2016 ANNUAL REVIEW

MOST

Ministry of Science and Technology

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Contents

Foreword

One of the most important features of science and technology is that they can transform the impossible into the possible. MOST is the government's dedicated agency in charge of the development of science and technology. The most important objectives of scientific and technological development are the use of innovative science and technology to boost national and industrial competitiveness, and the application of science and technology to protect Taiwan, while also promoting culture and the humanities. Accordingly, MOST will rely on the three major administrative directions of "laying the groundwork for basic research, and creating scientific and technological value," "cultivating innovative startups, fostering Moore's Law thinking," and "creating a foundation of scientific manpower, establishing ties to the world of the future" as it establishes platforms for scientific research innovation, stimulates forward-looking S&T and connections with industry, trains fresh scientific talent, and pursues S&T excellence.

In order to strengthen Taiwan's S&T capabilities, MOST held the 10th National Science and Technology Conference during 2016 as set forth by the *Fundamental Science and Technology Act*. The four major goals drafted following this conference consist of "reliance on innovation to regain economic momentum," "strengthening intelligent living S&T and industry," "cultivating and attracting talent and providing diverse channels for advancement," and "building up innovative scientific research ecosystems." MOST has also drafted relevant strategies and specific measures in order to formulate the National Science and Technology Development Plan, which will serve as the country's mid-/long-term S&T policy development blueprint.

Facing the opportunities and challenges posed by the development of the field of artificial intelligence (AI), MOST has begun promoting the establishment of an innovative AI research center, and also hopes to establish a platform that can realize disruptive innovation while linking interdisciplinary talent in relevant research fields. By ensuring that outstanding domestic and foreign manpower can research practical applications of AI in an innovative ecological environment, MOST looks forward to the development of forward-looking technologies, and hopes to make AI Taiwan's next representative high-tech industry.

In order to realize the goals of the Executive Yuan's Ten Major Innovative Industries program, MOST has established a "Biomedical Industry Innovation Promotion Project Implementation Center" in the Hsinchu Biomedical Science Park. This has helped provide a comprehensive biotech ecosystem with links to international market resources, and put Taiwan on the path to becoming an Asia-Pacific biotech medicine research and development stronghold, while also creating more employment opportunities and attracting more talent, as well as promoting local prosperity and development. In addition, in conjunction with the Green Technology Industry Innovation Promotion Program, MOST has established the Green Energy Technology Joint Research Center in the Shalun Green Energy Science City; this center is tasked with bringing together domestic academic organizations, research institutions, state-owned enterprises, and companies for the purpose of forward-looking green energy technology R&D focusing on the four areas of energy development, energy conservation, energy storage, and systems integration.

In the face of rapidly changing S&T trends, Taiwan urgently needs various types of top-notch talent capable of establishing linkage with S&T developments around the world. MOST has accordingly introduced the "Postdoctoral Innovation Star Program," which provides for sending doctoral-level manpower with innovative ideas and entrepreneurial ambitions to Silicon Valley to learn advanced industrial technology R&D, and eventually serve as innovative technological personnel with an international perspective and strategic thinking. MOST has further initiated the Leaders in Future Trend (LIFT) program in order to attract personnel who have gone overseas for their education back to Taiwan, where they can contribute what they have learned, including an international outlook, new S&T knowledge, and advanced application trends. Upon their return to Taiwan, such personnel can engage in in-depth interchange with domestic industry, academia, and research organizations, so that the new knowledge they have acquired overseas can stimulate industrial innovation and technological leaps. By systematically selecting and sending personnel overseas for training, cultivating human resources, and encouraging talented personnel to return to Taiwan, MOST will ensure that the country has constant supply of skilled manpower, and provide new impetus for Taiwan's research and development and industrial innovation.

With regard to the development of science parks, enterprises in Taiwan's science parks achieved a record-high revenue of NT$2.38 trillion in 2016, which represented growth of 2.94% compared with 2015. Employment in the science parks reached 269,041 persons, which was an increase of 3,950 compared with the end of 2015. Apart from actively establishing an environment in which startups can thrive, MOST has also been promoting the three major science parks as platforms on which industry, academia, and research organizations can engage in interchange, draw on the parks' peripheral resources, provide assistance and services, and attract entrepreneurial teams, which will accelerate the growth of startups. In conjunction with the "Silicon Valley Tech Entrepreneurship Training Program" and "Innovation & Entrepreneurship Platform Development Program," MOST is creating an all-inclusive entrepreneurial ecosystem, and is actively expanding recruiting in a wide range of industries in order to promote the science parks' innovative transformation.

Looking ahead to the future, MOST will take investigation of new science and technology and integration of S&T resources as its mission, continue to strengthen academic capabilities, establish an honest, effective academic research environment, fine-tune academic research award and grant regulations, induce outstanding personnel to engage in practical research areas, create innovative S&T ecosystems, train world-class innovative and entrepreneurial manpower, and inject boundless vitality into Taiwan's S&T innovation and industrial development.

MOST Minister

Liang-Gee Chen

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Chapter 1 Overview

Science and Technology Development Policies

Funding

I Science and Technology Development Policies

The development of science and technology in Taiwan has achieved many impressive successes in terms of both international competitiveness and academic research outputs. According to the IMD's 2016 *World Competitiveness Yearbook*, Taiwan ranked 14th globally in terms of overall competitiveness, was ranked 3rd in the Asia-Pacific region, behind only Hong Kong and Singapore, and was 10th and 12th in the S&T-related categories of "scientific infrastructure" and "technological infrastructure". Furthermore, according to the *Global Competitiveness Report*, *2016-2017* issued by the World Economic Forum (WEF), although the rankings of most Asian countries fell or remained the same, the rankings of Taiwan and India both rose, with Taiwan rising one notch to the 14th place. However, despite Taiwan's steady progress in science and technology, in the face of a rapidly-changing global situation and S&T development trends, Taiwan still faces numerous problems and challenges.

A. Challenges Faced by S&T Development in Taiwan

1. R&D and innovation

Because scientific research innovation requires a sound environment, including an effective legal and regulatory system, as the country develops an "innovative-driven" development model, the legal and regulatory system must respond to S&T development and rapid economic and social change through flexible, timely adaptation. In particular, the revision of the *Fundamental Science and Technology Act* is an urgent priority. Furthermore, linkage among industry, academia, and the research community must be strengthened, and needs-oriented innovative R&D and industry-academic collaboration will require reinforcement in order to pair R&D capabilities with industrial applications, and thereby encourage the establishment of new technological startups and drive industrial upgrading and transformation.

2. Manpower training and recruiting

Superior human resources are a key basis for innovative scientific research. Responding to the rapid development of the digital economy, MOST has actively drafted interdisciplinary human resources cultivation strategies that are strengthening practical industrial manpower training mechanisms and broadening the prospects of S&T research manpower, which will do much to consolidate Taiwan's S&T research foundation. In order to recruit top-notch international scientific research manpower, MOST must quickly optimize relevant policy systems, and create a living and working environment suitable for international manpower, which must be done if the country is to successfully attract international manpower and maintain international norms.

3. Industrial development and transformation

Many new S&T trends have emerged and grown in recent years, including the Internet of Things (IoT), virtual reality (VR), augmented reality (AR), and artificial intelligence (AI). These trends have stimulated new waves of competition among global industries, and domestic industries are consequently embarking on new developmental directions. As a result, in the current digital economy age, capitalizing on international S&T trends while leveraging local technological advantages, sketching out a vision for the future of industry, and maintaining balanced regional development will be the government's most important mission when assisting the transformation of industry.

4. Living and the environment

Healthy citizens and a safe environment are the nation's foundation. However, medical and health needs have become increasingly urgent in the face of Taiwan's aging population, declining birthrate, and a spate of food safety incidents, and intensive land development and the growth of information/communications technology have been accompanied by environmental quality and information/communication security worries. These problems and others deeply affect citizens' lives, and urgently require the commitment of resources to the development of relevant science and technology. With regard to land and the environment, since Taiwan has a high frequency of natural disasters, apart from using disaster mitigation science and technology to boost the country's resilience in the face of natural disasters, MOST must also promote diverse forms of

green energy and actively develop a cyclic economy if it is to enable citizens to pursue S&T research, development, and innovation in a safe, sustainable living environment.

B. Taiwan's S&T Development Vision and Strategies

In accordance with the *Fundamental Science and Technology Act*, the government must hold a National Science and Technology Conference once every four years to discuss the country's future S&T development blueprint in light of national development directions, the needs of society, and a desire to maintain balanced regional development, and determine a National Science and Technology Development Plan, which serves as a basis for the drafting of S&T policies and the promotion of scientific and technological R&D. Accordingly, at the 10th National Science and Technology Conference, which was held December 5-7, 2016, individuals from industry, government, academia, and the research community jointly discussed and hammered out the country's future S&T development directions.

The 10th National Science and Technology Conference had the focal topics of "intelligence, low-carbon, health, and sustainability," and addressed the three central themes of the infrastructure environment, intelligent living, and economic development. The results of the conference were subsequently used to formulate four major S&T promotion objectives, which consisted of "reliance on innovation to regain economic momentum," "strengthening intelligent living S&T and industry," "cultivating and attracting talent and providing diverse channels for advancement," and "nurturing innovative scientific research ecosystems," and relevant strategies and measures were also drafted. The following is an overview of the four objectives and relevant strategies:

Objective 1

Reliance on innovation to regain economic momentum includes strategies of formulating digital economy development models for innovative industries; strengthening of scientific research result application mechanisms promoting development of innovative industries; putting regional innovative systems on a sound footing and maintaining the growth momentum of industry clusters; and creating an environment favorable to the emergence of innovative startups and relevant development mechanisms.

Objective 2

Strengthening intelligent living S&T and industry includes development of new agricultural technology able to enhance the safety of agricultural produce; promotion of precision medical S&T in order to better maintain citizens' health; improvement of disaster mitigation S&T able to reduce the impact of natural disasters; development of green technology in order to realize a sustainable, low-carbon society; use of intelligent sensing technology to maintain environmental quality; and use of information and communications security technology to ensure that citizens enjoy superior everyday convenience.

Objective 3

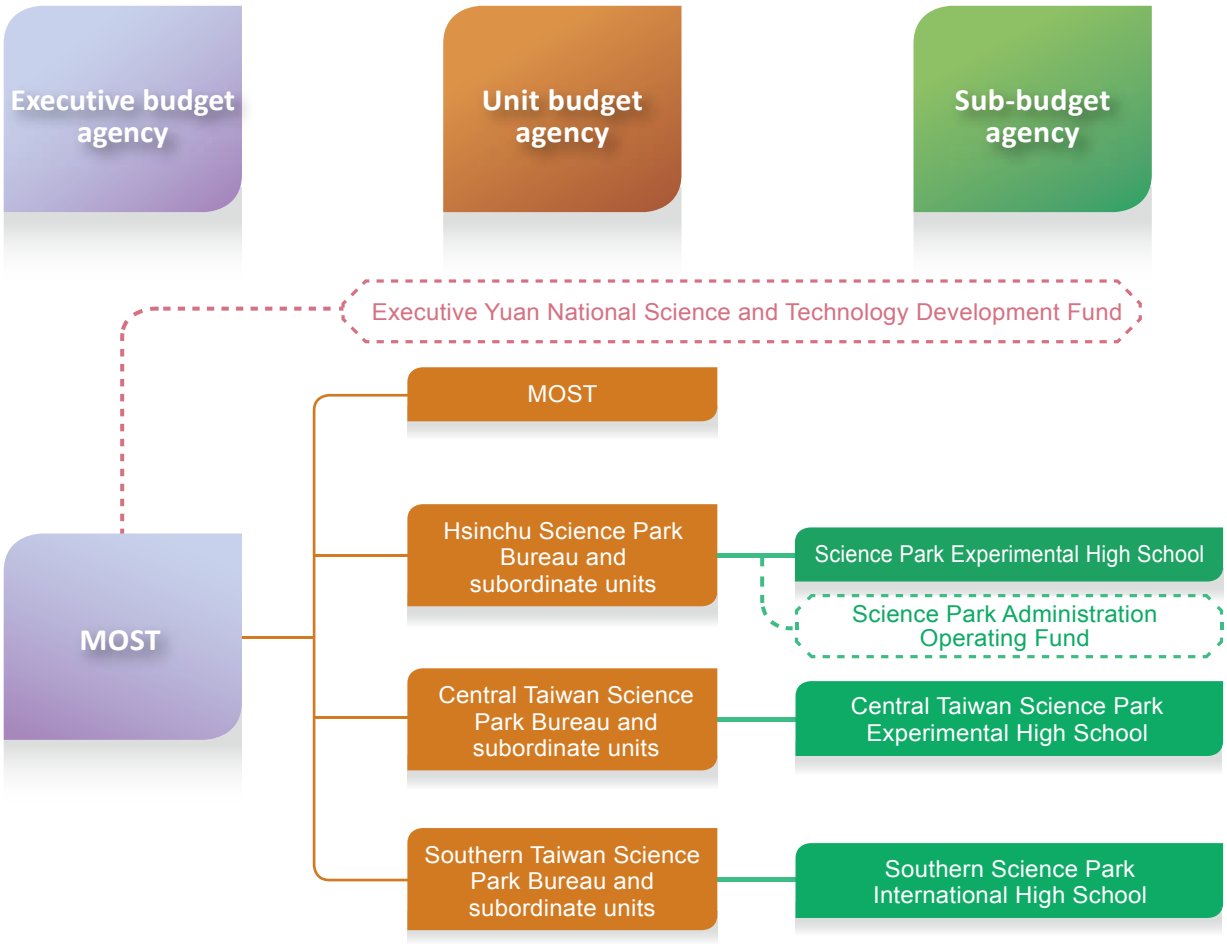
Cultivating and attracting talent and providing diverse channels for advancement includes cultivation of interdisciplinary human resources with digital economy skills; strengthening of training mechanisms for practical industrial technology manpower; provision of diversified, attractive channels for the cultivation of high-end scientific research manpower; and the recruiting and retention of top-flight international human resources.

Objective 4

Nurturing innovative scientific research ecosystems includes strengthening of S&T decision-making support systems; creation of a legal environment fostering the innovative development of science and technology; encouragement of original S&T research and development and reform of the academic R&D results evaluation system; and strengthening of collaborative ties among industry, academia, and research organizations.

II Funding

In 2016, MOST's executive budget consisted of four parts corresponding to MOST itself, the Hsinchu Science Park Bureau (HSPB) and subordinate units, the Central Taiwan Science Park Bureau (CTSPB) and subordinate units, and the Southern Taiwan Science Park Bureau (STSPB) and subordinate units. In addition, the budgets of the HSPB and its subordinate units, CTSPB and its subordinate units, and STSPB and its subordinate units also included sub-budgets for the National Science Park Experimental High School, National Central Taiwan Science Park Experimental High School, and National Southern Taiwan Science Park International Experimental High School. Furthermore, MOST is also the management agency for the Executive Yuan National Science and Technology Development Fund, and the HSPB is the management agency for the Science Park Bureau Operating Fund.



Note: Dotted lines indicate subordinate unit budgets

MOST's executive income budget for 2016 was NT$144 million, which was an increase of NT$11 million (8.27%) from the NT$133 million income budget of the previous year. This income budget included fine and compensation income consisting of NT$29 million compensation for late vendor deliveries; NT$26 million in fee income, which included construction licenses and establishment and status change registration fees from science park companies; NT$42 million in property income, which included income from leasing of space in the Hsinchu Biomedical Science Park's R&D center and technology building; and NT$47 million in other income, which included tuition and fees at science park experimental high schools.

MOST's executive expense budget for 2016 was NT$46.6 billion, which was a decrease of NT$2.36 billion (-4.82%) compared with the NT$49.0 billion budget of the previous year. Of this budget, the MOST expense budget accounted for NT$43.6 billion, and was mainly used to fund the National Synchrotron Radiation Research Center and National Applied Research Laboratories (NARLabs), and provide S&T project funding from the Executive Yuan National Science and Technology Development Fund. The HSPB and subordinate unit budget was NT$922 million, which was chiefly used for various park services. The CTSPB and subordinate unit budget was NT$1.32 billion, and was mainly used for park services and increased national treasury support for research park development projects funded through the Park Operating Fund. The STSPB and subordinate unit budget was NT$796 million, and was mainly used for park services.

