wide – range antimicrobial operator. Each chip contains 2.5 mg chlorhxidine.

PerioChip is demonstrated as an assistant to scaling and root planing methods for diminishment of pocket depth in patients with perpetual preiodontitis. PerioChip ought to be embedded in pockets, 5-8mm inside. After inclusion into the pocket, PerioChip shows a managed release of chlorhexidine over a time of up to 7-10 days. After that period the PeriChip biodegrades and vanishes. The chlorhexidine discharged from the Periochip has been known to suppress pocket flora till up to 11 weeks.

Product developed by; Michael Friedman, School of Pharmacy, Michael Sela, Doron Steinberg from the Faculty of Dental Medicine, Hebrew University (Yissum) & Aubrey Soskolne, Faculty of Dental Medicine (Hadasit)

Cherry Tomatoes and Long Shelf-Life Tomatoes

The Daniela assortment is just a single case of the novel improvements of a cocktail, which has improved shelf-life and better quality. Its genes make-up an aging inhibitor quality with some selected polygenes for solidness and moderate aging, together with different qualities creating exceptional traits of huge, quality organic product. Since its first release, Daniela was additionally enhanced and the quantity of inherent pest and disease resistance was incredibly improved. Over 15 years after its first discharge, Daniela and related cultivars are viewed today as among the world's leading greenhouse varieties. In Europe, they have turned into an industry standard.

Product developed by: Haim Rabinowitch & Nachum Kedar both from the Faculty of Agriculture, Food and Environmental Quality Sciences, Hebrew University (Yissum)

EXELON

Exelon is a cholinesterase inhibitor, a kind of prescription endorsed for individuals in the early or middle phases of Alzheimer's disease. In spite of the fact that there is not a cure, Exelon appeared to be a powerful solution for treating the manifestations(to a milder extent)of Alzheimer's disease. Exelon has come up with a ray of hope for individuals with Alzheimer's sickness and the general population who tend to them. It can slow down the spread of the disease and enable individuals with moderate

Alzheimer's disease to remain associated longer to the relationships they esteem and appreciate.

Product developed by: Marta Weinstock-Rosin, Department of Pharmacology, Hebrew University (Yissum)

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Australia

Contents

1. Introduction

Genesis of *aucourant*knowledge and establishing novel ideas, based on new discoveries and prior know-how, with an aim for solving relevant issues has been the priority of S&T in Australia. Identifying and translating research conducted within the public sector and passage of information amongst the ones who generated it and the ones who shall put it to use is the fundamental of prosperity and competitiveness in Australia.Accordingly, furthering the methods in which proficiency and know-how is dispersed and put to application, has also become a priority in today's scenario of knowledge based economies. Proficiency generation and application require enhanced levels of alliances and collusions between different stakeholders i.e. researchers, academicians, not-for-profits, businesses and the government sector.

In 2015-16, the Australian government provided $9.7 billion for supporting research and innovation activities. A major portion of the funds was dispersed to public research and private sector R&D, by means of tax incentives etc. It appears that the Federal Government concentrated its laborstowards, along with taxation incentives,the domain of national competitive grant funds, industrially oriented nationalR&D (through the public funded research agencies), mounting and implementing industry growth centre primacies, IP management, data compilation and dissemination, and innovation research.

An independent statutory body, the *Innovation and Science Australia,* is responsible for providing advice to the Government on all science, research and innovation related matters. The activities of this board are complementary to the *Commonwealth Science Council*, which advises the government on the scientific challenges faced by the country. The Australian Research Council (ARC) and National Health and Medical Research Council (NHMRC) are two main agencies of the Australian government for assigning research support to academics and researchers at Australian universities. Its mission is to deliver policy and programs that advance Australian research and innovation globally and benefit the community.

The Department of Industry, Innovation and Science, under the aegis of Ministry of Industry, Innovation and Science, is accountable for consolidating the efforts of the government for driving fiscal growth, efficiency and effectiveness by bringing together industry, resources and knowledge.

Innovation has driven the alteration of Australia from a country reliant on natural reserves to a knowledge motivated economy and according to the Global Innovation Index 2017-18, Australia ranks 23rdout of 127 countries. A few other S&T related indicators and global ranking of Australia has been enlisted in the table below.

Table1: Global ranking of Australia, as based on S&T related indicators.

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP	41
2.	Research & development (R&D)	13
3.	Gross expenditure on R&D, % GDP	16
4.	Global R&D companies, avg. expend. top 3, mn $US	19
5.	QS university ranking, average score top 3	7
6.	University/industry research collaboration (from GII or GCI)	32
7.	Capacity for Innovation*	24
8.	Company Spending on R&D*	25
9.	Availability of Scientists and Engineers*	16
10.	Quality of Scientific Research Institutions*	10
11.	Publications#	32
12.	H-index	10
13.	Intellectual Property Rights*	2
14.	PCT Patents	22

*Source: GII 2017-18; *GCI 2017-18*

#http://www.scimagojr.com/countryrank.php

A well performing innovation systemnecessitates the contribution of a series of performersthrough the gamut of industry, government, academe and addedfragments of the society.

Framework circumstances contribute essentially to thecapability of the country to build and endure asetting conducive for innovation. The Australian government realized this and introduced several reforms both direct and indirect for supporting and bolstering innovation.

In 2014, Australia embracedthe*National Industry Investment and Competitiveness Agenda (IICA)* and founded a ministerial taskforce for stimulatingefficiency throughR&D. Inherent to this new agenda, the government has also made 'industrialpolicy' and the 'translation of publicly funded research into commercial outcomes', thecentralprops of its approach towardsconsolidating economic vitality. The proclamation of the *NationalInnovation and Science Agenda (NISA)*, in 2015, added to the emphasis laid down by the IICA. The NISA aimsto boost Australia's science and innovation in the four key areas of capital and culture, collaboration, talent and skills, and government as an exemplar.

Few of the Australian government's initiatives for promoting PPP in R&D have been listed in the table -

Table 2: PPP programs in Australia

Initiative	Description	Period
CRC Program	The most important and notable initiative – the Cooperative Research Centers (CRC) program focuses on long standing collaborations for performing research in order to advance thedevelopment of industry and private firms by the means of transferring knowledge from the public domain to the private sector leading to commercialization and economic growth. The funds available in this program are from combined public and private sources.	1990 - present
Rural Research and Development Corporations (RRDCs)	RRDCs are a model of association amongst the government, including Public Research Organizations (PROs)and rural industries. This scheme comprises of many short term and long-term projects for advancing technology and building of capacity. The RRDCs are characterized by strong involvement and close cooperation of an industry participant in the projects of that particular sector.	1990 - present

ARC Linkage Grants	'Australian Research Council'has set into place a provision for funding strategic research undertaken jointly by higher education institutes and industry. The linkage grants also include funds for infrastructure, industry fellowships etc.	1999 - present
PreSeed Fund	Pre-Seed Fund is also an investment based scheme, which is looked after by fund managers from the private sector and aims at encouraging development of business from the stage of early research of public universities and PROs.Funding again is a mixture of backing from booth the public and private sectors.	2002 - present

Source: Department of Industry, Tourism and Resources

Of all the programs/schemes/initiatives enlisted in the portfolio above, the most substantial and successful has been Cooperative Research Centres (CRC) Program. This initiative has been in place for close to 27 years since its inception in the 1990s.

2. Schemes/Programmes/Organization

2.1. Cooperative Research Centers Program

Background:

This initiative was put into place by the Australian government in the 1990s and the functioning started in 1991 (https://www.industry.gov.au/industry/IndustryInitiatives/IndustryResearchCollaboration/CRC/Pages/default.aspx). The main aim of CRCs, according to the guidelines of the program, was tolink and build on outstanding research activities in the public and private sectors. Emphasis will be placed on enhanced research cooperation achieved through concentrating research activities in one location, or through effective methods of networking; strengthening research training; and on the economic and social benefits of research" (CRC Program: Guidelines for Applicants 1990; cited in Australian Government 2014).

The literature derivatives and other sources concede to the fact that it is likely that initiatives of foreign countries like the FraunhoferGesellschaft, Network of Centers of Canada may have been the plausible trendsetters for the idea of setting up a portfolio of CRCs (Australian Government 2014).

Governance

The Ministry of Department of Industry and Science is the main agency responsible for administering the program and looking into its modalities. The Ministry oversees the program on behalf of the Australian government and the Minister concerned assigns a sovereign advisory committee (CRC Association) for providing guidance and suggestions related to the program. The CRC Association, which came into being in December 1994, is not-for-profit organization with boosting science and other research disciplines as its main objective.

Administrative responsibility and cost

Department of Industry and Science

Budget 2015-16: $146.748m

The Ministry is responsible for providing secretarial backing and support to the CRC committee and the experts thereby aiding in administrative functioning of the centers. It is the duty of the Committee to feed in suggestions and recommendations to the Ministry concerned regarding functioning, sustenance, funding, planning, monitoring and evaluation of CRC program in whole.

The association's other main objectives are:

a) To act as the interface primarily between Cooperative Research Centres and the Australian Government as well as other stakeholders, to consider broad issues which affect the Cooperative Research Centres Program
b) To promote the overall Cooperative Research Centres Program
c) To provide a forum primarily for Cooperative Research Centres to have access to and share relevant information and experience concerning the operation of Cooperative Research Centres
d) To promote the provision of financial commitment to Cooperative Research Centres through the Cooperative Research Centres Program
e) To enhance scientific and technological capabilities and support research and education through primarily Cooperative Research Centres
f) To collaborate and cooperate to capture the benefits of research and to strengthen the links between research and its utilization.

A board comprising of not less than eight and not more than ten members regulates and controls the dealings of the association. Board members are chosen ensuring thatboard has an extensive range of proficiency pertinent to the essentials of the program in R&D, education, deployment, research administration, the industrial requirements and other end users.

The association opines on the selection as well as assessment of CRCs along with the applicable conditions for providing funds vide the program.

Objectives:

The primary and the most notable aim of the program is "to deliver significant economic, environmental and social benefits to Australia by supporting end-user driven research partnerships between publicly funded researchers and end-users to address clearly articulated, major challenges that require medium to long-term collaboration efforts" (Australian Government 2013).

In the above mentioned aim statement the end users are referred to as the public or private systems that possess the capacity to deploy the results and outputs of research in order for delivering significant benefits – social, environmental and most importantly economic in nature.

The Australian government drew out the objectives of the CRC initiative in a fashion that they enhance/bolster the overall innovation ecosystem of Australia

- Aims to improve the competitiveness, productivity and sustainability of Australian industries, especially where Australia has a competitive strength, and in line with *Government Priorities*.
- Aims to foster high quality research to solve industry-identified problems through industry-led and outcome-focused collaborative research partnerships between *Industry Entities* and *Research Organizations*.
- Aims to encourage and facilitate *Small and Medium Enterprise (SME)* participation in collaborative research.
- Collaboration amongst the researchers, between the researchers and industry or other users, and to improve efficiency in the use of intellectual and other research resources.

The main agenda of establishing the CRCs was to fulfill the framework laid by the above stated objectives.(Changed objectives over the years.. should that be added??)

The CRCs carry the onus of bringing at a single platform the researchers/research groups from public universities, research organizations, R&D units, federal/state and territorial laboratories, and the private business sector for carrying out innovative research. These Centers create strong networks of research and provide the researchers with an area of concentration thereby making sure that the national resources are utilized to their maximum capacity and judiciously.

This initiative fulfills an important role in the innovation system of Australia, working in the domains of:

- Collaboration between researchers and research users;
- Education of graduate researchers in an outcome oriented context;
- Excellence in long-term strategic research; and
- The transfer of research outputs into commercial or other outcomes of economic, environmental or social benefit to Australia.

Program and Funding:

The CRC Program essentially consists of two types of funding streams:

a) Cooperative Research Centers (CRCs) for supporting medium to long term industry-driven collaborations; and
b) Cooperative Research Center Projects (CRC-Ps) for supporting short term, industry-led collaborative research.

The users eligible for funding may either be from the private sector, public sector, universities or a research organization affiliated to a university. Of all the participants one must essentially be an Australian for the group to source funding. Also it is necessary for the essential participating members to contribute to the CRC resources.

Upon successful obtaining of the CRC funding, the applicants become participants in the appropriate CRC or CRC-P. These participants have to essentially sign a 'Participants Agreement'. In due time period, supplementary contributors may be added or prevailing participants replaced (including essential participants). Even though neither of the participating members are mandated to pledge for the entire period of funding, stability and steadiness is a critical criteria. Therefore it is essential for the CRCs to maintain a balance between assurance of the members and flexibility offered by the program. The CRC association, through its evaluating role, determines whether the fluctuations in the configuration of participants affects the capacity of the CRC to perform the proposed undertakings and recommends the Minister accordingly. The program guidelines as issued by the association do not specifyany particular roles to the members of CRCs.

CRC	CRC-P
At least 1 Australian Industry	At least 2 Australian Industry Entities (including at least one SME)
At least 1 Research Organization	At least 1 Research Organization
Activities	
a) Medium to long-term industry-led high quality collaborative research for solving problems identified by the industry. b) An industry-orientedstudy and training program. This must include, but is not limited to, a PhD program that complements the research program and that increases engagement, technology development, skilled employees and R&D capacity within Industry Entities; c) Implementation of strategies that build the R&D capacity within SMEs; d) Deployment of research outputs and encouragement of take-up by industry.	a) Short term, industry-identified and industry-led collaborative researchprojects for developing a product, service or process. Projects should benefit SMEs and increase their capacity to grow and adapt in changing markets; b) Industry-focused education and training activities, such as internships and secondments between Industry Entities and Research Organizations

Both the CRCs and CRC-Ps are funded for a single term and a specific time period for undertaking the projects and other related activities, as per the Funding Agreement. There is no provision of additional funding or extension other than the specified term. Also there is no specific limit to the amount of funding granted through the program and the funding is determined through appropriation. CRC

Program Funding is made available for varying time periods of up to ten years for CRCs and up to three years for CRC-Ps.

Organization:

The CRCs can be established either as an incorporated entity or as a unincorporated entity. the legal form chosen for a CRC is at the sole discretion of the applicant. However, the legal and taxation implications of the CRC structure as proposed in the application needs to be carefully considered by the applicants so as t effectively deal with the intellectual property generated through the CRC(Australian Government 2013).

The program guidelines have made it a compulsion for every CRC to employ a defined governance model, which clearly demonstrates –

- good practice in design (for the application)
- good practice in execution (for the operation of the CRC).

Even though the program guidelines do not provide any specific governance model for the operation of a CRC it does ask for apt justification for the chosen governance model in the application process. In addition the guidelines also have set down eight governance principles for the CRCs. These governance principles have been developed by the Australian Stock Exchange Corporate Governance Council and have also been adapted and modified according to the requirements of the CRCs.

Since the inception of the program in the year 1990, close to 210 CRCs have been funded by the government of Australia till date. This involves a commitment of nearly $3.9 billion in CRC Program funding. As of date (2016-17), 31 CRCs are active (Table 3).

Table 3: CRCs active as of year 2016-17

S. No.	Name of CRC	Year of Establishment	Grant (Years)	CRC Programme Funding	Incorporated (Yes/No)
Agriculture, Forestry and Fishing					
1.	CRC for High Integrity Australian Pork (porkcrc.com.au)	2011–12	8	$19.86m	Yes
2.	CRC for Sheep Industry Innovation (sheepcrc.org.au)	2014–15	5	$15.50m	Yes
3.	Invasive Animals CRC (invasiveanimals.com)	2012–13	5	$19.70m	Yes
4.	Plant Biosecurity CRC (B pbcrc.com.au)	2012-13	6	$29.65m	Yes
5.	Poultry CRC (poultrycrc.com.au and poultryhub.org)	2009-10	7.5	$27.00m	No
Mining					
6.	CRC for Optimising Resource Extraction (crcore.org.au)	2015–16	6	$34.45m	Yes
7.	Deep Exploration Technologies CRC (detcrc.com.au)	2009-10	8.5	$28.00m	Yes
Manufacturing					
8.	Automotive Australia 2020 CRC (excellerateaustralia.com)	2012–13	5	$26.00m	Yes
9.	CRC for Cell Therapy Manufacturing (ctmcrc.com)	2013–14	6	$20.00m	Yes
10.	CRC for Polymers (crcp.com.au)	2012-13	5	$14.50m	Yes
11.	Rail Manufacturing CRC (rmcrc.com.au)	2014–15	6	$31.00m	Yes
12.	Defence Materials Technology Centre (dmtc.com.au)	2007–08	10	Nil (Defence funded)	Yes
13.	Innovative Manufacturing CRC (imcrc.org)	2015-16	7	$40.00m	Yes
Services					
14.	Antarctic Climate and Ecosystems CRC (acecrc.org.au)	2014–15	5	$25.00m	No

15.	Bushfire and Natural Hazards CRC (bnhcrc.com.au)	2013-14	8	$47.00m	Yes
16.	Capital Markets CRC (cmcrc.com)	2014-15	5	$32.35m	Yes
17.	CRC for Alertness, Safety and Productivity (alertnesscrc.com)	2013-14	7	$14.48m	Yes
18.	Cancer Therapeutics CRC (cancercrc.com)	2014–15	6	$34.01m	Yes
19.	CRC for Contamination Assessment and Remediation of the Environment (crccare.com)	2011-12	9	$29.10m	Yes
20.	CRC for Living with Autism (autismcrc.com.au)	2013-14	8	$31.00m	Yes
21.	CRC for Low Carbon Living (lowcarbonlivingcrc.com.au)	2012-13	7	$28.00m	Yes
22.	CRC for Mental Health (mentalhealthcrc.com)	2011-12	7	$23.11m	Yes
23.	CRC for Remote Economic Participation (crc-rep.com.au)	2010-11	7	$32.50m	No
24.	CRC for Spatial Information (crcsi.com.au)	2009-10	8.5	$32.19m	No
25.	CRC for Water Sensitive Cities (watersensitivecities.org.au)	2012-13	9	$30.00m	Yes
26.	Data to Decisions CRC (d2dcrc.com.au)	2014-15	5	$25.00m	Yes
27.	Energy Pipelines CRC (epcrc.com.au)	2009-10	9.5	$17.48m	Yes
28.	Oral Health CRC (oralhealthcrc.org.au)	2009–10	8.5	$30.25m	Yes
29.	Space Environment Management CRC (serc.org.au)	2014-15	5	$19.83m	Yes
30.	The HEARing CRC (hearingcrc.org)	2014-15	5	$28.00m	Yes
31.	The Lowitja Institute Aboriginal and Torres Strait Islander Health CRC (lowitja.org.au)	2014-15	5	$25.00m	No
32.	Wound Management Innovation CRC (woundcrc.com)	2010-11	8	$27.93m	Yes

The following figure divulges a summary of commercialization metrics for CRCs for the years 2005-06 to 2014-15.

		2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
CRCs responding	No.	66	53	56	46	50	42	44	38	40
Research expenditure	$'000	889,381	821,658	740,809	593,983	570,246	517,214	515,602	359,215	348,559
Resourcing for commercialisation per $100m research expenditure										
Commercialisation expenditure per $100m research expenditure	$'000	12,238	12,233	14,018	17,334	17,885	13,830	14,078	15,862	15,895
Intellectual property protection activity per $100m research expenditure										
Patents filed In Australia	No.	8	10	12	9	7	9	5	13	7
Patents filed overseas	No.	6	7	7	6	7	10	10	7	7
Patents filed total	No.	15	17	19	15	14	19	15	19	13
Patents maintained in Australia	No.	28	26	27	30	38	39	37	55	43
Patents maintained overseas	No.	71	58	63	83	101	210	221	241	184
Patents maintained total	No.	99	83	90	113	139	249	258	296	226
Licensing activity per $100m research expenditure										
LOAs contracted	No.	8	16	14	37	28	44	42	30	83
Income from LOAs	$'000	2,705	2,490	3,306	5,281	5,840	2,449	830	1,572	1,336
Start-up company activity per $100m research expenditure										
Start-up companies formed	No.	1.2	0.7	0.3	0.5	1.2	0.4	0.8	0.3	1.1
Income from new start-up companies – total	$'000	118	105	0	2	0	685	0	0	375
Research contracts and consultancy activity per $100m research expenditure										
Contracts and consultancy agreements entered into	No.	61	73	81	91	75	-	-	-	-
Contracts and consultancy income	$'000	7,951	8,152	7,832	8,824	7,845	-	-	-	-
Training, development and knowledge exchange activity per $100m research expenditure										
Professional training courses offered to end-users	No.	39	26	39	44	54	-	-	-	-
Conferences provided for end-users	No.	61	53	76	123	70	-	-	-	-
Income from courses and conferences	$'000	259	187	208	176	144	-	-	-	-
CRC postgraduates taking up employment in industry	No.	38	39	43	34	53	62	31	38	36
Publications for end-users	No.	282	182	312	333	260	260	269	360	582
Confidential and unpublished reports for end-users	No.	95	108	134	179	138	-	-	-	-

Note: All dollar values have been adjusted to 2015 prices
Research contracts and consultancy activity and some metrics under training, development and knowledge exchange activity ceased have not been collected since 2009–10.

Figure 23: Summary of commercialization metrics of CRCs for 2005-06 to 2013-14 (https://www.industry.gov.au/innovation/NSRC/Data/2015/Pages/Table-4.aspx)

Success Stories:

The CRCs have been performing excellent research and producing effective outputs, which have not only enhanced the innovation index of Australia but have also significantly affected the society for the good. A few examples of the same are enlisted below-

a) Cancer Therapeutics CRC (CTx) is transforming Australia's highly deemed cancer biology studies into newfangled cancer treatments. The activities undertaken by its participants have lead to the assemblage of capacities that were required for discovering and developing new 'small-molecule' cancer drugs for children as well as adults. The CTx has been working diligently with biotechnology and pharmaceutical companies, its commercial partners, for moving the new drug molecules into clinical trials. Following seven years of research and operational activities, CTx has licensed 4 new 'cancer drug development' candidates and also has in channel 'drug discovery and optimization' projects that possess the potential for improving the living conditions of cancer patients. In order to manage the licensing and commercialization activities of CTx a *not-for-profit* company, CTx CRC Ltd (CTx2), has been established.

CTx along with its commercialization partner (U.K. based), Cancer Research Technology, has licensed the rights associated with a program of 'small molecule drugs' known as PRMT5 inhibitors to MSD (Merck in Canada and US). These drugs are clinically worthwhile in both non-cancer and cancer blood ailments. The license agreement involved a forthright payment of $21 million and potential payments in excess of $700 million. A minimum of 70% of those payments shall be returned to CTx (https://crca.asn.au/crca-knowhow-issue-7/).

b) CRC for Water Sensitive Cities (CRCWSC) in association with its partner, an organization called South East Water, have forged a smarter solution for managing the natural resources. A new community has come up in Melbourne, Aquarevo Community, which is an advanced, water sensitive urban development – a solution facilitated through CRCWSC. 'Aquarevo'demonstrates industry-lead innovation assisted by superior research and brought about by means of collaboration between the industry, government, and academia. CRCWSC contributed via bringing together the prime participants for innovation in the stage of early planning through its

Research Synthesis Workshops, and stipulatedacute evidence to back the acceptance of leading water-sensitive initiatives at Aquarevo.

A few other notable products/services have been enlisted in the table

Product/Service Name	Collaborators	Product/Service Details
Tooth Mousse Plus Product (https://oralhealthcrc.org.au/content/tooth-mousse-plus) 	CRC for Oral Health Science	This product re-mineralises tooth enamel thereby reducing tooth decay.The product is now sold in over 50 countries.
Cochlear™ Hybrid™ System (http://www.cochlear.com/)  http://hearandnow.cochlearamericas.com/wp/wp-content/uploads/2015/09/device_hybrid.png	HEARing CRC	Has aided in restoring the hearing of close to 1,40,000 children and adults worldwide
eBUS (http://www.excellerateaustralia.com/future-sustainable-public-transport/)	AutoCRC Swinburne University of Technology (Electric Vehicle Laboratory) Bustech (Transit Australia Group)	First electric bus to be designed engineered and manufactured in Australia, which is nearly 80% cheaper to maintain than the diesel buses run in Australia.

c) **Graduated Successful CRC**

An example of a CRC that has successfully graduated from the program is - the Vision Cooperative Research Centre (Vision CRC) Ltd. It was founded in 2003 under the CRC Programme and recieved funding for twelve years, from 2003-2015.

The Vision CRC along with its predecesor the CRC for Eye Research and Technology (CRCERT, 1991-2003) developed word-class contact lens products, which lead to the generation of nearly $300 million in royalties and close to $1.5 billion in cash and in-kind investment. Contact and spectacle lens technologies for controlling myopia were also produced by the two CRCs. Other technologies include – technologies for surgery, a prototype materail for curing presbyopia, advances in ocular health etc.

Outcomes of the Measure/Initiative:

The major outcomes incorporate the commercialization of high-end research studies being undertaken in the universities (academia) and public research institutions. The CRCs since their inception have been producing graduates possessing hands on industrial training and experience, which has aided in building a highly skilled workforce and capacity of the nation.

Figures related to CRCs

- 210 CRCs have been funded since 1991
- Approx. 1,905 participants
- 67% i.e. 1,277 industry participants
- 36,434 journal articles
- 42,838 end-user reports have been published from CRC research
- 12,684 patent applications
- 1,936 patents held
- over 3,600 PhD graduates

(Cooperative Research Centres Miles Review Growth through Innovation and Collaboration PDF.pdf).

Success Story CRC Projects

a) Power Efficient Wastewater Treatment Using Graphene Oxide Technology

An avant grade solution for wastwater filtration has been developed by the Monash University and two Australian industries. The industrial participants - Ionic Industries Ptv Ltd. And Clean TeQ along with the acacdemic partner have collaborated with backing from the Australian government by means of CRC-Ps have developed a material termed as 'Graphene'. This project was concieved with an aim at revolutionizing the wasterwater filtartion techniques to an approach that consumes lesser energy. The new graphene filter has the capacity of processing water nine times faster than the present day techniques.

b) Guardian technology platform that actively monitors for and alerts drivers to fatigue and distraction

Seeing Machines, an an industry leader in computer vision technologies which enable machines to see, understand and assist people, in partnership with Monash University's Accident Research Centre and Ron Finemore Transport, was awarded an Australian Government CRC Project Grant for $2.25 million. This project, which builds on Seeing Machines' Guardian technology platform that actively monitors for and alerts drivers to fatigue and distraction, was awarded for a time period of three years.

The Guardian system provides real-time, in-cabin alerts when fatigue or distraction is detected by driver facing sensors. The system works in all light conditions including night driving and the use of sunglasses.Guardian is further connected to a 24/7 monitoring centre and cloud analytics engine that gives fleet owners a variety of customisable intervention and analytics programs to complement their driver training and wellness initiatives. Data gathering, both using simulation and on-road measurements, will help to refine the system's current sensing abilities, along with applying the latest thinking around the design of the human machine interface.

The CRC-P grant has enabled SeeingMachines, through collaborative research, toengage in a transformational form ofproduct development R&D.

2.2 Industry Growth Centres Initiative

Background

The Industry Growth Centers (Growth Centers; https://industry.gov.au/industry/industry-growth-centres/Pages/default.aspx) Initiative [the Initiative] stands as an industry-driven approach motivating modernization, productivity and effectiveness by converging on areas of considered strength and precedence. The Initiative was brought into action for transforming Australia's private sector into a high-value plus exports oriented industries. It is the centerpiece of the new directive of industrial policy. The initiative was a component of the Commonwealth Government’s Industry Innovation and Competitiveness Agenda.

The Initiative assistsnationwideactivities on importantsubjects such as association, commercialization, engagements, skills and regulatory reform. The intent of the initiative will be achieved through the establishment of ‘Growth Centers’ – non-for-profit companies that are supposed to be limited by guarantee with a specific Board comprising of industry leaders.

The Australian government will provide $238 million over a time period of four years - 2017/18 to 2020/21. Six industrial sectors, which possess strength and the potential for competitiveness, have been chosen for establishment of Growth Centres. Thees key areas are:

- Advanced Manufacturing;
- Food and Agribusiness;
- Medical Technologies and Pharmaceuticals;
- Mining Equipment, Technology and Services;
- Oil, Gas and Energy Resources; and
- Cyber Security

All the above-mentioned sectors are well positioned and can leverage prospects in the said industry. More or less similar proposals have been efficacious and are operating successfully in countries such as US, UK and Canada.

Industry Growth Centres have been envisioned for helping to align other programmes in the portfolio, incorporating CSIRO and CRCs, to contribute towards the enhancement of their productivity and strengths.

Common Knowledge Priorities					
Common themes across Growth Centre knowledge priorities include developing and adopting technology and systems associated with automation, digitisation, and advanced materials; environmental impact and sustainability, and how emerging technologies will impact markets.					
Sector-specific Knowledge Priorities					
Advanced Manufacturing (AMGC)	Food and Agribusiness (FIAL)	Medical Technologies and Pharmaceuticals (MTPConnect)	Mining Equipment, Technology and Services (METS Ignited)	Oil, Gas and Energy Resources (NERA)	Cyber Security (ACSGN)
• Digital design and rapid prototyping • Sustainable manufacturing and life cycle engineering • Additive manufacturing, materials resilience and repair • Bio-manufacturing and biological integration • Nano-manufacturing and micro-manufacturing • Precision manufacturing	• Using genetics, novel technologies and processing techniques to produce highly differentiated and value added foods	• Clinical specialty/therapy; areas of science; and devices and diagnostics	• Advancing mining and beneficiation technologies such as selective mining, comminution, classification, reducing tailings/reject streams, in-situ recovery and bio-leaching	• Mapping prospective basin geology across the minerals and energy sectors • Developing new technology, business models and infrastructure to adapt to the changing energy mix	Cyber security for: • IT integrated with control systems for plant and machinery • Mobile internet • Artificial intelligence and big data • Cloud computing • Internet of Things (or connected products) • Quantum computing • Block-chain

Growth Centre Objectives

The Initiative aims at boosting the efficiency and output of the high growth sectors in Australia by: categorizing prospects for reducing regulatory load, enhancing collaborations and commercialization, cultivating competences to involve with global markets and international supply chain, and augmenting supervision and workforce abilities.

1. Reducing regulatory load: *Growth Centres will put in efforts in association with the industry, the government (state and centre) and rest of the stakeholders for identifying regulatory reforms that are specific and beneficial leading to improved conditions of efficiency and competiveness. Reduction in cost involved in doing business through amendments in regulations comes across as a promising and achievable outcome.*

   **Regulation Reform Agendas* provide an opportunity for Growth Centres to suggest regulation reform solutions to regulators, including governments, as part of their Sector Competitiveness Plans. These will be delivered within 12 months of each Growth Centre's commencement. Reform agendas need to be evidence based and can be prepared by the Growth Centre in accordance with a Guide that has been prepared by the department.

2. Enhancing collaboration and commercialization: *The engagements between the industry and research organizations are envisioned to strengthen due to the labors of the Growth Centres. Stronger collaborations within the industrial sector are also envisaged. This shall help to improve the transfer of research from PRIs into commercial markets and thereby capitalize on the funds invested by the Australian government.*

   **Industry Knowledge Priorities, a summary of priority knowledge and technology gaps in the sector, will be developed annually by each Growth Centre, as part of its Sector Competitiveness Plan. These Industry Knowledge Priorities will inform the science and research community of industry's needs and commercialization opportunities.*

3. Cultivating competences to involve with global markets and international supply chain: *Growth Centres shall put in efforts in their respective sectors for engaging with global markets and become accessible to the supply chain*

internationally. Impediments and bottlenecks towards successful global partnerships will be addressed by the Centres in their Sector Competitiveness Plans.

4. Augmenting supervision and workforce capabilities: *Growth Centres, in association with the industrial sector, government and academia, will identify challenges to the development of skilled and suitable workforce and correspondingly will develop actions for overcoming the challenges and enhance the productivity of their respective sectors.*

The predominantgoal of the Initiative is to progress the output and efficiency of the selected sectors. For the same, it aims at adopting a nationwide approach for restructuring and concentrating on the blockades in the course of efficiency, advancement and innovation.

Governance:

The administrative responsibility of the Initiative lies with the Department of Industry and Science.

Each Growth Centre is *not-for-profit* corporation, governed by a 'Board' that comprises of various experts from the industry of that specific domain. Even though the Centres are adaptable in their approach towards addressing the barriers, the industry experts i.e. the Board, carefully supervise their activities and operations. The Centres are also mandated to establish a long-term strategy in association with the industry.

Growth Centres Advisory Committee:

Suggestionsregarding various activities including, restructuring regulations, mounting business efficiency and commercialization are provided by the Industry Growth Centres Advisory Committee (https://industry.gov.au/industry/Industry-Growth-Centres/Pages/Growth-Centres-Advisory-Committee.aspx). The committe draws from the experiences of the Growth Centres and tries to provide assistance in sync with it.

The Committee is comprised of the Growth Centre Chairs and up to four independent members, which are all appointed by the Minister for Industry, Innovation and

Science. The Minister, from one of the independent members, selects the 'Chair of the Committee'. The Growth Centre Advisory Committee provides advice to the Minister regarding various intricacies like, merit of the proposal of each Growth Centre, their procedures and performance, their strategic plans, the funds granted etc. The programme guidelines, devised by the Minister, lay down a framework for functioning of the Growth Centres and are subject to revisions.

Industry Growth Centre Activities

The long-term sector strategies set by each of the Growth Centres highlight opportunities and drive activities to boost productivity by increasing collaboration and commercialisation, improving management and workforce skills, optimising the regulatory environment and assisting the sector to engage in international markets. Growth Centres work to unlock commercial opportunities and drive innovation by connecting businesses and industry organisations with research and technical expertise to solve challenges. They assist Australian industry to better capitalise on the excellent research and development undertaken generated in Australia. Growth Centres also help align industry and innovation policies and programmes to ensure research activities are targeted at areas of priority.

Example of a Growth Center:

a) MTP Connect (https://www.mtpconnect.org.au/)

The 'Medical Technologies and Pharmaceuticals Growth Centre' named as MTPConnect, is one of the six Industry Growth Centres founded in Australia. It was established for building Australia into a hub for biotechnology, medical technology and pharmaceutics. It was founded in November 2015 as a part of the $250 million Initiative. It was established in the form of a not-for-profit corporation.