Annual MOST executive income budgets, 2012-2016

Units: NT$100 m

Item	2012		2013		2014		2015		2016	
	Amount	Increase%	Amount	Increase%	Amount	Increase%	Amount	Increase%	Amount	Increase%
Fines and compensation	0.19	46.15	0.24	26.32	0.15	-37.50	0.20	33.33	0.29	45.00
Fee income	0.59	-1.67	0.42	-28.81	0.38	-9.52	0.28	-26.32	0.26	-7.14
Property income	0.38	11.76	0.44	15.79	0.78	77.27	0.37	-52.56	0.42	13.51
Other income	0.67	34.00	0.63	-5.97	0.47	-25.40	0.48	2.13	0.47	-2.08
Total	**1.83**	**-96.45**	**1.73**	**-5.46**	**1.78**	**2.89**	**1.33**	**-25.28**	**1.44**	**8.27**

Annual MOST executive expenditure budgets, 2012-2016

Units: NT$100 m

Item	2012		2013		2014		2015		2016	
	Amount	Increase%	Amount	Increase%	Amount	Increase%	Amount	Increase%	Amount	Increase%
MOST	416.21	6.72	422.64	1.54	405.51	-4.05	456.05	12.46	436.10	-4.37
HSPB and subordinate units	15.22	20.70	17.75	16.62	11.81	-33.46	8.84	-25.15	9.22	4.30
CTSPB and subordinate units	11.86	-6.54	11.57	-2.45	12.03	3.98	14.06	16.87	13.21	-6.05
STSPB and subordinate units	9.97	-25.09	9.24	-7.32	11.08	19.91	11.16	0.72	7.96	-28.67
Total	**453.26**	**5.75**	**461.20**	**1.75**	**440.43**	**-4.50**	**490.11**	**11.28**	**466.49**	**-4.82**

MOST's predecessor, the National Science Council (NSC), originally established the Executive Yuan National Science and Technology Development Fund in order to promote the long-term development of science and technology. The Fund's budget was included within the NSC's unit budget up to 1991, but was made a separate unit budget in 1992. In order to increase the flexibility and timeliness of fund implementation, the Fund's budget was changed to a subordinate unit budget in 1998. Following the promulgation of the *Fundamental Science and Technology Act* in 1999, the Fund was taken from the NSC and put under the Executive Yuan's oversight, but NSC retained its status as the fund management agency. The 2003 revision of the *Fundamental Science and Technology Act* specified that the Executive Yuan National Science and Technology Development Fund budget should be a subordinate unit budget.

The Executive Yuan National Science and Technology Development Fund received NT$37.2 billion in 2016, which chiefly consisted of appropriations from the national treasury and R&D results income. The fund's disbursements of NT$38.4 billion were chiefly used to fund various types of academic research, the replacement of marine research vessels I, II, and III, and investment in the establishment of the Taiwan Silicon Valley Technology Fund.

MOST's final executive income figure for 2016 was NT$162 million, which represented an increase of NT$18 million compared with the budget number. This increase was mainly attributable to the leasing of space in HSPB's R&D Center and Biotech Industry Development Building by companies, which has led to greater-than-expected rental income.

Executive Yuan National Science and Technology Development fund budget, 2012-2016

Units: NT$100 m

Item	2012		2013[2]		2014		2015		2016	
	Amount	Increase%	Amount	Increase%	Amount	Increase%	Amount	Increase%	Amount	Increase%
Source of funds	346.41	8.93	359.72	3.84	343.64	-4.47	390.82	13.73	372.23	-4.76
Government appropriations	330.17	8.60	341.60	3.46	327.46	-4.14	376.50	14.98	353.70	-6.06
Other[1]	16.24	16.17	18.12	11.58	16.18	-10.71	14.32	-11.50	18.53	29.40
Fund uses	354.91	-7.82	368.72	3.89	369.14	0.11	428.71	16.14	383.69	-10.50
Promotion of development	317.89	4.39	330.16	3.86	332.17	0.61	393.04	18.32	344.12	-12.45
Manpower training	22.41	27.91	23.91	6.69	22.34	-6.57	21.96	-1.70	22.34	1.73
Environment improvements	14.04	13.32	14.08	0.28	14.05	-0.21	13.18	-6.19	16.68	26.56
Administration & management	0.57	-3.39	0.57	0.00	0.58	1.75	0.53	-8.62	0.55	3.77
Payments to the national treasury		-100.00								
Surplus/shortfall for period (-)	**-8.50**		**-9.00**		**-25.50**		**-37.89**		**-11.46**	

[1] Includes royalty income, service income, miscellaneous income, and interest income, etc.
[2] The 2013 National Science and Technology Development fund budget had not yet been passed by the Legislative Yuan.

Annual MOST final income figures, 2012-2016

Units: NT$100 m

Item	2012		2013		2014		2015		2016	
	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number
Fines and compensation	0.19	0.00	0.28	0.04	0.33	0.18	0.34	0.14	0.37	0.08
Fee income	0.35	-0.24	0.19	-0.23	0.17	-0.21	0.20	-0.08	0.17	-0.09
Property income	0.41	0.03	0.62	0.18	0.82	0.04	0.48	0.11	0.57	0.15
Other income	0.52	-0.15	0.53	-0.10	0.55	0.08	0.48	0.00	0.51	0.04
Total	**1.47**	**-0.36**	**1.62**	**-0.11**	**1.87**	**0.09**	**1.50**	**0.17**	**1.62**	**0.18**

MOST's final executive expenditure figure for 2016 was NT$46.5 billion, which represented a decrease of NT$192 million compared with the budget number. This decrease was chiefly attributable to surplus personnel funds and surplus funds from procurement cases.

The Executive Yuan Science and Technology Development Fund had a final surplus of NT$1.48 billion for 2016, which reversed the budget shortfall number of NT$1.15 billion. This difference was chiefly attributable to the fact that NT$1.07 billion in funding for the replacement of marine research vessels I, II, and III and the Taiwan Silicon Valley Technology Fund Investment Program was left unspent until 2017 due to business needs. In addition, there was an unexpectedly low number of funding applications for the National Science and Technology Program-Energy, and also a lower number of approved projects and funding amounts following proposal review.

Annual MOST executive final expenditure figures, 2012-2016

Units: NT$100 m

Item	2012		2013		2014		2015		2016	
	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number
MOST	415.03	-1.18	419,65	-2.99	402.86	-2.65	455.55	-0.50	435.19	-0.91
HSPB and subordinate units	14.75	-0.47	17.14	-0.61	11.19	-0.62	8.48	-0.36	8.80	-0.42
CTSPB and subordinate units	11.30	-0.56	10.94	-0.63	11.56	-0.47	13.89	-0.17	12.76	-0.45
STSPB and subordinate units	9.57	-0.40	8.80	-0.44	11.02	-0.06	11.11	-0.05	7.82	-0.14
Total	**450.65**	**-2.61**	**456.53**	**-4.67**	**436.63**	**-3.80**	**489.02**	**-1.09**	**464.57**	**-1.92**

Final budget numbers of the National Science and Technology Development fund, 2012-2016

Units: NT$100 m

Item	2012		2013		2014		2015		2016	
	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number	Final number	Change from budget number
Source of funds	348.72	2.31	357.52	-2.20	346.36	2.72	392.04	1.22	370.93	-1.30
Government appropriations	330.17	0.00	341.60	0.00	327.46	0.00	376.50	0.00	353.70	0.00
Other[1]	18.55	2.31	15.92	-2.20	18.90	2.72	15.54	1.22	17.23	-1.30
Fund uses	324.96	-29.95	330.59	-38.13	337.64	-31.50	391.37	-37.34	356.10	-27.59
Promotion of development	293.37	-24.52	297.02	-33.14	303.97	-28.20	355.53	-37.51	321.13	-22.99
Manpower training	21.69	-0.72	23.00	-0.91	21.87	-0.47	22.28	0.32	23.05	0.71
Environment improvements	9.40	-4.64	10.05	-4.03	11.23	-2.82	13.02	-0.16	11.42	-5.26
Administration & management	0.50	-0.07	0.52	-0.05	0.57	-0.01	0.54	0.01	0.50	-0.05
Payments to the national treasury										
Surplus/shortfall for period (-)	**23.76**	**32.26**	**26.93**	**35.93**	**8.72**	**34.22**	**0.67**	**38.56**	**14.83**	**26.29**

[1] Includes royalty income, service income, miscellaneous income, and interest income, etc.

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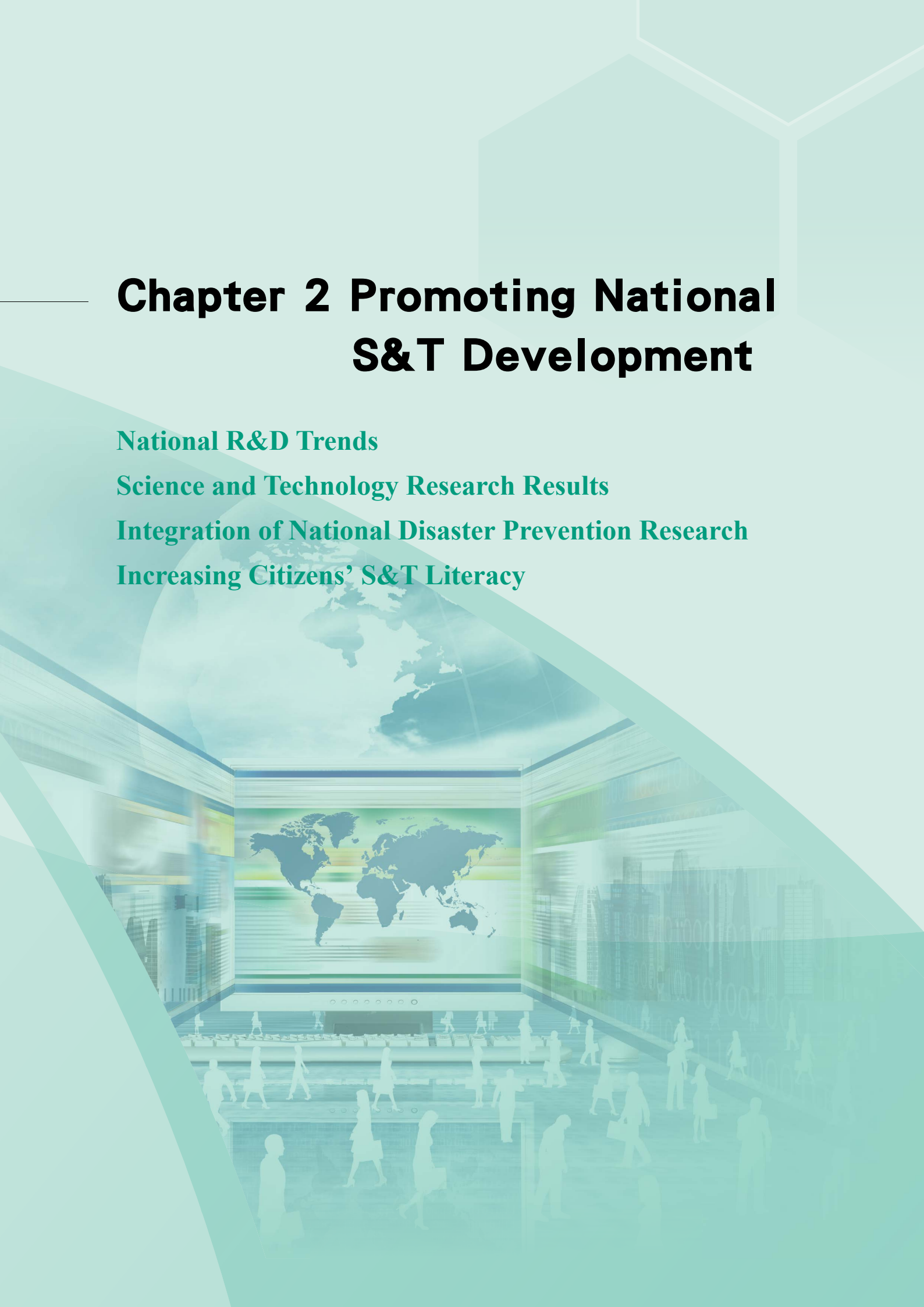
Chapter 2 Promoting National S&T Development

National R&D Trends

Science and Technology Research Results

Integration of National Disaster Prevention Research

Increasing Citizens' S&T Literacy



1 National R&D Trends

A. National R&D Expenditures

Taiwan's total research and development expenditures increased from NT$414.4 billion in 2011 to NT$510.4 billion in 2015, which is equivalent to an annual average growth rate of 5.7%. The private sector's R&D expenditures were NT$402.9 billion, and had a growth rate of 6.4%. The government had R&D expenditures of NT$107.6 billion, which represented an increase of 2.7% compared with 2014. Private sector R&D expenditures as a share of the nation's R&D expenditures grew from 78.3% in 2014 to 78.9%.

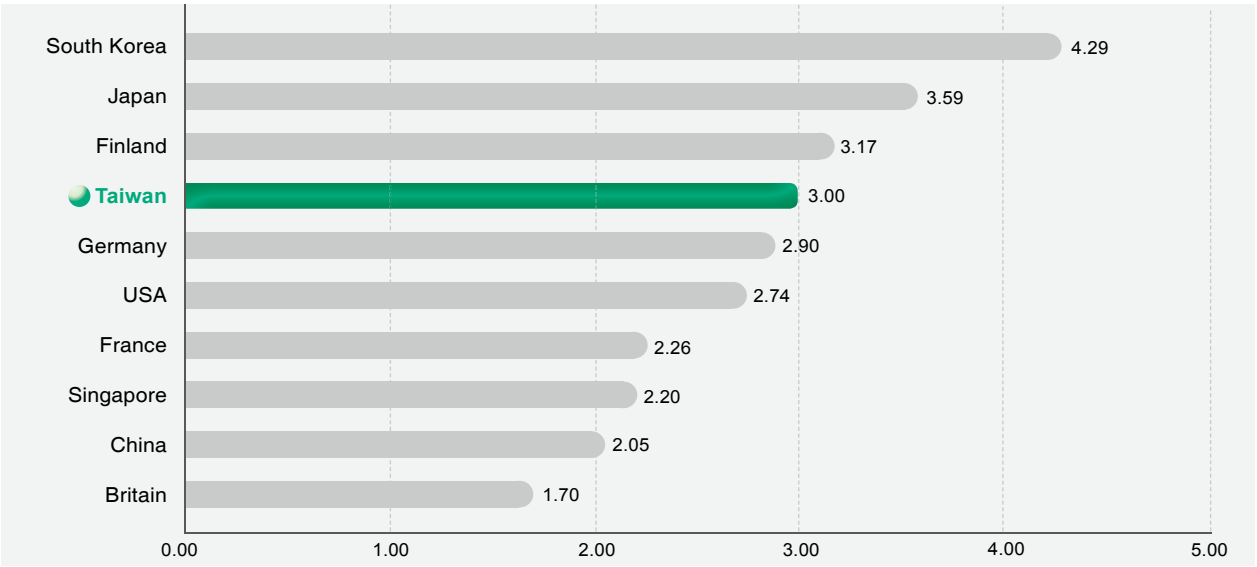
Taiwan's R&D expenditures as a share of GDP have increased steadily in recent years, and reached a historic peak of 3.05% in 2015. Compared with other countries, in terms of R&D spending as a share of GDP, Taiwan lags behind South Korea, Japan, and Finland, but is ahead of Germany, the US, France, Singapore, Mainland China, and Britain.

National R&D expenditures, 2011-2015

Item	2011	2012	2013	2014	2015
National R&D expenditures (NT$100 m)	4,144	4,335	4,576	4,835	5,104
As share of GDP (%)	2.90	2.95	3.00	3.00	3.05
By funding source (%)					
Government	26.2	24.6	23.3	21.7	21.1
Private sector	73.8	75.4	76.7	78.3	78.9

Source: *Indicators of Science and Technology*, 2016, MOST.

R&D expenditures as a share of GDP in various countries



South: Apart from 2013 data for the US, the remaining data is for 2014.
Source: 1. Various countries: *Main Science and Technology Indicators*, 1/2016, OECD.
2. Taiwan: *Indicators of Science and Technology*, 2016, MOST.

B. R&D Personnel

R&D personnel in Taiwan are classified as researchers, technicians, and supporting staff. Researchers have formed the mainstay of Taiwan's R&D over the years, and accounted for 59.1%-61.1% of R&D personnel during the most recent five years. The number of researchers grew over the most recent five years from 134,762 FTE (full-time equivalent) person-years in 2011 to 145,381 FTE person-years in 2015; the number of technicians grew from 74,534 FTE person-years in 2011 to 87,311 person-years in 2015; and the number of supporting staff grew from 12,972 FTE person-years in 2011 to 13,249 person-years in 2015.

The number of female researchers rose from 27,612 FTE person-years in 2011 to 30,951 FTE in 2015. The number of women researchers as a share of all researchers likewise rose from 20.5% in 2011 to 21.3% in 2015.

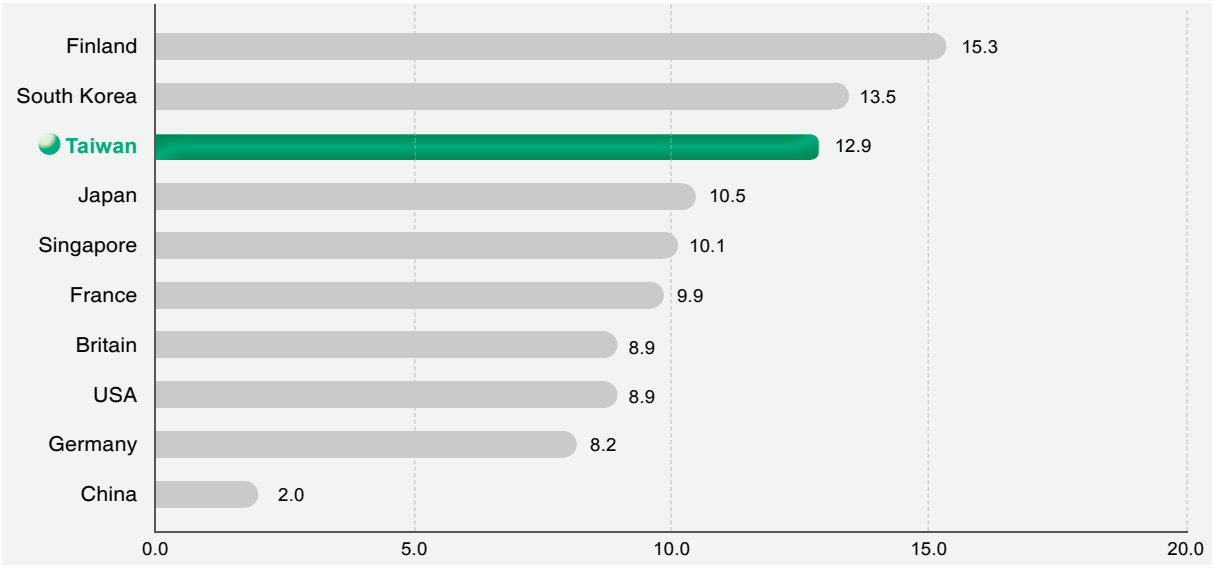
Compared with other countries, the number of FTE R&D personnel per 1,000 employed population in Taiwan was 13.0 person-years in 2015, which was less than the figures for Finland and South Korea, but higher than the figures for Japan, Singapore, France, the US, Britain, Germany, and Mainland China during the 2013-2014 period.

R&D personnel in Taiwan, 2011-2015

Item	2011	2012	2013	2014	2015
R&D personnel FTE (person-years)	222,269	229,167	234,248	240,528	245,941
Researchers	134,762	140,102	141,159	142,983	145,381
Technicians	74,534	77,500	80,909	84,874	87,311
Supporting staff	12,972	11,565	12,180	12,671	13,249
Female research personnel FTE (person-years)	27,612	29,003	29,423	30,187	30,951
Female research personnel as a share of all research personnel (%)	20.5	20.7	20.8	21.1	21.3
Number of researchers per 1,000 employment (person-years)	12.6	12.9	12.9	12.9	13.0

Note: Because of rounding, the sum of the given figures may not equal the total in some cases.
Source: *Indicators of Science and Technology*, 2016, MOST.

Researchers (FTE) per 1,000 employed population in various countries



Note: Apart from 2013 data for the US, the remaining data is for 2014.
Source: *Main Science and Technology Indicators,* 1/2016, OECD.

II. Science and Technology Research Results

A total of 26,715 research papers by authors from Taiwan were cited in *Science Citation Index* (*SCI*) in 2015, giving Taiwan a global rank of 21st. A total of 19,822 research papers from Taiwan were cited in *Engineering Index* (*EI*) in 2014, giving Taiwan a world rank of 14th. In order to provide a better understanding of the quantity and quality of Taiwan's research output, the following sections compare Taiwan with eight major industrialized countries and the leading Asian countries in terms of the three indicators of number of *SCI*-cited papers per million people, impact factor of *SCI*-cited papers, and number of *EI* papers per million people.

A. Number of *SCI*-cited Papers per Million People

This indicator is calculated by dividing the average number of papers cited in *SCI* during the most recent five years by the average population during the most recent five years. Taiwan's 1,137 *SCI*-cited papers per million people in 2015 put Taiwan behind Finland, Singapore, Britain, Germany, the US, South Korea, and France, but ahead of Japan and Mainland China. The best performer in this category, Singapore, increased its output from 2,052 cited papers in 2011 to 2,484 in 2015. Although China's output still remains far behind most of the other countries, its number of cited papers grew at the fastest average rate between 2011 and 2015 (14.1%).

Number of *SCI*-cited papers per million people and five-year average growth rate in various countries, 2011-2015

Units: papers

Country	2011	2012	2013	2014	2015	Average growth rate, 2011-2015
Finland	2,152	2,206	2,327	2,497	2,486	3.68%
Singapore	2,052	2,152	2,319	2,396	2,484	4.89%
Britain	1,815	1,847	1,946	1,904	1,908	1.25%
Germany	1,248	1,299	1,317	1,359	1,357	2.11%
USA	1,290	1,296	1,324	1,340	1,311	0.41%
South Korea	928	1,006	1,051	1,103	1,149	5.48%
France	1,084	1,105	1,141	1,134	1,138	1.22%
Taiwan	**1,192**	**1,203**	**1,224**	**1,196**	**1,137**	**-1.17%**
Japan	627	626	642	632	618	-0.36%
China	127	144	169	195	215	14.14%

Source: 1. *SCI*-cited papers: *InCites*™, Clarivate Analytics, date updated: 9/23/2016.
2. Population figures: World Bank, http: //www.worldbank.org/.
3. Population of Taiwan: *Statistical Yearbook of the Ministry of the Interior*, http: //sowf.moi.gov.tw/stat/year/list.htm.

B. Impact Factor of *SCI*-cited Papers

This indicator is calculated by dividing the number of times papers were cited during the most recent five years by the total number of published papers during the same period. Among the countries compared here, the European and North American countries generally have high impact factors, and Singapore, Britain, the US, Germany, Finland, France, and Japan all had impact factors higher than 6 in 2015. Taiwan's impact factor rose from 4.28 in 2011 to 5.31 in 2015, which shows that the quality of Taiwan's academic papers has improved, although it still lags behind that of the leading European and North American countries and Japan. In comparison with Singapore, the quality of Taiwan's academic papers has been improving at a relatively slow rate; the impact factor of Mainland China's *SCI*-cited papers rose from 4.20 in 2011 to 5.26 in 2015, putting it on a par with Taiwan.

SCI impact factors of various countries, 2011-2015

Country	2011	2012	2013	2014	2015
Singapore	6.76	7.47	8.18	8.89	9.40
Britain	8.13	8.46	8.57	8.59	8.55
USA	8.17	8.41	8.48	8.41	8.32
Germany	7.71	8.04	8.14	8.23	8.25
Finland	7.62	7.99	8.12	8.34	8.22
France	7.20	7.50	7.73	7.86	7.90
Japan	5.67	5.83	5.89	5.96	6.00
Taiwan	**4.28**	**4.60**	**4.87**	**5.06**	**5.31**
South Korea	4.34	4.62	4.89	5.12	5.31
China	4.20	4.55	4.77	4.98	5.26

Source: Web of Science, arranged by Science & Technology Policy Research and Information Center, NARLabs, date updated: 10/1/2016.

C. Number of *EI* Citations per Million Persons

This indicator is calculated by dividing the average number of papers cited in *EI* over the most recent five years by the average population during the same five-year period. Among the countries compared here, Singapore's citation rate was the highest during the most recent five years. Taiwan had an *EI* citation output of 844 papers per million people in 2015, and its *EI* citations per million persons has been in the range of 844-1,045 during the most recent five years. Although Taiwan was behind only Singapore and Finland in this category, the average growth rate of Taiwan's *EI* citations per million persons during this five-year period was the lowest of any of the countries included in this comparison.

Number of *EI* citations per million people and five-year average growth rate in various countries, 2011-2015

Units: papers

Country	2011	2012	2013	2014	2015	Average growth rate, 2011-2015
Singapore	1,196	1,243	1,922	1,961	1,974	13.35
Finland	777	791	1,323	1,374	1,405	15.96
Taiwan	**983**	**889**	**1,045**	**969**	**844**	**-3.73**
Britain	447	458	750	782	785	15.09
Korea	545	578	733	756	757	8.54
Germany	442	471	725	763	749	14.08
France	405	414	697	692	685	14.07
USA	412	419	600	584	579	8.89
Japan	359	357	462	439	422	4.11
China	187	189	206	222	196	1.06

Source: 1. *EI*-cited papers: Ei Compendex, Sept. Week1, 2016, Elsevier Inc., USA.
2. Population figures: World Bank, https: //www.worldbank.org/.
3. Population of Taiwan: *Statistical Yearbook of the Ministry of the Interior*, https: //sowf.moi.gov.tw/stat/year/list.htm.

III. Integration of National Disaster Prevention Research

The National Science and Technology Center for Disaster Reduction (NCDR) has continued to promote and implement disaster prevention R&D, integrate, realize, and apply R&D results, and use disaster prevention and mitigation technologies to assist disaster prevention work. NCDR also performs the missions of promoting international cooperation and interchange in disaster prevention S&T, assisting universities and research organizations to participate in disaster prevention R&D and applications, and other services connected with disaster prevention and relief.

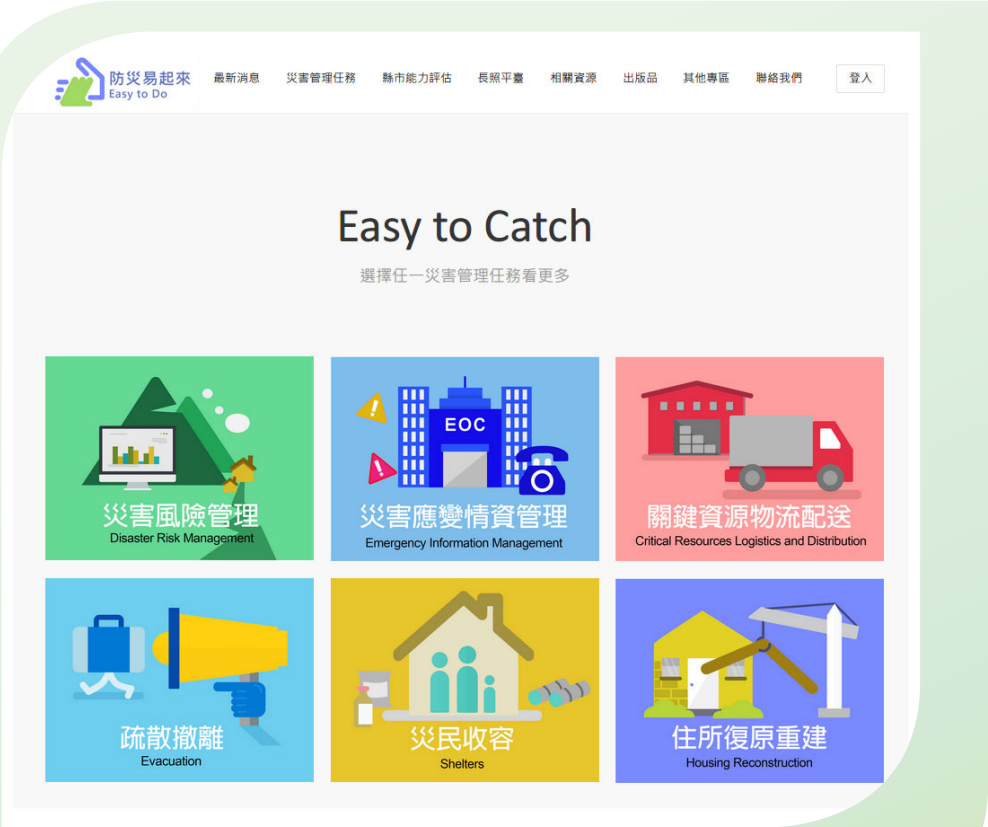
Apart from routinely planning disaster prevention and disaster mitigation technology R&D and applying R&D results, NCDR further serves as a disaster response operation support coordinator during the disaster response period. After a major natural disaster has occurred, NCDR assists with scientific investigation and makes recommendations concerning countermeasures. Responding to natural disasters in 2016, NCDR personnel staffed the central disaster response center, and assisted the intelligence and assessment team in studying the disaster. In 2016, NCDR supported various response tasks at the central disaster response center six times, and participation in these tasks involved over 404 persons-hours and 505 persons. NCDR further assisted the central disaster response center hold 31 intelligence and assessment conferences and 55 working meetings, as well as 26 newly-initiated explanatory meetings for journals, which strengthened communication and the transmission of information.

In addition, in order to boost the performance of the government's local disaster prevention and relief work, and in view of the fact that the city and county level is the basis of disaster prevention and relief management work, NCDR established the "Easy to Do" website (http://easy2do.ncdr.nat.gov.tw) in 2016; this website, which is specifically designed for county and city governments, lists important disaster management mission tasks; provides all counties and cities with a disaster prevention capability self-assessment function intended to find disaster prevention vulnerabilities; and offers relevant assistance resources and recommendations for the purpose of enhancing the overall disaster resilience of cities and counties, and mitigating the impact and losses of natural disasters.

The chief functions of the Easy to Do website include: (1) an explanation of its disaster management mission as a whole: In accordance with the four disaster management stages of disaster mitigation, readiness, response, and recovery, disaster managers will select among the six major tasks of disaster risk management, emergency information management, critical resource logistics and distribution, evacuation, arrangement of shelters for affected residents, and housing reconstruction as required by the situation; this section also provides explanations of each mission's definition, processes, legal basis, and importance, and presents county/city/foreign cases and strategies to assist city and county disaster management personnel to quickly understand the content of their missions. (2) Use of relevant resources: The website provides an introduction to the resources needed to implement various missions, including NCDR's R&D systems and platforms, other government systems and platforms, and the laws, regulations, handbooks, and standard operating procedures established by various agencies and organizations. (3) Assessment of county and city disaster prevention capabilities: To ensure that all county and city disaster management personnel are familiar with management strategies, procedural steps, and methods for their disaster management tasks, the website provides self-assessment items, and also offers recommendations and relevant resources connected to assessment results. (4) Case studies: The website gathers innovative disaster management actions by cities and counties,

interviews ten front-line workers, summarizes their experiences, and provides well-known overseas cases; the information from these cases is included in the explanation of disaster management tasks, and provides disaster management personnel specific, executable reference examples.

In this website, NCDR has summarized research results accumulated over the course of many years in simple, easily-understood language, and emphasizes visual methods, in order to provide city and county governments with a set of comprehensive solutions, in hope of lowering the disaster management mission learning threshold for management personnel. Looking ahead to the future, NCDR will continue to promote the website and add to its content. The systematic instruction provided by this website will enable disaster management personnel to quickly shoulder their missions, effectively boost city and county governments' disaster prevention capabilities, and reduce natural disasters' threat to public life and property losses.