MTPConnect
MedTech and Pharma Growth Centre

In its Sector Competitiveness Plan, MTPConnect has acknowledged 7 growth primacies in its concerned sector, which are –

1. Categorize and endorse 'Knowledge Priorities', which focus on the needs of the market both existing and forthcoming.

2. Design a favorable setting for commercialization - from R&D studies to phase of early clinical trials and proof-of-concept
3. Renovate the SME sub-sector for backing the growth and advancement of small companies into larger and economically stable companies.
4. Intensify attractiveness of Australia as a desirable destination for clinical trial studies.
5. Encourage the advance of digital MTP solutions.
6. Station Australia as the favored associate for markets emerging in Asia.
7. Support and encourage advanced manufacturing as a fragment of the wholesome innovation system of Australia.

MTPConnect in action

Grants of up to the amount of $93 million has been made available to the Growth Centres for supporting directed cooperative projects for building capability and capacity. A'Project Fund' has been devised in a flexible manner so as to fund and back a wide variety of R&D projects for delivering commercial outcomes that have an impact that is widespread. It is mandatory for the projects to be of national importance. As a component of this program, funds amounting to $73 million are provided on competitive basis for translating probable ideas into commercial entities.

$1 million of this element is also to be delivered through the Entrepreneurs' Programme.

Till date MTPConnect has undertaken the following activities:

- Founded its 'Project Fund Program'. In the two rounds of program i.e. 2016 and 2017, it has provided a total of $15.6 million for 34 nationwide projects. These projects can leverage an additional amount of $30.8 million from industrial partner funds.
- Supporting CRCs that are oriented in domains in sync with MTPConnect, for undertaking industry-lead research. It has signed Memorandum of Understanding with the Cell Therapies Manufacturing CRC, Autism CRC, Hearing CRC, Wound Management CRC, Capital Markets CRC, Oral Health CRC and Innovative Manufacturing CRC.

- Backing Clinical Trials in Australia. The Centre has published a report 'Clinical Trials in Australia', which brings forth a picture of the clinical trial scenario in Australia. This report also signifies the changes and boost that the Australian economy will experience as a result of conducting of clinical trials.
- MTPConnect is also working with Australian Research Council Industrial Transformation Research Programme for enhancing the outcomes from the industry and making sure that the research is industry oriented.

Other Programs

Apart from the schemes and initiatives launched by the federal and territorial governments, the other major measures have been initiated by the public research granting agencies. One of them is a commonwealth entity, the Australian Research Council (ARC). The purpose of Arc is to develop and create innovative knowledge for the benefit of the society by means of granting funds for high quality R&D, efficient collaborations, assessing the research and giving advice on matters of research.

The ARC provides funds for research and the researchers under the provision of National Competitive Grants Program (NCGP), which has three elements under it – *Discovery*, *Linkage* and *Excellence in Research for Australia (ERA)*.

Within these three elements, there are operated a number of schemes that are structured in a fashion to provide incentives and reinforce excellence across the wide spectrum of research activities undertaken in Australia. These schemes enable research performers to build scope of work and forge successful partnerships.

I. **Discovery Program** funds and backs fundamental and primary research, which is indispensible for the innovation ecosystem in Australia to bring about generation of novel ideas, thoughts, creation of opportunities/jobs, progress of the economy and an overall high quality of life. The Discovery Program includes: Discovery Projects; Discovery Indigenous; Australian Laureate Fellowships; Future Fellowships; and Discovery Early Career Researcher Award.

II. **Linkage Program** endorses and upholds research partnerships and collaborations both nationally as well as internationally amongst the key players of research and innovation i.e. providers of higher education (universities), government, private sector including small and large businesses, and the end users. The Linkage Program schemes include: ARC Centres of Excellence; Industrial Transformation Research Hubs; Industrial Transformation Training Centres; Linkage Projects; Linkage Infrastructure, Equipment and Facilities; and Special Research Initiatives.

III. **Excellence in Research for Australia,** whichassesses the worth of research assumed in the universities of Australia versus the nationwide and worldwide yardsticks. Committees of eminent researchers, from Australia and abroad, compute the evaluations and scores.

The Linkage program comprises the elements of collaborations and partnerships amongst the various stakeholder of the research and innovation chain. The initiatives under the linkage program are hence of significance to us and a few of them have been discussed below:

2.3. ARC Centers of Excellence (CoEs)

Background:

The ARC CoEs (http://www.arc.gov.au/arc-centres-excellence) are noteworthy nuclei of expertise wherein high-quality researchers uphold and improve the nation's global positioning in areas of key importance and priority.

The CoEs, funded by federal government, are comprehended as concerted instruments of research, which bring together the complementary capabilities and capacities of public (universities, publicly funded research organizations, research bodies, government) and private (industries, businesses, companies) sector for pursuing pre-defined considered goals and provide support for outstanding research.

The first CoEs of ARC came into being in 1982 – the Key Centre for Teaching and Research and the Special Research Centres. Both the institutions were set up with slightly different initial goals. The former was established with a view of indorsing quality teaching and supporting excellence in research in institutions of higher education, while the latter was aimed at backing and providing funding support for research in domains of national importance. However, at the core of the establishment of the Centres lied the common objective of enhancing collaborations between different sectors of the economy and advancement of national S&T was the priority purpose.

In 2003, the previous two programmes were extended and replaced by the ARC CoEs initiative. This initiative is also being implemented under the outline ofthe chief national funding programme for R&D, the ARC National Competitive Grants Programme.

Objectives:

The CoEs funded by ARC have been designed for providing support to and funding all sorts of R&D, comprising basic research, planned basic research, which might lead to useful inventions/discoveries, and applied R&D. The undertakings of ARC CoEs are directed by the following objectives:

- To undertake highly innovative and potentially transformational research that aims to achieve international standing in the fields of research undertaken and leads to a significant advancement of capabilities and knowledge.
- To link existing Australian research strengths and build critical mass with new capacity for interdisciplinary, collaborative approaches to address the most challenging and significant research problems.
- To develop relationships and build new networks with major national and international centres and research programmes to help strengthen research, achieve global competitiveness and gain recognition for Australian research.
- To build Australia's human capacity in a range of research areas by attracting and retaining researchers of high international standing as well as the most promising research students from within Australia and abroad.
- To provide high-quality postgraduate and postdoctoral training environments for the next generation of researchers.
- To offer Australian researchers opportunities to work on large-scale problems over longer periods of time.

- To establish centres of such repute in the wider community that they will serve as points of interaction among higher education institutions, governments, industry and the private sector generally.

Organizational Structure and Governance:

The CoEs might be located at a specific individual site (denoted as concentrated CoE), or be encompassed of networked nodes (denoted as distributed CoE), function virtually or may even assume a different approach towards managing research operationsprovided it meets all the eligibility criterion and the rules of funding stipulated for ARC CoE. It is mandatory for each CoE to be governed by a Board – an Advisory Board, which basically represents research and outcomes. A Director heads the CoE and the board is responsible for advising the Director of CoE and partnering organizations in regard to research focus areas and other general issues like structural elements, functioning elements, collaboration guidelines, IP dissemination and sharing, and commercialization etc. The advisory board, which comprises of deputy vice chancellors (reserach) of the partnering institutions and the CEOs of the partnering organizations, meets twice in a years time period for discussing strategies and the direction in which the Centre needs to work. The governing structure also comprises of a 'Scientific Management Committee'. It comprises of the Leaders or Managers of the various programmes run at the CoE.

Funding:

The Administering Organization and not the researchers are entitled towards the grants/funds provided under this initiative. Australian universities are eligible to apply as administering organization of a CoE. All the other establishments are designated as collaborating organizations if they are authorizedto obtain ARC funding, and partnering organizations if they are committed towards contributing to the activities of CoE but are not eligible for receiving funding from ARC. These establishments should essential establish a significant co-location of supplies/funds (in-cash contributions matching or exceeding the ARC grant) to the operation of CoE.

A funding of amount ranging between $1m and $5m per annum is provided for a time period of seven years, for each ARC CoE. However, the funding is subject to various factors such as satisfactory progress of CoE, availability of funds, regulatory guidelines etc.

Success Story:

A partnership between the *ARC Centre of Excellence for Electro materials Science* (ACES) and the Australian National Fabrication Facility (ANFF) has catapulted basic research into real-world and concrete structures. A group of engineers, scientists, researchers and clinicians have come together through this partnership for performing cross-disciplinary research. This has aided the industries in exploring novel opportunities and also in generation of new industries in manufacturing.

Breakthrough research outcomes include:

- Printing of biomaterials meant for cartilage regeneration for implantation in cases suffering from disorders like arthritis
- Islet Cell Transplantation – Biomaterial containing ink has been developed, which shields the islet cells through the process of 3D printing in treatment of type 1 diabetes
- AquaHydrex – development of novel biomaterial that aid the break down of water into oxygen and hydrogen, important fuels.

By bringing together world-class equipment, facilities and research expertise, the ACES-ANFF conglomerate has stood itself as an exceptional commercial researcher. For example, Aquahydrex Pvt. Ltd, a start-up, evolved out of the activities of fundamental research of ACES, and utilized on an extensive scale the fabrication facilities of ANFF.

2.4. ARC Linkage Project (http://www.arc.gov.au/linkage-projects)

Background

The scheme of ARC Linkage Project, initiated in 1999, came into being for promoting associations and collaborations between the players of research and innovation ecosystem. These players include a plethora of stakeholders from the higher education institutes (HEIs), R&D organizations/units, government agencies, private firms, industries, and business and community end-users. All R&D activities are undertaken for applying advanced knowledge to varied issues and problems, amass new expertise for attaining economical and related benefits from research.

To stand by its most fundamental aim of fruitful collaborations between the institutes of higher education and other elements of the national innovation ecosystem, the solicitation of ARC Linkage projects facilitate submission of project proposals all throughout the year and the outcomes are declared within six months.
Funding is administered to the proposals of the eligible organizations, for supporting the R&D activities, which are:

- Collaboration between researcher of HEIs and other stakeholders.
- Performed for attaining and amassing new expertise & proficiency, and
- Innovative activities involving high risk.

The proposal sent for evaluation, for receiving funding vide the scheme of Linkage Projects must have mandatorily one 'Partner Organization' (in the least). This partner organization should provide a contribution in the form of cash/or kind, towards the project. Also the total fund requested from ARC should match the total contributions of all the partner organizations.

Objectives: The fundamental objectives of the scheme of Linkage Projects (http://www.arc.gov.au/linkage-projects), are to:

- support the initiation and/or development of long-term strategic research alliances between higher education organizations and other organizations, including industry and other research end-users, in order to apply advanced knowledge to problems and/or to provide opportunities to obtain national economic, commercial, social or cultural benefits
- provide opportunities for internationally competitive research projects to be conducted in collaboration with organisations outside the higher education sector, targeting those who have demonstrated a clear commitment to high-quality research
- encourage growth of a national pool of world-class researchers to meet the needs of the broader Australian innovation system
- build the scale and focus of research in the national Science and Research

Priorities.

Funding:

The amount of funding provided by the scheme is $50,000 to $300,000 each year, for a time period of two-five years. The funding of the project can be utilized for a wide variety of uses such as (http://www.arc.gov.au/linkage-projects) -

a) Personnel i.e. research associates/assistants/technicians
b) Emoluments for higher degree education by the research students
c) Teaching assistance relief
d) Access to all facilities (research and infrastructure) and technical workshop services
e) Field activities
f) Outsourcing expert services
g) Materials, consumables and other equipment, web development
h) Dissemination of research results via publications,
i) Special computer software's
j) Travel costs

The Linkage Infrastructure, Equipment and Facilities (http://www.arc.gov.au/linkage-infrastructure-equipment-and-facilities) scheme gives finances to the eligible organizations for high-end facilities, research infrastructure, equipment etc. This allows institutes of higher education to share and cooperatively utilize expensive facilities, equipment, and infrastructure, with the industrial sector. The arrangement correspondingly nurtures collaboration and compliant usage of international or national research facilities.

Objectives:

The objectives of the Linkage Infrastructure, Equipment and Facilities scheme are to:

- Encourage Eligible Organizations to develop collaborative arrangements with other Eligible Organizations, higher education institutions and/or their Partner Organizations to develop and support research infrastructure
- Support large-scale national or international cooperative initiatives thereby allowing expensive research infrastructure to be shared and/or accessed

- Support areas of existing and/or emerging research strength
- Support and develop research infrastructure for the broader research community.

2.5. ARC Industrial Transformation Research Programme (ITRP)

Background:

The ARC – ITRP (http://www.arc.gov.au/industrial-transformation-research-programme) proposes a set of support schemes devised as appealing for both the industry as well as university-based researchers. The Programme funds –

- Industrial Transformation Research Hubs
- Industrial Transformation Training Centres.

These schemes initiating the establishment of Research Hubs and Training Centres, aim at fostering concerted research, creating partnerships between researchers and industry by bringing them together at a common platform for sharing skills and proficiency enabling them to devise new solutions, products, services and processes. Industrial Transformation Research Hubs - the eligible organizations are provided with funding for collaborative R&D between the industry and the higher education sector for devising strategic outcomes that are difficult to realize individually. The research in the priority domains[9], as identified by ARC, is supported by this scheme.

Industrial Transformation Training Centres – develops partnerships for supporting Higher Degree by Research (HDR) and postdoctoral researchers and providing them with practical/real-time skills by means of engaging with the industries.

Objectives: The objectives of the ITRP and its component schemes are to:

- Foster opportunities for Higher Degree by Research candidates and postdoctoral fellows to pursue industrial training

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[9]*The priorities for hubs and centres commencing in 2018 are:*

- *Advanced Manufacturing*
- *Cyber Security*
- *Food and Agribusiness*
- *Medical Technologies and Pharmaceuticals*
- *Mining Equipment, Technology and Services*
- *Oil, Gas and Energy Resources.*

- Drive growth, productivity and competitiveness by linking to key growth sectors
- Enhance competitive research collaboration between universities and organizations outside the Australian higher education sector
- Strengthen the capabilities of industries and other research end-users in identified Industrial Transformation Priority areas.

Funding:

Industrial Transformation Research Hubs

Funding Period	Funding level per year	Partner Organization Requirements	Partner Organization Contribution Requirements
Three to five years	$500,000 – $1,000,000	At least 1 Australian Partner Organization	Cash Contribution by partnering organization – at least 75% of total amount requested from ARC (unless all Partner Organizations have 100 employees or less)

Industrial Transformation Training Centres

Funding Period	Funding level per year	Partner Organization Requirements	Partner Organization Contribution Requirements
Four to five years (10 HDR stipends and 3 postdoc salaries)	$650,000 – $1,000,000 Minimum $650,000 - first 3 years. Minimum $150,000 - fourth year. No minimum amount defined for fifth year. The maximum level - $1 million/year/project for each year of the project.	At least 1 Australian Partner Organization	The combined Partner Organization cash and in-kind contributions are sufficient to support all the research projects described in the proposal and particularly that of the HDRs and postdoctoral researchers in the Training Centre

Success Stories:

- ARC Industrial Transformation Training Centre for Functional Grains

The ARC Industrial Transformation Training Centre for Functional Grains (The Functional Grains ITTC) was set up, at Charles Strut University, with an aim to transform the Grains Industry in Australia from an industry, which is commodity based into an industry which produces food and other feed products of high quality.

The Australian Government, through a $2.15 million ARC grant, supports the Centre. Industry partners also support the Centre:

- Sunrice
- Woods Grain
- MSM Milling
- Graingrowers Ltd
- NSWDPI
- Teys Cargill Joint Venture
- Flavour Makers

- ARC Research Hub for Transforming Australia's Manufacturing Industry through High Value Additive Manufacturing

Researchers at one of the ARC Research Hub, at Monash University, for Transforming Australia's Manufacturing Industry through High Value Additive Manufacturing, have effectively commercialized a novel 3D printing technology that has been a result of their R&D efforts. The Research Hub, in 2014, showcased the the first ever 3D printed jet engine at the Melbourne International Airshow, following which in 2016, the Hub became a qualified aerospace supplier.

2.6. Rural Research and Development Corporations

Background:

The rural industries and producers of Australia have had to go through a wide range of challenges - societal, biophysical or environmental in nature, along with facing extreme global competitions. A main object of response towards the solution of these challenges is a strong and effective rural innovation system, and one of the pillars of this system is the unique partnership between the industry-government, which is being delivered through the means of Rural Research and Development Corporations (RRDCs; http://www.ruralrdc.com.au/). This prototype of combined business and government funding takes a vital position in the triumph of R&D struggles in Australia for over three decades.

The existing model of RRDC comprises of a blend of statutory and industry-owned companies. The industry-owned R&D corporations are self-governing business entities with skill and proficiency based boards.They were designed in response to the desire of the industry to possess added control on their matters and improved flexibility, industry representation and for fostering R&D that is driven by the needs of the market and hence will be readily adopted by the private sector.

Funding:

The funding of the RRDCs is a contribution of financial support from the industry and the support form the government of Australia. The industry contribution is usually raised through levies on production. This levy procedure has been acknowledged as an efficient and equitable method for ensuring that all the producers pay a fair share towards R&D activities, tech. transfers and technology adoption undertakings, from which all can benefit. The government of Australia amasses levies on behalf of the industry as well as provides matching funding on a dollar for dollar basis up to a limit. The government support is for R&D activities of the program, adoption work and other basic operations that are required to back the investment program. All the other modalities are supported by means funds received through the industry.

The established corresponding funding between the government and industry resolves a number of substantial and associated matters that would else reduce the finances available for rural R&D and hence the subsequent innovations. The level of investment made is the most important lever through which the rate of innovative change can be affected.

Presently there are 15 RRDCs in Australia working in the domain of fisheries, agriculture and forest industries. Each of the RRDC, in Australia, has been accorded with the responsibility of dispensing tangible and prudent solutions for the community and for their respective industries and aid in improving the productivity, enhancing the profitability and sustenance. The corporations achieve these objectives by devising strategic plans and through focussed investments towards decisive partnerships for R&D, market access, development and promotion (http://www.ruralrdc.com.au/about-the-rrdcs/). Of the 15 corporations only 5 are statutory corporations, which are owned and retained by the Commonwealth of Australia and are set up vide the legislation, all the others are retained and owned by the industries and are established as *not-for-profit* companies. The industry owned RRDCs have been set up in conformity with the Corporation Law of Australiaand have also been declared through a regulation as 'the service providers to industry for specific activities'. Excise/duty payees can eventually be the members/shareholders of the RRDCs and can participate in the decision making process.

Governance and Accountability:

The Rural RDCs offer an assortment of services and facilities for the businesses that they provide for, and are financed by a combination of industrial and taxpayer contributions. Their specific role and position in the rural modernization system as guardians of public and private reserves, investment managers, and service contributors to the government and industry, ensures a robust emphasis on governance and accountability of funds.

Previously all the RRDCs were set up under the Commonwealth legislation of the Primary Industries and Energy Research and Development Act 1989 (now the Primary Industries Research and Development Act), as governmental agencies. The Act has laid down the purposes, roles, expectations and accountabilities of the RRDCs.

With the passage of time many RRDCs have transformed into independent, *not-for-profit* companies retained by the industries that they serve.

Presently there are 10-industry retained/owned company RRDCs. The industry-owned companies have been founded under Corporations Law of Australia and are bound by the requirements.

A Board of Directors commands each RRDC, which ensures that the assortment of funds and undertakings is well adjusted between small-, intermediate- and long-term needs of the government and industry, and also to ensure that prudent governance frame work is in place and operates efficiently.

Success Stories:

Through the funding of Horticulture Innovation Australia (Hort Innovation), an RRDC, an in-field robot has been developed, called the Ladybird. The robotdelivers intelligence on pests, crop nutrition and forecasts, and capability to eliminate weeds with possiblyenormousproficiency savings for horticulture growers of Australia.

The mechanization of on-farm procedures plays a conclusive role in diminishing input and amplifying output of imminent agriculture. Advanced technologies like this possesses the capacity for increasingthe productivity and yield, by having many of the manual tasks of farming performed by specially-designed agricultural robotic devices.

2.7. Entrepreneurs' Programme

The Entrepreneurs' Programme (https://www.business.gov.au/assistance/entrepreneurs-programme) is the Australian Government's flagship initiative for business competitiveness and productivity at the firm level. It provides practical advice and support for businesses, including: from people with private sector experience; co–funded grants to commercialize novel products, processes and services; funding to take advantage of growth opportunities; and connection and collaboration opportunities. This is building the capabilities of small and medium enterprises in key growth sectors.

The programme offers support to businesses through four elements:

- Accelerating Commercialization - helps small and medium businesses, entrepreneurs and researchers to commercialize novel products, services and processes
- Business Management - experienced Business Advisers and Facilitators review business operations, including business direction, strategy, growth opportunities and supply chain. They provide a report with strategies for business improvement and work with you to make them happen.
- Incubator Support - assists New and Existing Incubators to improve the prospects of Australian start-ups achieving commercial success in international markets, through helping them to develop their business capabilities.
- Innovation Connections - experienced Innovation Facilitators work with your business to identify knowledge gaps that are preventing your business growth. The outcome is an Innovation Facilitation Report.

Services are flexible, tailored and focused on value added advice and support. Services can be accessed by all Australian businesses, including those in regional Australia, subject to meeting the program's eligibility requirements. Practical support for businesses includes:

- advice from people with relevant private sector experience
- co-funded grants to commercialize new products, processes and services
- funding to take advantage of growth opportunities
- connection and collaboration opportunities.

Accelerating Commercialization

Provides successful applicants access to expert guidance and grants to find the right commercialization solutions for novel products, processes and services.	– Commercialisation Guidance – Accelerating Commercialisation Grant – Portfolio Services
Business Management	
Business Evaluation - Experienced Business Advisers review business operations, including business direction and strategy. The outcome of the review is an Evaluation Report that has business improvement suggestions.	A skilled Business Adviser will: – come to business premises for gathering information about the business – undertake further research and analyse the information off-site – prepare a tailored Business Evaluation Action Plan outlining strategies for taking the business to a more competitive entity.
Supply Chain Facilitation – Connect with and supply, within the present and upcoming markets	A skilled Business Adviser will: – Work closely to strengthen the supply chain – Improve the ability for accessing upcoming markets
Growth Services - will enable your business to identify and capitalise on growth opportunities more rapidly, easily, and capably, with less risk. The engagement will help your business build the capacity to accelerate growth.	A skilled Business Adviser will: – develop a Growth Plan to help reach a growth opportunity – provide support, advice and mentoring to build the necessary capabilities, culture, strategies and connections for growth – facilitate access to relevant advice, networks and knowledge – help maintain the growth momentum through regular meetings and follow-up.
Incubator Support	

The Incubator Support initiative provides grant funding to incubators to deliver support services to Australian start-ups with an international focus. Grants are available to support the establishment of new incubators in regions or sectors with high innovation potential, and for existing incubators looking to expand their services.	The Incubator Support initiative provides grant funding through two components to deliver Incubator Support projects, both of which require a funding contribution from applicants. • Support for New and Existing Incubators: – to help develop new incubators in regional areas and/or sectors with high potential for success in international trade – to boost the effectiveness of high performing incubators, including funding support to expand their services and/or develop the innovation ecosystem – to encourage incubators to work with more data-driven start-ups that use public data as part of their business. This component allows for a minimum grant amount of $26,000 and a maximum grant amount of $500,000 per project with a maximum grant period of 24 months. • Support for Expert-in-Residence: – to increase the capabilities of incubators and improve the chance of commercial success for start-ups in international markets by organizing and providing access to top quality research, managerial and technical talent through incoming and outgoing secondments of national or international experts. This component allows for a minimum grant amount of $5,000 and a maximum grant amount of $100,000 per project with a maximum grant period of 12 months.
Innovation Connections	
Innovation Connections Facilitation – provides the business with an innovation facilitator	Aids in – identifying gaps – identify opportunities to work with research organizations to test and develop new ideas – connect with other business assistance packages

	– find the expertise for supporting business.
Innovation Connections Grant - is available for undertaking a project based on critical and strategic research needs that were identified through facilitation and to engage in partnerships for the same.	Research projects must be in collaboration with a PRO and should develop a new idea with commercial potential. Researcher Placement – placing a researcher in your business (up to a maximum of $50,000) Business Researcher Placement – placing a researcher from your business into a PRO (up to a maximum of $50,000) Graduate Placement – employing a graduate or post-graduate with a relevant degree into your business to work on a specific Innovation Connections project (up to a maximum of $30,000).

Success Stories:

a) Stormseal – snugly getting owners back into their storm-damaged homes

Stormseal is a strong polyethylene film that heat shrinks to cover a damaged roof or wall. It is a highly cost-effective, versatile, premium product, for use by emergency responders, during insurance claim repairs, and in construction.

This invention was assisted to commercialisation by the Entrepreneurs' Programme, through $450,000 in Accelerating Commercialisation funding.

The Accelerating Commercialisation funding and services to Stormseal enabled the business to:

- build a nationally recognised training program for installation of the product
- establish a national logistic operation
- successfully complete a Suncorp insurance trial
- implement Intellectual Property protection strategies
- build a web portal for contractors which is used for continued learning and online ordering of Stormseal products
- and open international sales channels.

Stormseal is now being reviewed by various State Emergency Services.

Along with the various measures adopted by the Federal government, the governments of various states/territories in Australia have also taken steps for developing S&T and devise incentives/support programmes for encouraging the businesses and the academia to develop relations. Most states in Australia have appointed 'Chief Scientist' for developing keen relationships with the research society. The territorial governments have also looked upon the PRIs in that region for supporting initiatives in the priority domains. However, these programs and initiatives are significantly different over different jurisdictions.

A few of the important initiatives regarding translation of research for economic and societal benefit, in different territories, have been enlisted in the table –

Initiative	Rationale
New South Wales (NSW)	
Knowledge Hubs (http://www.industry.nsw.gov.au/business-and-industry-in-nsw/innovation-and-research/knowledge-hubs)	Industry oriented partnerships, between research organizations, businesses and industry associations, focused on industrial sectors in NSW. Purpose – sharing of knowledge, partner through means of shared projects. Sectors in which Hubs are active- • Digital Creative Knowledge • Energy Innovation Knowledge • Financial Services Knowledge • MedTech Knowledge • Transport & Logistics Knowledge
TechVouchers Programme (http://ww3.business.nsw.gov.au/TechVouchers/home.aspx)	Grants of up to $15,000 are provided to SMEs for accessing technical research structure and facilities like, testing, validation, and viability studies in NSW PROs like universities
Innovate NSW (http://www.industry.nsw.gov.au/business-and-industry-in-	For developing business-to-business (B2B) solutions and globally competitive industries. It associates technology SMEs and industries in key sectors of NSW economy. The program centers on development of

nsw/innovation-and-research/innovate- nsw)	answers that use 'enabling technologies'. *Enabling technologies - new technologies or new usage for prevailing skills that enable more efficient procedures, novel products/ services and more.* Innovate NSW acts in the following sectors: • E-health • Advanced manufacturing • Energy technologies and services • Online and interactive education • Transport, logistics and infrastructure
Medical Devices Fund (http://www.health.nsw.gov.au/ohmr/mdf/pages/default.aspx)	MDF aims at supporting individuals, companies, researchers, institutes, hospitals etc. in developing and commercializing medical devices and other related technologies. MDF has a funding of $5 million per annum. $16.4m has been committed towards the development and commercialization of 9 technologies in the first round.
Australian Technology Park (http://www.atp.com.au/Home)	The ATP was crafted in 1991 by the initiative taken by Universities of Sydney, NSW, UTS, and ANU for regenerating and re-using the site as an innovation hub. The ATP, which is managed by an independent Board, is a multiuse business zone where occupant companies are stimulated to network & collaborate.
Victoria	
Innovation and Technology Vouchers Programme (IVP and TVP) (http://www.business.vic.gov.au/su	IVP and TVP aspire to aid companies for undertaking R&D activities, plan research, absorb innovation-relevant abilities, and adopt novel technologies by offering a voucher, which can be substituted for approach to services, facilities, expertise, goods, or advice by other

pport-for-your-business/grants-and-assistance/innovation- technology-vouchers)	companies or PROs. Vouchers are available in different categories – • Tech. Student Accelerator Voucher (TVP) - Up to $10,000 • Innovation Skills Voucher (IVP) - Up to $10,000 • Smart Design Voucher (IVP) - Up to $25,000 • Business R&D Voucher (IVP) - Up to $25,000 • Tech. Development Voucher (TVP)- Up to $50,000 • Tech. Implementation Voucher (TVP) – Up to $250,000
Queensland	
Knowledge Transfer Partnerships Programme (http://advanceqld.initiatives.qld.gov.au/funding/best-brightest-fund/knowledge-transfer-partnerships.aspx)	Enables transfer of knowledge through means of encouraging SMEs to partner with academic institutions, for selecting specific graduates who will work on specific project of enterprise. Grants of upto $50,000 are available to the private sector for employing a graduate student. The funding endows two-thirds of the project costs and the business has to contribute only one third.
Business Development Fund (http://advanceqld.initiatives.qld.gov.au/funding/business-investment-attraction/business- development-fund.aspx)	Businesses are provided with access to $40 million investment through seed co-investment ranging from $125 000 to $2.5 million funding for assistance to turn novel ideas and inventions into commercial results. Investment of $1,25,000 to $2.5 million is available to match the money committed from private sector co-investors. An independent board of comprising of entrepreneurs evaluates and judges the applications. Grant of up to $50,000 /project is also available to the businesses for aiding the expenditure of engaging a graduate who will work on the project.
Brisbane Technology Park (http://www.brisbanetechnologypar	The initiative, originally founded by the Queensland government, aimed at connecting the research and technology oriented companies at one place. The Park is home to nearly 150 companies in the areas of biotech, mining, health, communications, software development,

k.com.au/)	electronics etc. Noteworthy medical and technical advances have materialized from the companies that started their set-ups on the Park. Example - *Endovascular Stent Graft Technology* developed by Cook Medical for treating aortic aneurysm disease, and the *Advancements in Food Safety Technology* developed by Symbio Alliance.
South Australia (SA)	
Innovation Voucher Programme (http://www.dmitre.sa.gov.au/manufacturing_works/programs_and_initiatives/innovation_voucher_program)	Aims at encouraging partnership between the SMEs and R&D organizations. This programme is a component of *ManufacturingWorks*, which is the manufacturing strategy of South Australia. Vouchers ranging from $10,000 to $50,000 are granted to research performers for helping SMEs, for solving technical issues and boosting innovation in the manufacturing area.
Premier's Research and Industry Fund (http://www.statedevelopment.sa.gov.au/science/premiers-research-and-industry-fund)	The PRIF aims at encouraging investments in R&D areas, which possess potential for commercial benefits. The various elements within the PRIF are - • *Catalyst Research Grants*–Grant for S&T research projects in SA, being undertaken by 'Early Career Researcher' in association with an industry or end user partner. • *South Australian Research Fellowships* – funding for expanding the research talent within the territory so as to benefit the industry as well as economy. • *Collaboration Pathways Programme* - for facilitating linkagesamongst the public and private sectors • *InternationalResearchGrant* - for supporting South Australian S&T research being in association with an international associate.
Photonics Catalyst Programme (http://www.adelaide.edu.au/ipas/pc	PCPfinances the maturity of pioneering photonic products such as lasers, sensors and optical fibres by means of project centered links between manufacturers of SA, research performers, government and

p/)	end-users. Participants are eligible for receiving commercial as well as technical viability evaluation of their venture and R&D services worth $45,000 for assistance in development of new prototype or product.
BioSA (http://bioinnovationsa.com.au/) **BioSA Industry Development (BID) Grant** (http://bioinnovationsa.com.au/programs-funding/biosa-grants/;http://bioinnovationsa.com.au/wp-content/uploads/2015/01/BID-Guidelines_20130213.pdf)	The initiative leverages topnotch services in R&D and commercialization and is positioned to facilitate connections between investors and the industry. Bio SA provides: • Access to funds - grants, venture capital and other finances • Connection to technology investment opportunities in SA • Infrastructure support through two business incubators • Co-location with a cluster of 60+ high-tech companies. • Business assistance catalyzing companies towards technology commercialization • Access to international networks Intends to enhance the commercialization activities assumed by bioscience companies, institutes and other enterprises in SA. It mainly assists organizations in commercialization of their research and gives early stage companies the funds for achieving their milestones for furthering their business and to raise equity finance. As directed by the BID guidelines, repayable funds amounting from $50,000 to $250,000 can be utilized for different activities leading to commercialization.
Small Business Innovation Research Pilot Programme (http://www.statedevelopment.sa.gov.au/industry/manufacturing/manufacturing-programs-and-initiatives/small-business-innovation-research-pilot-	It incites the SMEs to collaborate with various research providers for developingsolutions to the problems encountered by the government organizations. The SBIR pilot programme is undertaken in two phases – • Phase 1 (viability stage)– permits theactivity of development and proof of concept. Up to 5 companies can be contracted as part of Phase 1, for up to 6 months at $100,000 each.

program?q=small%20business%20innovation%20research)	• Phase 2 (development stage) – covers highly intensive R&D and detailed development of product. As the objective of the SBIR is to focus on advancement of SMEs and enhance commercialization activities, the following metrics are identified as success measures – • Commercialization activities undertaken • Turnover of the company • Number of IP generated – patents, copyright, trademarks etc. • Additional funding sourced through VCs or other sources • Partnerships between SMEs and research or SMEs and SMEs
Western Australia (WA)	
Advancing western Australian Research Education (AWARE) (http://www.waresearch.com/) (https://www.iprep.edu.au)	AWARE, an initiative supported by state government, is a linkage amongst five universities in WA. The initiative provides education, training, professional development and industrial experience for doctoral students postgraduate researchers. iPREP – one of the element of AWARE, fosters partnership for research between academia and industry, through the means of employing interdisciplinary teams of doctoral students for a short-term project with industrial partner.
Innovation Vouchers Programme (IVP)	IVP assists SMEs in overcoming several barriers that exist on the path to commercialization.IVP provides monetary assistance to the SMEs for accessing services and professional skills, for advancing their commercialization activity in WA. IVP eligible expenditure includes: • R&D services (e.g. technical development, compliance testing, proof of concept, product testing, validation, laboratory verification and certification) • Development of the product • Protection of IP, licensing, legal services, tech. transfer • Support services for commercialization (strategies and feasibility studies) An amount of up to $20,000 per voucher is allowed. Beneficiaries are required to provide a net cash co-investment of matched funds at a rate

	not less than 20:80 of applicant to State Government funding.
Australian Capital Territory	
Innovation Connect (http://www.business.act.gov.au/grants-and-assistance/grants/innovation-connect)	Supports businesses during the premature stages of production of an innovative service/product for commercialization. This initiative has two categories - • Proof of Technology: \$5,000 to \$50,000 of matching funding for development of prototype. • Accelerating innovation: \$5,000 to \$10,000 of matching funding to further the commercialization of innovation.
Epicorp (http://www.epicorp.com.au/index/home.html)	Epicorp was established in 2001 as a centre of commercialization excellence. It was supported by a \$4.57m ITC incubator programme (ICTIP) grant from the Federal Government Department of Communications, Information Technology, and The Arts (DCITA), a supporting grant from the ACT Government, and the provision of buildings by CSIRO. Epicorp has focussed on the early-stage commercialization of research from the country's pre- eminent centres of innovation by working closely with Australian's major research institutions

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Models of Public-Private Partnership in R&D being practiced in Asian Countries

Japan

Content

1. Introduction

Japan invested around 3.28% of its GDP for R&D activities during 2015 (World Bank data) and is ranked as the third most R&D- intensive country. By 2020, it is planning to increase the GERD to 4% of GDP, which amounts to about USD 246 billion PPP (JPY 26 trillion). In the Global Innovation Index, 2017, Japan is ranked 14th and as according to the Global Competitiveness (GCI, 2017-18) Index, Japan is ranked 5th regarding "*Company Spending on R&D*". In the same report it occupies 23rd rank regarding "*University- Industry collaboration in R&D*". The 5th S&T Basic Plan (2016-20), which was prepared by the Japanese Cabinet Office with the input of experts from various sectors, identifies the safety and security of the country and its people, sustainable development, climate change and biodiversity as overarching goals for determining a medium to long term STI strategy in Japan.