Front page of the Easy to Do website (https://easy2do.ncdr.nat.gov.tw)

IV. Increasing Citizens' S&T Literacy

In order to increase citizens' S&T literacy and knowledge, MOST actively promotes public science education, and hopes that every citizen will take pleasure in learning about science, understand the uses of science, enjoy the wonders of science, and appreciate the beauty of science. The following were some of the most important results achieved in 2016:

A. Popular Science Activities

MOST has promoted various popular science activities via a wide range of channels, and has encouraged domestic university scholars, either by themselves or in partnership with companies, foundations, academic groups, or associations, to use innovative, diverse, accessible, and interesting methods to hold workshops, hands-on activities, demonstrations, performances, guided readings of articles throughout the country, and also provide guided online popular science activities. A total of 3,200 popular science activities were held throughout 2016, and attracted 870,000 participants; the 56 websites established in conjunction with these activities provided free browsing and shared science resources with the public, and achieved outreach in excess of 1,452,000 person times.

The "Sci-Tech Vista" website is an online sharing service providing popular science resources. This website has had an average of more than one million visits monthly starting September 2014. Apart from setting up a Facebook fans page and a Google+ page, the website has its own YouTube channel, and has uploaded several hundred short popular science videos provided or licensed from academic personnel and multimedia companies. As of the end of 2016, the Sci-Tech Vista Facebook fans page had received over 30,500 "likes," and the YouTube channel had been viewed a total of more than 5.7 million times.

In order to enhance the online dissemination of S&T news, MOST has continued to implement the "Projects for News Media for Popular Science," which are meant to encourage interdisciplinary academic cooperation, introduce new S&T knowledge via special reports, and provide full-scale, in-depth reports on major news events and facts. The public can view reports and quickly obtain information using computers or mobile devices, and the projects promote public understanding of science and boost citizens' scientific literacy. The writing teams have completed more than 1,300 popular science areas up to the end of 2016, and 323 new articles were published during the year. Funding was provided to seven writing teams in 2016, and the topics reported on chiefly consisted of healthcare, food nutrition and safety, life science, space science and technology, energy development, environmental protection/ sustainability/environmental education, finance, and climate change. The project projects' implementing teams will produce at least 288 popular science articles within a year's time, and will rely on the Sci-Tech Vista website and Facebook posts to help the public to conveniently obtain new S&T knowledge.

MOST held over 120 lectures of the popular science lecture series "Vision" in northern Taiwan, "Meet the Scientists on Sundays" in southern Taiwan, "Let's go! Sharing the Master's Vision" in central Taiwan, and "Bringing Fun Science to the East" in eastern Taiwan. More than 25,000 students and members of the public took part in these events, which received 130 media reports. In order to give students living in remote areas near-live access to these fascinating lectures, videos of the lectures have been placed on the "Sci-Tech Vista" website enabling viewers to watch at times and places of their choosing.

B. Popular Science Communication Industry-Academic Program

In order to continue to provide citizens superior, domestically-produced science programs, and thereby achieve the goal of promoting scientific literacy, MOST

is continuing to foster industry-academic collaboration between the media industry and domestic scientists.

This program provided funding to domestic scientists involved in industry-academic collaborative projects producing, publishing, and broadcasting popular science content. Apart from popular science TV program series, an Internet section has been added to this program in light of the growing use of online media. In 2016, funding was provided for the production of 49 popular science video programs (1,884 minutes) in three groups, 206 science news items, and 130 minutes of popular science snap movies. Funding was provided for ten projects (including one extension project), in which four public universities and organizations, including National Taiwan Museum and National Taiwan University, and four private universities, including Kaohsiung Medical University, variously signed industry-academic collaboration contracts with the television companies CTS and FTV Culture, and eight other popular science corporate partners. These collaborative efforts are expected to result in the production of seven popular science films, one popular science animated short feature, and one micro-film.

In the area of extension, the "Science Discovery" popular science show continued to be broadcast every Saturday morning on FTV News in order to get the public in the habit of viewing, and 55 hours of programming (including a New Year's holiday special) was broadcast over the course of 2016. The program's highest viewing rate exceeded 0.79% (and averaged 0.31%), and it had an average hourly reach of roughly 415,000 person-times. This show's viewing rate is typically higher than that of the National Geographic Channel, Discovery channel, Animal Planet channel, and other knowledge/information programs during the same time period. The show's viewers tend to consist of middle-aged individuals with relatively high incomes, which reveals that the show is influential with an elite audience.

With regard to output quality, popular science programs produced with funding from MOST have been finalists in the Golden Bell Awards for nine consecutive years, and have won awards for six consecutive years. These programs won three awards in 2016: "Buzz Go Go Go," which involves the use of scientific experiments to prove or disprove online rumors, won the Best Science Program Award, "Go Go Giwas," which highlights the everyday wisdom of Taiwan's indigenous peoples, won the Best Animated Program Award, and "From Proverbs to Science," which looked at the scientific content of traditional proverbs, won the Best Children and Young Adult Program Host Award. Over the years, popular science content produced with funding from MOST has accumulated a total of 15 Golden Bell Awards, which indicates the high level of quality that has been achieved. Furthermore, the popular science animated program "Go Go Giwas" also was also a finalist at Korea's Bucheon International Animation Festival and the Chicago International Children's Film Festival.

Apart from production and promotion of popular science content, in the area of research and manpower cultivation, MOST conducted various seminars and workshops during 2016, issued 19 papers concerning scientific communications, supported faculty teaching scientific communications-related general education courses at universities in northern, central, and southern Taiwan, and held popular science news writing workshops; these undertakings provided training to more than 1,200 persons.

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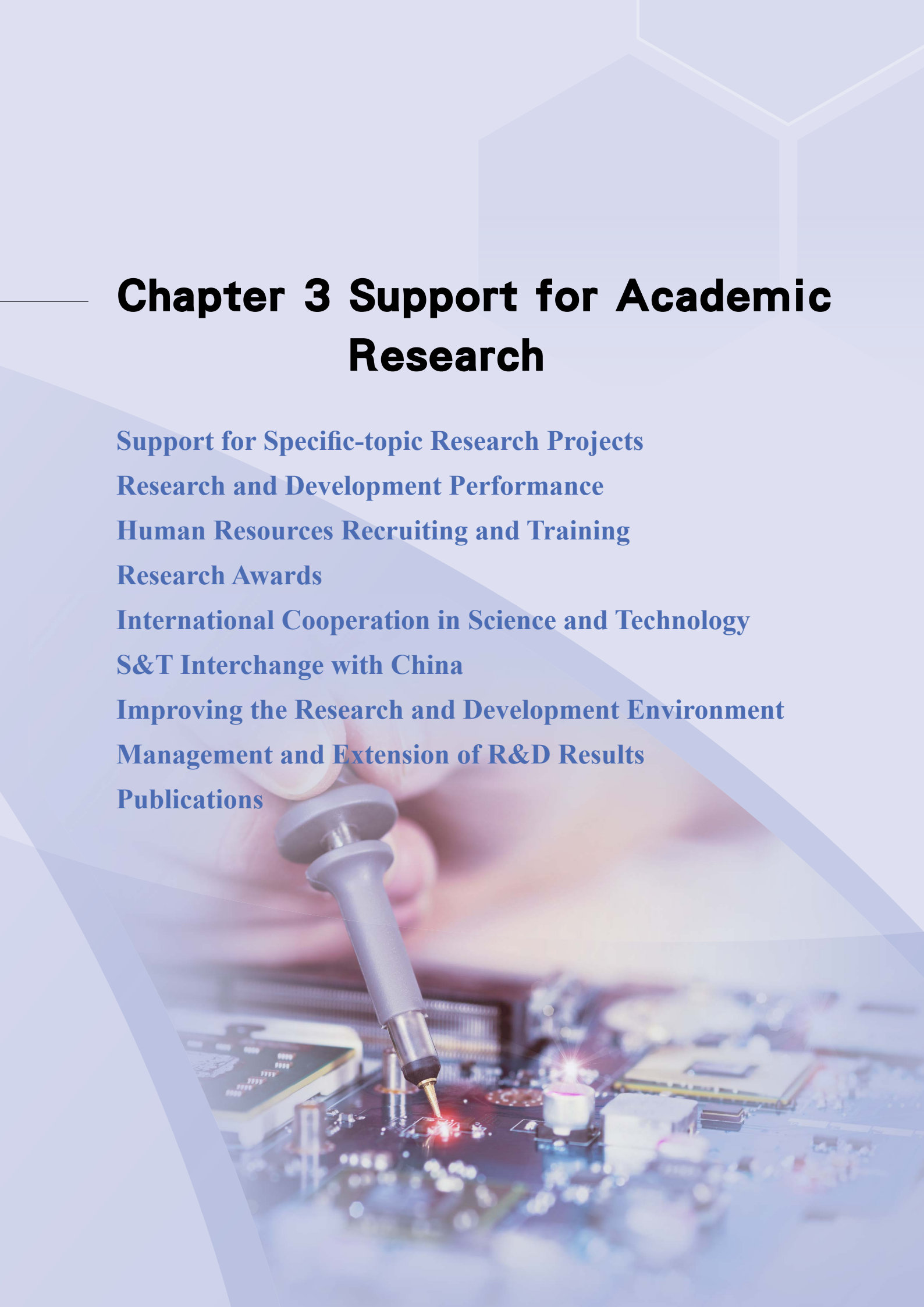
Chapter 3 Support for Academic Research



1 Support for Specific-topic Research Projects

A. Funding Principles and Methods

By supporting S&T research work at universities and academic research organizations, MOST's funding for specific-topic research projects serves to improve the country's research and development standards. All instructors and research personnel who meet MOST's specific-topic research project funding application requirements may, within a specified period of time, apply to MOST for research operation funding, equipment funding, or foreign travel funding based on the real needs of their research. Furthermore, in order to encourage long-term, in-depth research, MOST also promotes multi-year projects.

After a specific-topic research project application has been accepted, a two-stage review process consisting of initial and follow-up review in the relevant field is performed. Review results are submitted to the MOST Service Panel for approval, and an applicant who disagrees with the results of review may submit an appeal. Project funding is generally disbursed in annual installments. If, during the implementation period, a project has needs that differ from those of the originally-approved project items or funding amounts, or if the project implementation period must be extended, change procedures shall be performed in accordance with regulations. An online project results report and final funding report must be submitted via the MOST website within three months after the end of the implementation period.

B. Project Types

Specific-topic research projects are classified as either individual or integrated projects. Individual projects focus on research in the applicant's area of specialization or on a topic proposed in MOST's discipline plan. Integrated projects include main projects and subprojects; the principal investigator of a main project generally organizes a research team to address one of the mission-oriented focal research topics laid out by MOST, and proposes an interdisciplinary or inter-university project, or organizes a team research project on some specific topic.

C. Overview of Funding

A total of 18,865 specific-topic research projects were implemented during 2016 (including 13,719 newly-approved 2016 projects, 3,320 second-year projects of multi-year projects approved in 2015, 1,780 third-year projects of multi-year projects approved in 2014, 45 fourth-year project of multi-year projects approved in 2013, and one fifth-year project of multi-year projects approved in 2012). Total implemented funding was NT$21.93 billion, of which 65.77% went for research at public universities, 19.99% went for research at private universities, and 14.24% went for research at government research organizations and other units. Basic research projects accounted for 52.11% of the total, applied research projects accounted for 37.05%, and technology development projects accounted for 10.84%. By research field, natural science projects accounted for 21.15% of the total, engineering and applied science projects accounted for 31.91%, life science/medicine/agriculture research projects accounted for 25.92%, humanities and social science projects accounted for 13.46%, science education projects accounted for 4.14%, and other projects accounted for 3.42%. By research period, one-year projects accounted for 66.14% of the total, and multi-year projects accounted for 33.86%.

Numbers of specific-topic research projects and approval rate, 2012-2016

Item	2012	2013	2014	2015	2016
Applications	29,856	29,484	28,870	28,542	28,136
Approved projects	14,831	14,265	13,890	13,913	13,179
Approval rate	**49.68%**	**48.38%**	**48.11%**	**48.75%**	**48.76%**
Implemented projects	20,487	19,603	19,460	19,318	18,985[1]

Note: Research projects in this table and the tables below include general research projects, projects for junior researchers, national research projects, and industry-academic collaborative projects.

[1] Projects implemented in 2016 included projects approved in 2016, second-year projects of multi-year projects approved in 2015, third-year projects of multi-year projects approved in 2014, fourth-year projects of multi-year projects approved in 2013, and fifth-year projects of multi-year projects approved in 2012.

Numbers of specific-topic research projects at different types of organizations and funding, 2012-2016

Units: NT$1 m

Item	2012		2013		2014		2015		2016	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
Public universities	12,419	13,846.52	12,023	13,986.18	12,008	14,552.39	11,904	14,357.43	11,720	14,426.03
Private universities	5,982	4,688.94	5,514	4,446.46	5,334	4,560.65	5,238	4,516.38	4,947	4,384.55
Military/police schools	217	175.95	228	204.24	229	203.34	239	241.83	240	235.53
Government research organizations	963	1,577.15	914	1,549.90	907	1,532.61	924	1,483.5	926	1,449.93
Academic research organizations	290	635.37	282	618.96	325	822.11	334	770.74	360	696.79
Teaching hospitals	608	636.83	638	710.02	655	743.59	677	722.56	672	741.04
Other	8	122.80	4	57.75	2	3.19	2	47.39	0	0
Total	**20,487**	**21,683.57**	**19,603**	**21,573.51**	**19,460**	**22,417.91**	**19,318**	**22,139.83**	**18,865**	**21,933.87**

Numbers of funded basic research, applied research, and technology development projects and funding, 2012-2016

Units: NT$1 m

Item	2012			2013			2014			2015			2016		
	Projects	Funding	Funding %	Projects	Funding	Funding %	Projects	Funding	Funding %	Projects	Funding	Funding %	Projects	Funding	Funding %
Basic research	10,767	11,438.23	52.75%	10,418	11,399.41	52.84%	10,379	11,737.81	52.35%	10,534	11,794.94	53.27%	10,114	11,428.96	52.11%
Applied research	8,477	8,446.15	38.95%	8,051	8,363.62	38.77%	7,892	8,592.26	38.32%	7,610	8,203.49	37.05%	7,485	8,126.51	37.05%
Technology development	1,243	1,799.20	8.30%	1,134	1,810.48	8.39%	1,189	2,087.83	9.33%	1,174	2,141.39	9.68%	1,266	2,378.39	10.84%
Total	**20,487**	**21,683.57**	**100%**	**19,603**	**21,573.51**	**100%**	**19,460**	**22,417.91**	**100%**	**19,318**	**22,139.83**	**100%**	**18,865**	**21,933.87**	**100%**

Numbers of funded specific-topic research projects in each research area and funding, 2012-2016

Units: NT$1 m

Item	2012		2013		2014		2015		2016	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
Natural science	2,520	4,164.30	2,356	3,950.25	2,444	4,440.59	2,584	4,526.42	2,721	4,638.89
Engineering	7,428	6,878.11	6,886	6,513.72	6,740	7,343.21	6,390	6,898,6	6,231	6,999.39
Life science	4,412	5,951.85	4,274	5,939.49	4,398	6,212.24	4,341	5,885.34	4,247	5,685.07
Humanities and social sciences	5,147	2,821.55	5,120	3,001.91	4,948	2,963.12	4,851	2,951.32	4,658	2,952.60
Science education	896	922.42	850	815.10	905	1,122.22	969	1,058.54	827	907.08
Other	84	945.34	117	1,353.05	25	336.51	183	819.61	181	750.83
Total	**20,487**	**21,683.57**	**19,603**	**21,573.51**	**19,460**	**22,417.89**	**19,318**	**22,139.83**	**18,865**	**21,933.87**

Numbers of one-year and multi-year specific-topic research projects and funding, 2012-2016

Units: NT$1 m

Item	2012		2013		2014		2015		2016	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
One-year projects										
Natural science	1,072	1,139.26	1,058	1,137.35	1,122	1,432.14	1,229	1,314.17	1,318	1,416.91
Engineering	4,115	2,874.95	3,753	2,693.54	3,673	2,946.22	3,418	2,581.66	3,393	2,751.80
Life science	1,297	1,292.78	1,289	1,263.81	1,217	1,293.44	1,343	1,279.79	1,365	1,388.67
Humanities and social sciences	2,848	1,307.52	2,778	1,353.22	2,655	1,308.25	2,627	1,337.43	2,535	1,337.51
Science education	346	314.76	378	277.73	379	248.93	419	305.57	276	167.51
Other	27	221.51	65	587.94	21	260.72	67	368.43	83	364.90
Subtotal	9,705	7,150.78	9,321	7,313.59	9,065	7,489.72	9,103	7,187.05	8,970	7,427.31
Multi-year projects										
Natural science	1,448	3,025.03	1,298	2,812.90	1,322	3,008.45	1,355	3,212.25	1,403	3,221.98
Engineering	3,313	4,003.17	3,133	3,820.17	3,067	4,396.98	2,972	4,316.94	2,838	4,247.59
Life science	3,115	4,659.08	2,985	4,675.67	3,181	4,918.80	2,998	4,605.55	2,882	4,296.40
Humanities and social sciences	2,299	1,514.03	2,342	1,648.69	2,293	1,654.87	2,224	1,613.89	2,123	1,615.09
Science education	550	607.66	472	537.37	528	873.29	550	752.97	551	739.57
Other	57	723.83	52	765.11	4	75.79	116	451.18	98	385.93
Subtotal	10,782	14,532.79	10,282	14,259.92	10,395	14,928.19	10,215	14,952.78	9,895	14,506.56
Total	**20,487**	**21,683.57**	**19,603**	**21,573.51**	**19,460**	**22,417.91**	**19,318**	**22,139.83**	**18,865**	**21,933.87**

Numbers of female and male principal investigators of specific-topic projects, 2012-2016

Item	2012		2013		2014		2015		2016	
	person times	percentage	person times	percentage	person times	percentage	person times	percentage	person times	percentage
Female	4,469	21.81%	4,429	22.59%	4,488	23.06%	4,485	23.22%	4,473	23.71%
Male	16,018	78.19%	15,174	77.41%	14,972	76.94%	14,833	76.78%	14,392	76.29%
Total	**20,487**	**100%**	**19,603**	**100%**	**19,460**	**100%**	**19,318**	**100%**	**18,865**	**100%**

II Research and Development Performance

A. General Specific-topic Research Projects

1. Natural Science

Natural science research chiefly takes the form of basic scientific research, and encompasses the areas of mathematics, statistics, physics, chemistry, and earth science, etc. In order to strengthen interdisciplinary research involving the natural sciences and other areas of science and technology, while also taking into consideration international academic research trends, MOST has been actively planning and implementing focused research in relevant areas, and has sought to achieve the goals of promoting the long-term cultivation of natural science manpower and the pursuit of academic excellence in research. The following were among some of the most significant research results of the year:

(1) Use of mechanically interlocked daisy chain-like structures as multidimensional artificial molecular muscles

In recent years, large numbers of "smart materials" able to change their characteristics after receiving external stimuli or sensing environmental changes have begun appearing in people's everyday lives. As a consequence, the design and realization of such materials' molecular-level structures and behavior has become an extremely important part of the development of smart materials.

Because the products of molecular daisy chain assembly are dimers, and dimers can contract and extend in cyclic fashion under the influence of external stimuli-which is similar to the behavior of the molecules in biological muscles-these products can serve as excellent artificial molecular muscle units.

After successfully overcoming difficulties in achieving the self-assembly of higher-order ring daisy chains, a research team from the Dept. of Chemistry, National Taiwan University was able to complete the synthesis of ring daisy chain trimers and tetramers. The team also proved that the behavior of these materials can be controlled after performing structural interlocking, and they can serve as artificial molecular muscles simulating biological muscles in multidimensional spaces. The change in the length of the molecules in their extended and contracted states are 36% and 23%, which compares favorably with the change in biological muscle molecules (27%).

This study received support from MOST's Science Vanguard Research Program and National Taiwan University's Excellence Program, and a paper resulting from the project was published in the September 19, 2016 online edition of Nature-Chemistry (*Nature. Chem.* 2016, DOI: 10.1038/nchem.2608).

(2) Variable selection and discovery of model structure in a semiparametric higher-dimensional big data model

For more than a decade, thanks to the rapid development of data collection and access equipment, vast amounts of high-dimensional data in different formats have been produced as a result of applications and research in different areas. Data of this type includes genomic data, long-term tracking data, financial time series data, social networking data, and meteorological data. How to analyze huge bodies of complex data in order to obtain new knowledge and make decisions and forecasts, and be able to confirm the correctness and effectiveness of learning and applications, is an extremely challenging issue. As a result, there has been a great need for statistical learning theory and methods, which continue to make many groundbreaking contributions in this field.

Long-term tracking data is commonly seen in large-scale medical, epidemiological, and quantitative economic research. In particular, the marginal varying-coefficient regression model is one of the standard analytical models for cases in which the values of the explanatory and dependent variables of a single entity are observed at different points in time. In extreme high dimensional situations, most explanatory variables are unimportant, and only a small number of explanatory variables have a non-zero variation coefficient function. In such a case, important explanatory variables can be distinguished as having either a constant coefficient of variation or a nonconstant coefficient of variation.

In a paper published in *Annals of Statistics* in 2014, the research team in this project constructed a two-step method for obtaining the correct marginal varying-coefficient regression model, and this method

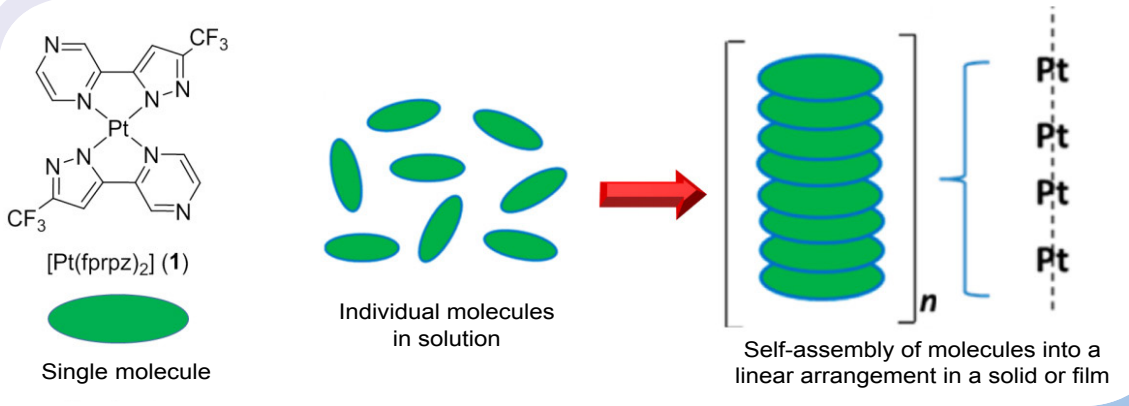
also found all important explanatory variables, and determined whether they had a constant coefficient of variation or nonconstant coefficient of variation. The method's two steps consisted of the selection of variables and determination of model structure, as follows: In the first step, the "sure independence screening" variable screening method was used to construct a marginal varying-coefficient model for each explanatory variables, and the L2 norms of the estimated values of the variation coefficient function were ranked from large to small. Afterwards, most of the least important explanatory variables were screened out. In the second step, group SCAD was used to form the group SCAD penalty term of the L2 norm of the fit spline variation coefficient function and deviation constant of the explanatory variables remaining from screening in the first step. This process not only obtained the important explanatory variables, but also automatically classified them on the basis of whether they had a constant coefficient of variation or nonconstant coefficient of variation. In 2016, the research team also proposed a variable screening method for use in extreme high dimensional coefficient of variation regression models in a paper published in the *Journal of American Statistical Association*. This paper employed stepwise procedures to perform the variable screening process. In this stepwise variable screening method, the residual sum of squares was used as a standard for further selection of potential variables, and BIC was used as a guideline concerning whether to stop variable selection. This method can also achieve variable selection consistency under some conditions, which involves discarding explanatory variables with parametric functions that are zero functions and retaining explanatory variables with parametric functions that are non-zero functions.

The two foregoing research results represented pioneering efforts in both obtaining valid solutions and also performing in-depth theoretical exploration of extreme high dimensional semiparametric model variable selection and model structure determination problems.

(3) World-leading advances in near-infrared light-emitting materials and elements

A research team made up of researchers from National Taiwan University and National Tsinghua University has overcome theoretical restrictions to design and synthesize a platinum complex compound that can self-assemble into a linear arrangement. The material's perfect molecular arrangement extends its emission wavelength to the near infrared region (740 nm), and, from a theoretical perspective, weakens the interaction of excitons and phonons, which strengthens exciton emissions. Using advanced process technology, the research team set a new world record by boosting the efficiency of near infrared organic LEDs by a factor of nearly ten, and achieved an external quantum efficiency allowing commercial production (24%).

With regard to near infrared organic LEDs (OLEDs), because the human eye cannot see near infrared light, this technology cannot be used to produce display elements and lighting, it can be used in other types of applications, and is expected to provide new opportunities to domestic industry. The most promising potential application consists of near infrared illumination units for vehicle collision sensors. Because near infrared OLEDs offer such advantages as planar emissions, diversity of product type, and inexpensive production, they may be able to replace the LEDs currently used in vehicle sensors, and



Synthesis of a platinum complex compound that can self-assemble into a linear arrangement. The material's perfect molecular arrangement extends its emission wavelength to the near infrared region (740 nm), and, from a theoretical perspective, weakens the interaction of excitons and phonons, which strengthens exciton emissions.

may create a huge global market. And because near infrared can effectively penetrate animal tissue, they have important medical applications. For instance, they can be used to activate animal cells and accelerate cellular repair. In photodynamic therapy, near infrared illumination can be used to activate photosensitive drugs under the skin or within the body and thereby kill tumor cells. Because conventional near infrared illumination has poor efficiency, the development of relevant medical technologies has been severely restricted. However, this breakthrough in near infrared OLEDs totally eliminates these restrictions, paving the way for further progress .

This study was completed with funding support from MOST's Science Vanguard Research Program and the Ministry of Education's Aim for the Top University Projects, and a resulting paper was published in the November 28, 2016 online issue of *Nature Photonics* (2016, DOI: 10.1038/NPHOTON.2016.230).

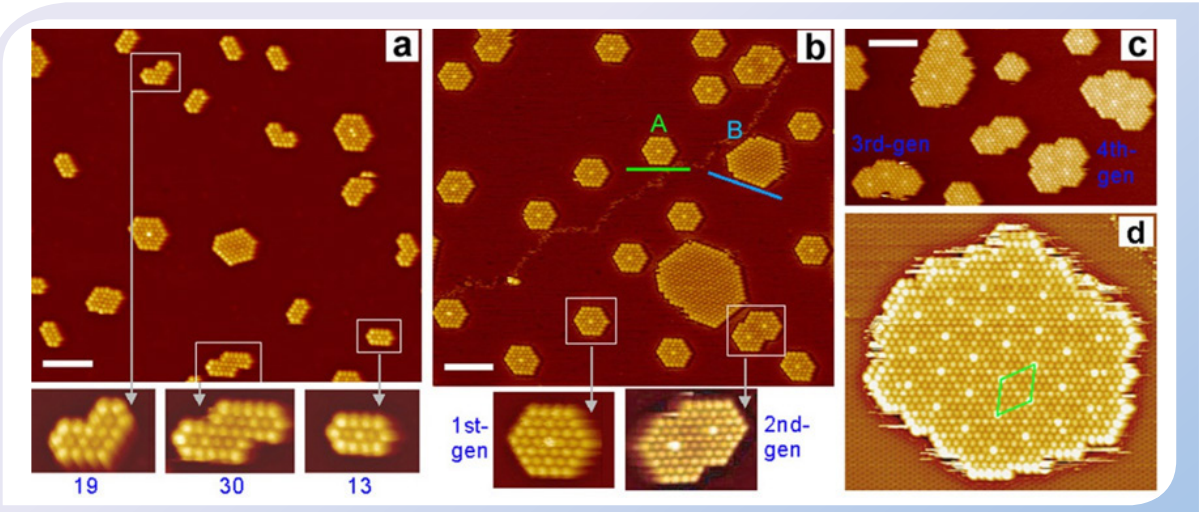
(4) Self-assembly of C_{60} molecules guided by a moiré pattern into magic molecular clusters

C_{60} is a round, hollow molecule consisting of 60 carbon atoms and shaped almost exactly like a soccer ball; C_{60} molecules interact chiefly via the Van der Waals effect. When a small quantity of C_{60} molecules is deposited on a silicon substrate via low-temperature (110°K) via vapor deposition, the random aggregation of C_{60} molecules can be observed, and the resulting molecular clusters are irregular in form. When the temperature is increased to room temperature, the molecular clusters adjust themselves and assume a regular form, but this form consists of loose small islands. If 0.2 layer of C_{60} is deposited at the beginning, when the sample is warmed to room temperature, many medium-size islands will appear. These islands are often hexagonal in form, and tend to be more compact. When a larger amount is deposited, large islands form, and their images under a scanning tunneling electron microscope appear as periodic points of light, with the image as a whole appearing as a moiré pattern consisting of two overlaid patterns with different periods.

Although samples resulting from low-temperature deposition contain hexagonal islands with many different sizes after warming to room temperature, molecular migration and selection of molecular clusters occur after a sample remains at room temperature for several hours. If a sample remains at room temperature for 48 hours, almost all remaining islands will have only 37 molecules, and these especially stable islands are referred to as "magic molecular clusters." This study was the first time that molecules had been observed to aggregate via self-organization on a surface, and this phenomenon results in the selection of molecular clusters with uniform size.

Theoretical calculations based on first principles indicate that C_{60} has a maximum potential energy when located at the central point between three gold atoms. This location is a potential energy peak, and other locations are potential energy valleys. It was further observed in a computer experiment, which minimized the islands' energy in the surface potential energy field, that the potential energy field felt by clusters of C_{60} molecules is actually the transversely magnified projection of the periodic potential energy field sensed by a single C_{60} molecule. It can therefore be said that the potential energy field has the form of a moiré interference pattern. In order to avoid potential energy peaks, small molecular clusters typically have a loose or even bent form. But when a hexagonal molecular cluster consisting of 37 molecules is centered on a potential energy peak, the cluster's six sides will be in potential energy valleys, and the cluster will consequently be very stable.

In summary, this study uncovered a new molecular self-organization phenomenon, which is caused by a moiré interference pattern formed by the molecular cluster lattice and substrate lattice. The study also discovered that the potential energy field felt by the molecular clusters is actually the transversely magnified projection of the periodic potential energy field sensed by a single C_{60} molecule. As the molecular clusters adjust their form and size in response, and self-organize into molecular clusters with the lowest energy. We can take advantage of the fact that molecular clusters in the surface lattice feel a potential energy field in a moiré pattern to select and control the shape and size of molecular clusters through the selection of lattice types and unit cell size.



(a) Deposition of a 0.1 layer of C_{60} molecules at 110°K; some irregularly-shaped C_{60} molecular clusters have appeared after the sample has returned to room temperature for 2 hr., and some medium-sized hexagonal clusters can be seen. (b) Medium-sized hexagonal clusters are visible after 0.2 layer of C_{60} has returned to room temperature for 2 hr. (c) Relatively large and roughly hexagonally-shaped islands have appeared in a room temperature sample with heavy deposition of C_{60} molecules. (d) A large island from a room temperature-deposition C_{60} molecular sample-a periodic moiré pattern has appeared. The scale of figures (a), (b), and (c) is 10 nm.