Table1: Global ranking of Japan, as based on S&T related indicators.

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	85
2.	Research & development (R&D)[a]	3
3.	Gross expenditure on R&D, % GDP[a]	3
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	4
5.	QS university ranking, average score top 3[a]	8
6.	University/industry research collaboration[a]	17
7.	Capacity for Innovation[b]	21
8.	Company Spending on R&D[b]	5
9.	Availability of Scientists and Engineers[b]	8
10.	Quality of Scientific Research Institution[b]	14
11.	Publications[c]	5
12.	H-index[c]	4
13.	International Property Rights Index [d]	8
14.	PCT patents[b]	1

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

Highlights of the Japanese STI system

The first *Science and Technology Basic Plan* which was based on the Science and Technology Basic Law (1995) was launched in 1996. It envisages the creation of new systems for R&D to adapt to the changing times and to promote cooperation and interactions among the public and private sectors.

Through the instrumentality of the Ministry of Economy, Trade and Industry (METI) and Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan made some crucial changes in its legal system for promoting public-private partnership. The **TLO** (Technology Licensing Office) **Act** which is an Act for the promotion of technology transfer from universities to private business operators was established in 1998, though which METI and MEXT promoted the TLO by providing support and subsidies etc. Subsequently, the Act on Special Measures Concerning Revitalization of Industry and Innovation in Industrial Activities, which included the Bayh-Dole clause, was established during 1999. Through this act, universities or public research institute are enabled to license their patents developed through utilization of public funds.

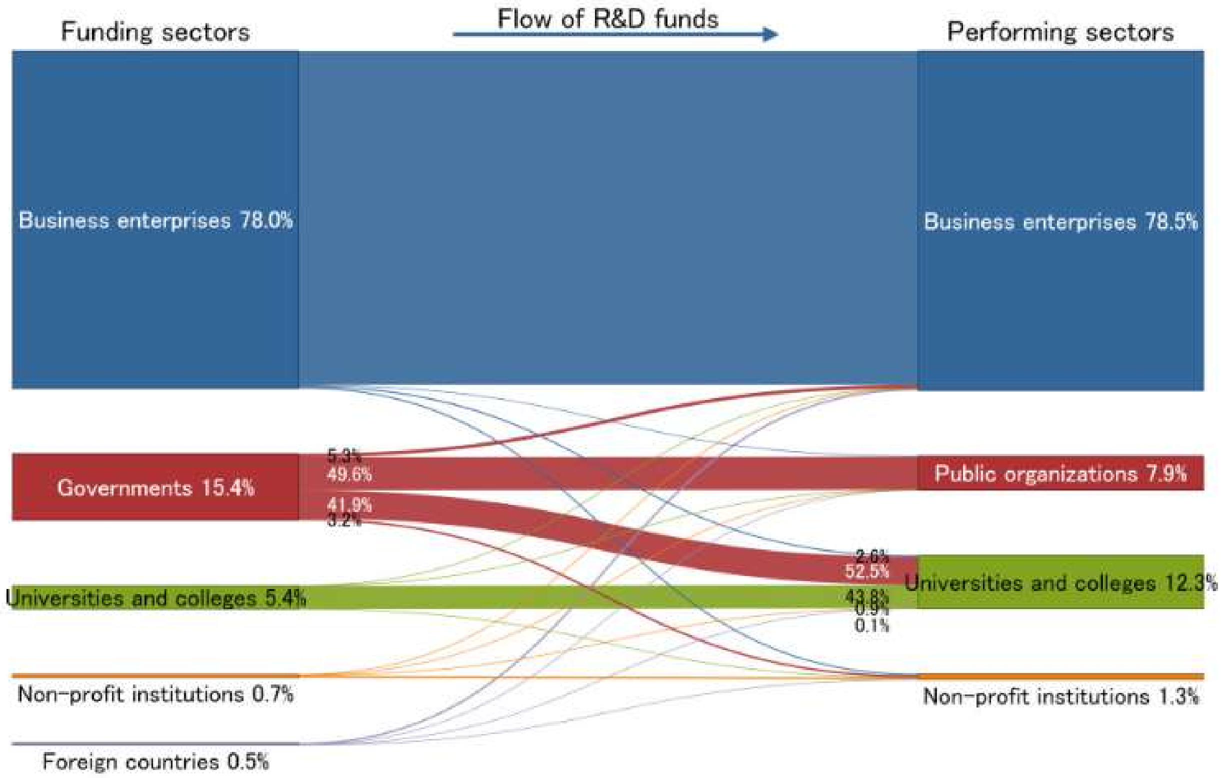
During the restructuring of Japan's Central a Council for Science and Technology Policy (CSTP) was established in the Cabinet Office of Japan in 2001. In the same year the second *Science and Technology Basic Plan* was also introduced. The importance of linking industrial activity with R&D activities in order to pass on the R&D outcomes to the society at large was one of the important focus of this plan thereby stressing on the importance of Public Private Partnership for R&D. The publicity to the issues of public private partnership in the universities and the private sector industries was the responsibility of the CSTP. An exhibition known as '*Innovation Japan*' was initiated by CSTP in order to highlight the R&d strengths of the Japanese universities. Such initiatives helped in enhancing the cooperation between the industry and university.

Apart from these measures, there are various other programs in this direction. Universities were encouraged and supported in their efforts to establish Intellectual property offices in their campuses through the instrumentality of MEXT. In 2004, universities which were earlier affiliated to MEXT were incorporated as independent universities of national status thereby enhancing their possibility of collaborating with the industry. The *Basic Act on Education* in 2006, was also amended to include the social contribution as the third role of universities apart from education and research. MEXT, METI and ministries for technology transfer and collaboration between universities and companies also took up other relevant measures in order to boost university-Industry collaborations. Just for instance, for joint research with industries universities were provided special subsidies for building joint research facilities where industry and university scientist work under one single roof. As a cumulative result of such measures, after 2001 the number of technology transfer and collaboration increased substantially.

The number of universities patents increased ten folds for domestic patents and seven folds for overseas patents in the period 2005 to 2013. The income from licensing and tech transfer also increase 3.5 folds in the period 2005(6.4 billion yen) to 2013 (2.2 billion yen). During 2013, the joint research income was 51.7 billion yen which was just 32.3 billion yen in total in 2005.

All the subsequent S&T Plans of the Japanese Government focused on PPP as an integral part for the purpose of building and sustaining a technologically advanced nation. The Fifth *Science and Technology Basic Plan*, launched in 2016, gives due importance on establishing systems for expanding the partnerships between industry, academia, and government and for the promotion of inclusive innovations. The *Japan Revitalization Strategy, 2016,* has a clear policy prerogative & target for achieving reforms in the university system to foster Industry-Academia-Government collaboration.

The Japan Business Federation report which was released in February 2016 and titled "*Towards Strengthening of Industry-Academia-Government Joint Researches*" elaborates on the requirement for promoting full-scale, top-level industry-academia-government cooperation along with necessary reforms in the domestic universities and research institutes.



Reference: Chart 1-1-5, Japanese Science and Technology Indicators 2017 (in Japanese)

Figure 1: Flow of R&D funds from funding sectors to performing sectors in Japan (based on OECD estimate, 2015.

The above figure 1 exemplifies the involvement of the industrial sector in the Japanese R&D activities where the Japanese business enterprises contributed 78% of the total research funding which can be taken as a successful outcome of the above mentioned policy interventions. The government agencies contributed around 15.4% while the universities and colleges shared 5.4%. The non-profit institutions and foreign countries catered to 0.7% and 0.5% R&D funding respectively.

In the pages that follow we will briefly discuss the various schemes and programs under various agencies which facilitate the flow of knowledge between Industry and Academia with the vision of promoting translational research.

2. Schemes/Programmes/Organization

Japan Science and Technology Agency (JST)

The Japan Science and Technology Agency (JST) is responsible for the development of Japan's science and technology (S&T) and acts as an innovation navigator with the main aom of achieving a sustainable society through application and promotion of S&T by opening up opportunities in innovation. Since its inception, (Mention year) JST's has many outstanding achievements which have been recognized at the global level through collaboration with the government, universities and the industrial sector.

The R&D Programs focused on Technology Transfer through Industry Academia Interaction under the aegis of JST can be divided into the following groups:

A) Promotion of Practical Application

I) Adaptable and Seamless Technology Transfer Program through Target-Driven R&D **(A-STEP)**
II) Collaborative Research Programs based on Industrial Demand
III) Strategic Promotion of Innovative Research and Development (S-Innovation)
IV) Newly Extended Technology transfer Program (NexTEP)
V) Development of Advanced Measurement and Analysis Systems
VI) Matching Planner Program

B) Formulation of Innovation Hub

I) Centre of Innovation (COI) Program
II) Program on Open Innovation Platform with Enterprises, Research Institute and Academia (OPERA)
III) Research Complex Program
IV) Super Cluster Program
V) Support program for starting up innovation hub

C) University Start-ups foundation & Investment

I) Project for Creating Start-ups from Advanced Research and Technology (START)
II) SUpport program of Capital Contribution to Early-Stage companies (SUCCESS)

Funding Programs for PPP under Japan Science and Technology Agency (JST)

A) Promotion of Practical Application:

2.1 A-STEP Program

A sizeable percentage of government expenditure for R&D activities are directed to the universities and close industry , and its research results are needed to contribute partnership is required in order to pass on their research output to the society. For this purpose, the *A-STEP (Adaptable and Seamless Technology Transfer Program through Target-Driven R&D)* program is utilised for the practical application of university research. This scheme supports the R&D collaboration between industry and academia across a range of phases that lead to the commercial applications of research output generated by basic research in Japanese universities. A-STEP is specifically designed to provide support for collaborative university- industry R&D for technology development across different phases. It is up-to JST to determine the suitable A-STEP funding for each phase. The optimal fundingis decided on a medium to long term basis taking into consideration the phase of R&D and the expected outcome. The main aim of this program is to realize highly effective and efficient innovation based on the academic research carried out in the universities by bridging the gap between university R&D and actual industry needs.

The A-STEP program takes into consideration three different stages-Stage I, Stage II, and Stage III. The whole spectrum of technology development that ranges from the potential verification of technological seeds to development for practical application is covered in this program.

Stage I: The first stage that is Stage I consists of two support types- “Strategic theme-focused type” and “Industrial needs response type.”

- The main mission of the “Strategic theme-focused type” translate the outstanding research outputs generated through JST’s basic research programs to products and processes of social relevance by establishing new industries. The selection of R&D projects under this program is based on the potential application of the research achievements of JST’s basic research programs. Every year one or two R&D themes are selected for support by the JST, open proposals for funding are called and five projects for each theme are supported. A research team consisting of academic and industrial scientists can apply for such support.
- The main aim of the “Industry needs response type” is to enhance the competitive advantage of the Japanese industries by providing practical solutions to the technical challenges prevalent in the industry. Based on the inputs from groups of industry, JST selects the R&D focus, rather than individual companies. Every year one or two research themes are selected and about 10 projects for each theme are supported. In this type of support, only be

academic researchers can apply however, JST annually organizes meetings between industry and academia once or twice for each theme so cross flow of ideas can happen across the sectors.

Stage II: The difference between stage I and Stage II is that in stage II all S&T fields except for the medical and pharmaceutical fields are targeted whereas in stage I it is restricted to only the selected specific R&D themes. Stage II has only one support type, the “Seeds development type” where the aim is to minimize the technical risks accompanying the academic research outcomes and to select the relevant and competent private companies for utilizing the technology seeds developed by the academia.

Under this funding type, both academic and industry researchers can utilize the funds from JST, however a portion of the R&D expenditure needs to be shared by the participating companies. A matching fund equal to one fourth to half of the fund provided by JST needs to be provided by the participating company which is determined according to their capital size.

Stage III: This stage supports the R&D phase that is very close to the product commercialization stage. Private companies are the main applicant in this stage. There are two types of funding in this stage i.e., “NexTEP-A type” and “NexTEP-B type”. The categorization in these two types is dependent on the R&D scale and its time period, as well as the size of the applicant company.

NexTEP-A type provides an interest-free loan, suitable for private companies that will undertake the challenging task of exploring the practical application of high risk academic research outcomes. If the participating company succeeds in achieving their technological goal (which was set together with JST) through this support, they have to repay the loan received through this program along with some percentage of their sales proceeds resulting from the project. However, if the pre determined technological goal is not achieved, only 10% of the total R&D cost needs to be repaid.

- *NexTEP-B type* is meant only for SMEs and restricted to relatively small-scale development research activities. There is no repayment obligation under this program, however there is a requirement to share a matching fund of half of the total R&D cost involved in the R&D project. Additionally it is obligatory to pay a percentage of the revenue generated from the R&D results from such project supported by the JST for a period of up to 10 years.

A summary of the support offered by the program to various applicants at different stages of R&D has been depicted in Table 2.

Table 2 Support offered by the A-STEP Program

	Stage I		Stage II	Stage III	
Support Type	**Industrial needs response type**	**Strategic theme-focused type**	**Seeds development type**	**NexTEP-B type**	**NexTEP-A type**
Objectives	Bolster Japanese industrial competitiveness by contributing to the solution of technical issues common in industry	Return outstanding achievements of JST’s basic research programs to society and create the foundations of new industries	Lower the technical risks of research outcomes of academia and establish core competency of private companies by utilizing academia’s technology seeds	Support private companies who carry out high-risk development which uses research achievements of academia. + (NexTEP-B is available only for small and medium-sized enterprises whose capital is 1 billion yen or less.)	
R&D Fields	Specific R&D themes*1		Broad area*2		
Applicants' Affiliation*3	Academia	Academia and Industry	Academia and Industr-y	Industry	
IP	Not required		Required		
R&D Expenses (supplied by JST)	up to \ 25 million per year	up to \ 50 million per year	\ 20 million ~500 million per R&D period	Up to \ 300 million per R&D period	Up to \ 1.5 billion per R&D period
	Grant		Matching funds	Matching funds plus payment of royalties	Quasi-loan plus payment of royalties
R&D Period	2～5 years	Up to 6 years	2～6 years	up to 5 years	Up to 10 years

Source:https://www.jst.go.jp/tt/EN/univ-ip/a-step.html#supportContent

Example of products/technologies developed through the A-STEP Program

a) *Product Name: Autologous Cultured Cartilage "JACC" Development*
Company: Japan Tissue Engineering Co., Ltd. (J-TEC)
Academic Institute: Hiroshima University
Prof. Mitsuo Ochi of Hiroshima University established the therapeutic technique of autologous cultured cartilage transplantation, where a cartilage is isolated from the patient's knee, and cultured along with atelocollagen gel and structured into a three-dimensional form. The technology was transferred to Japan Tissue Engineering Co., Ltd. (J-TEC). This technology has been approved by the government in July 2012, and is covered under the national insurance from April 2013.

b) *Product Name: Clearforest*
Company: Japan Aroma Laboratory Inc.
Academic/Research Institute: Forestry and Forest Products Research Institute

It is a novel method for the distillation and purification of air purifying essential oils from the abandoned coniferous trees and branches. This technology was jointly developed by the Japan Aroma Laboratory Inc. along with Forestry and Forest Products Research Institute. Along with other applications, the spraying of this essential oil has the ability of eliminating pollutants like nitrogen dioxide. The extraction method is based on a microwave vacuum controlled extraction apparatus known as the "Clearforest". This apparatus enables the extraction of range of essential oils which are useful for air purification.
The translation of advanced technology seeds developed by universities and other public research institutions is promoted by the JST. The development of critical human resources which are required for I-A collaboration including tech transfer activities for the translation of academic research is also supported by JST.

Other initiatives (table 3) of JST for enhancing collaborative R&D include:

Table 3 Initiatives of JST

Initiative	Characteristics
J-STORE (JST Science and Technology Research Result Database for Enterprise Development)	J-STORE is a database open to the general public free of charge, comprising patents and unpublished patents held by universities, JST and other parties, which are available for licensing to companies.
Innovation Japan: University Technology Exhibitions	To promote the practical application of research output from universities and public research institutions, JST organizes national-scale university knowledge fairs with the aim of matching high-quality technology seeds with the needs of industry.
New Technology Presentation Meetings	Inventors present their own perspectives on the potential for commercial applications for their new technologies to companies. In addition, opportunities are provided for direct dialogue with individual inventors. Companies may ask questions relating to presentation themes and discuss requests relating to joint research and the adoption of technologies. Approximately 60 New Technology Presentation Meetings are held each year.
Open Innovation Seminars	Companies communicate their research-related needs to universities, including issues that require short-term solutions and issues on which companies wish to conduct collaborative research. The main objective of Open Innovation Seminars is to facilitate the generation of new technology.
Portal Site for Industry-Academia-Government (IAG) Collaboration	The Industry-Academia-Government Guidepost Website provides a wide range of information relating to IAG collaboration for all interested parties to meet their information needs. The site

	is open to the general public for free.
Industry-Academia-Government collaboration support database	Online database that has a wide range of available information to support the parties involved in IAG collaboration • Program and project database ➢ R&D support programs conducted by public institutions like national and regional government agencies ➢ Financial assistance programs operated by foundations and other bodies ➢ Venture capital • Database of experts involved in coordination and promotion of IAG collaboration • Database of events related to IAG collaboration

2.2 Collaborative Research Based on Industrial Demand

Vision:

The promotion of basic research that has the potential to bring about practical solutions to technical themes across the industrial sector.

Objectives of the Scheme

This program provides mechanism for feedback for the alignment of basic research based on the perspective and requirement of the industrial sector. It facilitates interaction between the industrial and the academic sectors. Through such a mechanism, universities and public research institutions conduct basic research that will lead to solutions to technical challenges that are common across the industrial sector, as well as provides solutions to technical themes in the industrial sector. The stimulation of basic research at universities and alignment with industrial needs in order to enhance Japan's competitiveness is the main aim of this program.

Table 4: Important feature of Collaborative Research

Number of projects approved	Up to approximately 10 per technical theme
R&D period	Approximately 10 years maximum for each technical theme (approximately 2–5 years for each research project)
R&D phase	Basic research driven by the needs of industry
Research funding (including indirect costs)	Approximately ¥300 million per year for each technical theme (Contract fund)
Research system	In addition to universities carrying out basic research, industry and academia keep in close contact for the exchange of opinions through a "Forum for Collaboration and Innovation."* * This refers to a communication platform for the exchange of opinions between industry and academia so that the output from basic research at universities can be utilized by industry.

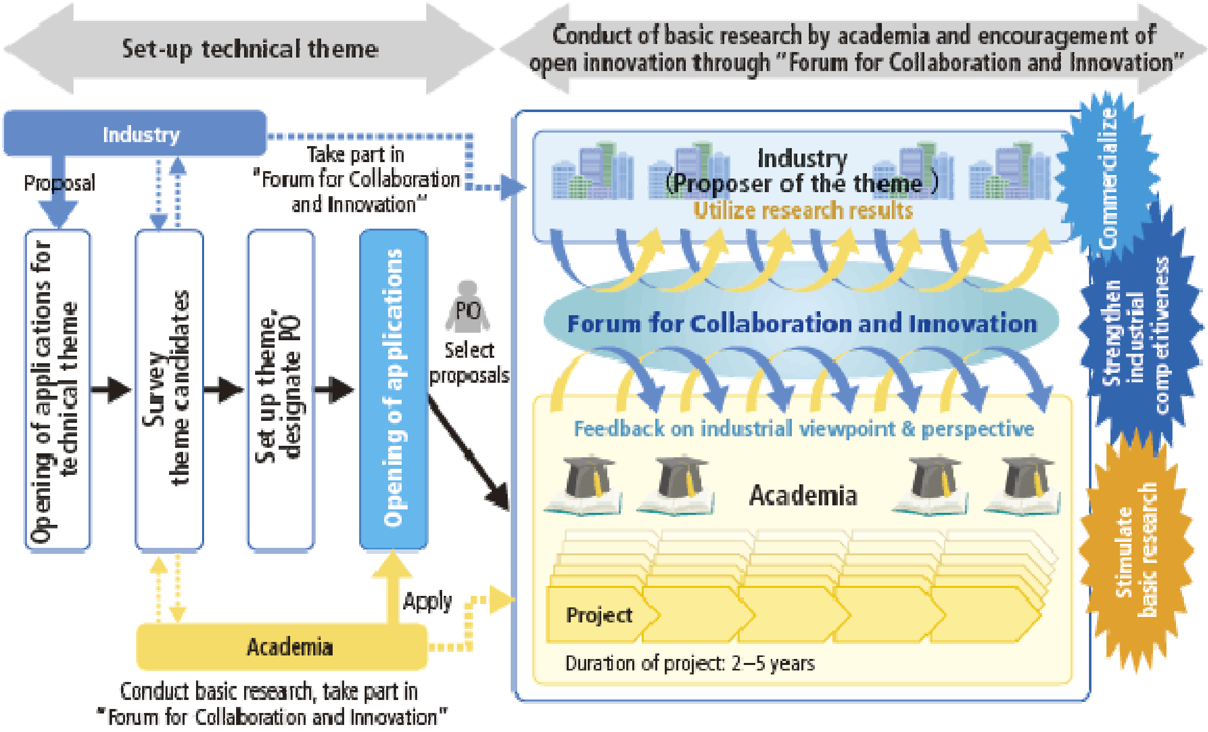


Figure: Schematic representation of Collaborative Research Based on Industrial Demand

2.3 Strategic Promotion of Innovative Research and Development (S-Innovation)

Vision: Providing a common platform for bringing together academic and industrial researchers in order to generate innovation, based on attractive R&D themes.

Objectives

S-Innovation program is geared towards the seamless and long-term pursuit of R&D activities directed for achieving practical applications of novel technologies. The technologies resulting from such innovative research will lead to the formation of future new industries. The R&D themes for this program are selected from among the research outcomes of basic research programs supported by JST, such as CREST, ERATO, PRESTO and SORST.

S-Innovation Support Content

Number of projects approved	Approximately five projects per R&D theme		
R&D period	Maximum period of 10 fiscal years (comprising three stages)		
R&D phase	Stage I	Stage II	Stage III
	Basic and foundational R&D aiming to establish component technology	R&D of component technology	R&D of applications (verification testing aimed at commercialization of product)
R&D period by stage (approximate)	2~3 years	3~4 years	2~3 years
R&D funding (including indirect costs)	Up to 70 million yen per project team		
	Contract fund	Contract fund	Matching fund
R&D system	Industry-academia collaborative R&D teams are formed through partnerships between companies and universities, etc. The Project Manager (PM), who is responsible for team coordination, is chosen at the time a proposal is submitted. Centering on the PO, each PM works to share information among teams as R&D proceeds.		

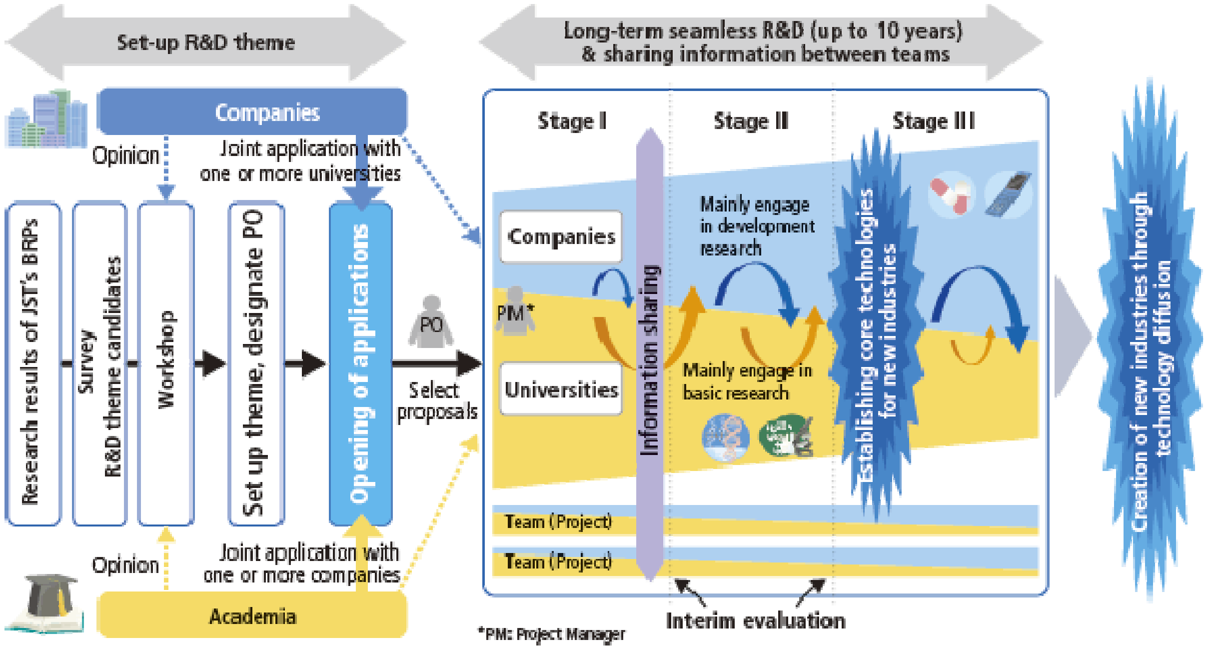


Figure: Schematic representation of S- Innovation

Table: R&D themes and topics (projects) of FY2012

R&D theme: Bio-functional Materials

PO: Dr. Hiroo Iwata (Director and Professor, Institute for Frontier Medical Science, Kyoto University

Topic (project)	Main company (industry)	Main university (academia)
Creation and application of core technology of extracorporeal circulation treatments aiming at immunological control	Asahi Kasei Corporation	Kyoto University
Biofunctionalization of Metallic Biomaterials -A vital point of supporting long healthy life in musculoskeletal medicine-	Nakashima Medical CO., LTD.	Tokyo Medical and Dental University
Reconstruction of motor and sensory functions by mRNA-integrative biofunctional structural materials	Teijin Limited	The University of Tokyo
Development of Hyper-biocompatible Surface Technology on Biomedical Materials Based on Photochemical Science	NOF Corporation	The University of Tokyo
High strength TiNi alloy stent by atomic/nano-scale microstructure control	Terumo Corporation	Osaka University
Creation of innovative system for regeneration and reconstruction of hard tissues	GC Corporation	Kyushu University

Tissue regeneration with bioactive scaffolds based on spatial arrangement and functional manipulation of cells	JMS CO.LTD.	National Cerebral and Cardiovascular Center
Development of the specific adsorbent for LAP positive T cells and TGF-b for application to cancer therapy	Toray Industries, Inc.	Shiga University of Medical Science

2.4 Newly Extended Technology transfer Program (NexTEP) (Text in Japanese Only)

Adapting measures to mitigate financial risks involved with Company's high risk development.

Companies have their own business plans based on university's research results, yet many are not executed due to the developmental risks. NexTEP aims to accelerate commercialization by supporting company's large-scale practical development and obtain the sutainable business growth.

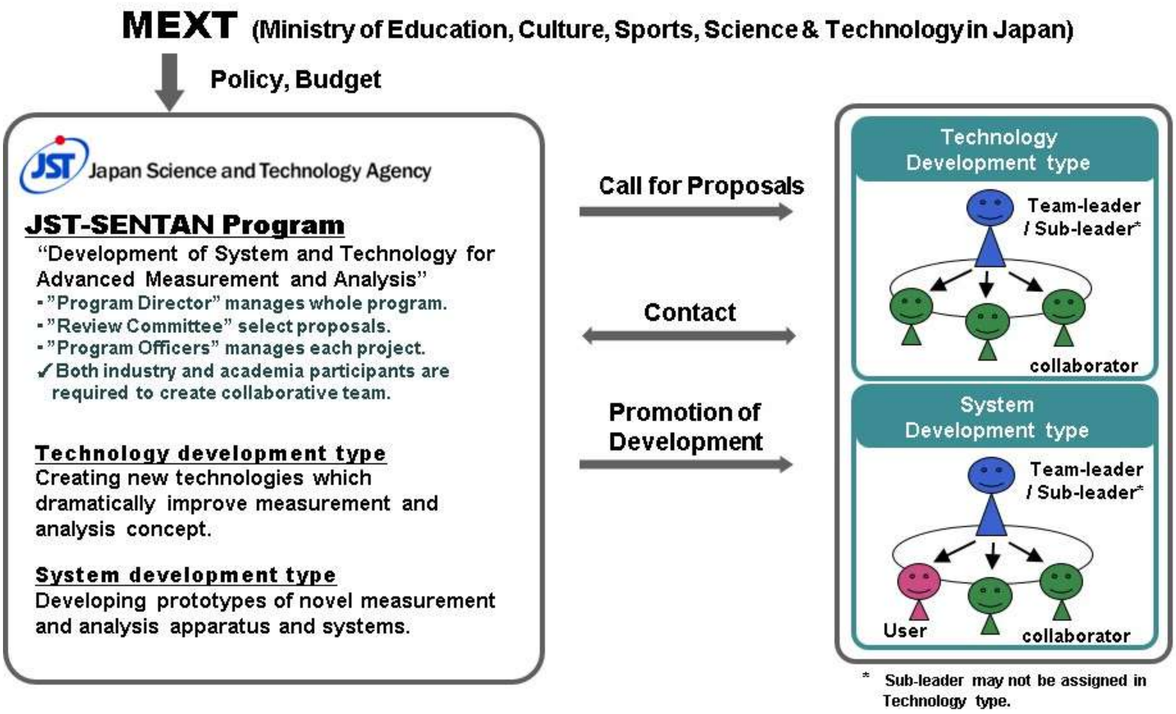
2.5 Development of advanced measurement and analysis systems

Purpose

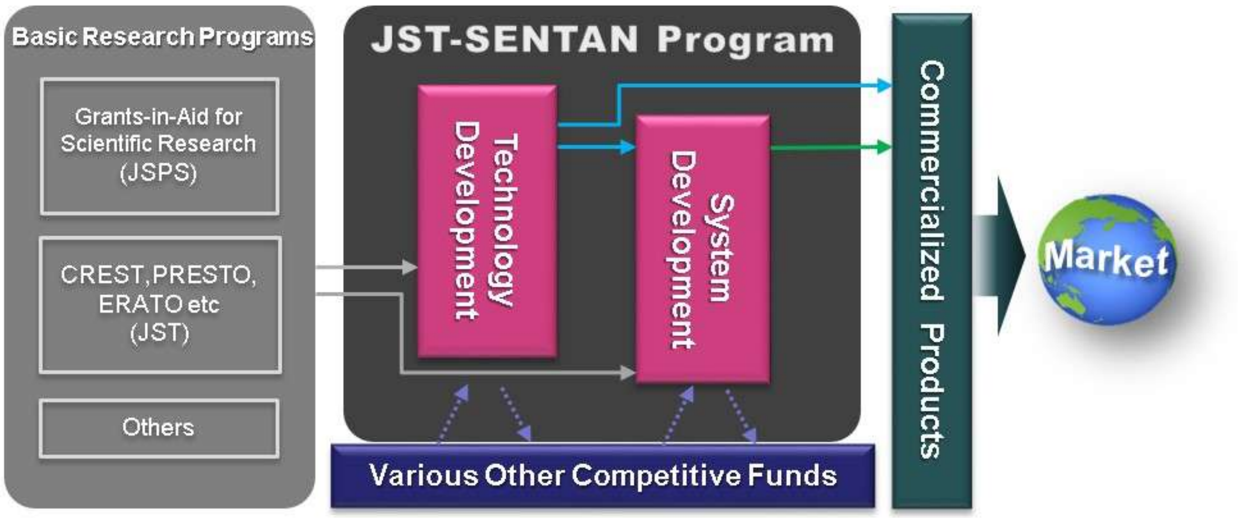
The aim of this program is to develop innovative systems and technologies in the area of advanced measurement and analysis through four programs covering the various stages of technology development in order to satisfy the frontier needs in academic research as well as industrial research and production.

Features of JST-SENTAN Program

- JST-SENTAN program is directed towards development of systems and technologies for advanced measurement and analysis, in order to meet the frontier research needs and production requirements.
- The three support types are set to promote the effective implementation of each development project.
- JST calls for proposals though wide publicity reviews the proposals and them and selects relevant projects.
- It is compulsory for the development team to include both researchers from Industry as well as the academia.



Scope of JST-SENTAN Program



2.6 Matching Planner Program (Text in Japanese Only)

Vision: Solving local company's technological problems by introducing universities' research outcomes.

"Matching planners" who have lots of experience in technology transfer are assigned to several regions in Japan. They figure out local company's technological challenges and match them to high-potential research outcomes from universities all over Japan by utilizing JST's networks. Through these activities, this program aims to solve local company's technological problems and eventually lead to creation of the regional innovation.

B) Formulation of Innovation Hubs

2.7 Center of Innovation (COI) Program

Objectives

This program which was launched during 2013, by the ministry of Education, Culture, Sports, Science and Technology (MEXT) is one of the funding programs under the Center of Innovation Science and Technology based Radical Innovation and Entrepreneurship Program (COI STREAM).