Numbers of natural science and mathematics specific-topic research projects and funding, 2016

Units: NT$1 m

Item	Applications		Approved		Implemented projects	
	Projects	Funding	Projects	Funding	Projects	Funding
Mathematics & statistics	639	345	362	202	487	295
Physics	574	1,337.75	310	590.99	558	1,039.76
Chemistry	693	1,663.53	402	701.74	568	1,108.48
Earth science, atmospheric science, oceanography	693	1,357	387	613	437	696
Interdisciplinary research[1]	141	1,106	129	273	129	273
Sustainable development research	179	283.71	101	122.12	113	137.51
Disaster prevention and mitigation science and technology	385	415.87	215	218.52	225	229.73
Technology and Industry Upgrading Program	21	190.61	19	83.13	19	83.13
National Science and Technology Program-Energy	11	282.44	10	138.33	10	138.33
Forward-looking applications of nanotechnology	34	417.92	23	191.09	23	191.09
Science Vanguard Research Program	27	340.08	25	168.09	25	168.09
Novel materials	11	61.59	10	34.94	25	83.66
Academic Summit Program	4	100.22	4	61.45	4	61.45
空間資訊科學	160	160.55	81	59.61	83	60.84
都市化下有關水、糧食與能源安全之鏈結	10	94.55	9	21.00	9	21.00
貴儀中心	0	0.00	0	0.00	4	1.94
研發成果萌芽計畫	1	5.65	0	0.00	0	0.00
Other	2	21.48	1	17.88	2	49.80
Total	**3,585**	**8,184.40**	**2,088**	**3,497.31**	**2,721**	**4,638.89**

[1] Interdisciplinary research: Interdisciplinary research involving the use of cutting-edge physical/chemical methods to explore biological systems, interdisciplinary research involving the application of spatial information to humanities/social science/economics, and other interdisciplinary research establishing a blueprint for technologies meeting the needs of society.

Research manpower in natural science specific-topic research projects, 2012-2016

Units: person-times

Item		2012	2013	2014	2015	2016[1]
Research personnel	Professors	1,431	1,302	1,433	1,533	1,549
	Associate professors	692	694	762	829	836
	Assistant professors	759	682	692	699	733
	Lecturers	0	6	0	0	7
	Other	708	664	702	800	900
Subtotal		3,590	3,348	3,589	3,861	4,025
Research assistants	Full-time assistants	833	803	892	947	1,038
	Part-time assistants	73	39	30	45	67
	Graduate students	8,901	8,563	9,088	9,692	9,779
Subtotal		9,807	9,405	10,010	10,684	10,884
Total		**13,397**	**12,753**	**13,599**	**14,545**	**14,909**

[1] 2016 data is to February 5, 2016.

Numbers and percentage of one- and multi-year specific-topic research projects in natural science, 2012-2016

Year	All projects	One-year projects (%)	Multi-year projects (%)
2012	2,520	1,072（42.54）	1,448（57.46）
2013	2,356	1,058（44.91）	1,298（55.09）
2014	2,444	1,122（45.91）	1,322（54.09）
2015	2,584	1,229（47.56）	1,355（52.44）
2016	**2,721**	**1,318（48.44）**	**1,403（51.56）**

2. Engineering

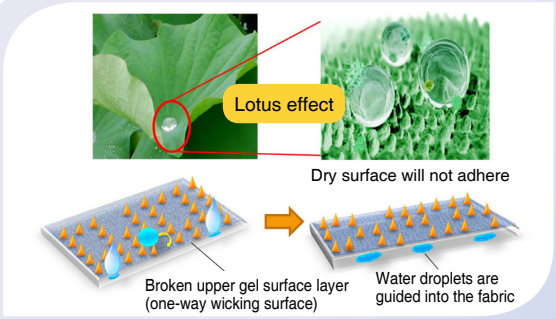
Research in engineering and applied science encompasses 19 disciplines in the three major areas of electronics/information/communications, mechanical engineering/electrical engineering/energy, and chemical engineering/materials/consumer applications, and also includes academic collaborative projects in applied technology. The chief goal of this discipline is to promote basic research in engineering technology and train high-level R&D manpower needed by industry in the future via the funding of specific-topic research projects, and to foster the upgrading of Taiwan's industrial technology through the extension of research project results. In addition, by encouraging interdisciplinary joint research involving different research teams, MOST hopes to further the development of major technologies improving people's lives and livelihoods, and thereby enhance public health and welfare, while integrating knowledge and applications in different fields. The following were some of most important research results achieved during 2016:

(1) New coating process and development of functional textiles

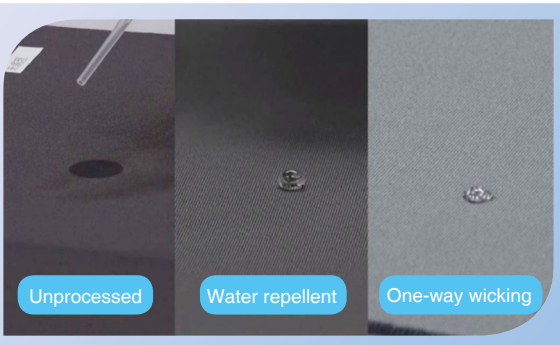
Although the weaving industry is often considered a sunset industry in Taiwan, new technologies developed in recent years have injected renewed vitality into this traditional industry. A research team from the Department of Molecular Science, National Taipei Institute of Technology established the "Functional Fabric Membrane Coating Process and Coated Material R&D Center," which is actively collaborating with domestic weaving and chemical material companies in resolving commercial coating problems and enhancing the added value of Taiwan's textile products, and the establishment of this center has increased the profits of participating firms by more than 20%. The center has recently focused on the following four major R&D topics: (a) development of PU-type coating materials, (b) multifunctional rotary cutter fabric applications, (c) dipping & slot-die techniques, and (d) the sprinkle coating technique, and has made numerous new product and new process development breakthroughs.

The Coating Center has used the new "one-way moisture-wicking broken coating technique" to develop textiles that can rapidly wick away sweat when they are in contact with the skin. These textiles contain a waterproof layer possessing the "lotus leaf effect," and this layer ensures that absorbed sweat does not diffuse back to the skin, which enables the textiles to quickly wick up sweat and gives them a dry and comfortable feel. This type of textile is particularly suitable for use in high-end bras. In addition, while the production of conventional dyed and dusted blue jeans requires ten complicated procedures, including water-hungry dyeing and dusting steps, the Center has been able to create various colored patterns on the surface of fabric by varying the speed of a coating machine's rotary cutter, and has used this method to apply or remove color from irregular patches of denim. This revolutionary coating technique can conserve 90% of process water, making it very environmentally friendly.

In the future, the Center expects to attract even more domestic firms to engage in collaboration in the form of both joint R&D and manpower training. The Center is thus creating even greater value for Taiwan's weaving industry, and is becoming an important R&D platform for fabric membrane coatings.



Schematic diagram of the lotus effect created by the one-way moisture-wicking broken coating technique



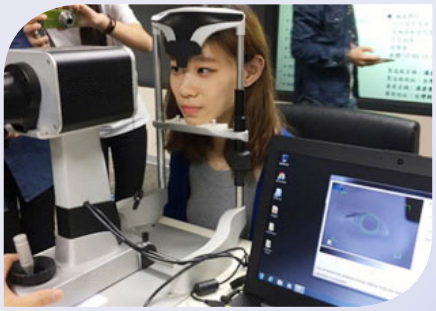
Samples of one-way wicking fabrics

Source: Provided by the Coating Center, National Taipei Institute of Technology

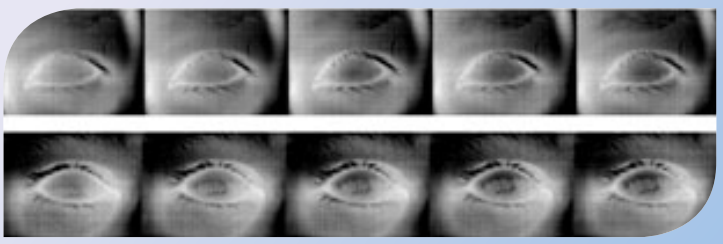
(2) Advanced technology R&D on domestically-produced smart machine tool controllers

"Dry eye syndrome" is a commonly seen problem in ophthalmological outpatient clinics, and has symptoms including dry eyes, the feeling of foreign objects in the eyes, painful burning, aversion to wind, aversion to light, and sensitivity to external irritation. In severe cases, patients' eyes are bloodshot and swollen, with abrasion of the corneal epithelium. Over the long term, dry eye syndrome may cause pathologies of the cornea and conjunctiva, which will affect vision. Most patients with dry eye syndrome are middle-aged or older, and account for approximately 10-15% of the population as a whole. Dry eye syndrome is chiefly caused by insufficient tear secretion and excessively rapid tear evaporation (resulting in an unstable tear film), and is considered to be another modern "disease of civilization".

The most common ophthalmological diagnostic method for dry eye syndrome is to place tear test paper in a patient's eyes for five minutes to measure the amount of tear secretion, but this method causes discomfort in patients. Furthermore, measurement of tear stability, which involves the use of a fluorescent agent to stain the surface of the eyeball, is often unacceptable to patients, and yields results with limited reproducibility. A research team has relied on thermal imaging algorithmic analysis technology developed by the Department of Biomedical Engineering at National Yang Ming University, clinical trials at Far Eastern Hospital, and United Integrated Services Co., Ltd.'s thermal imaging system to develop a more reliable computer-aided infrared thermal imaging diagnostic system for dry eye syndrome. This project has verified that infrared thermal imaging can replace the use of fluorescent imaging and tear test paper in the measurement of "tear breakup time" (tear film stability) and amount of tear secretion. The system also allows non-contact screening for meibomian gland dysfunction, avoids the discomfort caused by traditional contact-type testing methods, facilitates excellent patient compliance with testing, and greatly shortens testing time.



Use of system in actual testing



Upper row: Normal eyes display an even temperature decrease, and the tear film remains stable and unbroken.

Lower row: Dry eyes display an irregular temperature decrease, and the tear film is broken and unstable (one-second interval between frames).

Source: Research team under Prof. Chiang Hui-hua of National Yang Ming University

(3) Development of rapid testing technology for ketamine

Motivated by the increasingly severe abuse of various types of new drugs in Taiwan, and a wish to remedy the current lack of an on-site rapid drug screening instrument, a research team from the Department of Engineering Science, National Cheng Kung University completed development of a prototype portable saliva ketamine quantitative testing instrument. The use of this instrument requires subjects to hold a saliva collector in their mouths for only 1-3 minutes, after which the saliva specimen is dripped into reagent in the fast-screening instrument; the instrument can automatically complete readings within 5 minutes. Apart from being able to determine a positive or negative reaction for ketamine, the instrument can also display the ketamine concentration, and it has a testing precision of over 90%. A desktop version of the instrument has received a Class 1 medical equipment license from the Ministry of Health and Welfare. Specimen collection and interpretation time is 10 min., and the lowest measurable concentration of ketamine is 25 ng/ml.

Desktop testing instrument

Handheld quantitative drug testing instrument

At the same time, a research team from the Department of Bio-industrial Mechatronics Engineering, National Taiwan University has also developed a saliva rapid screening system for ketamine. The testing method employed by this system involves the use of a new type of gold nanoparticle, which serves to increase sensitivity and detection limit. The team's research results can be extended to many-in-one drug reagent cassettes, and the system can display drug metabolite test results in digital form. This system can be used for direct, rapid testing during traffic stops and in other situations.

The readers developed by the two teams both rely on commercial antibody reagents to ensure testing consistency. To compare the systems with saliva specimen testing instruments currently on the market, a research team affiliated with China Medical University Hospital and Taipei Veterans General Hospital performed clinical saliva ketamine testing. Analysis performed at China Medical University Hospital revealed that the instruments developed by the research teams achieved an accuracy of over 90%, which complies with the minimum standard prescribed by medical equipment clinical trial laws (which require that both sensitivity and specificity be higher than 80%). The automatic ketamine readers developed by the two teams offer the advantages of objective interpretation and reading results that are not affected by ambient lighting and changes in operators. In view of the fact that clinical testing results have indicated that there are good correlations between urine ketamine concentration and saliva test results, it will be very feasible for police units to perform saliva testing of suspected users of ketamine or other drugs when conducting traffic stops.

Source: Research team of Prof. Lin Yu-cheng, National Cheng Kung University

(4) Toppling a long-held myth with the development of high-entropy alloys

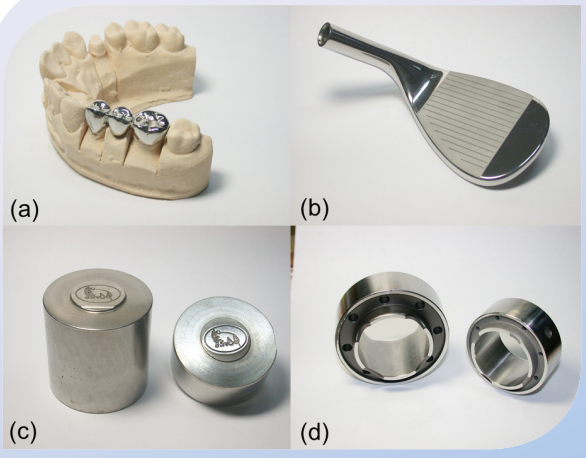
A research team from the Department of Materials Science and Engineering, National Tsinghua University has toppled a longstanding myth with the development of high-entropy alloys, which have become a new field in materials science. The team's results have been published as the special report "Stronger, tougher, and more ductile alloys made from multiple metal types" in Vol. 533, no. 7603 of *Nature*, and this work has brought credit to Taiwan.

Since ancient times, almost all conventional alloys have contained one chief metallic element and small additive quantities of other elements, which improve the alloy's properties. For instance, carbon steel refers to steel to which 0.02-2% carbon has been added, and aluminum alloy contains at least 80% aluminum. This approach to alloy composition has long been limited by the belief-now revealed as a myth-that when a greater content of alloying elements is added, large amounts of brittle compounds will form, and the alloy will be brittle and useless. However, the high-entropy alloys that toppled this myth contain five or more chief metallic elements, and each chief element has an atomic percentage in the range of 5%-35%. The multiple chief elements in these alloys give them high entropy, which can inhibit the formation of compounds and promote the mutual fusion of different elements, yielding alloys that are strong and tough. For instance, the CrMnFeCoNi alloy discussed in the foregoing report has a greater low-temperature strength-toughness combination than traditional materials.

While there are approximately 30 types of conventional alloys containing a single chief element, there are vastly more types of high-entropy alloy systems; if 13 metallic elements are available, and five elements, six elements, and so on up to 13 elements are used together, a total of 7,099 combinations are possible:

$$C_5^{13}+C_6^{13}+C_7^{13}+C_8^{13}+C_9^{13}+C_{10}^{13}+C_{11}^{13}+C_{12}^{13}+C_{13}^{13}=7{,}099$$

This would therefore allow the creation of 7,099 alloy systems, and each system includes alloys with equal and unequal atomic ratios, such as CuCoNiCrAlFe and CuCo0.5Ni1.2CrAlFe1.3. High-entropy alloys possess great application potential, and many applications in which conventional materials cannot be satisfactorily used provide high-entropy alloys with an opportunity to shine. Such applications include abrasion-resistant, heat-resistant lathe blades and coatings, jet engine blades resistant to extremely high temperatures, structural materials for use in next-generation nuclear reactors that are resistant to a temperature of 900℃ and radiation damage, films with an extremely low resistance temperature coefficient, room temperature superconductors, and anti-adhesion films.