Though this program MEXT:

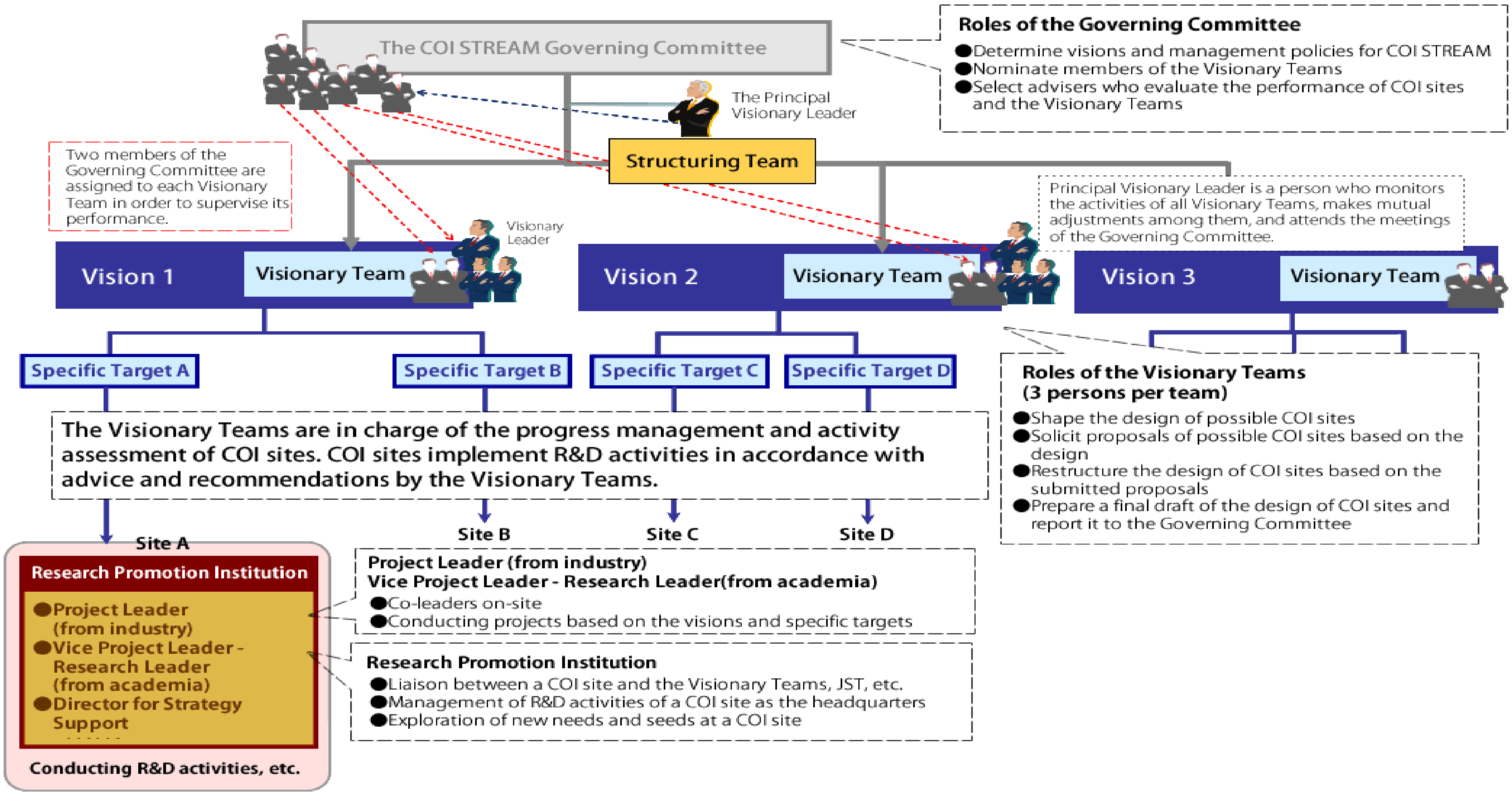
- Uses backcasting method in order to realize a desirable society and way of life
- Identifies R&D challenges that hinders the realization of the envisaged goals
- Works independent of the traditional research fields and existing organizations
- Provides strong support for industry-academia collaboration aimed at translating basic research to practical application.

In this program, Industry-Academia collaborative teams are formed and supported by JST with a focus aim to solve high risk, fundamental, multi- and interdisciplinary R&D challenges with great potential for social applications.

There is flexibility ingrained in this program and at any stage during the R&D period, the I-A collaborative structure of their collaboration adjusted and optimized according to the overall circumstances. The main locations where the team activities are conducted are known as the "COI site." The participating companies in a team make suitable contributions in terms of financial, human resources and other resources.

Structure

The COI STREAM comprises of COI STREAM Governing Committee and Visionary Teams. The Governing Committee is responsible for determining visions and management policies for COI STREAM while the Visionary Teams are set up for each vision and in charge of shaping the detailed design of COI sites along the visions.


The COI STREAM Governing Committee
The Principal Visionary Leader
Roles of the Governing Committee
●Determine visions and management policies for COI STREAM
●Nominate members of the Visionary Teams
●Select advisers who evaluate the performance of COI sites and the Visionary Teams
Two members of the Governing Committee are assigned to each Visionary Team in order to supervise its performance.
Structuring Team
Visionary Leader
Principal Visionary Leader is a person who monitors the activities of all Visionary Teams, makes mutual adjustments among them, and attends the meetings of the Governing Committee.
Vision 1
Visionary Team
Vision 2
Visionary Team
Vision 3
Visionary Team
Specific Target A
Specific Target B
Specific Target C
Specific Target D
Roles of the Visionary Teams (3 persons per team)
●Shape the design of possible COI sites
●Solicit proposals of possible COI sites based on the design
●Restructure the design of COI sites based on the submitted proposals
●Prepare a final draft of the design of COI sites and report it to the Governing Committee
The Visionary Teams are in charge of the progress management and activity assessment of COI sites. COI sites implement R&D activities in accordance with advice and recommendations by the Visionary Teams.
Site A
Site B
Site C
Site D
Research Promotion Institution
●Project Leader (from industry)
●Vice Project Leader - Research Leader (from academia)
●Director for Strategy Support
Conducting R&D activities, etc.
Project Leader (from industry)
Vice Project Leader - Research Leader(from academia)
●Co-leaders on-site
●Conducting projects based on the visions and specific targets
Research Promotion Institution
●Liaison between a COI site and the Visionary Teams, JST, etc.
●Management of R&D activities of a COI site as the headquarters
●Exploration of new needs and seeds at a COI site

1. Structure of a COI Site

A COI site comprises of one Project Leader from industry and one Research Leader from academia.

It is the responsibility of Project Leaders to manage the overall working of COI sites and their R&D activities, while Research Leaders overlook the day-to-day activities of the headquarters of COI sites and provide support in the R&D strategic planning, etc. If a COI site is made up of several research institutes, a single leading institute is identified as a representative institute for the COI site.

2. Conclusion of Entrusted Research and Development Agreement

Al the research institutions involved in a COI site need to tender a R&D agreement with JST along with a consent letter for the implementation plan of the COI site. A Memorandum of Understanding (MoU) regarding general collaborative activities as well as sharing of intellectual property arising from the cooperative research, etc needs to be signed by all the participating stakeholders.

3. Research and Development Expenses

The maximum R&D funding including overhead expenses for a COI site is fixed at 1 billion yen per year.

4. Research and Development Period

The COI site is supported by JST up to a period of 9 years after which they are expected to transform into an industry-centered innovation platform having their own resources for self-sustenance and work towards the accomplishment of radical innovations.

5. Required Documentation

The various reports that are required to be submitted to JST by the COI are as follows:

- Annual implementation report
- Annual accounting management report
- Final completion report

6. Program Management by the Visionary Teams

A supporting committee is formed by the JST which works in close association with each of the Visionary Team of a COI. This committee conducts reviews for the proposals of potential COI sites, and carries out interim performance assessment after every three years on the request of the COI visionary team. At the conclusion of the R&D period, the final performance assessment is also carried out by this committee. The progress of its COI sites are closely monitored and mentored by the Visionary Teams through both online means and onsite visits. If the need for redirection of the COI activities and restructuring of the teams are felt to be necessary by the visionary team, the Structuring Team under the leadership of the Principal Visionary Leader effects the required changes and undertakes adjustments among the participating stakeholders.

2.8 Program on Open Innovation Platform with Enterprises, Research Institute and Academia (OPERA) (Text in Japanese Only)

In order to promote new major industries in this program, industry and academia collaborate on planning a "technology and system innovation scenario", and the program promotes R&D based on this scenario executed by their tight collaboration. The main aim is to enhance industry-academia partnership concerning basic research and human resources development, and to develop open innovation in our country.

2.9 Research Complex Program

This program was initiated by JST during 2015 and is a five year program. It is aimed at providing support for the establishment of a research complex that will generate a continuous flow of technological innovations. For this purpose the strategic integration of universities, research institutes and private companies is a critical requirement.

The program highlights is as follows:

(1) Use of aid

The following areas listed below will be supported by JST:

- R&D collaborations in different fields
- Venture funding
- Advanced equipment sharing
- Employing world class manpower
- Putting in place effective management system

(2) Organization eligible for receiving aid

The following Organizations are eligible for funding

- University

- Public research institute
- Foundations

A contract will be signed between the corporation and JST in order to promote the program.

(3) Support period

Five years

(4) Amount of financial support

Maximum 700 million Japanese yen/site annually.

Table: Research campuses developed under this Scheme

Sr. No	Name of Research Complex	local government	Name of core organization
1	Compass to Healthy Life Research Complex Program	Kobe City, Hyogo Prefecture	National Research Institute RIKEN
2	Wellbeing Research Campus:Creating new values through technological and social innovation	Kawasaki City, Kanagawa Prefecture, Yokohama City, Ota City	Keio University
3	Global Research-Complex to create “meta-comfort” smart society by i-Brain x ICT.	Kyoto Prefecture	Public Foundation of Kansai Research Institute

Example of Research Complex Programs

- **Compass to Healthy Life Research Complex Program**

Background

This Research Complex program was proposed by RIKEN as the core organization. Other stakeholders are Hyogo Prefecture, the city of Kobe, Kyoto University, Kobe University, the University of Hyogo and 9 other universities and research institutions, and Hankyu Hanshin Holdings and 30 other private enterprises and organizations. This research Complex was funded by the Japan Science and Technology Agency (JST) in 2015 with a vision to establish world-leading regional research, development and testing hubs. Its major aim is to form an international hub for health sciences and related business by establishing mechanisms for generating and supporting the rapid implementation of innovative ideas and nurturing entrepreneurs in this sector.

Overview

The "Compass to Healthy Life" aims to help people lead healthier lives by developing a "virtual-self" tool that offers accurate guidance for better promotion and management of health issues. In order to fulfill its aim of creating a multidisciplinary working group, it combines leading Scientists from nanotechnology, measurement sciences, life sciences, and computer sciences from various research institutes and universities both in Japan and abroad at the Kobe Biomedical Innovation Cluster (an advanced medical technology R&D hub).This group conducts research on the frontiers of understanding the workings of the human body and the development of a computer-based virtual-self tool that can be used to predict future health status and challenges.

Outlook

The data and knowledge generated through such research will lay the foundation for the development of novel health related products and services in the future covering a wide industrial sectors. Over and above the main aim of joint R&D, concerted efforts will be made towards building an international hub for health sciences-related business and nurturing entrepreneurs in these areas.

2.10 Super Cluster Program

Objective

This program envisages the formation of a globally competitive Super Cluster by bringing around wide-range collaboration with the aim of creating high-impact innovation in Japan. While keeping in view the S&T achievements, the government is also intent on incorporating social and market needs by striking a balance between S&T, society and the economy.

Management by Strategy Directors (SDs)

Each Cluster constitutes an SD team made of three SDs. This team chalks out clear policies for the running of the cluster along with marketing plans and decides the allocation of budget and the management of Super Clusters.

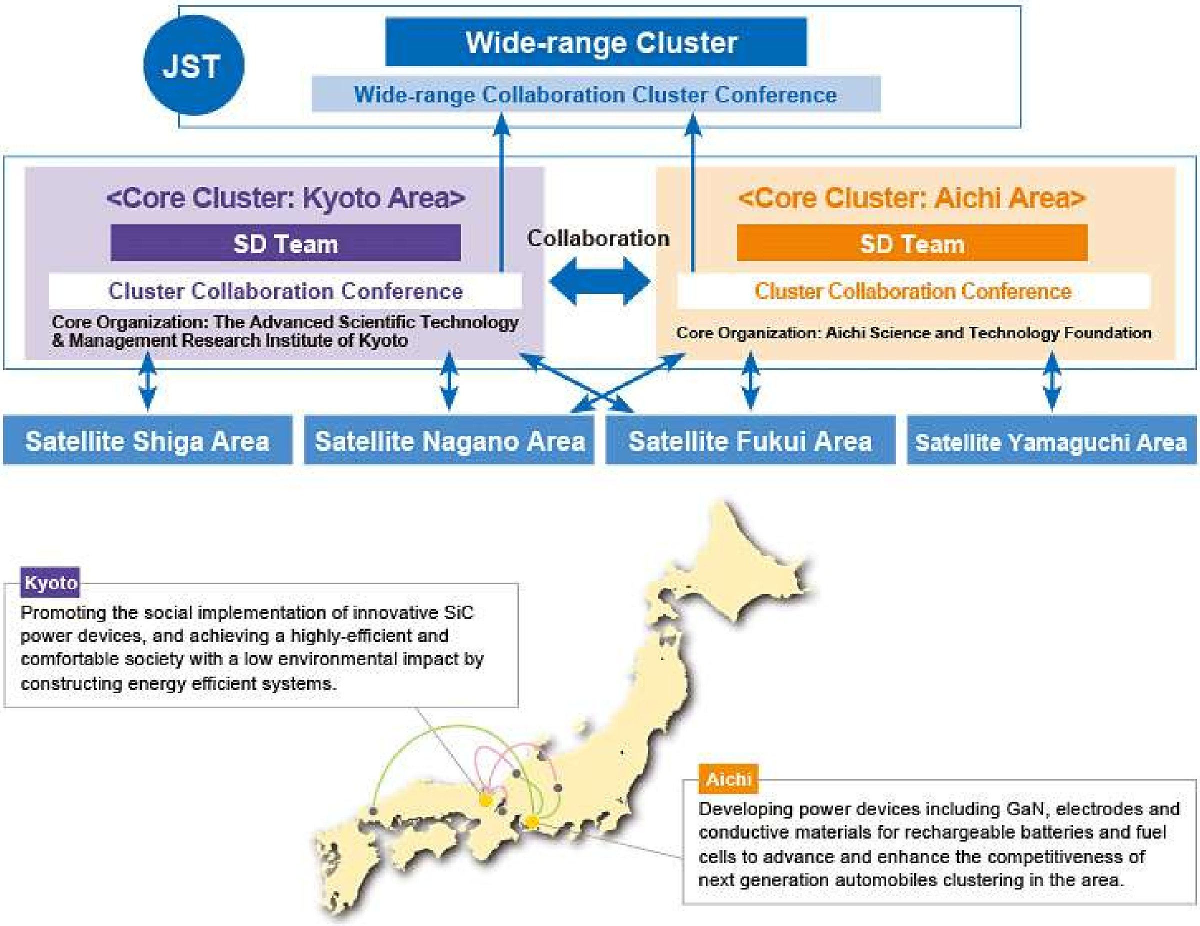


Figure : Super Cluster designed for Cooperation Beyond Regions

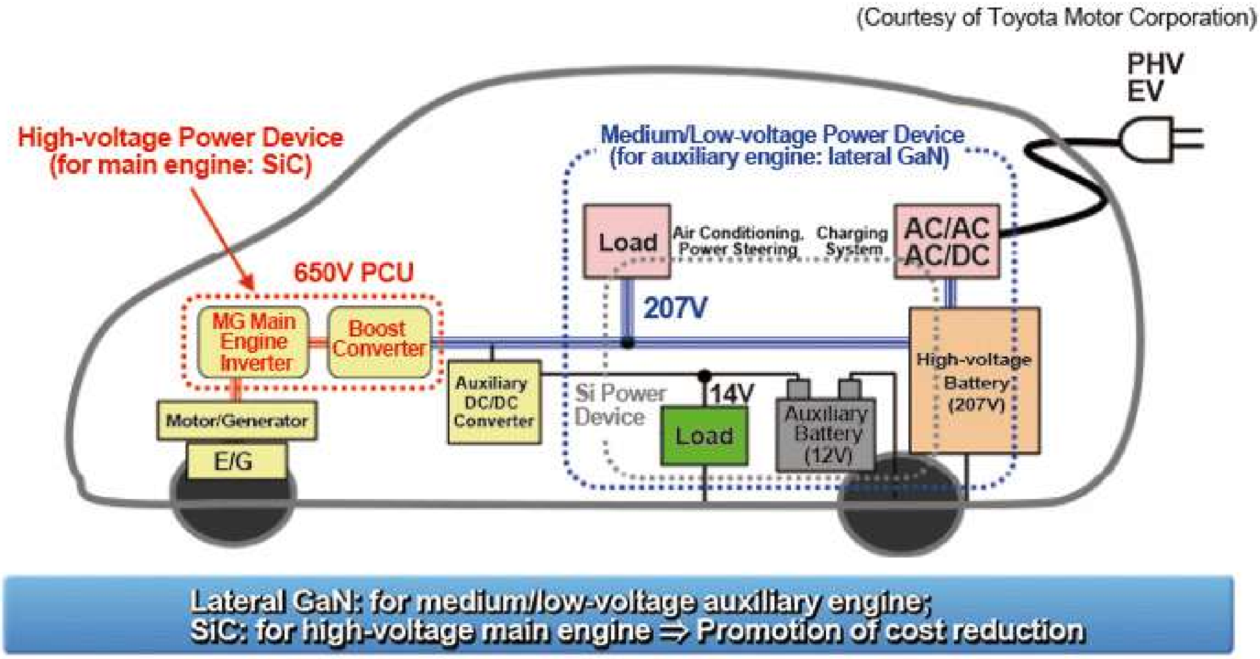


Figure: Power Electronics

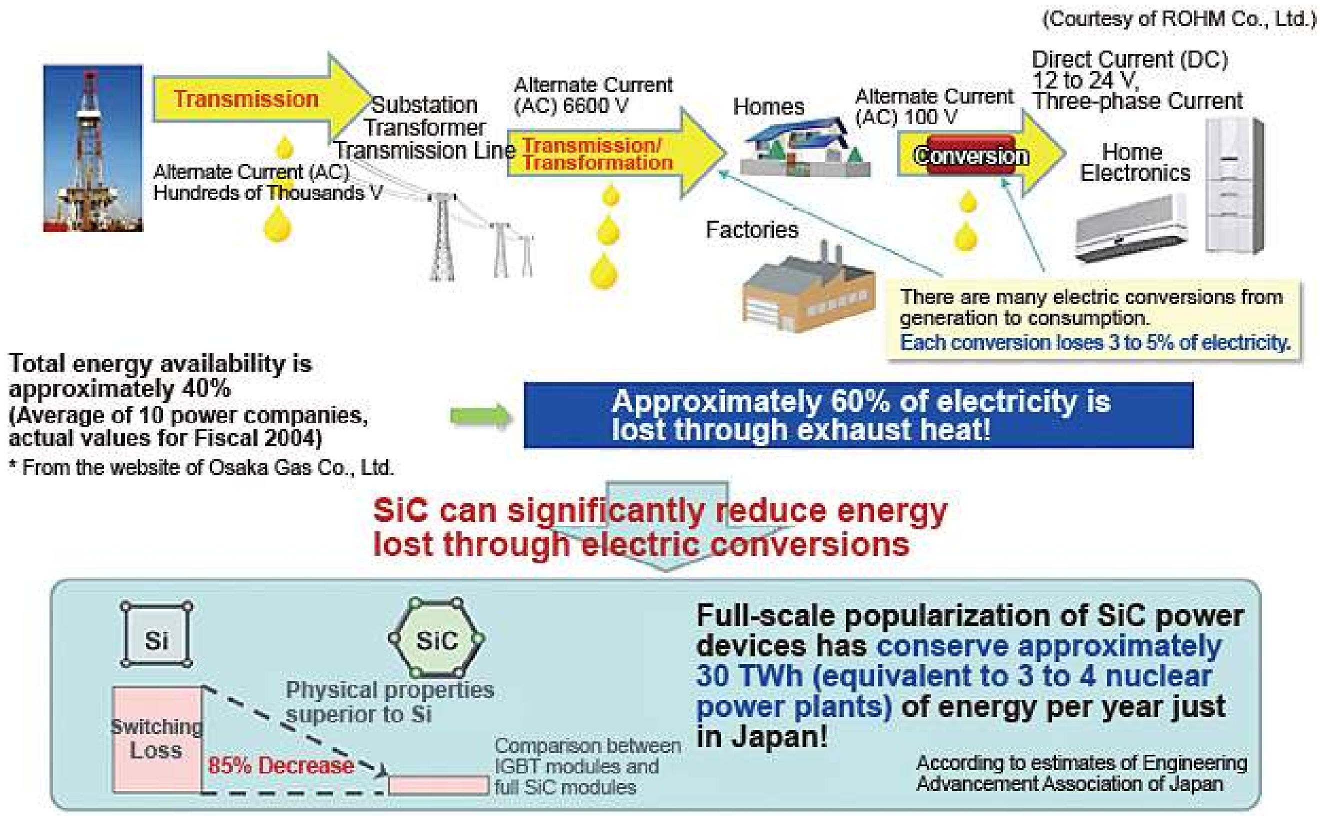


Figure: Background and Aim of Developing SiC Power Device Technology

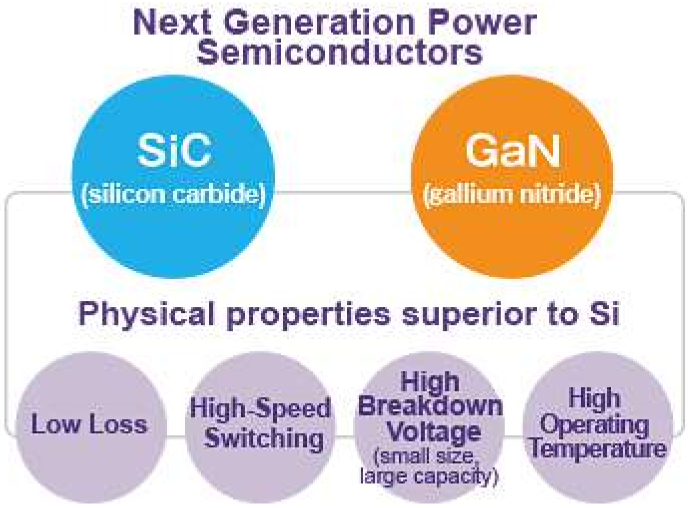


Figure: Next generation materials for replacing Silicon

SiC (silicon carbide)

Half of the silicon material is replaced with carbon in SiC, which allows the creation of a robust crystalline structure, with a more precise and stable crystal structure compared to that of Silicon. This enables a low loss, high breakdown voltage device to be created, compared to conventional silicon devices. SiC devices are suitable for motor drive applications due to its high breakdown voltage.

GaN (gallium nitride)

GaN is another compound that has more connective stability, and has a higher breakdown voltage than SiC. GaN is also used for blue LEDs. GaN devices has good application in the development of compact, switching power supply involving high frequency applications.

3 (Source: http://www.jst.go.jp/super-c/en/index.html)

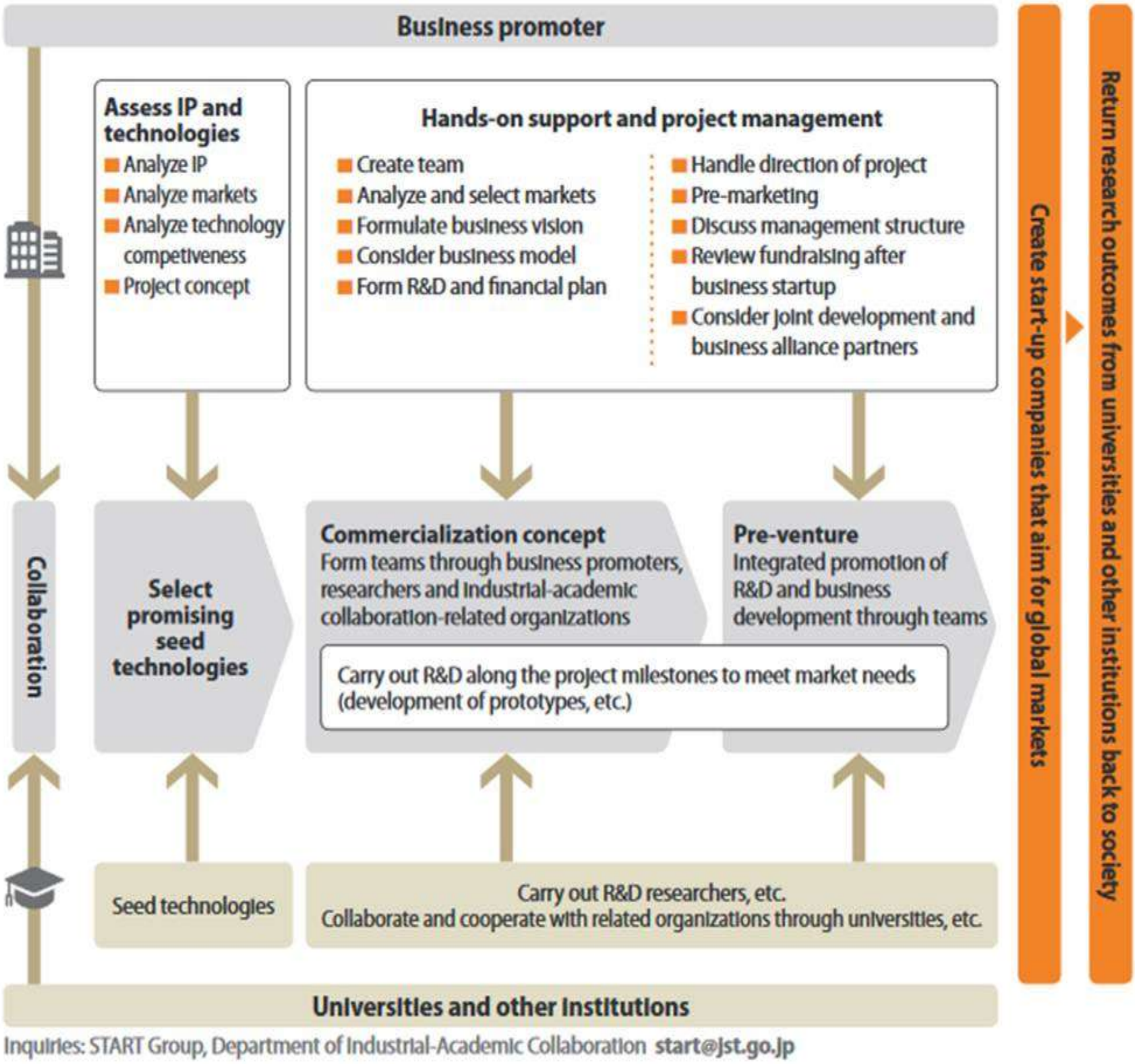
2.11 Support program for starting up innovation hub (Text in Japanese only)

Vision: Enhancing the potential of national R&D agencies to promote innovation. JST supports national research and development agencies to establish open innovation hub where resources for innovation among both public and private sectors, including human resources and technological seeds, accumulate.

C) University Start ups Foundation and Investment

3.1 Project for Creating Start-ups from Advanced Research and Technology (START) (Most Text in Japanese)

The main aim of START is the translation of high end technological innovations arising from the universities. It is strategies to develop the best ways to combine public funding options and private sector business acumen to commercialize the promising technologies through the foundation of start-up companies. In such START units, experts in technology translation provide critical support to the scientist with promising nascent technologies.



Some Major Achievements:

Through Water Bain Partners Co., Ltd (venture capitalist) (Need to verify the name of the Company)

Interprotein Co., Ltd.: This is a venture company founded by the researchers at Osaka University. They developed their own method for designing new low molecule / peptide leading to faster and more effective drug discovery. Various pharmaceutical companies are collaborating with this company.

Celentech Co., Ltd.: This Company originated from the efforts of a team of researchers from Chiba University. It specializes in developing transgenic adipocyte therapeutics. The Chiba University Medical School affiliated hospital provides a platform for clinical trials for this venture.

Kinofama Co., Ltd.: A research team from the Tokyo Medical and Dental University working on small-molecule therapeutic drug development founded this venture company which is funded by the JST funds.

Anero Pharma Science Co., Ltd.: Researchers working at the Shinshu University School of Medicine developed this Company which works on development of anticancer drugs. This firm utilizes funds from the Industrial Innovation Organization.

Tokiwa Bio Co., Ltd.: It's is a company founded through collaboration between National Institute of Advanced Industrial Science and Technology with major pharmaceutical companies in the area of regenerative medicine and gene therapy. START business fund was utilized for setting up this Company.

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2.13 SUpport program of Capital Contribution to Early-Stage companies (SUCCESS) (Text in Japanese only)

The main aim of the new program "SUCCESS" is to invest in start-up companies which attempt to translate the outputs from JST-funded R&Ds into practical application. Not only seed money but also supports from human and technical points of view can be offered to these companies. The program has been designed based on the awareness that the number of new university-initiated start-up companies has been declining recently, though entrepreneurship is essential for economic revitalization.

National R&D projects by New Energy and Industrial Technology Development Organisation (NEDO) (Expand further)

In response to the increased need for energy diversification following the two oil crises during the 1970s, the New Energy and Industrial Technology Development Organization (NEDO) was established in 1980 as a government organization. Its main mandate is to promote the research and development of technologies related to new energy sources. Later on, R&D activities related to the development of industrial technology were added. In the current scenario, in Japan, NEDO is actively engaged in a many research areas and is regarded as one of the largest public R&D management organizations.

NEDO's Missions

NEDO has the following two basic missions:

- Addressing energy and global environmental problems, and
- Enhancing industrial technology.

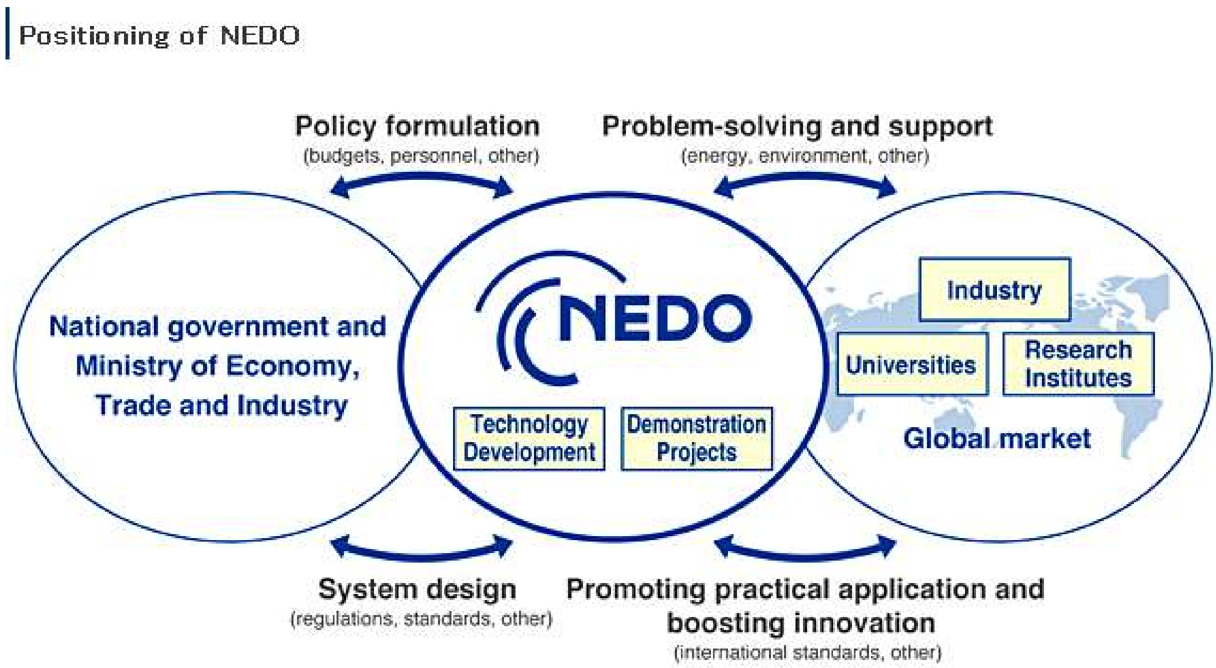
Addressing energy and global environmental problems

NEDO carries out R&D activities towards development of alternative energy sources such as wind power, biomass and waste, photovoltaic, geothermal power, thermal utilization, and fuel cells etc along with development of technologies for energy conservation. The verification of technical results in the area of alternative energy and energy conservation is also one of its important activities. It promotes the greater utilization of alternative energy sources and improved energy conservation. The contribution of NEDO towards technologies and systems for stable energy supply along with solutions for environmental problems through the promotion and demonstration of new energy source, ways and means of energy conservation, and environmentally technologies is immense. The knowledge and know-how gained through various domestic projects is applied in order to realize the mandate of NEDO.

■ Enhancing industrial technology

NEDO undertakes R&D on new technologies with the main aim of upgrading the industries working in the domain of New Energy sources. Equipped with a strong management structure, projects on promising technologies as well as mid- to long-term projects that will strengthen industrial development in the future is supported by NEDO.

As one of the three main R&D funding agencies in Japan, NEDO funds projects exploring future technologies between business enterprises in collaboration with universities and/or National Institute of Advanced Industrial Science and Technology (AIST). During 2015 NEDO managed around 64 R&D projects (duration of 5-10 years) with a budget of ¥121.5 billion. NEDO is funded by the Ministry for Economy, Trade and Industry (METI). Most of the supported projects are high risk projects involving high R&D costs which could not be developed by private sector alone. The employment of young graduates and mid career scientist and engineers for such projects are supported by funds from NEDO. The research outputs may be in the form of publications or patents, the commercialization of technologies are taken up by the participating industrial companies. At 30% NEDO has set a very high target rate of commercialization of R&D results, and during 2009, it has surpassed this target by reaching 36% commercialization (Nomi T, 2015).



NEDO Project Activities (Budget: 1.27 billion US dollars)

NEDO aims to address energy problems and raise the level of industrial technology through integrated management of technology development from the discovery of technology seeds to the promotion of mid- to long-term projects and support for practical application.

National Projects (1.17 billion US dollars)

NEDO coordinates and integrates the technological capabilities of private enterprises and research abilities of universities, instead of hiring its own researchers, and organizes technology development activities as national projects to realize fundamental technologies (including technology demonstrations) that are difficult for private enterprises to develop by themselves due to the high level of risk before practical application.

- New energy (380.9 million US dollars)
- Energy conservation (91.8 million US dollars)
- Rechargeable batteries and energy systems (30 million US dollars)
- Clean coal technology (139.1 million US dollars)
- Environment and resource conservation (23.6 million US dollars)
- Electronics, information, and telecommunications(111.8 million US dollars)
- Materials and nanotechnology (113.6 million US dollars)
- Robot technology (99.1 million US dollars)
- New manufacturing technology (29.1 million US dollars)
- Crossover and peripheral fields (0.9 million US dollars)

Support for International Expansion (150.9 million US dollars)

Includes JCM demonstration and verification projects

Public Solicitation for Proposal Activities (38.2 million US dollars)

For urgent economic and social issues which need to be immediately addressed in Japan, NEDO publicly solicits proposals on technology development themes which contribute to addressing such issues, and then supports and promotes them.

* As only an outline of NEDO' s activities is shown above, individual budget amounts do not equal the total.

* Budget amounts are calculated at a rate of 110 yen per US dollar.

Some selected Examples of research supported by NEDO which are successfully commercialized (Nomi T, 2015):

- The results obtained through Solar power generation projects which were supported by METI and NEDO have been implemented successfully by many Japanese companies.

- Railcar traction inverter which used SiC power module in the world resulting in a reduction of power consumption by 38.6% was successfully commercialized by Mitsubishi.

- FeRAM semiconductor Technology developed by using NEDO support has been commercialized by Fujitsu.

- High-efficiency Solid Oxide Fuel Cells specially developed by NEDO for Residential Fuel Cell System was successfully commercialized by Osaka Gas.

3. References

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South Korea

Contents

1. Introduction

Till 1970s, South Korea (S. Korea) was one of the feeble nations of the world and was essentially categorized as an agrarian economy. Yet today, it is one of the richest and technologically advanced nations of the world that has been developing its innovation profile rapidly. This transformation was brought about by laying emphasis on education, research and sustained industrial development through innovation and engaging in global competitions. Global Innovation Index (GII) Report, 2017-18 has ranked S. Korea at position 11 out of 127 countries investigated for this study. It is one of the top 10 economies in the 'Innovation Output Sub-Index' along with other countries like the USA, U.K., Germany, Switzerland etc. This nation spends enormously in R&D (>4.0 % of its GDP), which is highest in the world.

A domain of great strength of S. Korea is 'Knowledge Creation' (Rank: 2nd, GII Report 2017-18), where it has maintained its top ranks in both patents by origin and PCT patent applications and advanced to the apex spot in utility models by origin. Global ranking of S. Korea in S&T related indicators and a few other parameters have been enlisted in the table 1 below.

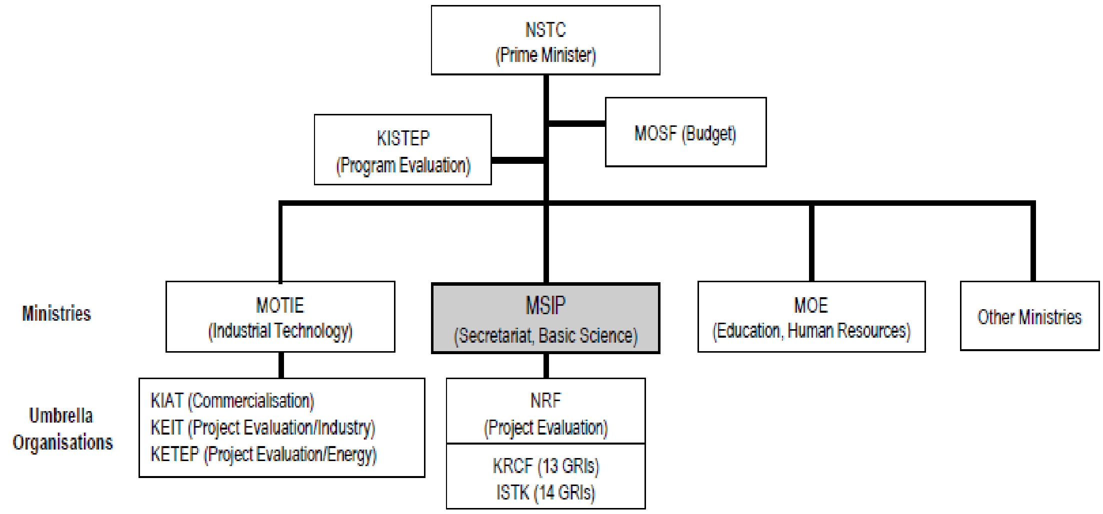
Table 1: Global ranking of S. Korea in S&T indicators

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	62
2.	Research & development (R&D)[a]	1
3.	Gross expenditure on R&D, % GDP[a]	2
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	5
5.	QS university ranking, average score top 3[a]	9
6.	University/industry research collaboration[a]	28
7.	Capacity for Innovation[b]	35
8.	Company Spending on R&D[b]	28
9.	Availability of Scientists and Engineers[b]	38
10.	Quality of Scientific Research Institutions[b]	32
11.	Publications[c]	12
12.	H-index[a]	19
13.	Intellectual Property Rights[d]	27

14.	PCT Patents[b]	5

Source: *[a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php ; [d]IPRI Report, 2016 (http://internationalpropertyrightsindex.org/ipri2016)*

The ecosystems of Education, Science, R&D and Innovation, in S. Korea, are highly organized and are governed by different ministries alon with other umbrella organizations as depicted in figure 1.



NSTC: National Science &Technology Council; MOSF: Ministry of Strategy and Finance; MOTIE: Ministry of Trade, Industry and Energy; MSIP: Ministry of Science, ICT, and Future Planning; MOE: Ministry of Education; KISTEP: Korea Institute of S&T Evaluation and Planning; KIAT: Korea Institute for Advancement of Technology; KEIT: Korea Evaluation Institute of Industrial Technology; KETEP: Korea Institute of Energy Technology Evaluation and Planning; NRF: National Research Foundation; KRCF: Korea Research Council of Fundamental Science and Technology; ISTK: Korea Research Council of Industrial Science and Technology.

Figure 24: Technology and Innovation system in Korea, 2013

Source: OECD Reviews of Innovation Policy. Industry and Technology Policies in Korea, 2014

The Korean government is a promoter of industrially relevant and collaborative research activities which is evident from the fact that it has been proactively supporting and bolstering research under PPP mode. To uphold its stance towards collaborative and industrially relevant R&D, the government has introduced and enforced several 'Acts & Laws', which have been briefly discussed in table 2.

Table 2: Acts and Laws enacted by the government of S. Korea for the promotion of PPP in R&D

S. No.	Act/Law	Brief details
1.	**Cooperative Research and Development Promotion Act** [Enforcement Date 23. Mar, 2013.] [No.11690, 23. Mar, 2013., Amendment by other Act]	This Act promotes scientific and technological collaborations by supporting cooperative R&D among foreign organizations, research institutes, universities and enterprises. The government agencies at the centre and state level promote cooperative research on priority basis under this act. A special type of fund that manages loans for development and deployment of technology is provided to the enterprises undertaking cooperative research.
2.	**Act on the Support of Industrial Technology Research Cooperatives** [Enforcement Date 23. Mar, 2013.] [No.11690, 23. Mar, 2013., Amendment by Other Act]	Under this Act, the government promotes development of industrial technology and thereby contributes towards the national economy by promoting establishment of cooperative units for fostering joint R&D activities. The government supports the cooperation, along with providing funds for infrastructure and R&D activities mainly for commercialization of technology along with support in taxation.
3.	**Special Act on Promotion of Special Research and Development Zones** [Enforcement Date 28. Sep, 2015.] [No.13231, 27. Mar, 2015., Partial Amendment]	This Act promotes creation of R&D zones for accelerating research in universities, research institutes, colleges and companies. It also supports cooperation for R&D and commercialization of research outputs. Through this Act central and state governments reward research institutes, universities, colleges and

		companies who have successfully developed technologies and commercialized them. This Act also deploys a provision for the government to assign special status to the companies working zealously towards innovation. The Act also supports formation of joint collaborative research based spin offs, provides special tax benefits to the start-ups, spin offs and companies registered in special economic zones.
4.	**Industrial Development Law** Legislated in 1999	In accordance with this Law, each city and region of S. Korea should have strategic plan to promote industry under the unique set of conditions.
5.	**Industrial Cluster Development and Factory Establishment Act**	Under this Act agglomeration of industries for enhancing their core capabilities in various regions of S. Korea is promoted.
6.	**Technology Transfer Promotion Law, 2000**	Before the introduction of this Law, national universities and research institutes could not claim patent rights. However, with the enforcement of this act, the public universities can engage with enterprises, commercialize technologies and claim their rights for the same.
7.	**Industry Education Promotion and Industry University Cooperation, 2003**	This Law promotes the cooperation between national universities and industrial set ups in S. Korea and has been credited with improving University-Industry (U-I) collaboration and technology commercialization Monetary incentives are provided for promoting collaborative research vide this law.

Source: *http://english.msip.go.kr/english/main/main.do*

The 'Acts and Laws' enforced by the government of S. Korea are recognized as the backbone of a robust system comprising of various programmes and schemes introduced for promoting industry oriented R&D in S. Korea.

2. Schemes/Programs/Organizations

The major programmes/schemes and initiatives that have been undertaken in S. Korea for promoting R&D under PPP mode are briefed in this section.

2.1 Korea Small Business Innovation Research (KOSBIR) Program

For creation of innovation-based growth SMEs, the Korean government introduced the KOSBIR programme in 1998, which was based on highly successful 'Small Business Innovation Research (SBIR; https://www.sbir.gov/)' programme of USA. This programme was introduced under the special act of 'Venture Business Promotion', August 1997. Three percent of the total R&D budget of the nation was set aside for implementation of KOSBIR programme for supporting innovative practices of SMEs. Three percent of R&D budget was kept for SMEs in 1998 which was enhanced to 5% from 2000 onwards.

The major requisites of the early KOSBIR program were –

- Participants should include government ministries and enterprises possessing an annual R&D budget of 30 billion K₩ or more, as of 1997
- A percentage of the R&D budget be allocated to SMEs.

Subsequently, a total number of participants included 18 organizations, which consisted of 10 central government ministries and 8 public enterprises.

With the changing laws of the Korean government, KOSBIR programme also evolved. With the introduction of 'SME Technology Innovation Development Program' in 2007 and 'Technology Innovation Assistance Body' in 2009, R&D budget of KOSBIR was enhanced significantly.

According to the latest available report, the total numbers of organizations participating in KOSBIR are 19 with an annual R&D budget of 30 billion K₩ and over.

The major outputs of the programme have been:

- Increased participation of public sector in SMEs R&D
- R&D support in terms of financial support steadily increased from 344 billion K₩, in 1998 to 1,728 billion K₩ in 2013 with an average 11.4% annual increase in R&D support to the SMEs.

- The KOSBIR programme led to the development of 'Purchase-conditioned New Product Development Program' in 2002.Through this programme, Korean government guarantees the purchase of a newly developed indigenous product from the SME or a big company.
- The KOSBIR programme led to the expansion of SMEs in terms of their R&D investments and R&D output. The number of SME units involved in R&D increased from 10,748 in the year 2000 to 33,991 in the year 2012, with 3.2 times increase in SMEs undertaking R&D in the manufacturing sector.
- The total R&D investment of SMEs increased to 11,152 billion K₩ in the year 2012 that amounted to 20.2% of total national R&D of S. Korea.
- SMEs recorded tremendous growth of 15.4% in their R&D from 2004 to 2012 which was significantly high in comparison to the R&D growth of 11.6% and 11.5% by universities and large companies, respectively.
- Total growth of business by SMEs was recorded at 25%.
- Total number of SMEs collaborating with universities and research institutes reached 27,154 in the year 2013.
- The total number of researchers in SMEs reached 1,55,580 in 2013.
- Ratio of research personnel to the total employee strength of SMEs on an average reached 5.3% in 2013
- Innovative firms increased from 2042 in the year 1998 to 29,555 in the year 2014.
- Venture firms accounted over 454 billion K₩ turnovers in 2013
- Realization of SMEs contribution to the national research innovation system. The government also modified and reviewed its policy and has took steps to change focus from university centric R&D to business-centric R&D in S. Korea.
- The government introduced research incentives for cooperative projects involving research work in partnership with business houses, universities and other academic institutes in S. Korea.
- Government efforts through KOSBIR programme led to increase in employment along with strengthening regional economy of the country.

2.2 The Industrial Complex Cluster Program (ICCP)

The ICCP (https://www.clustercollaboration.eu/) was implemented as a part of 'National Balanced Development Policy', 2004. The programme was initiated with an aim 'to bring transformation in factor-driven-production-centered industrial complexes into the knowledge-based growth of the industrial clusters'. Through this programme virtual network(s) of enterprises, academic and research institutes have been promoted in S. Korea. Through the formation of clusters, the Korean government has focussed on enhancing the industrial competitiveness of local industries by promoting the exchange of knowledge and innovation.

The ICCP programme is tightly regulated by Korean government mainly under supervision of 'Ministry of Knowledge Economy' (http://www.koisra.co.kr/en/partners/governmental/187-ministry-of-knowledge-economy.html) under 'Korean Regional Industry Support System' and 'Industrial Cluster Policy' which were based on Industrial Development Law, 1999. The programme was initiated under Industrial Cluster Development and Factory Establishment Act, 2002 and the Special Act on the Balanced National Development, 2003. The main body (outsourced independent body) under Ministry of Knowledge Economy responsible for execution and management of ICCP is 'Korean Industrial Complex Corporation (KICOX;www.kicox.or.kr)'. KICOX has established individual cluster agencies for each complex supported under ICCP. In 2006, to enhance the academic involvement in the ICCP, Korea Academic Society of Industrial Cluster (KASIC) was created. The basic organizational set up of KASIC is described in figure 2. This society, with over 200 expert members, aids in developing technical collaborations between academic and research institutes, government organizations and industries in the specific complex regions.

The programme is implemented under 'consumer-customized bottom up approach' through which problems faced by industries or real customer are solved through university-industry alliance. The basic structure followed for execution and implementation of ICCP supported project is presented in figure 3.

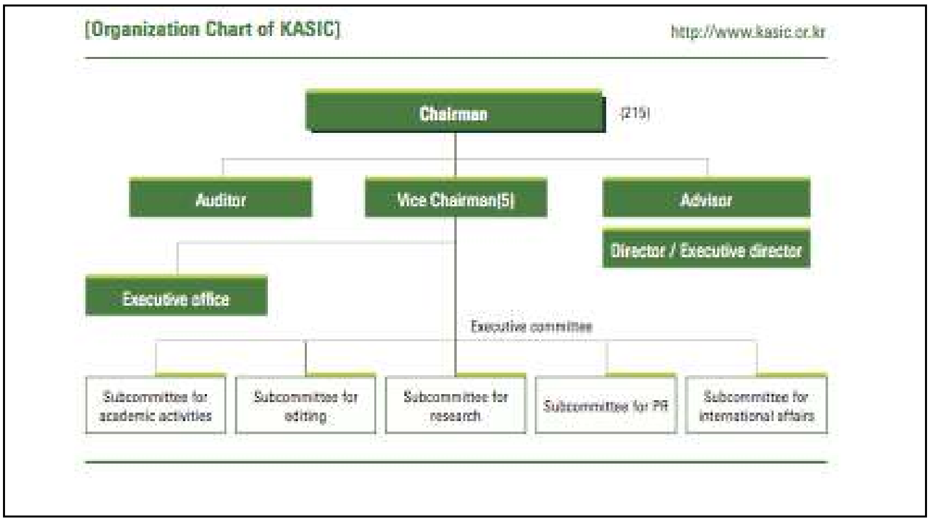


Figure 2: Organization Chart of KASIC

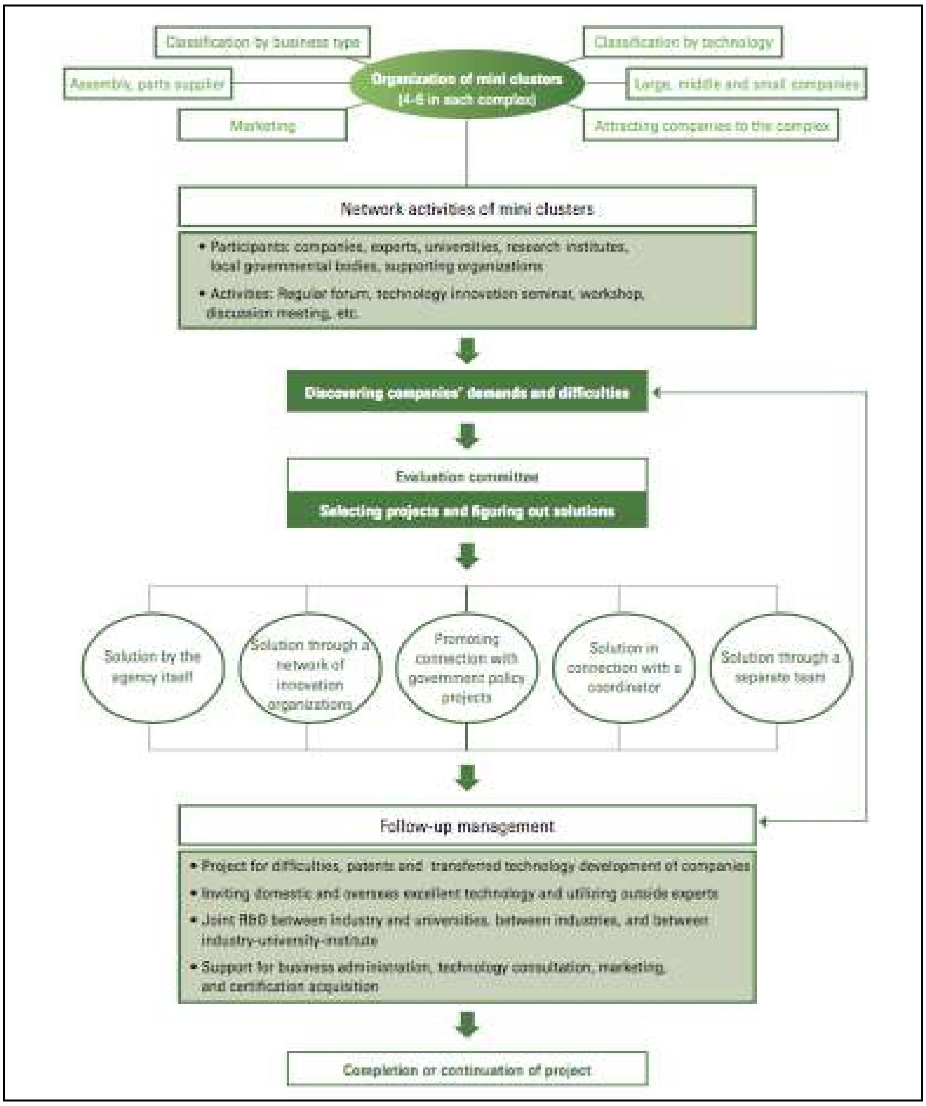


Figure 3: Execution and implementation of ICCP supported projects

The most successful type of cluster programme is ICCP. The other types of cluster programmes initiated in S. Korea are listed in table 4.

Table 4: Projects undertaken through cluster programme in S. Korea

S. No.	Project Types	Brief Details	Supporting Organization
1.	Promoting Regional Strategic Industries	Supporting 9 industrial regions in 1st phase and 4 industrial regions in 2nd phase Support infrastructure and technology development Support of $358 million provided	Government
2.	Nurturing Daeduck R&D special district	Initiation of special district support centre Creation of special district business model Creation of global venture ecosystem Supporting institute company and high tech company foundries Support of $ 43.4 million	Government
3.	Nurturing hub universities for industrial collaboration	Supporting 13 universities in S. Korea for educational reforms, and manpower training in association with industries	Government
4.	Building Osong Bio-health Science Park	5 government run organizations to move into one cluster to develop common facility sites	Government
5.	Building Clusters for regional cluster industry	Creation of specialized industry clusters and districts in various regions of S. Korea 6 regions have been supported for creation of cluster with $ 128.3 billion	Government

		support	
6.	High Tech IT Complex	Creation of specialized high tech companies in Sangam regionwith support of $ 127 million	Government
7.	Regional specialized IT Clusters	Supporting IT specialized companies in the regions of Daegu, Kyongbuk and Gaegyang with support of $ 3.9 millions.	Government
8.	University Centered Clusters	Nurturing collaborative potential of industries with Hamyang University and Korea Polytechnic University	Private sector

Source: *the_industrial_complex_cluster_programme_of_korea_2010*

The ICCP programme focuses on building an innovation network where academic and research institutes along with companies participate in collaborative research. A specific region or cluster is supported by the local government by providing education services for leaders in innovation, enhancing their planning capabilities and diffusing knowledge amongst various research groups.

The government has been strongly promoting ICCP programme in S. Korea. The major strategies adopted through ICCP programme are described below (figure 4).

- Creation of a collaborative open network of university-government-industry
- Strengthening industrial R&D capabilities
- Creation of open clusters in association with domestic and foreign players
- Improving working and living conditions of technical professionals and industry personnel
- Linking government policies with innovation programmes

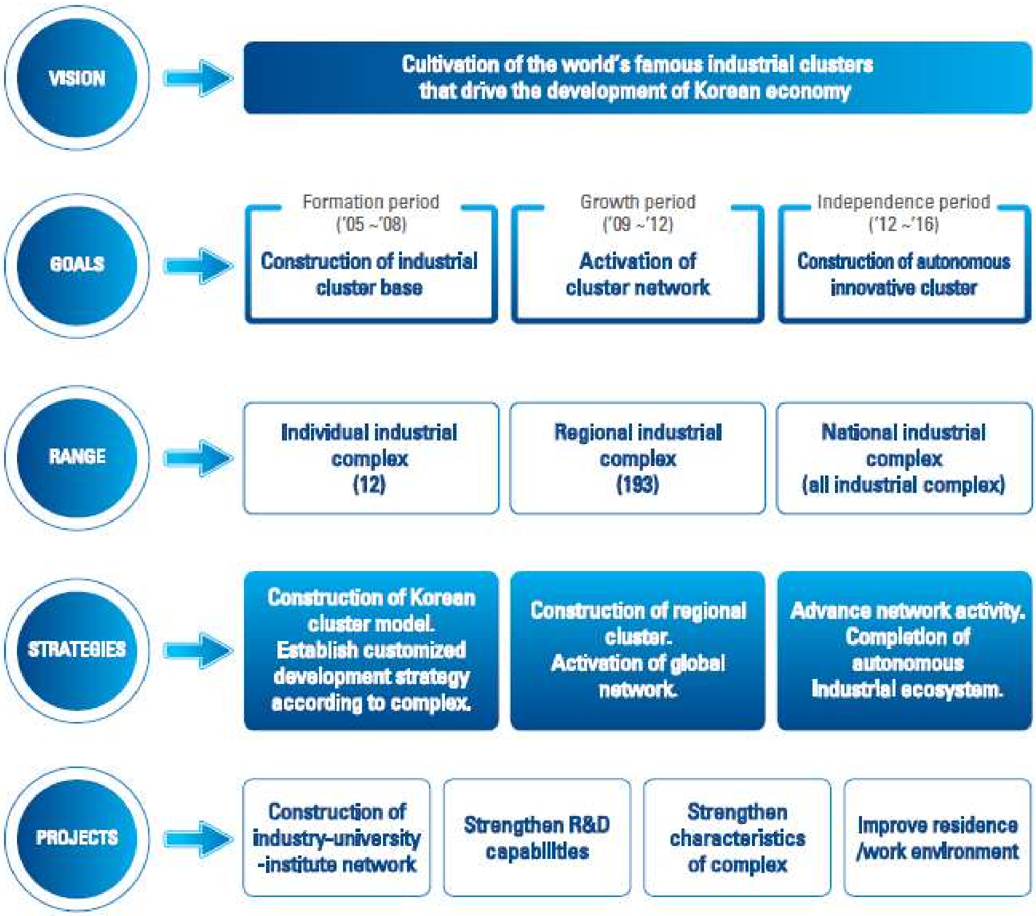


Figure 4: The vision and strategies of the Industrial Complex Cluster Program

Source: *The Industrial Complex of Korea Cluster Program, Brochure; Industry-university-institute integrated information network* www.e-cluster.net/en

In 2005, the programme was officially launched and 7 pilot industrial complexes (manufacturing) were promoted. Five more pilot complexes were added in the year 2008. The major complexes promoted through ICCP are Changwon, Ulsan, Gwangju, Ochang, Daebul, Wonju, Gunsan, Gumi, Namdung, Noksan and Seongsea. These complexes were provided with assistance for business administration including support for running a business, procuring supplies and other related support services at low cost and in shorter span of time. Within clusters, easy exchange of innovative ideas and business models has led to the innovative growth of various industries. Under this initiative other government-led programmes namely 'Turning Industrial Complexes to Innovation Clusters'; 'Nurturing Hub Universities for Industrial Collaboration' and 'Promoting Regional Strategical Industries' were introduced to build infrastructural and technology base for the Korean industries. Some of the successful clusters developed in S. Korea are listed in the table below and figure 5.

Table 5: Successful cluster developed with government support

S. No.	Cluster developed under government support
1.	Daeduk R&D Special District
2.	Osong Bio-Health Science Park
3.	High-Tech IT Complex
4.	Semiconductor and Digital Valley
5.	LCD Cluster

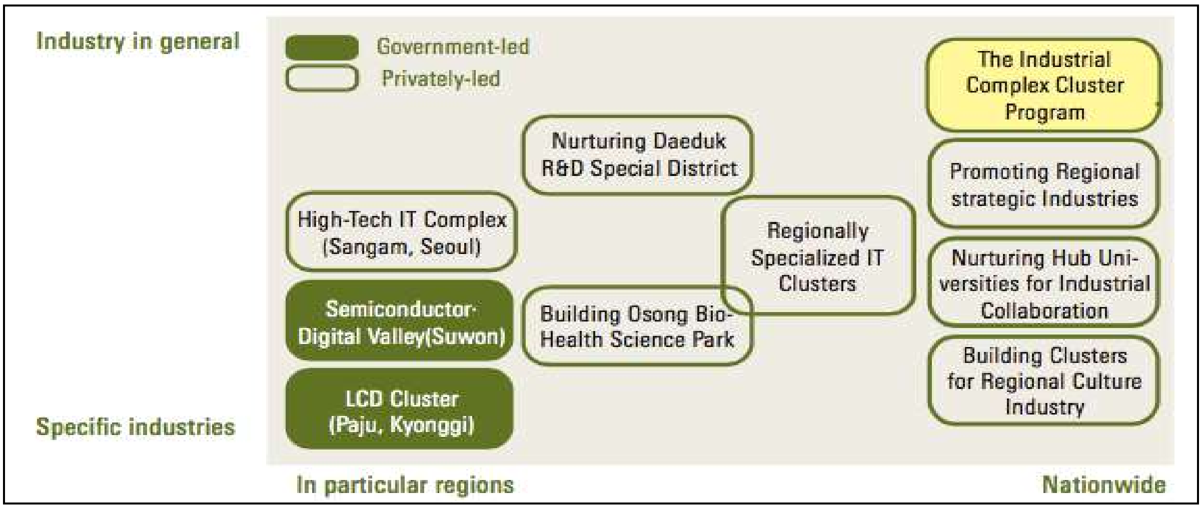


Figure 5: Types of cluster projects supported by the government

Source: *the_industrial_complex_cluster_program_of_korea_2010*

The major characteristic features of the ICCP are as:

- ***Supporting existing industries:*** Supporting existing industrial agglomerates in specified regions. Improving core capabilities of industries in existing industrial complexes and clusters (Incheon, Sihwa-Banwol, Changwon, Gwangju, Gunsan, and Ulsan).
- ***Creation of mini clusters:*** Mini cluster is defined as a small scale networking group of companies, universities, research institutes and government organizations that share their knowledge and experience to resolve specific problems faced by the industries under collaborative mode. Till the year 2015, nearly 78 mini clusters were established in S. Korea with over 7500 expert members associated with mini clusters. Government organizations such as local government bodies and innovation parks also provide support to these complexes. Mini clusters address three areas affecting growth of

companies which are a) technology development; b) technology commercialization and c) technology adoption to the market.

- ***Creation of Business Growth Support Centres:*** Through ICCP, Business Growth Support Centers were established in 2010 to provide financial, technical and management expertise to the companies located in industrial complexes. In 2011, 4 regions (Changwon, Banwol and Sihwa, Gwangju, Gumi) were selected for creation of these centres. In 2015, 3 additional centres were created in Cheonan, Wonju and Pangyo. Each centre supports selected SMEs from particular industrial complexes and prepares strategic plan for its R&D growth for period of 3 years. The centre provides services like new product generation, patent registration and management, human resource development, consulting, short term training and coaching etc.
- ***Creation of theme clusters:*** ICCP programme has created theme clusters in order to share common objectives and goals. These clusters differ from mini clusters where cooperative research is carried out in the domain of similar technologies. The programme supports varied domains of projects as per the cluster or complex regional specificity and specialization (e.g. Changwon region supports machining industry; Gumi region supports electronic industry; Daebul region supports ship building and Gunsan region supports automobiles and machinery).

  The programme supports industry at every stage of its life cycle from planning to execution. The services like business analysis, technology development, technology commercialization, technology sales etc. are shared amongst the various participants in the industrial complex.

2.3 Accelerator Investment-Driven Tech Incubator Program for Startup/ Tech Incubator Program for Startups (TIPS)

The programme (http://www.jointips.or.kr/about_en.php) was introduced with an aim to nurture and assist technology promising start-ups working in groundbreaking technologies. The programme provides exposure to start-ups in incubators and accelerators and various venture founders, angel investors and leaders of technology-oriented enterprises. Through this programme group of angel networks, technology leaders and professional support along with R&D funding is promoted. The basic structural setup and participants of TIPS are described in figure 6.

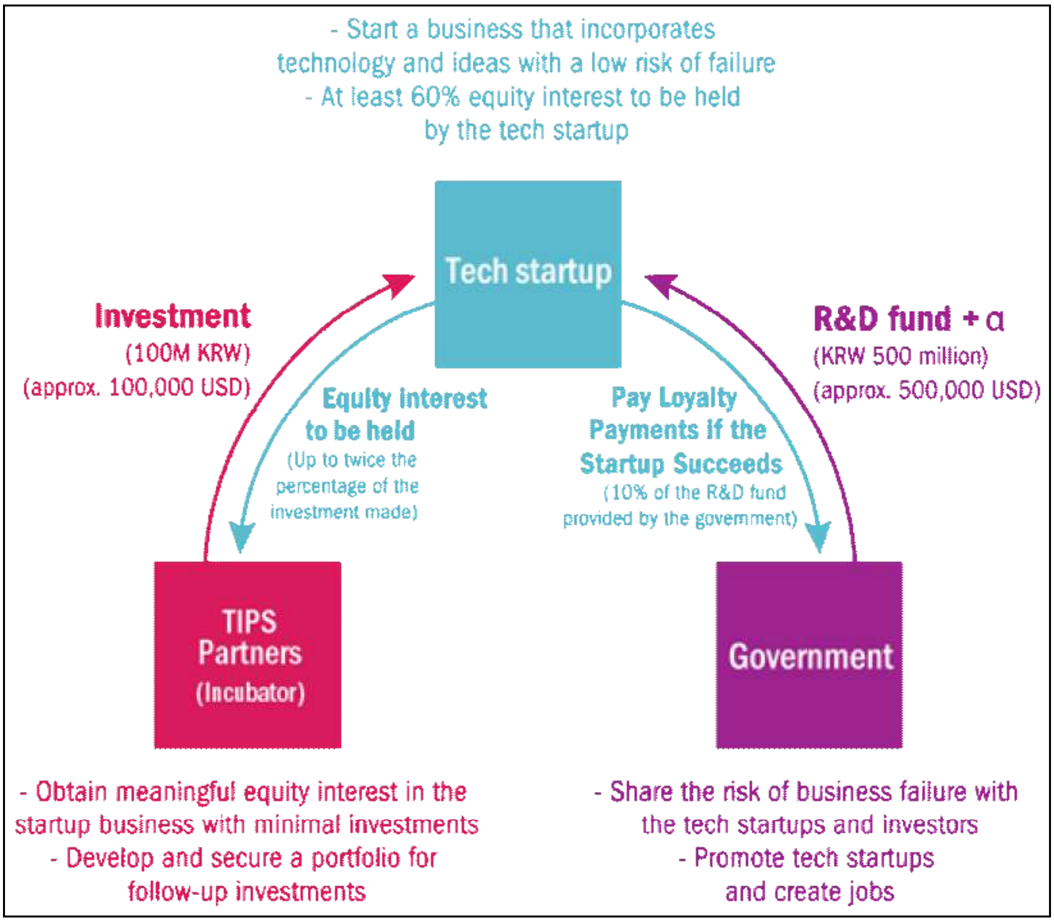


Figure 6: The basic structural set up of TIPS

Source:http://www.jointips.or.kr/about_en.php

The R&D support (up to 1 billion K₩ for three years per start-up) is provided by the government organizations in a form of equity to the start-ups. If the business set up by a start-up is successful, the start-up has to pay back 10% of the R&D funding support provided by the government in a form of loyalty payback which can be paid in the time period of 3 years. An overview of the R&D funding mechanism implemented through this programme is presented in table 7.