Products made from high entropy alloys

Source: High-entropy materials laboratory, Department of Materials Science and Engineering, National Tsinghua University

Numbers and percentage of one- and multi-year specific-topic research projects in engineering, 2012-2016

Year	All projects	One-year projects (%)	Multi-year projects (%)
2012	7,428	4,115（55.40）	3,313（44.60）
2013	6,886	3,753（54.50）	3,133（45.50）
2014	6,740	3,673（54.50）	3,067（45.50）
2015	6,390	3,418（53.49）	2,972（46.51）
2016	**6,231**	**3,393（54.45）**	**2,838（45.55）**

Numbers of engineering specific-topic research projects and funding, 2016

Units: NT$1 m

Item	Applications		Approved projects		Implemented projects	
	Projects	Funding	Projects	Funding	Projects	Funding
Electrical/mechanical/energy[1]	2,661	2,316.80	1,359	1,096.14	1,690	1,417.18
Chemical/materials/consumer applications[2]	2,848	3,139.49	1,324	1,280.26	1,874	1,867.58
Electronics/information/communications[3]	3,069	3,191.96	1,493	1,305.29	2,054	1,873.30
National Energy Program and energy technology	573	1,627.45	319	803.55	370	855.42
Atomic energy and applied radiation technology	36	33.28	24	19.83	24	19.83
Academic technology development programs	1	4.50	1	4.50	1	4.50
Interdisciplinary research	8	40.92	8	31.16	8	31.16
Special projects	257	1,757.27	168	876.30	180	900.60
Gender mainstreaming technology projects	4	1.74	3	1.38	3	1.38
Other	42	48.35	27	28.43	27	28.43
Total	**9,499**	**12,161.76**	**4,726**	**5,446.84**	**6,231**	**6,999.38**

[1] Includes aviation technology, remote sensing, mechanical statics, fabrication and stress, shipbuilding engineering, electrical engineering, industrial engineering, production automation technology, control engineering, space technology, heat transmission and fluid dynamics, and marine engineering.

[2] Includes materials and applied chemistry, chemical engineering, materials engineering, food engineering, civil and hydraulic engineering, environmental engineering, medical engineering, and polymers and fibers.

[3] Includes electronic and information systems, telecommunications engineering, microelectronic engineering, and optoelectronic engineering.

Research manpower in engineering specific-topic research projects, 2012-2016

Units: person-times

Item		2012	2013	2014	2015	2016[1]
Research personnel	Professors	4,769	4,568	4,881	4,802	4,682
	Associate professors	2,827	2,587	2,596	2,509	2,298
	Assistant professors	2,531	2,268	2,049	1,795	1,641
	Lecturers	66	30	25	28	17
	Other	638	653	762	779	832
Subtotal		10,831	10,106	10,313	9,913	9,470
Research assistants	Full-time assistants	461	423	708	663	704
	Part-time assistants	54	68	52	37	4
	Graduate students	24,606	22,733	23,183	22,142	21,477
Subtotal		25,121	23,224	23,943	22,842	22,185
Total		**35,952**	**33,330**	**34,256**	**32,755**	**31,655**

[1] 2016 data is to February 5, 2016.

3. Life Science

Life science encompasses 18 fields within the three main disciplines of biology & agriculture, basic medical science, and clinical medicine. MOST's primary mission in life science consists of planning and implementation of research and development projects in the areas of biology, agriculture, and medicine, improving life science research quality and R&D capabilities, training outstanding research talent, and promoting the formation of research teams, with the goal of creating an outstanding academic environment and providing effective research funding, pursuing academic excellence, fostering S&T interchange and collaboration, and achieving the development of life science. The following major results were obtained during 2016:

(1) Biology and agriculture

The discipline of biology and agriculture includes the fields of the bio-agricultural environment and diversity, agricultural production and resource science, and biological science; the chief results during 2016 included the following:

Researchers established a photosynthetic potential and physiological functional trait database for 94 species of woody plants; this database can be used to investigate the relationship between the physiological and functional traits of trees and their spatial distribution and environmental factors, which can be used to examine the survival mechanisms and habitat differentiation mechanisms of these forest trees. Changes in population density during different seasons were found to significantly influence the reproductive performance of the burying beetle *Nicrophorus nepalensis*, and it was also found that these seasonal variations in reproductive performance were not affected by physiological factors in this species. The researchers concluded that the relationship between reproductive performance and environmental factors is not fixed, but is instead limited by the species' population density. The concentrations of chromium and nickel in soil resulting from the weathering of serpentinite are far higher than in soils derived from other parent materials, and when the groundwater is acidic, these heavy metals have high leaching concentrations. This finding indicates that acid rain may cause the release of heavy metals to increase. A barcode method was used to assess types and abundance of fish eggs, fry, and immature fish in the coastal waters around Taiwan; the database resulting from this project contains a cumulative total of 1,618 species of fish in 221 families. In strongly developed limestone terrain, speciation of plants of the genus *Primulina* with preference for a limestone substrate has occurred through continued geographical isolation; the significant correlation between geography and species affinity is also reflected in a geographical model of the kinship of *Chiritopsis bipinnatifida*.

A research project elucidated the role played by genes OnTCP4, OnTCP2-2, OnTCP2-4, and OnMyb21 in calyx/petal/labellum development mechanisms in Oncidium orchids. This work opens the door to control of flower shape in the *Orchidaceae*, made an important contribution to the domestic flower biotechnology industry, and significantly boosted Taiwan's international academic standing.

A research project sequencing the whole genome of the plant *Aquilaria agallocha*, which is a source of agarwood and has high economic value, and this project also provided a convenient test tube tissue culture system for *Aquilaria agallocha*. Researchers investigating mechanisms and regulation of the activity of the gene OsGA2ox developed a high-yield rice variety that can resist environmental stresses; the results of this study have made a contribution to efforts to adapt to environmental changes and boost food production, and have received two US patents. It was verified that ethylene is able to effectively promote the transformation of terminal buds in *Plumeria rubra* from vegetative buds to flower buds; because it can resolve growers' past inability to control the formation of flower buds in *Plumeria rubra* and the problem of plants becoming too tall and spindly, this innovative technical method can greatly enhance the blooming period and industrial value of *Plumeria rubra*.

While the fruit fly brain is relatively tiny, it is nevertheless capable of controlling complex behavior. A project performing neural network topological analysis of the fruit fly brain and verifying brain functions developed innovative technology that can be applied to the human brain in the future. Maintaining telomere length is an important step in the proliferation of cancer cells. Research on the telomere protein Cdc13 shed light on how telomere length is controlled in cancer cells, which can make a contribution to cancer treatment. The genetic stability of living organisms depends on maintaining a high level of integrity in the chromosomes within cells. Research on the ciliate *Tetrahymena* found that chromosome breakage is connected with the elimination of certain genes, which can be used in new strategies for controlling the development of relevant genes.

(2) Basic medicine

The field of basic medicine includes morphological and physiological medicine, biochemistry and

pharmacology, immunity and testing, pharmacology, and traditional Chinese pharmacology. The following research results were obtained in 2016:

The discovery of a new site regulating glycine and the GABAA receptor may prompt novel thinking concerning glycine and GABAA receptor regulating drugs. A study found that, apart from being able to accumulate in tissues or organs, and directly influence their functions, nanometer gold can also influence the endothelial cell barrier and increase its permeability, which can indirectly cause greater sensitivity to endogenous toxins in living organisms.

Researchers relied on animal experiments to verify that social isolation during one's early years will cause an abnormal increase in NMDA receptors within the hippocampus, which may be a factor in the abnormally violent behavior that such individuals may exhibit when encountering stress following adulthood. The findings of this research may lead to the development of new drug strategies for treating violent behavior. It was successfully confirmed that modification following protein translation in human mesenchymal stem cells during the process of adipose differentiation affects the mechanism controlling changes in energy metabolism, which may have a significant impact on the development of new clinical drugs for diabetes and insulin intolerance.

Research proved that the drug Sorafenib, which is used in targeted therapy of liver cancer, and its chemical derivatives can specifically inhibit the androgen signal transmission pathway in the liver via the liver-specific protein SHP1, and will not affect the male reproductive system. As a consequence, SHP1 can reduce the occurrence of liver cancer in men, while also preserving normal male reproductive function, and therefore presents a possible new direction in the development of liver cancer prevention drugs.

Development of a molecular probe for the 7th serotonin receptor as a promising PET drug: Researchers have developed a molecular probe for the 7th serotonin receptor as a promising PET drug for use in the treatment of diseases of the central nervous system, such as sleep disorders, depression, schizophrenia, epilepsy, and migraine. Basic research on the use of acupuncture to treat Parkinson's disease has suggested the possible use of acupuncture in treatment of Parkinson's disease in order to increase the economic effectiveness of drug therapy. Research employing proteomics and transcriptomics technology to investigate the functional mechanism of Jinchuang Ointment verified the effectiveness of this traditional Chinese medicine and helped promote its usage, which will enhance human welfare.

The formation of some amino acid residue groups may be connected with binding to metal ions, and the role of these amino acids in promoting the structural stability of BIGT is the result of autocatalysis, enzymatic activity, and thermal denaturation resulting from four types of single-site Ala mutations. This work is being used to develop garlic-flavored products. Lotus seedpod extract (LSE) is able to effectively protect pancreatic tissue and cells from damage due to oxidative stress via the mechanism of cellular autophagy. LSE can also inhibit liver inflammation and the expression of lipid-forming enzymes, and promote the synthesis of glycogen. LSE can therefore be used to reduce inflammation and the accumulation of lipids in the liver. This research can further explain how LSE extracted from lotus seed pods and its functional component EGC can improve metabolic syndrome.

(3) Clinical medicine

The field of clinical medicine includes social medicine, engineering medicine, digestive medicine, cardiac medicine, thoracic medicine, neurology, women's and children's medicine, hematology and immune medicine, nephrology/urology/endocrinology, and sensory system medicine. The following research results were obtained in 2016:

Research on vascular dementia following strokes relied on whole exome sequencing to find inflammation gene polymorphisms linked with mild cognitive functional impairment. The findings of this research indicated that there were extremely great differences in the distribution of 144 single nucleotide polymorphisms (SNP) causing missense mutations among stroke patients with cognitive functional impairment and members of a control group. This finding can provide information on individuals' genetic susceptibility to vascular cognitive functional impairment following stroke.

The use of transpedicular screws in osteoporosis patients commonly leads to postoperative screw loosening, which has long been a major challenge in the field of orthopedics. Recent research has proven that the use of expansion screws and fixation using bone cement can significantly enhance pull-out strength, and compared with various factors such as geometric design of the bone screws, the use of bone cement constitutes the most important factor influencing the effectiveness of expansion screw fixation.

Researchers using the Taiwan Clinical Trial Consortium for Helicobacter and Gastrointestinal Diseases' platform to perform multi-center clinical trials found that bismuth-containing quadruple therapy yielded the best therapeutic effectiveness, and was

significantly better than triple therapy, This result concerning the selection of first-line helicobacter treatment has particularly great reference value in countries such as Taiwan, where resistance to clarithromycin has reached 10-15%.

The results of the recent study "possible role of monocyte differentiation controlled by dipeptidyl peptidase-4 in abdominal aortic aneurysms" may allow the development of clinical abdominal aortic aneurysm prevention, treatment, and tracking strategies. Apart from this study's academic value, it may also benefit patients by facilitating the improvement of clinical treatment.

Research on lung cancer continued to perform in-depth investigation of the biological characteristics of lung cancer, explored new mechanisms of resistance to therapeutic drugs, and determined the influence of resistance mechanisms on clinical prognosis. This research project has found many genetic and cellular signal transmission pathways that are connected with epithelial-mesenchymal transition, metastasis, and cancer stem cell drug resistance, and may provide new therapeutic targets.

Glioblastoma multiforme is the most common form of brain cancer in adults, and average patient survival time following surgery, radiation therapy, and chemotherapy is only around one year. Research has found that miR145 can inhibit the ALDH+, CD133+, and sphere-forming ability of glioblastoma multiforme cancer stem cells, and the use of SPONGE to inhibit miR145 expression can increase glioblastoma multiforme tumor formation.

Respiratory distress syndrome caused by the immaturity of premature infants' lungs is the largest difficulty in the care of premature infants. Researchers have found that the interactions of Notch-VEGF constitute a key pathway for the maturation of the lungs in fetal rodents, and this discovery may point the way toward ways of improving respiratory distress syndrome caused by lung immaturity in premature infants.

A research team developed the low-dose, highly-effective small molecular drug Cf-02, which has been applied to treatment of lupus nephritis in mice. Research on the effectiveness of Cf-02 in treating autoimmune diseases found that Cf-02 can inhibit arthritis induced by collagen, can also improve kidney function and proteinuria in mice with lupus nephritis, and can inhibit the aggregation of peripheral monocytes in patients with lupus. This drug should have great potential in the treatment of lupus nephritis.

A research team discovered that flavopereirine possesses an inhibitory effect against human thyroid cancer cell lines, and is especially effective against differentiated carcinomas that have metastasized and cannot be treated with atomic iodine and differentiated carcinomas of the thyroid. This discovery will facilitate understanding of flavopereirine's ability to inhibit cancer and its mechanism, and will allow the further development of highly-safe drugs for treatment of thyroid cancer, particularly in cases of differentiated and undifferentiated cancers that cannot be treated effectively with radioactive iodine.

When patients receive radiation therapy, to avoid further injury to the skin, the epidermis must not be subjected to unnecessary drugs or procedures during the 6-hour injury period after radiation exposure. Substances that can be applied topically and enhance the effectiveness of the Wnt/β-catenin pathway may be potentially developed as drugs that can treat radiation damage to the skin, and can be used to mitigate or prevent unnecessary skin side effects induced by radiation therapy. When used during the repair/regeneration period, such substances can perhaps achieve even better effects, and accelerate skin repair and regeneration.

Numbers and percentage of one- and multi-year specific-topic research projects in life science, 2012-2016

Year	All projects	One-year projects (%)	Multi-year projects (%)
2012	4,412	1,297（29.40）	3,115（70.60）
2013	4,274	1,289（30.16）	2,985（69.84）
2014	4,398	1,217（27.67）	3,181（72.33）
2015	4,341	1,343（30.94）	2,998（69.06）
2016	**4,247**	**1,365（32.14）**	**2,882（67.86）**

Numbers of life science specific-topic research projects and funding, 2016

Units: NT$1 m

Item	Applications		Approved		Implemented	
	Projects	Funding	Projects	Funding	Projects	Funding
Medicine	4,601	7,270.32	1,997	2,307.93	3,188	3,789.37
Biology	395	832.19	181	292.96	295	463.29
Agricultural science	676	1,039.47	310	375.05	485	606.59
Special projects and other	217	659.28	177	395	178	396
Ocean science	121	733.66	101	430.31	101	430.31
Environmental protection	0	0	0	0	0	0
Total	**6,010**	**10,534.91**	**2,766**	**3,800.76**	**4,247**	**5,685.07**

Research manpower in life science specific-topic research projects, 2012-2016

Units: person-times

Item		2012	2013	2014	2015	2016[1]
Research personnel	Professors	2,830	2,822	2,967	3,006	2,914
	Associate professors	1,578	1,632	1,634	1,514	1,483
	Assistant professors	1,557	1,386	1,443	1,378	1,355
	Lecturers	68	55	62	47	38
	Other	2,796	2,923	3,084	3,213	3,291
Subtotal		8,829	8,818	9,190	9,158	9,081
Research assistants	Full-time assistants	2,625	2,687	2,937	2,799	2,825
	Part-time assistants	22	25	23	16	10
	Graduate students	5,559	5,321	5,393	4,956	4,584
Subtotal		8,206	8,033	8,353	7,771	7,419
Total		**17,035**	**16,851**	**17,543**	**16,929**	**16,500**

[1] 2016 data extends to February 5, 2017.

4. Humanities and Social Sciences

The humanities and social sciences comprise 17 disciplines in the three major areas of the humanities (literature, history, philosophy, and art), the social sciences (law, political science, sociology, education, and psychology), and management (administration, finance and accounting, regional studies, and geography). The following is an overview of major research efforts, planned projects, and database projects during 2016:

(1) Major projects

a. "Revival of Taiwan's Indigenous Languages and Indigenous Language Education: Topics, Challenges, and Prospects"

This project focused on indigenous language revival education, and was conducted by a research team consisting of scholars of education, language, and digital technology, as well as indigenous citizens. The project took in-school, informal, and digital indigenous language education as its research domains, and performed a systematic, in-depth investigation of major topics in these three research domains and indigenous language revival education. Thanks to the participation of indigenous personnel, the project was able to complete a full-scale, systematic assessment of all policies and measures connected with the revival of indigenous languages during the past two decades or more. The research team further provided recommendations that will improve the effectiveness of indigenous language revival measures, and hopes to facilitate the drafting of future indigenous language revival policies in order to help the maintenance and development of Taiwan's indigenous languages.

b. "Growth of Enterprises in Emerging Nations in the face of Global Competition: A Hybrid Perspective"

The rapidly growing affluence of developing nations has induced large numbers of multinational firms to invest in these countries and serve their

local markets. These multinational firms possess certain advantages in developing nations, and their rate of growth far exceeds that of many prominent multinational firms with their headquarters in developed countries. Motivated by the fact that this phenomenon is at odds with conventional thinking about international corporations, this project used a hybrid perspective to interpret the phenomenon, and provided important information with decision-making value for further research on international business.