Table 7: R&D funding support mechanism under TIPS

Support Candidate	Incubation Period	Initial Funding	Technical Development Funding (R&D)			Additional Financial Assistance
		Angel Investment (Accelerator)	Govt. Fund	Private Spending		
				Cash	In Kind	
Tech start-ups	2-3 years	100 million K₩	Up to 500 million K₩	Greater than	Required amount	100 million K₩ in

		(minimum 20% is government funding)		50% of the private spending		startup funding, 200million K₩ in matching Angel funds, 100 million K₩ in overseas marketing assistance
			Less than 80% of the R&D fund	Greater than 20% of the R&D fund		

Source:http://www.jointips.or.kr/about_en.php

2.4 Centres of Excellence

In 1990s, Centres of Excellence (CoEs) were established in various parts of S. Korea by a non-profit organization 'Korea Science and Engineering Foundation (KOSEF). In 2009, KOSEF merged with Korea Research Foundation and Korea Foundation for International Cooperation of Science and Technology (KICOS) to form National Research Foundation (NRF; http://www.nrf.re.kr/eng/main) to run R&D activities in the country and maintain CoEs to support private industries. The major programmes covered under the scheme of CoEs are:

- Science Research Centre (SRC) Program
- Engineering Research Centre (ERC) Program
- Regional Research Centre (RRC) Program
- Medical Research Centre (MRC) Program

The SRC and ERC primarily encourage basic innovation aspect of research in order to develop new technologies and commercialize them. The RRCs focus mainly to establish cooperation between the regional industries and regional universities. The main difference between the above centres is as that the SRCs and ERCs focus simply on the research capabilities, but for the RRCs, their contribution to the regional economy and community are also important factors. NRF also included MRC program for creation of centres of excellence in the field of medical research. The CoEs are working with following objectives:

- Promote collaborative research between industries, start-ups, universities and research institutes
- Promote R&D activities in universities
- Promote international co-operation for R&D

The CoEs are provided a financial support, from NRF, for 9 years with evaluation after every 3 years. Based on funding CoEs are segregated and categorized as:

- A centres: Funding support is increased
- B centres: Funding support remains same
- C centres: termination or reduction of funding support

Each centre is provided with financial support of US $ 1 million on annual basis to strengthen R&D capacities. In case of ERCs, the industry provides addition US $ 1 million support for enhancing R&D capabilities of the region. Table 7 provides funding mechanisms for centres of excellence in promoting overall R&D capabilities of the universities, research institutes and Korean enterprises.

Table 8: Funding mechanisms for supporting CoEs

Type	Eligibility	Budget	Funded Period
Science/Engineering Research Centre (S/ERC)	Universities with master's and doctoral programs in science and engineering	1.3 ~ 1.5 billion K₩	7 (4+3) years
Medical Research Centre (MRC)	Medical, oriental medical and dental universities with programs in basic medical science	1 billion K₩	7 (4+3) years
National Core Research Centre (NCRC)	Universities with master's and doctoral programs in science and engineering	2 billion K₩	7 (4+3) years

2.5 Korea Credit Guarantee Fund (KODIT)

In order to strengthen the R&D base of S. Korea, the Korean government has taken the initiative to boost the R&D activities of SMEs. In 1976, Korea Credit Guarantee Fund (KODIT) was founded under Korea Credit Fund Act. The credit guarantee scheme is managed under the ambit of the Ministry of Finance and Economy (MOFE). Under this funding scheme, SMEs are provided financial support under credit guarantees. The companies in the hotel and recreational, restaurant, financial service and real estate business are not eligible for procuring credit guarantees against their loan amounts from the banks. The funding is contributed by Korean national government and various financial institutions of S. Korea. The leverage ratio kept for the fund is on an average 20 times the actual capital fund which was further reduced to 10 times capital fund in order to maintain and manage the fund. The scheme is managed by various stakeholders that form decision-making system under tight regulatory control.

The KODIT system of financial support is further subjected to the external evaluation of its supported business activities and yearly inspection by national assembly and Board of Audit and Inspection of Korea (BAI). In addition, evaluation of fund operation of the KODIT is carried out by the dedicated body under Ministry of Planning and Budget (MPB).

Under the Scheme of KODIT, business activities supported are:

- Credit guarantee
- Business consulting
- Management of credit investigation
- Management of credit information

Under the KODIT system, for bank loan guarantee nearly 85% credit guarantee is implemented after consultation of KODIT managing body with the bank on a particular loan. The SMEs receiving the 'Credit Guarantee' are subject to the payment of pay guarantee fee with basic fee rate of 0.5-2.0 on annual basis of the total guaranteed amount issued to the specific SMEs. In case of the large company applying for credit guarantee addition 0.5% fee is added to the final rate of fee. The loan is generated by getting approval letter of a credit guarantee from the KODIT body. KODIT scheme is implemented under two methods a) direct method and b) indirect method. Under the direct method, KODIT conducts several credit investigations and credit based evaluation of SMEs before granting approval for the credit guarantee. On the other hand, under indirect method, KODIT imparts responsibility of credit investigation and issuance of the credit guarantee approval letter upon the banks. Banks can provide two types of credit guarantee one is general indirect guarantee and another one is a special indirect guarantee. Around 13 banks are participating in providing a general indirect guarantee to SMEs through which these banks can issue credit guarantee up to 100 million K₩. The special indirect guarantee is provided by Industrial Bank of Korea (IBK) through which it can provide the guarantee to various cooperatives.

The other programmes implemented in S. Korea to promote private sector contribution in R&D activities are listed in table 9.

Table 9: Projects implemented in S. Korea for promoting private sector participation in R&D

S. No.	Initiative/project	Brief Details
1.	**Creation of Korean Industrial Research Council**	This project aims to strengthen the capabilities of the Technology Liaison Offices (TLOs) and also support programmes on IP Management and Technology Transfer. This endeavour would spread the research outcomes of the universities and the government funded TLOs.
2.	**Creation of Daedok Science Town**	The Daedok Science Town (Daedok Innopolis, since 2005) was created as a driver of national competitiveness in areas of technology and prosperity, by facilitating collaborations between universities, businesses and research organisations. Currently, it has around 30 government research institutes (GRIs), 42 private research institutes (PRIs), 5 universities, 8 support agencies, over 400 corporate R&D centres and more than 1200 high-technology companies (SMEs). Daedeok Innopolis is supported by the investments of central and local governments. The various constituents of the Science Town are: a) Industry: Daedeok Innopolis has a good quality of R&D functions, and the innovative technologies developed there find worldwide applications. At Daedeok, not only does the high-tech company develop their technologies, but the start-ups also find a place to contribute their entrepreneurial skills. b) Academia: Daedeok Innopolis has around 15% of the PhD level engineering and science researchers in Korea, indicating that it has such great R&D capability in Korea. Daedeok, therefore, plays a great role in producing world-class leaders. c) Research: Technology creativity is due to the very much qualified manpower, which has proven records of innovation in areas of IT, aerospace engineering, etc.

3.	**Creation of Private Universities**	Private universities make up a large section of Korea's educational institutions. One such university, Pohang University of Science and Technology (POSTECH) was able to achieve world class status within just two decades. It was established by POSCO (Pohang Iron and Steel Company) in 1986 for managing research institute, skill development of upcoming engineers and developing future high-tech products. Today, POSTECH has not limited itself to just POSCO and has established research collaborations with other companies as well. POSCO's research fund still accounts for the largest portion of research revenue, about 50% (World Bank, 2011).
4.	**Korean Small-Medium Business Administration**	The administration started an initiative named 'Small & Medium Business Technology Innovation Development' to support SMEs in S. Korea. Under this initiative, the government provides support to the SMEs that collaborate with universities and research institutes to resolve industrial problems. The initiative promotes the formation of a consortium of industry and academic/research institute working on common technical problems. This consortium is supported by central government (50%), local government (25%), and SMEs (25%).

One of the stand-out outcomes of PPP in R&D in S. Korea is the development of ***Code-Division Multiple Access (CDMA) technology.*** This communication-based technology was designated as a Korean national project and was heavily supported by the government. Agroup of S. Korean companies in association with Electronics and Telecommunications Research Institute (ETRI; https://www.etri.re.kr/eng/main/main.etri) and US-based Company Qualcomm developed CDMA technology, which revolutionized telecom sector world over.

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China

Contents

1. Introduction

The association and partnerships between the business/commerce i.e. the private sector and the universities/academia for working towards advancement of science and industrial exoertise began, in China, in the 1950s as a result of the governmental instructions and interventions. However, with the advent of time and with the ever increasing economic needs of the country this trend of association has rather been a result of mutual benefits and significance for the partnersing private and public sectors. China, during the last tow decades, has grown not only in scientific research but has also become a leader in technology development. A large amount of advancement and success can be attributed to the collaborations that has generated industry-ready and industry-oriented workforce along with producing economic benefits through means of innovations technologies and products. The public sector and academia has also gained in terms of adopting novel research strategies, refurbishment of infrastructure capabilities, updation of syllabi, skill development amongst the youth and young scientists.

The government of China, in order to facilitate the advancement of science and technology in the country and endorse the translation of research outputs for the benefit of society, established the concept of independant agencies at various ministrial levels.

This startegic governmental establishment involves a top down, multi-layer, and well connected administrative system in China (Figure 1).

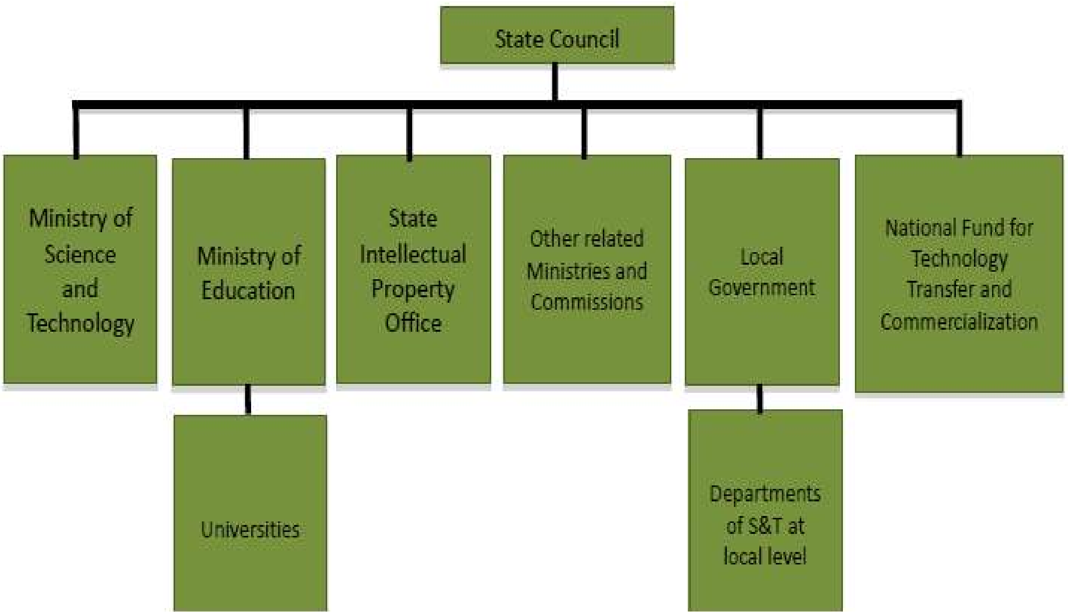

Figure 1 Major agencies for the development and advancement of S&T in China (Gao, 2015)

Table 1: Global Ranking

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	-
2.	Research & development (R&D) [a]	17
3.	Gross expenditure on R&D, % GDP[a]	17
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	6
5.	QS university ranking, average score top 3[a]	4
6.	University/industry research collaboration[a]	29
7.	Capacity for Innovation[b]	44
8.	Company Spending on R&D[b]	21
9.	Availability of Scientists and Engineers[b]	29
10.	Quality of Scientific Research Institutions[b]	36
11.	Publications[c]	2
12.	H-index[a]	14
13.	Intellectual Property Rights[d]	52
14.	PCT Patents[b]	30

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

In the Peoples Republic of China (PRC), the major and most crucial managerial and directorial jurisdiction is of the State Council. This highest authority is chaired by a 'Premier' and each agency/department is lead by a 'Head', which make up the Council. 25 ministries and 38 central organizations of the government report to the Council.

The main organizations/ agencies, of China, which work towards the advancement of R&D and and are liable for looking into translation of R&D outputs into substantial achievements are, the Ministry of Science and Technology, the Ministry of Education, and the Ministry of Finance.

In the year 2011, a committed initiative, 'National Fund for Technology Transfer and Commercialization' came into being, primarily intended at enhancing the assistance and aid for the transformation of R&D efforts and outcomes. The Chinese government has been prioritising the conversion of the S&T efforts of its researchers, which is evident from the fact that huge deal of emphasis has been laid on its a great deal of stress has been laid on its importance and magnitude in both - the *National Mid-Long-Term S&T Development Framework (2006-2020)* and the *National Mid-Long-Term Education Reform and Development Framework (2010-2020)*. In addition the government has also enforced a significant number of laws and regulations for providing encouragement, support, aids, guidance and guarantees for translation of research.

One of the most crucial government organization that is involved in the development and building of S&T policies in China is Ministry of Science and Technology (MoST). This ministry, which is also responsible for looking after the scientific activities of the country, consists of different departments and directorial bodies that work towards implementing the S&T policies and directives. Majority of the initiatives taken nationwide for encouraging research translation and endorsing the conversion of research outcomes into commercial/tangible outputs are looked after, implemented, conducted as well as assessed by MoST. Along with all other policy related matters and national research activities, MoST also looks provides assistance to the private sector enterprises in China.

The other governmental body that plays a significant part in the S&T environment of China is the Ministry of Education (MoE), which holds the responsibility of all the educational and research undertakings of the Chinese universities. Under the MoE, the Department of Science & Technology indulges in providing advive and direction to the universities as well as institutions of research for conducting industry oriented research, innovative activities undertaking translation activities, alliances with the private sector etc. This department is also responsible for connecting and commiting the universities towards the national S&T projects, in association with the other governmental bodies and ministries like MoST, Ministry of National Defense, Ministry of Environment Protection etc.

The third governmental channel that is hugely implicated into the S&T ecosystem and the goal of research translation is, National Fund for Technology Transfer and Commercialization (NFTTC), established in 2011. The idea behind establishing this instrument was accelerating the translation of research, backing up non-governmental support and encouraging more investments, especially to realise the *National Mid-Long-Term S&T Development Framework (2006-2020).*

A number of different initiatives and methods were employed and created for bolstering translation activities through this fund, such as –

- establishment of sub-funds (funded jointly by NFTTC and other competent investors) for venture capital – made available to the organizations that work towards accomplishing the conversion of research outputs & efforts.
- provision of incentives in accordance with the performance,
- provision for compensation of risks in loans etc.

A few other departments and agencies, in China, along with the ones stated above, have also been involved in research translation, commercialization and supporting such as, Ministry of Finance, Ministry of Agriculture, National Development and Reform Commission etc.

In China, the core R&D is being undertaken majorly by six performers, which are -

1. Chinese Academy of Sciences
2. R&D institutions under the various ministries and administrative agencies
3. Industrial enterprises
4. Universities and colleges
5. Local R&D institutions
6. R&D institutions affiliated to defense

In order to seek effective enactment and regulation of all the initiatives begun for accomplishing the conversion of research efforts, the PRC promulgated the *Law of the PRC on Promoting the Transformation of Scientific and Technological Achievements* in the year 1996. In 2015, in order to make amendments to this law according to the modern needs and requirements, a proposal was submitted. The amendment so proposed basically aimed at alleviating hurdles and barriers that were encountered during the tedious process of research output translation and commercialization. The State Council, in 1999, had also issued another regulation i.e. the *Regulations for Transforming Scientific and Technological Achievements*, for pursuing the cause of eefective commercialization of public sector research in China.

Gauging the intensity and initiatives taken by the Chinees government, it is apparent that transformation of the research outcomes and achievements has been of crucial concern for the officials. Hence, strategic plans, robust manifestations, strong policy guidelines, concerning laws and acts, strict implementation freamework, make up the S&T ecosystem of China.

Few of the schemes and initiatives endowed by the government of China are -

the Spark Programme, Torch Programme, Science and Technology Programme of Wellbeing, and the Transformation Fund for Agricultural Science and Technology Achievements, among others.

2. Programs/Schemes/Organizations

2.1 The Torch Program

Background

One of the primary programs aimed at invigorating the capacity and competency of the Chinese S&T ecosystem and fulfilling the objective of conversion of R&D accomplishments into commercial entities for societal good is the Torch Program (www.chinatorch.gov.cn/english/xhtml/Program.html). This initiative was started with the goal of promoting research outcome translation and thereby developing innovative high-technology goods/products/services and help the R&D industries create a global niche. Through this initiative attempts to create an enabling environment for the R&D talent was made so that the outcomes of research could be converted into commercial ventures. This program also supported the adoption of novel high-tech products/services and assimilation of firms in the industrial supply chain.

This program, also known as China National Hi-Tech Industrial Development Plan, was brought into force in the year 1988 and was administerd under the management of MoST. As the executor of the program, Torch High Technology Industry Development Centre (Torch Centre) was founded in October 1989, as an independent legal entity, funded by MoST.

Objectives

The prime objective of the program was to boost the innovative capability of industries, foster entrepreneurial culture and develop skilled workforce. Ensuing its objective one of the major missions that the Torch Program works on is the creation and development of Science and Technology Industry Parks (STIPs). The development of such conducive constructs enabled private businessese to pursue independant research objectives and hence encourage their skills and innovative capacity.

Through its various arms, the program also provides aid in funding problems faced by the private sector by means of creation of a financing system comprising of business incubators along with capital market.

This program enables even the private sector to take part evenly in the competitions for government S&T funds and also allows companies to utilize stock options for encouraging entrepreneurship and innovation. This format aids the growth of private technology companies in the competitive markets thereby becoming an important resources in the developemnet of high-tech industry and heightening the innovation landscape of the country.

The Torch Program is designed for assimilating and combining the S&T resources, enhancing and building up the procedures involved in the translation and commercialization of research, exploring newer modalities for developing a stronger functioning structure, which works in accordance with and is motivated by the needs of the industry and regulated by the governmental regime. This programme provides for commercialization activities in the domains of biologiocal and medical technologies, IT, new materials, electronics and machinery, novel energy sources and energy efficiency and environmental protection. Even though Torch is a MoST program, but roughly 70 percent of the funding for the activities of the Spark and Torch comes from industrial enterprises themselves.

The main functionaries and activities of the Program include:

- Formation of industrial development zones
- Formation of technology business incubators
- Formation of a online central industrial base
- Supporting the application of high-end research by promoting its usage in industries to yield economic gains for China

Four major instruments i.e. Innovation Clusters, Technology Business Incubators (TBIs), Seed Funding (Innofund) and Venture Guiding Fund, have been established under the program for it to achieve its objectives (https://www.huffingtonpost.com/steve-blank/chinas-torch-program-the-_b_3063069.html).

i. **Innovation Clusters:** Innovation clusters are defined as clusters of different yet corresponding industries, in a particular geographical location. These clusters have an advantage over a sole industry by means of resources as well as capabilities. By combining

the assets and coalescing together the strengths, the money as well as expertise, the clusters hold a competetive edge over individual private firms.
The Innovation Clusters, vide this program were established as - Science and Technology Industrial Parks (STIPs), Software Parks, and Productivity Promotion Centers (PPCs). One of the most successful examples of the same is the first STIP, *Zhongguancun Science Park* (http://en.zhongguancun.gov.cn/) in Beijing, which has developed into China's Silicon Valley.

Nearly, 146 high tech zones and parks have been developed under this instrument with a large number of companies hosted by these very zones (approx. 50,000). The program has promoted economic growth of the nation by constructing and establishing these parks and also creating an optimum environment for the development of industries/private sector. Technology specific and domain oriented clusters have also been formed, such as, Donghu Technology Development Zone in Wuhan, specializes in optoelectronics, Shenzhen High-tech Industrial Development Zone specializes in telecommunications etc. The implementation of this programme also brought about the promulgation and employment/usage of new and high-technology findings in the industries of traditional origin thereby upgrading industries and revamping the organization of local economies. For instance, a significant number of technologies have been put to use in the traditional industries housed in Tianjin STIP. Approximately, more than ten new types of technologies have been put to use in the production of *Tianjin Xiali Automobile Factory*, such as, the automatic control system for the assembly line and the hanging integrated spot-welder etc.

In addition to the Torch program, a major part of the Cluster Approach of China also included enhancing cooperation amongst the private sector i.e. large businesses and technology based small firms and SMEs. This goal was achieved through the institutionalization of special centres, called Productivity Promotion Centres, which rendered support services like consultation, incubation amenities, training, testing facilities, enlistment of start-ups of candidates etc.

ii. **Technology Business Incubators (TBIs):** The TBIs in China grew at a rapid pace under the authority and guidance of the Torch program. Though the specific regions where high end research takes place are known as Innovation Clusters, it is actually the incubators in these clusters, which house the start-ups that perform intensive R&D. The TBIs are designed to offer a wide range of services for the advancement and evolution of knowledge intensive companies, especially the SMEs. They create a conducive environment for fostering entrepreneurship, facilitation of technology transfer, catalyzing the growth nof company during its start-up period and thereby enhancing the rate of success of the enterprises. TBIs provide companies with a space for operation, access to resources & knowledge of academia, and technical facilities at reduced prices. As TBIs have demonstrated to be effective in cultivating technology based enterprises, creating new job opportunities, nurturing novel sources of economic advancement, and hence are considered to be one of the critical tools for achieving tenable economic growth. In China, the growth of TBIs made them an important factor that pushed forward the high-technology industry in a big way. There also has been the development of scope/field specific TBIs, e.g. Advanced Material Incubator in Beijing, Biomedicine Incubator in Shanghai, Marine Technology Incubator in Tianjin, etc. A few of the present day international businesses like Suntech Power, Lenovo, Huawei etc. were start-ups in these incubators in the past.

iii. **Seed Funding (Innofund):** Taking inspiration from the SBIR and STTR programs of the United States, China established InnoFund in the year 1999 (http://innofund.chinatorch.gov.cn/english2/index.shtml). The main stream of contribution of this fund is through grants, loans, equity etc. and the goal behind establishment of this fund was to provide funding to the enterprises and companies that possess a technology in its early stage. The seed funding aimed at supporting new technologies, which even though demonstarated great market capability but were not mature enough to receive loans from banks or venture capitalists. Certain prerequisites were set for industries eligible for the Fund, such as, should work in the domain of high-tech R&D, should have a maximum number of 500 employees, minimum of 30% of the employees should be technical and the major number of partners/owners should be of Chinese origin. The eventual goal of this fund was to support the small technologies based firms and facilitate the transalation of R&D efforts and results. There are three main features of the InnoFund that distinguish it from other non-governmental funds. First being the fact that this fund is policy-oriented, demonstrating the guiding role of the government for developing new and technology oriented enterprises (encouraging innovation). Secondly it promotes novel mechanism of investments i.e. it aims at attracting higher investments into the technogu based firms from the governments, corporations and financial institutions. Finally, InnoFund does not aim at making profit for itself but enhancing the revenue and jobs, thereby contributing to the advancement of the national economy.

iv. **<u>Venture Capital Guiding Fund</u>:** For gathering the attention of the venture capitalists, MoST and Ministry of Finance, collaboratively set up the Venture Capital Guiding Fund. Through the means of this fund the ministries aimed at engaging VCs into investing more into the new start-ups and SMEs. This fund was established, under the aegis of the Torch Program, in 2007 for focussing at the advancement of SMEs. A major transformation that came about with the introduction of this fund was the introduction of the *SME Promotion Law*. This law was enforced in 2003 and advocated the thorough involvement of the government of China in the protocol of advancement of SMEs and start-ups. This law revolved around rising establishments/organizations, schemes/initiatives and services for fostering growth and economic advancement of small technology based enterprises.

The VCG Fund invests in four diverse methods (Figure 2) –

- Directly into VC funds
- Co-investment with VCs,
- VC investment funding
- VC comfort subsidy

Type	Features
Fund-of-funds	VCGF plays a role in fund-of-funds, contributing initial capital to a VC fund with other private founder-members and selling its founder's shares in pre-agreed terms. However, SVGF shares shall not exceed 25% of the registered capital of the newly funded VC fund, and shall not become the largest shareholder.
Co-investment	Both the VCGF and the VC firm co-invest in early-stage SMEs. This is designed to support VC firms in order to reduce the investment risk.
VC investment subsidy	VCGF subsidizes certain VCs so as to help them withstand risks.
VC comforting subsidy	VCGF subsidizes certain VCs so the guarantee takes place before and after an investment.

Figure 2 The main forms of public venture capital scheme in China

Source: Wang et al., 2013

- **National Technology Transmission Centre**

The Torch Centre established under MoST also has an additional responsibility for the setting up and management of the 'Technology Transmission Centres (TTCs)'. The TTCs are mainly the organizations that provide variety of services like provision of brokerage, integration & management of technology, financial services etc. The primary function of these establishments is facilitate knowledge & technology transfer. The services provided by TTCs include –

- Technical information – collection, screening & analysis
- Technology – integration, secondary development & transfer
- Paltform for pilot testing, engineering, analysis, technology trading & networking
- Technical advisory
- Intellectual Property – advisory, bidding, transactions etc.

TTCs mainly serve SME's in regard to creation of public service platform/ technology support systems in high-tech. areas.

2.2 Blue Flame Program

Background: The program – Blue Flame, was launched in 2008, by the Chinese Ministry of Education, Science & Technology Development Centre (STDC). This program aimed at promoting direct partnerships between the industries and higher education institutes (HEIs) by involving the local governments. It aims at boosting the industrial competency and innovation through the utilization of talent in R&D for addressing the societal needs. The main idea behind initiating this program was to accelerate the translation of research being undertaken in the HEIs for the betterment of the society and gradually advancing the industry and trade competitiveness.

Objectives: The key objectives of the program -

- Provision of a platform for the academicians/researchers and businesses for communicating so as to address the issues of both the sectors adequately. These issues might include technical problems or ceratin practical applicability problems, the solutions for which may be attained collaboratively.
- Building a long term plan for fostering strong collaborations between industries and HEIs, this includes establishment of technology transfer cells in the universities. These cells would ensure transaltion of research being carried out in the universities to the industry and private sector.
- Building a team, for supporting the collaboration between the two entities. This team shall maintain focus and ensure smooth movement of talent from the universities to the industry and skills from the industry to the universities.

Administration

This program is administerd jointly by the S&T Development Centre (STDC) of the Ministry of Education and the local government. The overall modalities and function of the program are also looked after by the two jointly. The program moves ahead in different phases i.e. in its initial phase the program objective focuses on the cities and regions that are in urgent need of new innovation oriented companies and enterprises.

Prior to the beginning of the initial phase, the local governments or regional authorities provide information in regard to the development quotient viz-a-viz industrial and economic, technical levels, major enterprises and companies in the area etc. This information is applied for identifying the city/region where the first phase of the program needs to be launched. It is also the responsibility of the local government to provide information regarding ceratian specific initiatives/measures that need to be put into place for encouraging collaborations between the businesses and the HEIs.

Once the city/region is identified and the plan of implementation is approved, both the local government and the S&T Development Centre jointly enforce the program and the activities related to it.

Procedure of the program

1. A compliance report comprising of the economic and industrial environment/surroundings of a specific region, besides the profiles of the existing industries and the plan of local government for the advancement of S&T in that particular region is submitted.
2. The requirements and demands of local/indigenous industries are collected and provided to the STDC, by the local government, in a well documemnted form. The Centre further passes on this document (needs and prerequisites) to the HEIs, which work in that exacting domain.
3. Upon examination and valuation, the local government and the STDC, establish a Blue Flame Program Office. The various modalities and undertakings of the Program in that particular area are looked after and implemented by this especially established Office.
4. The Office works towards bringing into place long-standing connections between the experts from academia and industry. The academicians are encouraged to converse with the industry, understand their issues, provide them solutions and vice versa. This

establishment also looks after facilitation of transfer of technology/product/services from the universities/HEIs to the private sector and also ensures its practical application. The officials of this specialized Office also identify key areas for collaboration, designing projects according to the partnerships and further creation of 'Technology Transfer Centres' in universities.

5. Correspondingly, the local authorities are responsible for devising policies, strategies and impetus for encouraging translation as well as transfer of research from the HEIs to the industries and enterprises.

2.3 The Spark Programme

Background: One of the first plans approved by the Chinese government for promoting economic development in rural areas through the fruits of science & technology was the Spark Program. This program, which was permitted by the State Council was devised for renovating the wealth & financial system of the agrarian/rural sections and resurrect S&T endeavours through an approach that may prove beneficial to the farmers as well. The rapid development of townships, also lead the rural economy to become more active and the commercialization of agricultural produce made the farmers aware of the importance of S&T thereby heightening the requirement of S&T in the rural regions.

In May 1985, the MoST submitted a suggestion to the State Council, stating to *"implement a batch of scientific and technological projects of quick benefit so as to promote local economy"*, and the program was implemented in 1986. The purpose of the program was to introduce advanced technologies into the agrarian system for promoting productivity of the rural areas and expedite the sustainable development of the economy. The program sought to upgrade technological standards and assist in issues like lack of access to technology, qualified staff, business-oriented information etc. It aimed at accomplishing the aforementioned objectives through transferring and diffusing knowledge & technology to the rural areas for improving the overall life quality of the farmers.

This program, whih was initiated with a rationale of 'scinece & technology equals productivity'and foussed on rural areas, enterprises in townships and entrepreneurs frpm rural regions, concluded in 2015. The program was stopped due to the changes and reforms that were carried out in the S&T system of China.

Objecties:

The purpose of the Spark Plan was to revamp and push forward the economy of rural areas through S&T and to disseminate S&T in non-urban areas. The main objectives were -

i. to improve labour productivity and economic efficiency through S&T
ii. encourage farmers to change traditional production methods and lifestyles
iii. develop pillar industries in specific regions through S&T advancement
iv. promote township enterprises in key industries to advance S&T progress
v. train personnel on rural applicable technology and management
vi. improve the overall quality of life of rural workers

Administration and Strategy:

The Spark plan was conducetd at many levels and also involved the S&T departments of the government at different levels i.e. municipal, regional, state and national levels. Hower, the main ministry that looked after its implementation and protocols was MoST. The ministry also instituted a Spark Office, which was responsible for ontrolling and managing all the processes of the plan. Local authorities and State Council were responsible for carrying out the various protocols of the program in their respective regions, municipalities and provinces. The assessment and evaluation of the program is also carried out by the State Counils.

Each year, the MoST used to issue call for proposals from agricultural enterprises, research institutions, rural entrepreneurs and farmers, in areas of key support as announced by the MoST only. The most suitable and relevant proposals were then selected by experts and chosen for support. Fixed funds of CNY 250 million per year (approx. USD 70 million) were provided for the projects along with unfixed funds that were proided by the local governments, private funding agencies and bank loans etc.

For improving the skills and knowledge of the township enterprises, rural entrepreneurs, farmers, technology training was provided. This training was funded under the aegis of the program and was implemented by the S&T departments at different levels. Training was also provided in the domain of management. The projects, which utilized S&T knowledge and know-how from the research institutes, for solving technology projets were also offered support. The projects included were, designing of products, technical demonstrations, and development of quality control techniques.

Additionally, Spark pillar industries were also developed in certain specific regions and the projects selected under this programme were eligible for favourable loans from the banks and preferential taxation policies.

As of the year 2012, a total of 1473 national projects had been funded through this program. Amongst them approx. 130 projects were of national importance. Figure 3 illustrates the major stakeholders and performers of the national projects, funded under this program.

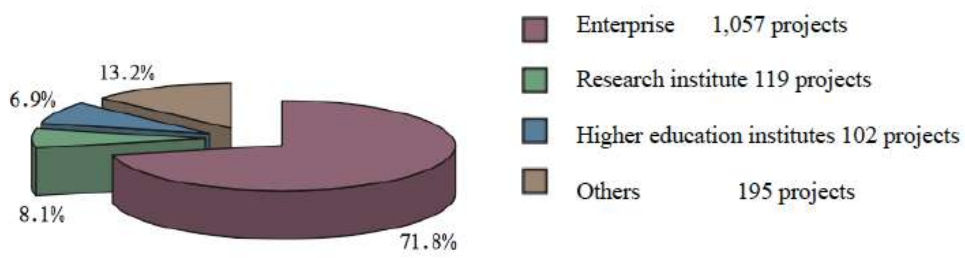

Figure 3 Allocation of key national projects by performers

Source: Gao, 2015

2.4 Science and Technology for Wellbeing Programme

As a part of implementation of the National Mid-Long-Term Science and Technology Development Framework, the Ministry of Finance and MoST, brought in the Science and Technology for Wellbeing Program. This program was initiated with a clear aim of translating the R&D outcomes and achievements for societal advancement and enhancing the quality of life. This modalities of the program also aimed at simplifying and easing the process of translation of research results for improvement of the lives of the general public. The major fields in which the program is active are public health, safety, societal management, ecological development and a few other fields related to societal development.

The driving force of this program was essentially the demand of technologies for improving the standards of livelihood and is lead by innovative activity in S&T. Incidences of innovation and S&T breakthroughs entail partnerships amongst the stakeholders i.e. universities, research laboratories and the industries.

The authorities at the central and local levels jointly invest and also promote other investments from an assortment of investment sources. This program is managed and implemented jointly S&T departments of all levels and the Ministry of Finance (MoF) even though each department at each level has individual responsibilities.

Administration

The main supervisor of the program is MoST, which looks after the modalities of the program. MoST in collaboration with the MoF, designs the plan of the program, manages the finances involved,

is in charge of the broad supervision of the program. In association with the Ministry of Finance, it designs, plans, manages the funds, executes, supervises and evaluates the projects under this program. The budget of the program is assessed as well as approved by the Ministry of Finance. The consultation for projects is in hands of other relevant departments. The departments of S&T and finance at all levels also work towards integration of resources, assuring funds, synchronizing with the central authority and disseminating the accomplishments.

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Singapore

Contents

1. Introduction

Singapore is designated as an enormous success story of Asia, which has transformed itself from the status of a developing economy to a modern advanced economy in the time span of one generation. Amongst the Asian economies Singapore excels and holds the top position. It has an overall rank of 7 in the Global Innovation Index 2017-18. Singapore has scored the highest average points amongst Association of Southeast Asian Nations (ASEAN) members in almost all of the indices. Scores of few of the indicators have been enlisted in the table 1 below-

Table1: Global ranking of USA, as based on S&T related indicators.

S. No	Indicators (2017-18)	Global Rank
1.	Expenditure on education, % GDP[a]	102
2.	Research & development (R&D) [a]	11
3.	Gross expenditure on R&D, % GDP[a]	15
4.	Global R&D companies, avg. expend. top 3, mn $US[a]	22
5.	QS university ranking, average score top 3[a]	12
6.	University/industry research collaboration[a]	7
7.	Capacity for Innovation[b]	20
8.	Company Spending on R&D[b]	17
9.	Availability of Scientists and Engineers[b]	9
10.	Quality of Scientific Research Institutions[b]	12
11.	Publications[c]	32
12.	H-index[b]	25
13.	Intellectual Property Rights[d]	2
14.	PCT Patents[b]	12

Source: [a]GII 2017-18; [b]GCI 2017-18; [c]http://www.scimagojr.com/countryrank.php; [d]IPRI Report, 2017 (http://internationalpropertyrightsindex.org/ipri2016)

Singapore has been identified as a vibrant country with a dynamic S&T ecosystem, which has aided in its growth as a knowledge-driven economy. The advancement of the country towards an entrepreneurial country has been largely driven by intensive R&D activities and strong partnerships. Two main agencies that trail and support collaborative research amid the public sector and the private sector in Singapore are -

2. Agency for Science, Technology and Research (A*STAR)
3. National Research Foundation (NRF)

2. Schemes /Programs/Organizations

2.1 Agency for Science, Technology and Research (A*STAR)

The A*STAR (https://www.a-star.edu.sg/) agency in Singapore drives and endorses research that is specific in nature and further aims at evolving scientific discoveries and innovative activities. The agency makes strong efforts for bridging the gap between the academia and the industry. The agency portrays and executes an essential role in fostering and nurturing capacity building for organizations conducting research and research oriented private enterprises. Until the year 2001 it was called the 'National Science & Technology Board' and was still considered as one of the foremost agency for providing finance for research activities, providing assistance for collaborative R&D and linkages with global industries. The agency, A*STAR is made up of dedicated councils for Biomedical Research Council (BRC) and Science and Engineering Research Council (SERC), which aim at promoting core research capacities in the above mentioned domains. In order for the agency and the councils to work efficiently in regard with the needs of the industry, these councils possess proactive industrial core groups that facilitate active R&D engagements with the industry. Furthermore, the agency also has a dedicated wing for its commercial activities i.e. the Exploit Technologies Pte Ltd. (ETPL), which acts as 'one-stop-co-innovation partner' for private industries in Singapore.

Being the commercial arm of A*STAR, the main role of ETPL is aiding the translation of innovations into the commercial circle and the marketplace. ETPL comprises of dedicated teams which have experts from the fields of intellectual property (IP), technology transfer (TT) and commercialization. These teams help in evaluating and enhancing the value of IP and incubate new business ventures for generating commercial impact.

The figure 1, represents the organizational structure of A*STAR -

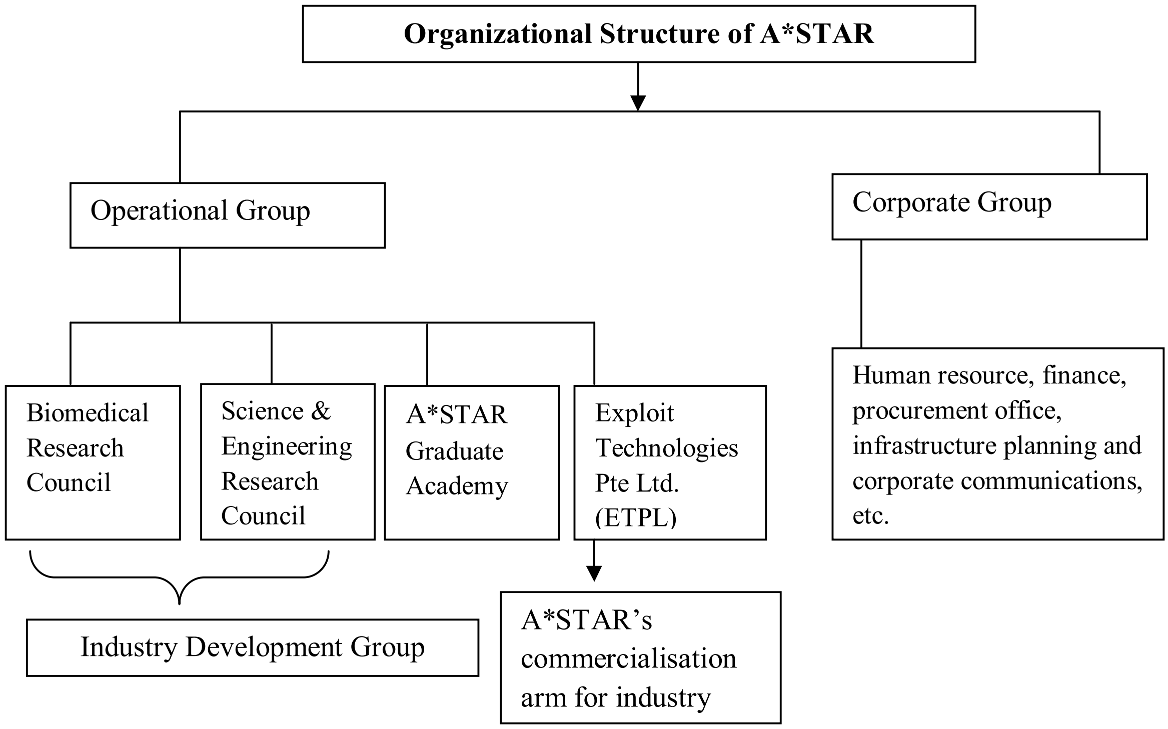


Figure 1: Organizational Structure of A*STAR

A*STAR has initiated a large number of programmes for supporting collaborative R&D through public private partnerships (PPP) in R&D. A few of the initiatives have been listed belwo:

1. ***Industry Alignment Fund Pre-Positioning Programme (IAF-PP):*** **- Advanced Manufacturing and Engineering, and Health and Biomedical Sciences domains (AME and HBMS domains) (https://app.a-star.edu.sg/rie2020fip/):** The IAF-PP supports research conducted in the public sector in alignment with industry requirements of Singapore. The program does so by developing integrated capacities and programmes, which provide outcomes for the challenges that, are faced by the industry or promise the potential for transforming the advancements existing in the industry. Both new as well as existing programmes (previously established a sound success record and strong potential for industry) are supported through this initiative.

The initiative is governed by a Strategic Oversight Committee (SOC) that comprises of board members from the agencies A*STAR, the National Research Foundation (NRF) and the Singapore Economic Development Board (EDB).

2. ***Industry Alignment Fund (IAF) Industry Collaboration Projects (ICP)*** **(https://app.a-star.edu.sg/rie2020fip/):** The IAF-ICP is open for all the public sector research performing institutions in Singapore and aims to provide support for collaborative research activities in premeditated domains of national importance. The main difference between IAF-ICP and other academic grants is that the proposals are assessed primarily on the basis of economic impact that they stipulate. The economic impact includes-
    a. the level of assurance of the industry partner towards R&D spending in Singapore
    b. Capability for creation of new jobs
    c. Capacity for development of new products/services etc. or any other significant economic activity.
    d. Capacity building in locally based SMEs

    The initiative is governed by a Strategic Oversight Committee (SOC) that comprises of MD A*STAR, MD EDB, CE SPRING and CEO NRF.

3. The ***Industry Consortia Programs*** of A-STAR takes advantage of the wide base of the technical proficiency existing at the Science and Engineering Research Council (SERC) Research Institutes for aiding the indigenous industries in developing new technologies and move ahead. These programs also provides conduit and an opportunity for the small local industries to work in association with the SERC research institutes as well as big multinational corporations by means of research partnerships and membership initiatives. In such sort of consortium setting the pre-competitive research being undertaken benefits all the members.

4. The ***Joint-Research Programs*** are necessarily one-on-one partnerships between an industry and A*STAR research institutes (RIs) for research activities. Through such a programme the technology edge of the industry can be improved through the transfer of technology from the RI. Aforesaid association has the capacity to serve as a platform for the industry to learn new insights from researchers thereby facilitating advancement of technology and the devising of novel methodologies and techniques. Under this programme Singapore Bioimaging Consortium was established with A*STAR research institutes and Nikon Imaging Centre and Clinical Imaging Research Centre was created in collaboration of Seimens with A*STAR and National University of Singapore.

The Lab-in-RI is an A*STAR initiative in which the research institutes provide partners with infrastructure and framework at an early stage of their R&D projects. For the partnering companies, this has the advantage of implementing their plans under favorable conditions, to allow the companies to jumpstart their R&D activities in Singapore before making major capital investments.

5. ***Gap funding for Co-Development:*** A*STAR technologies that has to be readily taken up by industry players will be provided with gap funding to carry out further research for licensing the technology at commercial platform. Under this programme of co-development A*STAR has supported SME-Special Media Pte Ltd. and associated research institute for carrying out further research with licensed software to build profile system for users based on their browsing patterns over many websites. A*STAR has also funded SME-XJERA Labs Pte Ltd for taking forward multi outlet entity detection and classification software in association with ETPL for developing Video Intelligence Technologies for Retail (VITR).
6. ***A*STAR Collaborative Commerce Marketplace (ACCM):*** it is the free online portal to facilitate public private partnerships between research institutes and industry by matching technological competencies and requirements of both industry and research institute as partners.
7. ***Collaborative Industry Projects (CIP):*** the programme was started under spring Singapore initiative of a*star to promote collaborations between industry and solution providers to address common industry linked problems. It has led to creation of consortia composing of 3 SMEs which are subjected to 70% funding from A*STAR for pursuing collaborative R&D. Lead example of CIP project led consortia is:
    - Printed Electronics for Smart Packaging consortia set up by A*STAR's Singapore Institute of Manufacturing Technology (SIMTech) in association with SMEs.

A*STAR institutes have also established dedicated *Centres of Innovation* (CoI) which are open to local and multinational companies to access laboratory facilities and avail technology consultancy for improving their technological competencies. Under A*STAR various industry groups have been formulated to bring various SMEs to discuss their problems and share their technology offers.

Initiatives of A*STAR dedicated towards the growth of SMEs in Singapore have been listed in table 1. These initiatives have been drawn up to enhance the technological capability of SMEs and hence augment their contribution towards the economic growth of the country.

Table 1: A*STAR Programmes for SMEs

S. No.	Programme	Brief Details
1.	**Tech Depot** (https://www.smeportal.sg/content/tech-depot/en/home.html)	• It is a centralised platform within the [10]SPRING SME Portal, which is focussed at enhancing the access of SMEs to the digital and technology solutions. • Nearly 30 technological solutions in about 10 domains are featured and available for licensing. These solutions are the ones developed and/or pre-qualified by A*STAR, Info-communications Media Development Authority of Singapore (IMDA) and SPRING Singapore for funding support.
2.	**Tech Access** https://www.a-star.edu.sg/Collaborate/Programmes-for-SMEs/Tech-Access.aspx	• Through this initiative, SMEs, for enhancing their capabilities, can gain the right to use A*STAR's facilities of advanced manufacturing, their equipments and expert knowledge. Tech Access is provided in field of robotics, inspection tools and additive manufacturing.
3.	Capability Upgrade (https://www.a-star.edu.sg/Collaborate/Programmes-for-SMEs/Capability-Upgrade.aspx)	• Local enterprises are aided in technology up gradation through Growing Enterprise Through Technology Upgrading (GET-Up) programme wherein A*STAR provides support through means of technology road mapping, technical advisory and allocation of skilled manpower to the companies. Under this initiative of capacity building, A*STAR has launched certain schemes like:

[10] SPRING Singapore is an agency under the Ministry of Trade and Industry responsible for helping Singapore enterprises to grow and build trust in Singapore products and services. SPRING works with partners to help enterprises in financing, capability and management development, technology and innovation, and access to markets. As the national standards and accreditation body, SPRING develops and promotes an internationally-recognised standards and quality assurance infrastructure.

		• *Operation & Technology Road mapping (OTR)* • *Technology for Enterprise Capability Upgrading (T-Up)* • *Technical Advisory (TA)* • *Knowledge Transfer to SMEs*
4.	**Faster Time to Market** (https://www.a-star.edu.sg/Collaborate/Programmes-for-SMEs/Faster-Time-to-Market.aspx)	• A*STAR has a developed a simple and lucid method of licensing technologies to the commercial players by devising shorter 'licensing deal documents' with simple and easy to understand language. • Furthermore this initiative provides the SMEs, that have worked in association with A*STAR, royalty free exclusive license of the jointly developed IP for period of 36 months. This can be further extended up to 18 months.
5.	***A*STARTCENTRAL*** ttps://www.a-star.edu.sg/Collaborate/From-lab-to-market/Enhancing-the-Ecosystem-for-Technopreneurship.aspx	An open innovation based community of A*STAR that works under the ETPL branch of the agency. It works for the support and training of researchers, which shall help them to establish and develop their own technology based ventures in Singapore. It aids through the means of incubation services, guidance by industry mentors, expert advice of academicians etc. Community provides two business related services as mentioned below: • Investment services • Spin-off services

Source: *https://www.a-star.edu.sg/*

For evolution and advancement, it is imperative that there is generation of new technologies, services and products. For this the research being conducted should be in alignment f he interests of the industry as well as academia. In light of this aspect A*STAR through its belief of forging strong relations with industries has taken many initiatives. By virtue of the eminence of the establishment, A*STAR has the capability to serve as a platform enabling new learning of industry players and hence facilitating evolution of S&T. The agency has hence made provisions for associating with industries and other public sector research organizations through different models. The four types of engagement models are listed below:

a) Many to Many

Source: *https://www.a-star.edu.sg/*

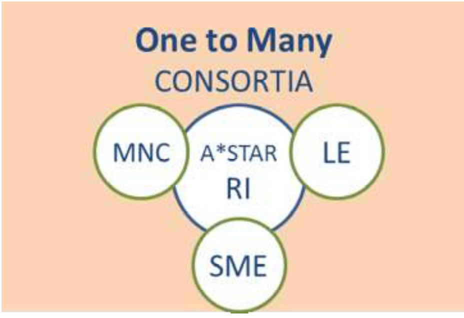
This model entails the existence of multiple Research Institutes (RIs) and industries for creating an efficient platform of collaboration between the private and the public sector, to work on special themes and bolstering the research capabilities. An example of the same is the 'EpiGen Global Research Consortium' that engages the Singapore Institute of Clinical Sciences (SICS) [an international research organization with 5 member parties in 3 different countries]

b) Many to One

Source: *https://www.a-star.edu.sg/*

This model entails the participation of numerous public researchers while engaging with one partner for materializing long-term planned partnerships. Through this model the scientific expertise of different disciplines are integrated for delivering impactful solutions. The collaborative lab established through the joint efforts of Applied Materials, Inc. (American corporation), Institute of Microelectronics (IME), Institute of Materials Research and Engineering (IMRE) and the Institute of High Performance Computing (IHPC) is an example of the model. The lab makes use of the cross-disciplinary R&D capacities, thereby catalyzing the advancement of novel techniques/protocols for developing the fabrication methodology of semiconductor devices.

c) One to Many



Source: *https://www.a-star.edu.sg/*

In this model several companies come together with one RI to develop a consortium, which focuses on the strength of the research institute. Example –'Nano-imprint Foundry' anchored by the Institute of Materials Research and Engineering (IMRE) collaborates with industries like Toshiba Machine, Micro Resist Technology and Kyodo International for working on the applications of Nanoimprint technology.

d) One to One

Source: *https://www.a-star.edu.sg/*

This model includes work on an individual research project and formation of a joint laboratory for the same. The Institute of Bioengineering and Nanotechnology (IBN) and Delta Electronics, cooperatively created a diagnostics laboratory for focusing on emerging know-hows for better infectious disease recognition and custom-made medication.

The impact created through the initiatives of A*STAR towards strengthening partnership with the private sector for undertaking joint R&D projects with public research institutes is presented below:

More than Singapore Dollars 220 million investment in Industrial R&D
More than 60 research funding and support to local enterprises for enhancing their R&D efforts
More than 1700 collaborated projects undertaken with industry
More than 200 licenses deployed to the local and multinational companies in Singapore
~448 technologies offering listed for uptake and up gradation by industry partners
~70 technology start-ups generated

Source: *https://www.a-star.edu.sg/*

Some of the successful technologies developed jointly by Industry and A*STAR research Institutes upon technology licensing are listed below:

Table 2: Success stories of A*STAR licensed technologies to or with industry

S. No.	Industry	A*STAR Institute/unit	Technology
1.	Knorex Pte Ltd.	Institute for Infocomm Research (I2R)	Semantic Technologies to enable data aggregation, integration and mining to expedite knowledge discovery and application
2.	US company	Singapore Institute of Manufacturing Technology (SIMTech)	Liquid Forging
3.	Maha Chemical	Singapore Institute of Manufacturing Technology (SIMTech) and Workforce Development Agency	OmniMethodology[T]

		(WDA)	
4.	Burning Bush Connexion Pte Ltd.	Singapore Institute of Manufacturing Technology (SIMTech)	Radio Frequency Identification (RFID)
5.	Compex Systems	Infocomm Research (I2R)	Compex focuses primarily on OEM/ODM supply of network communication systems and wireless broadband systems.
6.	Component Technology Pte Ltd.	Singapore Institute of Manufacturing Technology (SIMTech)	A cost effective solution for post wire bond inspection and measurement
7.	Niometrics	Institute for Infocomm Research (I2R)	CUB4 Engine Tightens Enterprise Network Security
8.	Bio-Scaffold International (BSI)	Singapore Institute of Manufacturing Technology and the National University of Singapore	Bio-Scaffold International's futuristic and degradable scaffolds for ridge preservation after tooth extraction made its way to clinics locally and overseas
9.	Nanoveu, Temasek Polytechnic (TP) and entrepreneur Alfred Chong	Institute of Materials, Research and Engineering (IMRE)	EyeFly3D
10.	LDR Pte Ltd.	Institute for Infocomm Research (I2R)	Mobile application and e-learning solution
11.	HistoIndex	Diagnostics Development (DxD) Hub	Imaging system Laennec™, a liver disease diagnosis system targeted for clinical diagnosis.

Source: *https://www.etpl.sg/engage-us/success-stories/*

Some of the ongoing industrial research collaborations with A*STAR are presented in table below.

Table 3: Industrial collaboration with A*STAR

S. No.	Sector	Industry	Strategic Partnership
1.	**Chemical and Energy** https://www.a-star.edu.sg/Collaborate/Industry-Sectors/Chemical-and-Energy.aspx	**Procter & Gamble (P&G)**	Master Research Collaboration Agreement (MRCA) with A*STAR in 2013 to span five years' of research partnerships with Singapore's vast network of over 25 research institutes, medical institutions and the academe.
		LION Corporation	Research Collaboration Agreement (RCA) with Institute of Materials Research and Engineering (IMRE) to develop safer, anti-odour and anti-bacteria household products that eliminate the use of harmful biocides.
2.	**Electronics** https://www.a-star.edu.sg/Collaborate/Industry-Sectors/Electronics.aspx	**Hitachi Asia Ltd.**	Collaboration with Data Storage Institute (DSI) to develop data compression technique to tackle the increasing volume of genome sequencing data generated by the health-care and biomedical industry.
		Applied Materials	Collaboration with Institute of Microelectronics (IME) for semiconductor technology
		KLA-Tenor	Collaboration with Institute of Microelectronics (IME) future process control trends, driving technology development for our next-generation tools.
		Nikon Corporation	collaboration with Institute of Microelectronics (IME) for future process technology and total solutions, which will be important for our lithography system development
		Panasonic Factory	Strategic alliance with A*STAR for development of advanced flip chip bonding

		Solutions Co., Ltd	technologies that will support next generation's semiconductor packaging.
		Tokyo Electron Ltd	Collaboration with Institute of Microelectronics (IME) for semiconductor technology
3.	**Engineering** https://www.a-star.edu.sg/collaborate/industry-sectors/engineering.aspx	**Lloyd's Register**	Lloyd's Register has established a world-class Group Technology Centre (GTC) in Singapore to deliver innovation and solutions to the energy and maritime sectors. They have reached an agreement with A*STAR to collaborate on R&D projects as a key part of the centre's activities.
		Rolls-Royce	Played an instrumental role in the development of the Advanced Remanufacturing and Technology Centre (ARTC) as a collaborative platform that connects public sector research laboratories, academia and industry players from MNCs and SMEs to bridge technological gaps in the adoption of advanced remanufacturing processes.
4.	**Infocomms** https://www.a-star.edu.sg/Collaborate/Industry-Sectors/Infocomms.aspx	**Rolls-Royce**	Computational Engineering Lab (CEL) was jointly set up by the Institute of High Performance Computing (IHPC) and Rolls-Royce.
		ERS Industries	Collaboration with Institute of High Performance Computing (IHPC) to develop a rack that could efficiently disperse the built-up heat generated from the equipment.
5.	**Medical Technology** https://www.a-star.edu.sg/Collabo	**Eastern Health Alliance (EHA) and SingHealth Polyclinics**	MyHealth Kiosk is a second-generation patient self-help kiosk developed with Bedok polyclinic and Thye Hua Kwan Moral Charities senior activity centre

	rate/Industry-Sectors/Medical-Technology.aspx	**(SHP)**	
6.	**Pharmaceuticals & Biologics** https://www.a-star.edu.sg/Collaborate/Industry-Sectors/Pharmaceuticals-Biologics.aspx	*Chugai Pharmabody Research (CPR)*	Chugai will invest approximately S$200 million over the next five years to establish Chugai Pharmabody Research (CPR), Singapore's first corporate laboratory in the area of antibody engineering.

Source: *https://www.a-star.edu.sg/*

2.2 National Research Foundation (NRF; https://www.nrf.gov.sg/)

Under the aegis of the Prime Minister's Office, the National Research Foundation (NRF) of Singapore was established in 2006. NRF aims at setting a national direction for R&D by drafting policies, strategies, and plans of action for research, innovation and entrepreneurial activities. It has taken the onus of honing and nurturing research by funding well planned initiatives and building R&D capacities. With these pursuits, NRF aims to transmogrify the country into a dynamic and tenacious R&D hub, which will provide for a knowledge-intensive and enterprising economy, thereby effecting Singapore into an appealing destination for S&T and innovation.

The NRF works on the following 'Mission' statement (https://www.nrf.gov.sg/about-nrf/national-research-foundation-singapore):

- Developing policies, plans and strategies for research, innovation and enterprise;
- Funding initiatives that strengthen research and scientific capabilities, and achieve economic and national impact;
- Building up R&D capabilities and capacities through nurturing our people and attracting foreign researchers and scientists; and
- Coordinating the research agenda of different agencies to transform Singapore into a knowledge-intensive, innovative and entrepreneurial economy.

Four pillars of thrust undermine the plan of action to evolve the economy of Singapore. The transformation of the economy into an innovative and enterprising one has been realized through building the innovation ecosystem on these very four pillars, which are-

- Strengthening foundational capabilities;
- Developing talent;
- Driving research excellence through competition; and
- Ensuring impact through public-private collaborations, industry-oriented R&D, and commercialization.

The NRF has defined The Research, Innovation and Enterprise (RIE) scenario in Singapore is composed of different ministries, R&D funding agencies and R&D analysts/performers (figure 2).

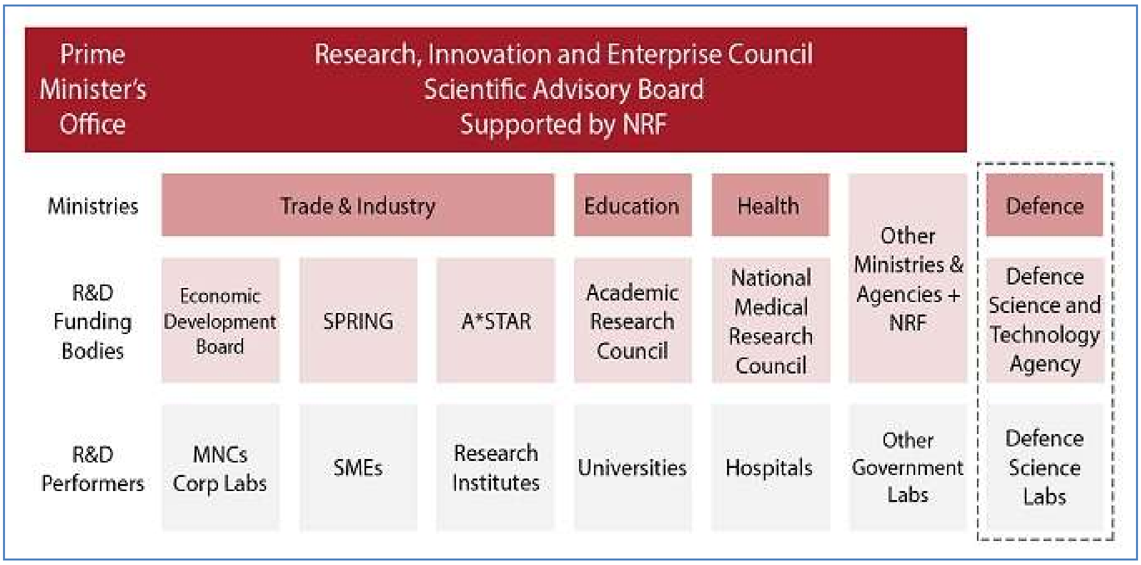


Figure 2: Research, Innovation and Enterprise (RIE) system in Singapore

Source: *https://www.nrf.gov.sg/about-nrf/rie-ecosystem*

The Research, Innovation and Enterprise Council (RIEC), is supervised and regulated by the Prime Minister and is responsible for overseeing the long term strategic plans with respect to science, technology and innovation. The NRF also supports RIEC, which draws out five-year plans and policies in accordance with the national issues and challenges.

Major programmes brought into action by NRF for supporting industrial partnerships with academic and research institutions and technology up gradation of industry/entrepreneurs/start-ups are listed in table 4.

Table 4: NRF Programmes for supporting Industry/entrepreneurs/start-ups

S. No.	Programme	Brief Details
1.	**Central Gap Fund** https://www.nrf.gov.sg/funding-grants/central-gap-fund	• The National Research Foundation (NRF) Central Gap Fund (Central Gap) aims to support the translation of research outcomes into useful products, processes and services that generate economic and societal benefits. • The scheme provides a national-level platform to resource impactful projects and encourage collaboration across public research performers and/or industry.
2.	**Early Stage Venture Fund (ESVF)** https://www.nrf.gov.sg/funding-grants/early-stage-venture-fund	• It is an initiative under the National Framework for Innovation and Enterprise (NFIE). ESVF seeds funds with selected venture capital firms to invest in Singapore-based early-stage technology start-ups. • Under this initiative, the National Research Foundation (NRF) Singapore invests S$10 million on a matching basis, to seed corporate venture capital (VC) funds that invest in Singapore-based early stage high-tech companies. • As an incentive, the corporate VCs have the option to buy out NRF's share of the fund within five years by returning NRF's capital with interest. The first batch of five VC funds were: ✓ Bioveda Capital ✓ New Asia Investments ✓ Raffles Venture Partners ✓ Extream Ventures ✓ Walden International

		The second batch of VC funds were : ✓ Jungle Ventures ✓ Golden Gate Ventures ✓ Tembusu ICT Fund I ✓ Walden International ✓ New Asia Investments ✓ Monk's Hill Ventures • Techventure 2013 that the Singapore government would inject S$50 million to energise the early stage investment ecosystem. • In 2016, NRF awarded venture capital funds to four large local enterprises (LLEs) namely: ✓ CapitaLand Ltd. ✓ DeClout Ltd. ✓ Wilmar International Ltd. ✓ YCH Group Pte Ltd.
3.	**Science of Research, Innovation and Enterprise Programme** https://www.nrf.gov.sg/funding-grants/science-of-research-innovation-and-enterprise-programme	The NRF launched the Science of Research, Innovation and Enterprise (SRIE) programme in 2014 to support evidence-based policy-making in research, innovation and enterprise involving stakeholders from government, academia and industry to jointly formulate roadmap for Singapore S&T Ecosystem.
4.	**Artificial Intelligence (AI) Singapore** https://www.nrf.gov.sg/programmes/artificial-intelligence-r-d-programme	• AI Singapore bring together all Singapore-based research institutions and the vibrant ecosystem of AI start-ups and companies developing AI products, to grow the knowledge, create the tools and develop the talent to power Singapore's AI efforts. • It is driven by a government-wide partnership comprising NRF, the Smart Nation and Digital

		Government Office, the Economic Development Board, the Infocomm Media Development Authority, SGInnovate, and the Integrated Health Information Systems. NRF will invest up to $150 million over five years in AI Singapore. • Beyond research institutions, AI Singapore will also harness the significant AI capabilities in the industry, whether within AI start-ups or corporate laboratories. AI Singapore will work with these companies and even individual enthusiasts via networking events, hackathons, to use AI to tackle real-world challenges.
5.	**Marine Science R&D Programme (MSRDP)** https://www.nrf.gov.sg/programmes/marine-science-r-d-programme	The MSRDP integrates R&D in tropical marine science and promote active engagement of industry in the drive towards environmental and marine sustainability. It seeks to advance marine science research in Singapore by leveraging Singapore's location in a region with rich marine biodiversity, to develop nationally relevant R&D and to build capabilities that would address the strategic needs of Singapore in the future.
6.	**Strategic Research Programmes (SRPs)** https://www.nrf.gov.sg/programmes/strategic-research-programmes	The SRPs support investments in areas of research to create new industries and enable high growth. These are in following sectors: ✓ Biomedical Sciences Translational & Clinical Research ✓ Environmental & Water Technologies ✓ Interactive & Digital Media ✓ Marine & Offshore ✓ Satellite & Space

7.	**Innovation & Enterprise (I&E) Cluster Fund** https://www.nrf.gov.sg/innovation-enterprise/innovation-enterprise-cluster-fund	The I&E Cluster Fund is an initiative under Research, Innovation and Enterprise 2020 (RIE2020), aimed at supporting projects catering to address the specific needs of each domain and to help capture value through translation of research to impact. The Fund seeks to strengthen partnerships across companies, universities, research institutes and government to bring ideas quickly to market, raise productivity, create jobs and grow the sector. The clusters considered under this support programme are as: • Diagnostics Innovation Cluster • National Additive Manufacturing Innovation Cluster
8.	**Innovative Projects Showcase** https://www.nrf.gov.sg/innovation-enterprise/innovative-projects-showcase	Innovative Projects Showcase features prototypes and products that have been translated from research and innovations undertaken in our R&D labs and by local start-ups and spin-offs.
9.	**National Research Infrastructure (NRIs)** https://www.nrf.gov.sg/programmes/national-research-infrastructure	NRIs serve as a platform for collaborative and inter-disciplinary research among local and international, and public and private researchers. This encourages synergies from interdisciplinary and collaborative research, which can drive the development of novel approaches and new technologies.

Source: *https://www.nrf.gov.sg/*

The various initiatives and schemes operating in the PPP mode in Singapore under NRF are as following:

1. Corporate Laboratory@ University

The scheme of Corporate Laboratory@University (https://www.nrf.gov.sg/programmes/corporate-laboratory@university-scheme) was put into motion by NRF in 2013, for securing the foundation of laboratory set up of key industries in the universities. Through this kind of initiative this scheme seeks to strengthen the innovation scenario by reassuring the collaboration of public (universities) and private (companies) sector for R&D. This scheme caters to establishing laboratories of domestic as well as international companies in autonomous universities for performing industry-driven and relevant research activities. This arrangement ensures that the academic institutions bring about conclusive impacts by working on effective solutions for the issues faced by the industries, with whom they have collaborated. The environment created by this sort of collaboration ensured that the researchers from the public domain as well as private domain work alongside on mutually selected areas and generating outputs that possess relevance to the private firms. This initiative has lead to marginal increase in the effective translation of public research into commercial entities and services. Apart from this there are multiple benefits brought about by the laboratory set up of an industry in a university. The research activities being undertaken are geared for supporting growth of companies and for spawning financial benefits. The scholars at the universities advantage from the industrial involvement and emerge as better prepared for employment in the industrial sector. The partners from the industries gain complete access to the intelligentsia of the university and can effectively utilize the scientific and technological expertise of the faculty/mentors. Beginning from 2013, nine such laboratories have been set up at various universities of Singapore. The table below enlists the collaborating partners of the Corporate Labs set up till date:

Table 5: List of Corporate laboratories set up at different universities in Singapore

S. No.	Name of the Corporate Lab	Investment	Industrial Partner	Academic Partner	Year of Establishment	Projects supported	Core Areas
1.	Rolls-Royce@NTUCorporate Lab http://www.ntu.edu.sg/ohr/career/CurrentOpenings/ResearchOpenings/RollsRoyce/Pages/index.aspx	S$75 million	Rolls-Royce	Nanyang Technological University (NTU)	2013	>40	• Electrical Power and Control Systems • Manufacturing and Repair Technologies • Computational Engineering.
2.	Keppel-NUS Corporate Laboratory	S$75 million	Keppel Corporation	National University of Singapore (NUS)	2013	-	• Offshore industry • Future Systems • Future Yards and Future Resources
3.	Urban Computing and Engineering Centre of Excellence https://unicen.smu.edu.sg/	S$54 million	Fujitsu Limited	Singapore Management University (SMU) and A*STAR	2014	-	• Dynamic Mobility Management, • Maritime and Port Optimization

							• Urban Computing Platform
4.	ST Engineering-NTU Corporate Laboratory http://ste-ntulab.ntu.edu.sg/Pages/Home.aspx	S$53 million	ST Engineering	Nanyang Technological University (NTU)	2015	~ 16 projects	• airport precision • airside technology • Effectual Material Handling • Robust Autonomous Mobility
5.	Sembcorp-NUS Corporate Laboratory	S$60 million	Sembcorp Industries	National University of Singapore	2016	-	• Optimise power generation • Enhance industrial water and wastewater treatment systems
6.	ST Electronics-SUTD Cyber Security Laboratory https://www.stengg.com/en/innovation/industry-partnerships/st-electronics-sutd-cyber-security-laboratory/	S$44.3 million	Singapore Technologies Electronics Limited (ST Electronics)	Singapore University of Technology and Design (SUTD)	2016	-	• Cyber security big-data analytics • Developing trusted monitoring and mitigating techniques
7.	SMRT-NTU Smart Urban Rail Corporate Laboratory http://www.eee.ntu.edu.sg/aboutus/Video/Pages/SMR	S$60 million	SMRT Corporation Ltd.	Nanyang Technological University	2016	-	• Innovative urban rail solutions

	TNTUSmartUrbanRail4July2016.aspx			(NTU)			
8.	Delta-NTU Corporate Laboratory for Cyber-Physical Systems	S$45 million	Delta Electronics	Nanyang Technological University (NTU)	2016	-	• Cyber-Physical Systems
9.	NUS-Singtel Cyber Security Lab	S$42.8 million	Singapore Telecommunications Ltd. (Singtel)	National University of Singapore (NUS)	2016	-	• Novel data analytics techniques • IT systems that are secure by design

Source: *https://www.nrf.gov.sg/*

2. Technology Consortia

NRF along with Institutes of Higher Learning (IHLs) worked for setting up of Technology Consortia (https://www.nrf.gov.sg/programmes/technology-consortia). NRF also through its schemes like 'Competitive Research Programme' (CRP) cultivates the creation of multi-disciplinary groups/crew for conducting high expertise and high-risk (cutting-edge) research activities that are relevant to the country and society. Under this scheme, the research being undertaken is inclusive and coordinated and the initiative also brings together complementary researchers under an aegis for undertaking high impact research and innovation. Through the measures of CRP, capacities and expert groups in specific technology domains have formed in Singapore. The Technology Consortia has been structured around the pockets developed through CRP and works on individual domains for generating outcomes in a specific technology area.

The basis of each consortium is partaking of knowledge and transferring technology by means of effective university-industry partnerships. The benefits accrued through this initiative are almost similar to the ones bestowed by other PPP initiatives.

The consortia seek to invigorate user-encouraged studies, translation of know-how, instructing and training manpower, and generate awareness in the specified technology domain. All these purposes are accomplished through nurturing and upholding research dialogues amongst academia, business and government organizations.

The IHLs streamline their agendas according to the private sector and develop protocols, which are more affiliated to the prerequisites of the industries. Enterprises also receive opportunities to form basis on the knowledge findings of the IHLs for strengthening their technical capabilities, join for expertise seminars prearranged by the researchers for learning about the latest findings of research, and engage investigators for their intramural R&D exertions. The members of the industry and the academia can also obtain other grants and support from the authoritative agencies through formulation a new collaborative project.

As of present, the NRF has established five technology consortia –

a. Singapore Spintronics Consortium (http://sg-spin.nus.edu.sg)

Investment Fund for Collaborative R&D : S$39 million + S$5million

Source: *https://www.nrf.gov.sg/*

The first of the Technology Consortia to be established was the Singapore Spintronics Consortium (SG-SPIN). It was founded in December 2014 through the joint efforts of National University of Singapore (NUS), Nanyang Technological University (NTU), and National Research Foundation (NRF). The main task of the syndicate is to cultivate interactions and promote further alliances amid academia and business R&D groups in the general zones of spintronics and magnetics.

The instituting affiliates of SG-SPIN are NUS, NTU (academia), Applied Materials, Inc., Delta Electronics and GLOBALFOUNDRIES (industry members). The Industry Liaison Office (ILO) of NUS, seized the opportunity to lead in compelling and motivating this association, reinforced by NRF and NTU's NTUitive*.

*NTUitive – NTUitive Pte Ltd (NTUitive; http://www.ntuitive.sg/about-us) is the NTU's 'innovation and enterprise company'. NTUitive was created to support the task of the university mission to advance groundbreaking ecosystem to inculcate revolutionary innovations, further entrepreneurship and expedite the commercialization of universities research outputs.

b. LUX Photonics Consortium (http://luxphotonicsconsortium-sg.org)

Investment Fund for Collaborative R&D : S$75 million

Source: *https://www.nrf.gov.sg/*

The LUX Photonics Consortium leaped across in September, 2015 and was founded in association with NTU, NUS, the Agency for Science, Technology and Research (A*STAR) and Technolite (industry partner). Nearly nine projects have been awarded under this initiative. A few of the major projects that have been carried out are -

- Ultraefficiency excitonic energy transfer next-generation lighting and displays
- Fiber optic medical devices for diagnosis of coronary artery diseases
- Heterogeneous integration of low power electronics with high performance photonics.

c. ***Singapore Cybersecurity Consortium***

(http://luxphotonicsconsortium-sg.org)

Investment Fund for Collaborative R&D : S$45 million

Source: *https://www.nrf.gov.sg/*

This consortium is affixed at NUS and was set up in 2016. It serves as a platform for cross-section interactions between the public agencies, industries, academia and the National Cyber-security (NCR) R&D program. Presently there are 26 member industries, six government agencies (apart from NRF) and ten IHLs including NUS, in the consortium. The consortium was founded by 14 industry partners in consultation with NRF. The founding industry partners were as:

1. Acronis Asia Pte Ltd
2. Attila Cybertech Pte Ltd
3. Banff Cyber Technologies Pte Ltd
4. Cloak Pte Ltd (formerly Clault)
5. Custodio Pte Ltd
6. Excel Marco Industrial Systems Pte Ltd
7. Parasoft South East Asia Pte Ltd
8. PwC Singapore
9. SecureAge Technology Pte Ltd
10. Singapore Telecommunications Ltd (Singtel)
11. ST Electronics (Info-Security) Pte Ltd
12. Standard Chartered Bank Singapore
13. StarHub
14. Vantage Point Security Pte Ltd

d. ***Singapore Consortium for Synthetic Biology (SINERGY; https://www.nrf.gov.sg/programmes/technology-consortia/singapore-consortium-for-synthetic-biology)***

Investment Fund for Collaborative R&D : S$34 million

Source: *https://www.nrf.gov.sg/*

It has been established by the efforts of significant partners i.e. NUS, NTU, A*STAR and Temasek Life Sciences Laboratory, with the backing from NRF. Close to S$34 million have been invested in eight research projects in the domain of synthetic biology by NRF, vide the grant of Biological Design Tools and Applications (BDTA) and CRP. The group will leverage from the R&Dactivities undertaken by the above-mentioned projects and look for opportunities to translate the research outputs. The consortium has more than 10 industries as its member partners. Some of the founding members are:

1. AdvanceSyn Pte Ltd
2. Bio Basic Asia Pacific Pte Ltd
3. Becton Dickinson Biosciences
4. Engine Biosciences Pte Ltd
5. GlaxoSmithKline
6. Singer Instruments Co. Ltd
7. Wilmar International Limited.

Both the industrial as well as academic partners have an access to different knowledge partnerships, training of human resources, global collaborations and joint research activities under the seed grants of the consortium.

e. Singapore Data Science Consortium (https://www.nrf.gov.sg/programmes/technology-consortia/singapore-data-science-consortium)

Source: *https://www.nrf.gov.sg/*

It was established for intensifying Singapore's prevailing assets in the field of data science and analytics. SDSC like other consortia, aims at strengthening linkages amid IHLs, research institutes and industries. This shall facilitate industry's acceptance of the latest advances in data science and analytics technologies. The consortium, set up by NRF in alliance NUS, NTU, SMU and A*STAR, will operate in association with the Economic Development Board (EDB) and the Infocomm Media Development Authority (IMDA). The EBD and IMDA would involve businesses in six different economic sectors, i.e. healthcare; finance; manufacturing; customer and retail; logistics; and transport. This consortium works towards the mandate of concerting with local enterprises SMEs for collaborative R&D.

3. Test-Bedding and Demonstration of Innovative Research

The 'Test-Bedding and Demonstration of Innovative Research' (https://www.nrf.gov.sg/programmes/test-bedding-and-demonstration-of-innovative-research) initiative targets at making use of the efforts in direction laid by the Government for demonstrating probability of pioneering technologies and foster adoption by the private enterprises. The projects approved for funding encompass partnerships with indigenous industries, which certifies commercialization of solution obtained through dedicated research efforts. Examples of a technology industrialized through this initiative.

- **QuicaBot (short for Quality Inspection and Assessment Robot)**

It is a technology that can move around independently and examine/scan a room within a very short time period. It employs cameras of latest technology and laser scanners to identify defects such as uneven surfaces, cracks etc. The researchers from NTU in association with JTC Corporation and a local start-up Ctrl Works invented this technology.

Source: *https://www.nrf.gov.sg/*

- **PictoBot**

The Device PictoBot was co-developed by JTC Corporation, Aitech Robotics & Automation and Nanyang Technological University (NTU). The device has the capacity of scanning the environment through the means of its laser scanner and producing an image with the aid of the optical camera, for purposes of navigation uptill the height of 10 meter.

Source: *https://www.nrf.gov.sg/*

- **Auto Rider**

Source: *https://www.nrf.gov.sg/*

Auto Rider is a vehicle with self driving mode, which is presently functional and has also initiated operations of transporting passengers around the Bay Garden area in Singapore. This technology has eased the transportation and has also strengthened the connectivity of the area. The Auto Rider was jointly developed by ST Engineering and Gardens by the Bay.

Taiwan

Contents

1. Introduction

Taiwan is situated in South East Asia. Taiwan is officially regarded as Republic of China. The total area under current Taiwan jurisdiction is 36, 193 km^2 with population of 23.5 million people. Taiwan is 137^{th} largest country in the world. Taiwan exceptional economic growth since past two decades is credited to robust industrial development. Taiwan is one of the world's top economies as measured by GDP per capita value of 22,453.4 US$. Taiwan spends 2.45% of GDP for national R&D. The Taiwanese global rank on various parameters associated with Global Competitiveness Index for the year 2017-18, with overall rank of 15 out of 142 countries 2017 is presented in table below.

Table 1: Global Ranking of Taiwan as based on S&T related Indicators

S. No.	Indicators (year)	Rank
1.	Publications[a]	17
2.	Gross Expenditure on R&D,% GDP*	14
3.	University-Industry Collaboration in R&D	16
4.	Capacity of Innovation	22
5.	Company Spending on R&D	10
6.	Availability of Scientists and Engineers	30
7.	Quality of Scientific Research Institutions	26

Source: GCI 2017-18; *IRI & ARM, 2017
(Note: S&T indicators from Global Innovation Index Report 2017-18 are not available for Taiwan)

Taiwan's exceptional economic growth since the beginning of 21^{st} century is credited to its strong commitment to its technology and innovation based ecosystem leading to remarkable development in the industrial sector. The stimulation in the economic development has been effectively supported, financially and otherwise, by the Taiwanese government through the **Ministry of Science and Technology** (MOST; https://www.most.gov.tw/) and **Ministry of Economic Affairs** (MOEA; http://www.moea.gov.tw/MNS/english/home/English.aspx). Both the ministries have formulated as well as implemented policies for strengthening industrial growth in Taiwan.

2. Programs/Schemes/Organizations

The major programmes implemented in Taiwan under PPP mode or for promoting PPP for R&D in the country are presented below:

2.1 Ministry of Science and Technology (MOST)

National Science Council was established in 1959 as dedicated government unit for promoting S&T agency. This unit evolved and was restructured as Ministry of Science and Technology (MOST) (https://www.most.gov.tw/) in 2014 to facilitate strong linkages between academia and industry in domains of S&T. MOST carries out annual R&D survey and has registered Business/enterprise share in national R&D Expenditure ~77.2% followed by government share of 21.7%, domestic higher education and non profit organizational sector share of 1% and o.1% comes from foreign investors. The ministry has in total eight departments and out of these eight departments it has dedicated department of 'Academia-Industry Collaboration and Science Park Affairs'. Major programmes under MOST to promote collaborative R&D with industry are listed in following table.

Table 2: MOST programmes to promote industry collaborated R&D

S. No.	Programme	Brief Details
1.	**Industry-Academia Cooperative** **Research Projects**	• The programme facilitates matching industry and academic cooperative research needs and objectives. Through this programme industries are encouraged to tie up knots with research and educational institutes as per the needs of business undertaken by private sector. • In the year 2008, the model presented scope of university based applied research outcome and promoted developmental models for technology transfer and technology authorization. • The programme supports the I-A linked research projects at three different levels as: ✓ Pilot level: that involves high risk based innovation and long time R& activities

		✓ Development level: ✓ Development type: that provides support to industry to develop application based technologies ✓ Applied technology and knowledge level: that provides support to train talent in field of industry requirements especially in management and improvement in present technology status.
2.	**PIONEER** **Grants for Frontier Technologies Development** **by Academia-Industry Cooperation (PIONEER** **Grants for AIC)**	• This programme was jointly initiated and is executed by MOST and MOEA. The programme aims at developing cooperative based research linkages between national and international firms with universities. • Through this programme industry presents the research problems before universities and universities address these problems and then both the industry and the university jointly work to resolve the industry problem in practical sense.
3.	**Minor Alliance Projects-The Industry-Academia Technology Alliance Cooperation Programme**	• Through this programme the technological capabilities of university researchers is explored by setting up technology laboratories in universities in association with leading industrial firms.
4.	**From IP to IPO** **(Intellectual Property to Initial Public Offering)**	• This initiative supports creation of start-ups and new ventures by young researchers in research and academic institutes. The programme also facilitates conversion of innovative research into industrialized R&D product. • The programme introduces twice a year call, and nearly 40 teams are selected and are trained by Taiwan and Silicon Valley experts in creation of new ventures from the novel ideas.
5.	**Germination Program**	• Under this programme, 8 germination centres have

		been established in universities that provide a common platform for universities and industries to explore their research potential into common commercial applications.
6.	**Industrial Fundamental Technology** **Projects**	• MOST and MOEA together started this project to enhance the technical capabilities of Taiwan Manufacturing industry. Under this programme, universities are provided with special subsidies to create R&D centres for undertaking high risk based innovative research work as per the needs of industry. Economic rewards were also introduced to facilitate development of technologies with high market value.
7.	**Applied Research Incubation** **Projects**	• Through this scheme, MOST supports matching of industry-academia linked collaborative research projects with high tech business requirements. The programme was initiated in 2013 and provides funding to universities to undertake such collaborative research projects and display applicative potential of academic research carried out in the universities. The programme also supports milestone based funding for the projects along with the portfolio management of the collaborative research teams.
8.	**Using Legal Entity to Link Industry-** **Academia Collaboration Project**	• Through this programme, research based institutions and organizations having industrial experience are promoted to act as a mediator for linking academic and industrial research. • The programme also supports various universities for commercializing academic research by locating industrial match for the research outcomes. • Under this programme, assistance for developing patent portfolio, training and guidance for commercializing academic research is provided.
9.	**Connecting to Silicon Valley's**	• The programme was started in 2014 with an aim to

	Innovation **and Startup Resources**	coordinate government activities in relation to promoting entrepreneurial culture in the country. • A dedicated Innovation and Start-up taskforce was established to execute this programme. • Under this programme, a dedicated 'Taiwan Innovation and Entrepreneurship Center' was established in Silicon Valley, US. In this centre Taiwanese companies and start-ups are selected with accelerators at Silicon Valley to give future directions to the novel ideas and research work of Taiwanese start-ups. • The programme provides international connections and market linkages for the home companies.
10.	**Industrial Bridging & International Collaboration Services**	• National Research Programme for Biopharmaceuticals (NRPB) started 'Academia-Industry Bridging Program (AIBP)' to support technology transfer from academia to industry through commercialization and authorization and 'Industrial Bridging and International Collaboration Group (IBIC)' to enhance the research potential of academic researchers and promoting collaborations between research and academic institutes with pharma and biotech based industry in Taiwan. • The programme supports creation of industrial alliance, co development of technology, licensing, tech. transfers etc.
11.	**Accelerate the Bio-economy Industry Research Transfer Added Value Chain**	MOST has taken this initiative to integrate private sector and government to provide technology commercialization value added system and entrepreneur platform for technology development.
12.	**National Core Facility**	The programme was initiated in 2011 to promote biotechnology amongst companies and industries by

	Program for Biotechnology	providing technical consultancy and services in field of biotechnology. 10 such core R&D facilities have been set up in Taiwan under this fund programme.

Source: *https://www.most.gov.tw/*

<u>Development of Science Parks:</u>

MOST has created 13 science parks for boosting technological growth of Taiwan's industries. Science parks are located in three major locations such as a) Hsinchu Science Park (HSP) region (http://www.sipa.gov.tw/), b) Central Taiwan Science Park (CTSP) region (http://www.ctsp.gov.tw/), and c) Southern Taiwan Science Park (STSP) region (http://www.stsp.gov.tw/). The major industrial domains promoted by each of Science Park are are mentioned below:

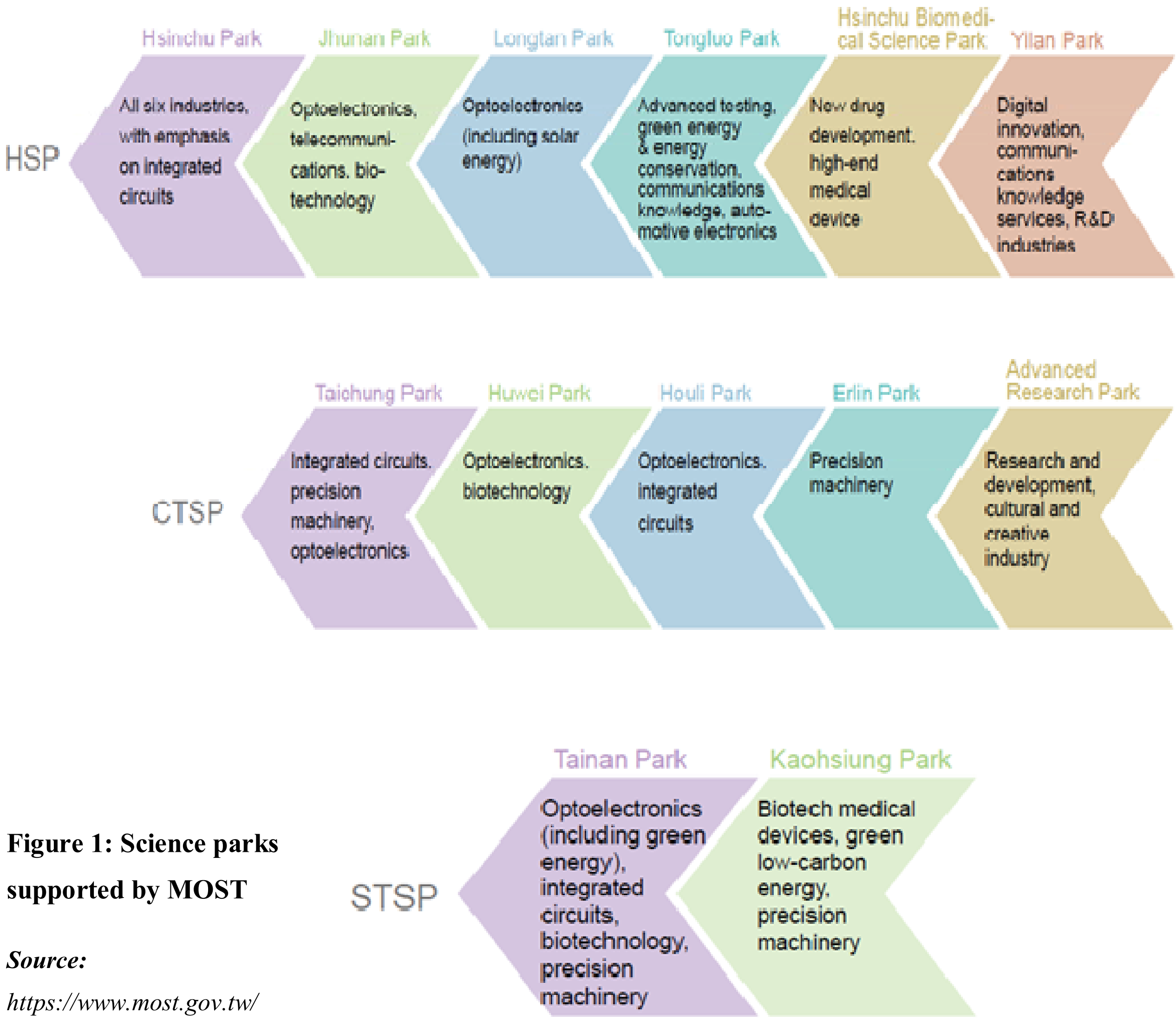


Figure 1: Science parks supported by MOST

Source: *https://www.most.gov.tw/*

Total number of companies associated with the Taiwan's science parks is presented in table below.

Table 3: Number of companies associated with science parks (till 2016)

Industrial Domain	**Number of companies approved**		
	HSP	**CTSP**	**STSP**
Integrated circuits	192	7	17
Computers and peripherals	56	14	2
Telecommunications	45	1	11
Optoelectronics	94	40	58
Precision machinery	42	67	47
Biotechnology	83	37	63
Other	9	14	6
Total	521	180	204

Source: *https://www.most.gov.tw/*

Under the Science Park initiative of MOST, the Science and Technology Parks Administration have promoted '***Research and Development Cooperation Program of Science and Technology Industrial Parks***' (http://rdweb.nthu.edu.tw/List_Detail.aspx?g=2&t=2&i=1352). The main objective of this programme is to encourage various manufacturers to engage in R&D activities in collaboration with research and academic institutes. The collaborated research work will be supported by subsidy up to NTD 10 million and not less than 30% of subsidy should be provided to academia/research institute. Some of the ongoing collaborated research projects are presented in table below.

Table 4: Industry-Academia collaborated research work under Research and Development Cooperation Program

S. No.	**Project Title**	**Academic /Research**	**Industry/Science Park**

		Institute Partner	Partner
1.	Field of view of light field near-eye display technology development plan	National Chiao Tung University	Zhongqiang Optoelectronics Co., Ltd.
2.	Novel insecticidal mosquito biological agents Streptomyces abikoensis insecticidal secondary metabolites and product efficacy	National Chung Hsing University	100 Thai Biological Technology Co., Ltd. Hsinchu Science Park Branch
3.	Development of bone graft-containing intervertebral fusion cage and its peripheral surgical instrumentation system	Cathay Pacific Medical Foundation Guotai General Hospital	Taiwan minimally invasive medical equipment Co., Ltd. Park Branch
4.	Commercialization and Application of Hearing Impaired Gene Chip	Mackay School Mackay Medical School	Crystal Biotechnology Industry Co., Ltd. Science Park Branch
5.	Liver cirrhosis stem cell drug GXHPC1 process sophisticated project	National Institutes of Health	Guoxi Stem Cell Technology Co., Ltd. Hsinchu Medical Park Branch
6.	Megahertz (THz) Single Pixel Fast Imaging System Based on Spatial Modulator and Compressed Sensing	National Tsing Hua University	Tsukuba Technology Co., Ltd. Hsinchu Biomedical Park Medical Branch

Source: http://rpcp.scipark.tw/main_frame.php?wt=si

2.2 Ministry of Economy Affairs (MOEA)

The National Economic Council of Taiwan created MOEA (http://www.moea.gov.tw/MNS/english/home/English.aspx) in 1934 to coordinate functioning of industry, agriculture and mines. With time MOEA evolved with 16 staff units, 64 commercial offices abroad, 14 administrative agencies and 6 national corporations. Under MOEA dedicated administrative agencies are formed to support technological growth of Taiwan industrial sector through promoting R&D support programmes. The industrial R&D promotional initiatives by MOEA under Public Private Partnership (PPP) mode are discussed in coming sections.

I. **Department of Industrial Technology (DoIT)**

(https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5436)

MOEA established dedicated office of Science and Technology in 1979 under S&T Development Plan of Government. This office evolved as the Department of Industrial Technology (DoIT) in year 1993 under organization law enacted by MOEA. This department is working with a mandate of implementing various programmes under technology development initiative of MOEA and consolidate the research capabilities of academic institutes, research institutes and industry to come up with advanced industrial technologies. The department has led to creation of innovation network system linking research and academic institutes with industry in order to enhance the national innovation ecosystem. DoIT is headed under supervision of Director and Deputy Director General appointed by MOEA. DoIT has S&T Advisory Offices to assist the operation of various Technology Development Programmes under 6 sectional offices as (Figure 2):

- Technology Administration
- Technology Development Policy
- Innovation, Research and Development
- Electronics, Information, Communications and Optoelectronics
- Machinery and Transportation
- Biotechnology, Pharmaceutical, Materials and Chemical

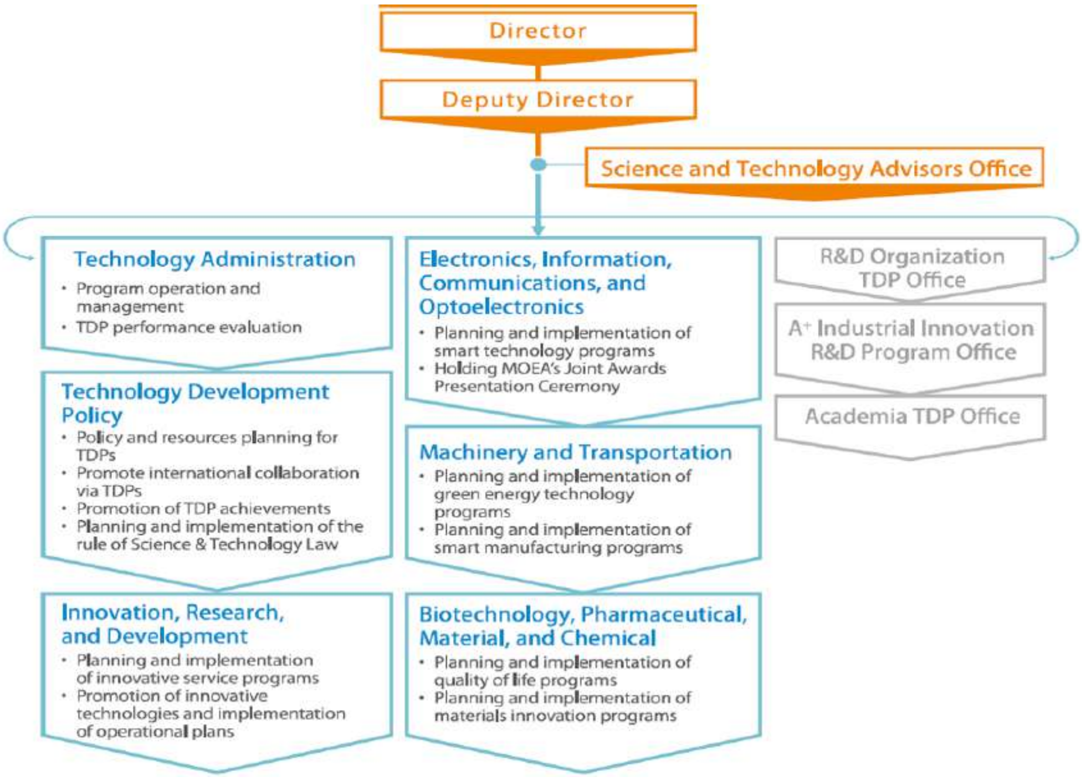


Figure 2: Organization structure of DoIT

Source:https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5436

DoIT has initiated various programmes to support PPP for technology development of industrial sector of Taiwan. Some of the successful PPP initiatives are discussed below:

- **Technology Development Programs (TDP)**

DoIT has initiated TDP under three sectional heads:

- ✓ Business Innovation TDP
- ✓ Academia TDP
- ✓ R&D Organizational TDP

Under Business Innovation TDP (https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5442), DoIT is actively working with government to formulate and implement industry linked innovation policies. Under PPP mode, innovative business model was set up for R&D service and technology promotion. Through this programme Taiwan government has attracted various industries to invest in R&D and apply innovation technologies for their growth. Various initiatives undertaken under Business Innovation TDP are listed in table 5.

Table 5: Business Innovation TDP initiatives

S. No.	Initiative/Scheme	Brief Details
	A+ Industrial Innovation R&D Program	
	It was initiated in 2014 to guide businesses to invest in high tech value adding industrial innovative technologies. Through this programme subsidies are provided to companies to invest in innovative technologies by establishing R&D centres, R&D partnerships etc. Various programmes under this initiative are listed below.	
1.	**Industrial Technology Foresight Research Program**	The programme aims to provide guidance to private sector for indulging in forward looking and challenging research programmes in order to meet market demands of products, technologies and various services.
2.	**Integrated R&D Program**	Through this programme, collaborations between public and private sector are promoted to carry out research work under coalitions and develop strengthened vertical and horizontal research integration groups.
3.	**Industrial Technology Innovation Center Program**	With this programme, infrastructural set up for businesses is created to indulge in innovative R&D activities. The programme supports various businesses to set up R&D teams or organizations for designing and developing technology roadmaps.
4.	**Global R&D Innovation Partner Program**	Through this initiative DoIT invites foreign enterprises to join hands with local start-ups and ventures having common objectives.
	Special Programmes	
5.	**Fundamental Industrial Technology Development Program**	The programme specifically supports and finds technology solutions for the business facing technological bottlenecks in their innovative R&D programme.
6.	**International Innovation and R&D Collaboration Program**	The programme provides support for strengthening the R&D capacity of various industries by providing the platform for indulging into international collaborations for R&D. Some of the successful examples are as:

		✓ Taiwan-Israel Collaboration on Innovation R&D ✓ EU Research and Innovation Program ✓ Taiwan-EU Targeted Open Call Program
7.	**Fast Track Clinical Trial Program**	The programme supports the businesses to collaborate with medical research teams to jointly carry out clinical trials for new medical devices and new drug entities on fast track basis in order to accelerate the process of commercialization.

Source: *https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5442*

<u>Outcomes of Business Innovation TDP:</u>

The Business Innovation TDP has incentivized private sector to invest and engage in developing innovative technologies. Till date, 25 R&D centres have been established by Taiwanese companies and 65 R&D centres by multinational companies in Taiwan. In total 1073 collaborative R&D projects have been supported by DoIT. The Business Innovation TDP has released investment of NID 60.3 billion to support innovation in industrial sector of Taiwan. High number of Industry supported projects under Business Innovation TDP as listed in table 6.

Table 6: Industry supported projects under Business Innovation TDP

Initiative /Scheme	**Number of Projects**
Industrial Technology Foresight Research Program	162
Integrated R&D Program	157
Global R&D Innovation Partner Program	9
Special Programmes	112
Joint R&D Projects	1073

Source: *https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5442*

Under industry support and development programme of DoIT following research outcomes have been reported till September 2017.

- ✓ Participant Companies: 1678 companies

- ✓ R&D Manpower supported: >34,000
- ✓ Approved Projects: 1079 projects
- ✓ Total investment induced: NTD 168 billion
- ✓ Proportion of total patents approved: 44.8%
- ✓ Proportion of total patents cited: 43.78%
- ✓ Total number of patents used for new product formation: 1821
- ✓ Total number of patents granted: 4159
- ✓ Total number of publications: 3575
- ✓ Technological reports/ trainings generated: 64,084

Under Academic TDP (https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5443) DoIT promotes collaborations between industry, academia and various research institutes to develop innovative services and products under PPP mode. Under academic TDP support, subsidies are provided to universities to collaborate with industry, generate business and commercialized in-house technologies. Two types of projects are supported under Academic TDP:

- ✓ General Value Creation Projects: this is a supportive programme for developing technologies still at university level to pilot level and commercialization by collaborating with industrial sector. As a concluding outcome of a project support a new business/technology company or business department should be set up.
- ✓ Flagship Type Value Creation Projects: for these projects an integrated team of academician, government officials and industry leaders is formed to address technology gaps in the industry.

Academia TDP consists of two set of programmes for both kind of projects. These programmes are as:

a. ***Industrial Value Creation Program for Academia (till 2017)***

- ✓ Participant Universities: 33
- ✓ Participant enterprises and research institutes: 115
- ✓ Total number of projects supported: 32
- ✓ New ventures created: 24

b. ***Technology Development Program for Academia (till 2016)***

- ✓ Total number of patents filed: 4299
- ✓ Total number of patents granted: 2901

- ✓ Collaborative projects: 568
- ✓ Investments induced by DoIT: NTD 500 million
- ✓ Investments induced by industry: NTD 11.2 billion
- ✓ International collaborations formed: 299 with investment of NTD 130 million
- ✓ Technology transfers: 1380 with revenue of NTD 1197 million
- ✓ Technologies available for transfer: 2552
- ✓ Contract services provided: 1086 worth NTD 1050 million

Third programme under TDP is R&D Organization TDP (https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5441). Under this programme 21 research institutes of Taiwan are included which are provided with support to develop cutting edge industrial technologies. From period 2014 to 2016, under R&D Organization TDP, enterprise investment came out to be of worth NTD 10.72 billions.

DoIT also plays significant role in promoting international co-operations through initiative: **Taiwan Rapid Innovation Prototyping League for Entrepreneurs (TRIPLE); (**https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=20967**),** launched in 2015 and provides top level platform for start-ups related to hardware and provides value added services to the start ups through TRIPLE model. Under this programme different stakeholders from academia and research institutes and industry have came together to provide advanced technology development to budding entrepreneurs and start ups. The platform helps in match making of start ups with prototype partners all across the world. This programme has associated with ~250 industrial members and provide following services:

- ✓ Prototyping services
- ✓ Value added research
- ✓ Value added marketing
- ✓ Value added designing

2.3 Small Business Innovation Research (SBIR) Programme

The programme SBIR (http://www.sbir.org.tw/index) was initiated by MOEA to encourage uptake of R&D by SMEs in Taiwan. This programme was formulated on lines with China and US's SBIR programme in order to accelerate industrial competitiveness. MOEA took up this programme under MOEA scheme for Enterprises to Develop Industrial Technologies. The programme aims to provide subsidized incentive to SMEs to reduce the cost associated with innovation and technology advancement and reduce the risk associated with the same. SMEs can apply up to 50% subsidies on total R&D investments with additional government funding support. Major requirements from SMEs to apply funding support and subsidies for technology up gradation are as:

- ✓ The company should be recognized as SME
- ✓ There should be no back taxes to the government
- ✓ No contract cancellation with government funded technological projects in last five years

The SBIR support is extended in three phases:

- ➢ Phase I: Government provides subsidy to the SME applicant for period of 6 months. Total amount of subsidy initiated by government was NTD 1 million. In this phase SMEs need to address their key technologically related problem, concept idea for solving the problem, benefits anticipated from the research work and R&D track record and plan of implementation of R&D activities for the technological problem statement.
- ➢ Phase II: government provides subsidy of total worth NTD 10 million to the SME applicant for period of 2 years. In this phase SMEs display R&D ramp-up and trial production activities.
- ➢ Phase II+: Government provides subsidy of worth NTD 5 million for period of 1 year that involves practical application of the research outcomes in order to facilitate customer and market demands.

SBIR has conglomerated with total of 105 government offices to promote development of local industry under ***'Plan to Promote R & D of Local Industry Innovation'.***

Table 7 lists down the successful examples of SMEs supported under SBIR programme.

Table 7: SMEs supported under SBIR programme

S. No.	SME	Domain
–	Newsletter King Digital Media Limited http://www.kotsms.com.tw/	E-commerce
–	Think Cool Network Technology Co., Ltd. http://www.go1buy1.com	Shopping Media platform
–	Arbon division famous brand identification Limited http://bang-master.com/	E-commerce, knowledge services

–	Rabbit Creative Film Co., Ltd. http://www.twrglobal.com/	movie visual effects technology
–	Absolute Technology Co., Ltd. http://www.absolute.com.tw/	mobile WIFI, flat WIFI, cell phone signal enhancement shell
–	Sugar Talk Co., Ltd. http://www.bonchaboncha.com/	Food Catering

Source: http://sme.moeasmea.gov.tw/startup/modules/funding/detail/?op=highlight&sId=2

3. References

- http://sme.moeasmea.gov.tw/startup/modules/funding/detail/?op=highlight&sId=2
- https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5442
- https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5442
- https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5436)
- https://www.moea.gov.tw/Mns/doit_e/content/Content.aspx?menu_id=5436