(2) Promotion of planned projects

a. Humane Innovation and Social Practice

The first stage of this project (2013-2016) was conducted at four universities, namely National Chengchi University, National Chi-Nan University, National Cheng Kung University, and National Dong Hua University, and each school employed different operating models. The school-wide projects, established different cases, and providing other schools reference information concerning innovation and social practice in the humanities. The second stage of the project (2016-2019) will also be implemented at four schools, which consist of Taipei Medical University, National Chi-Nan University, National Cheng Kung University and National Dong Hua University. This project's results have included:

(a) In a project combining geography with local organizations, a youth sharing group at National Chengchi University designed a series of panel discussions giving young people from Wulai who did not have a clear understanding of the indigenous community chances to get in contact with other indigenous villages, and encouraging local young people to engage in discussion and reach a consensus concerning relevant issues. Various regular activities helped achieve a consensus that old houses should be reused. In addition, the project established a typhoon information website providing real-time information, help Wulai rebuild after a typhoon, and promoting senior care at a local center.

(b) National Chi-Nan University relied on "community (village) stations" and practical classes to establish effective interactive relationships with local residents, public groups, and local administrative offices. Furthermore, teachers and local villages jointly produced the indigenous village consciousness "Meixi Report."

(c) National Cheng Kung University helped community residents to achieve autonomous living community capabilities and support systems. Results included reliance on community organizations to encourage participation by residents and shops in the Yintong Community; use of a participative activity design to induce even more people to find out about Dongshan's industry culture and its value through action in the Lingnan Community; the use of distance accompanying instruction to bring study partner resources to the Gongguan Community; and help with earthquake reconstruction in Tainan.

(d) At National Dong Hua University, apart from the signing of a knowledge development cooperation memorandum by the university's College of Indigenous Studies, Port Community Development Association, Hualien Tribal College, Eastern Taiwan Environmental Humanities Research and Social Practice Center, Hualien County Gangkou Elementary School, and Arts and Culture Worker Workshop, students from community arts and crafts industry classes and village youth jointly arranged for the use of idle village buildings, and established a series of "millet workshops," which act as places for serving villages during the summer, and also provide gathering places for cultural industries.

(e) Taipei Medical University conducted a "millet ark" agricultural conservation activity at Houshan Village, Jianshi, Hsinchu County, which promoted the preservation of millet cultural knowledge and an agricultural conservation plan among members of the Atayal indigenous tribe.

b. Joint Promotion of Local Cultural Development by Universities and Local Government and Interregional Governance Plan

This plan is encouraging universities to become involved in research on and solution of practical problems in Taiwan from the perspective of humane concern and value innovation, and exploring the cultural development and interregional governance issues facing various isolated counties and cities throughout Taiwan. The plan promotes collaborative discussion between local governments and universities, with local governments providing matching grants, and the participating universities proposing innovative solutions with funding from MOST, and the plan is

highlighting the contributions that the humanities and social sciences may make to the cause of social reform. The first stage of the plan (2016-2018) provided total funding of approximately NT$63.8 million to seven projects, and the cooperating local governments have consisted of the governments of Penghu County, Keelung City, Hsinchu, Miaoli County, Nantou County, Yunlin County, and Pingtung county. This collaborative model has successfully brought together universities and local government, and led to the creation of an interregional cultural development collaboration mechanism characterized by public-private cooperation and fusion. Looking ahead to the future, the plan will seek to foster and sustain structured collaboration and research that also focuses on universities' academic and practical objectives, while also proposing tangible and feasible short-/mid-/long-term improvement recommendations based on the state of local cultural development in relevant areas to serve as a reference for the planning and implementation of local cultural and interregional management policies.

c. Promotion of Research in Cognitive Neuroscience

After beginning from the acquisition of brain imaging instruments, MOST's promotion of research on cognitive neuroscience has encouraged scholars of the humanities and social sciences to embark on new areas of research via different routes via the "Research Projects in Cognitive Neuroscience and Brain Imaging." The brain imaging instruments needed for these projects are now all in service. Functional magnetic resonance imaging (fMRI) has an average use rate of 83%, and magnetoencepalography (MEG), which entered service relatively late, has had a gradually increasing use rate, which reached approximately 51% during the second half of 2016.

With regard to the key issues proposed in the "Research Projects in Cognitive Neuroscience and Brain Imaging," the first stage of projects had wide-ranging topics intended to plant the seeds of brain research in the humanities and social sciences. In contrast, the second stage is focusing on the establishment of distinctive domestic focal topics in brain imaging research and cognitive science: "Investigation of the relationship between cognitive functioning and brain function in the context of sociocultural and individual traits," and encouraging the formation of interdisciplinary research teams.

Funding was provided to 25 projects during the first year of the second stage of the Research Projects in Cognitive Neuroscience and Brain Imaging, of which 5 are integrated research projects. A project results announcement meeting was held on October 15, 2016, and a total of 31 research results were shared at this event.

(3) Compilation of databases

a. Child Development Database

This project's goal is to establish a comprehensive long-term child development tracking database for Taiwan with contemporary and local cultural significance. The purpose of this database is to provide a better understanding of the health, cognitive/language, social and emotional, and physical activity development of children in Taiwan from birth to the age of eight, as well as the status and experience of the children's families and childcare environment. The database will examine long-term influences on child development, and provide a reference to help the government draft child health, welfare, family, childcare, and early health intervention policies.

The research subjects consist of two groups of children with ages of 3 months and 3 years respectively. The project uses household registration data for Taiwan as a sampling frame, and employs a two-stage sampling method. After first taking small towns/townships and urban districts as sampling units, the project then selects individuals to serve as subjects. Data is collected via questionnaires aimed at parents, relatives, and childcare personnel, and data types consist of child development assessments, visits with the children, and observations at childcare organizations. The first stage of the project is currently underway; development of 0-6 year-old child questionnaire, development of sample management platform and online version of the questionnaire, establishment of an information security system, and establishment of a dedicated project website have been completed, and nationwide data collection via interviews has begun.

b. Taiwan Database for Empirical Legal Studies

Eleven years have gone by since the Taiwan Database for Empirical Legal Studies was first established in 2006. The database currently contains a "statistical database for the Japanese colonial period," "legal document database," "legal image database," "legal image and audiovisual database," "legal and social change database," and

"Taiwan post-war elementary and middle school legal education image database." The statistical database for the Japanese colonial period currently contains a cumulative total of 103,732 data items, the legal document database contains 11,007 data items, the legal image database contains 736 data items, the legal and social change survey database contains 5 survey reports, and the legal change image and audiovisual file database contains 232 audio and video files.

Since the start of database establishment, the research personnel taking part have been gradually accumulating and arranging documentary and image data, designing, testing, and analyzing questionnaire survey questions, and integrating the resulting data on the database website for open use by all parties as a reference and source of citations. In addition, the project has also issued an e-bulletin containing data overviews and analysis. Apart from serving as instructional materials for jurisprudence education and a reference concerning papers on jurisprudence, the database also provides reference information for use in research on history and literature. The Taiwan Database for Empirical Legal Studies website has been visited a cumulative total of 67,812 times thus far, and this figure represents a large jump from the 44,801 visits of just a few years ago, which indicates that use of the database is gradually spreading and applications of its information are bearing fruit.

Numbers and percentage of one- and multi-year specific-topic research projects in humanities and social science, 2012-2016

Year	Total projects	One-year projects (%)	Multi-year projects (%)
2012	5,147	2,848（55.33）	2,299（44.67）
2013	5,120	2,778（54.26）	2,342（45.74）
2014	4,948	2,655（53.66）	2,293（46.34）
2015	4,851	2,627（54.15）	2,224（45.85）
2016	**4,658**	**2,535（54.42）**	**2,123（45.58）**

Numbers of humanities and social science specific-topic research projects and funding, 2016

Units: NT$1 m

Item	Applications		Approved		Implemented	
	Projects	Funding	Projects	Funding	Projects	Funding
Literature/history/philosophy[1]	1,435	768.71	696	389.14	918	529.21
Law/political science/sociology/education/ psychology[2]	1,691	1,176.14	759	476.30	1,141	764.98
Management/economics[3]	2,169	1,298.29	1,034	611.18	1,304	825.55
Mass communication, regional studies & geography, gender studies, and religion	797	484.93	333	188.50	410	251.70
Art, physical education, library science	726	503.59	302	181.81	354	219.91
Digital humanities	156	152.28	63	46.79	99	79.81
Taiwan's development in a global context	113	94.53	47	27.86	79	45.28
Indigenous communities and social development	43	31.97	20	13.24	48	34.05
Information and innovation management	404	243.24	173	101.18	248	159.62
Other[4]	126	251.13	36	22.46	57	42.51
Total	**7,660**	**5,004.81**	**3,463**	**2,058.46**	**4,658**	**2,952.62**

[1] Includes literature of China and Taiwan, Hakka literature, indigenous literature, foreign language literature, history, and anthropology.

[2] Includes anthropology, education, psychology, law, political science, sociology, cognitive science brain imaging research, and social practice.

[3] Includes economics, management, finance, and accounting.

[4] Includes ethnic group research, cultural research, Projects for Books Writing on the Field of Humanities and Social Sciences, University and Local Government Collaborative Projects, and Flagship Projects in the Social Sciences.

Research manpower in humanities and social science specific-topic research projects, 2012-2016

Units: person-times

Item		2012	2013	2014	2015	2016[1]
Research personnel	Professors	1,912	2,025	2,079	2,067	2,072
	Associate professors	1,886	1,915	1,890	1,928	1,799
	Assistant professors	2,141	1,928	1,731	1,587	1,480
	Lecturers	43	34	22	16	12
	Other	435	445	430	445	491
Subtotal		6,417	6,347	6,152	6,043	5,854
Research assistants	Full-time assistants	538	625	648	628	631
	Part-time assistants	108	136	108	114	24
	Graduate students	10,452	10,383	9,918	9,946	9,298
Subtotal		11,098	11,142	10,674	10,688	9,953
Total		**17,515**	**17,489**	**16,826**	**16,731**	**15,807**

[1] 2016 data is to February 5, 2017.

5. Science Education

Science education research includes research in the fields of mathematics education, science education (including multiethnic science education), information education, applied science education, medical education, technology, society, and mass communications, and science education practice. Addressing issues of special importance in science education, MOST plans the implementation of research projects in key areas, and seeks to achieve goals of enhancing academic standards of science education, boosting the effectiveness of science education instruction and learning, realizing research-based science education practice, and training future science and technical manpower. The following were among some of the most significant research results of 2016:

(1) Teacher professional development focused on children's mathematical reasoning in elementary school

This project seeks to create opportunities to let schoolchildren in elementary school math classrooms experience the process by which mathematicians form mathematical knowledge. This process consists of the steps of observation of data, discovering rules, forming conjectures, validation of conjectures, generalization, verification, and submission of conclusions. The stages of observation of data, searching for rules, forming conjectures, validation of conjectures, and generalization can enhance schoolchildren's inductive reasoning, and the proof stage can also boost inductive reasoning. Research has shown that elementary school students can use counter-examples to refute claims that are unreasonable or with which they disagree, and the students can also use their prior mathematics knowledge to explain and support their own claims. The results of this project have included the holding of six results announcement conferences, the holding of three international forums on mathematical argument and reasoning, and the invitation of the American mathematical problem-solving master Alan Schoenfeld to Taiwan, where he saw mathematics argumentation in the classroom together with mathematics argumentation and reasoning scholars from Britain, Israel, and the US. Furthermore, the book "Mathematics Conjecture Task Design: Theory and Practice," which was published by Lucky Bookstore, records the conjecturing activities designed by classroom teachers on the research team in accordance with mathematics textbook needs, and includes such topics as range numbers, quantities, geometry, and algebra. The results of this project can provide a reference for the writing of textbooks and drafting of the core mathematics qualifications of classroom teachers in the twelve-year basic education system.

(2) Research on serious educational games and emotions: The relationships among cognitive appraisal, emotions, motivation, learning strategies, self-regulated learning, and cognitive resources

Game-based learning integrates game elements with learning content, and appropriately incorporates learning activities in game tasks. In game-based learning, students can employ a series of problem-solving processes to acquire knowledge and

train themselves in high-level thinking skills. As a consequence, game-based learning has attracted widespread attention during the last few years, and has become a flourishing new research topic. This project designed a digital game involving abstract human immunological concepts, and this game incorporates biological immune defense mechanisms among its rules, which helps students to gradually learn as they play. This game has received an ROC invention patent. The results of this project indicate that (a) the game can indeed promote students' learning of immunological concepts, and there is significant learning retention; (b) when engaging in game-based learning, negative emotion will have a negative influence on science learning; (c) positive emotion during game-based learning will have a significant positive influence on self-regulated learning strategies; (d) students' assessment of the value of game learning will affect their emotional presentations, and their emotions will influence the effectiveness of their science learning via motivation and the use of cognitive resources.

(3) High school and junior high school students' reading and understanding of images and text provided by the Internet and relevant problem-solving: Learning motivation, online-offline process, and gaze promoting scaffold

The three goals of this multi-school integrated project were (a) to investigate reading motivation, ability, and cognitive integration when engaging in problem-solving via an online learning interface integrating text and images; (b) taking eye movement analysis as a chief research method, to develop intensive, universal research instruments able to investigate students' attention, distraction, cognition, and understanding when facing an interface containing integrated graphics and text; (c) taking international assessments such as the Programme for International Student Assessment (PISA) as a reference framework, to recommend on the basis of integrated research results learning interface design and learning strategy development approaches able to boost citizens' digital learning motivation and ability. Each of the project's subprojects proposed many research topics, which were implemented through a collaborative approach involving theory, systems, and instruction.

This project conducted teaching experiments and teaching model extension work via collaboration with several universities, high schools/vocational high schools, and junior high schools/elementary schools. In research on eye movement behavior, data was obtained 885 person-times at five universities, 457 person-times at six high schools/vocational high schools, and 595 person-times at seven junior high schools and elementary schools. Non-eye movement experiments accumulated data 136 person-times at one high school/vocational high school, 734 person-times at five junior high schools, and 655 person-times at three elementary schools. This provided a sufficiently large research sample and facilitated the widespread extension of instruction.

The members of this project have published 39 papers in international journals, issued 46 domestic and foreign conference papers, and developed 10 teaching/research systems: (a) an eye movement pop-up scaffold, (b) an eye movement instrumental measurement system, (c) an eye movement video analysis system, (d) an eye movement reading focal point friendly reminder system, (e) an eye movement virtual mouse system, (f) an online network anchoring learning system, (g) the EyeLink eye movement trajectory analysis kit, (h) the Ogama eye movement trajectory analysis kit, (i) a mobile role-playing picture book story system, and (j) a role-playing electronic picture book system.

(4) Cultivation of forward-looking technology integration skills: New models and new applications

Respond to the development of technology, skills learning should keep up with the times, and existing advanced technologies should be applied to education in order to create forward-looking skills learning models and assessment methods. This project took the repair of malfunctions causing auto engines to shake as a topic, and compiled an animated massive open online course (MOOC) instructional video. This video includes four units focusing on the air intake system, fuel injection system, fuel pump system, and ignition system, and also contains a starter circuit repair unit with a QR code learning framework. With regard to the application of advanced technology, the project incorporated measurements of physiological data including brain waves, eye movements, heart rhythm, pulse, galvanic skin response, and body temperature in the skills learning process, while emphasizing learners' practical skills, professional knowledge, involvement, and problem-solving ability. This project achieved the following results: (a) Incorporation of QR code in an auto repair electronic circuit course; (b) creation of an auto engine shaking malfunction repair MOOC video and study of effect on learning; (c) use of eye movements and brain waves to analyze learners' attention and skills learning effectiveness; and (d) use of physiological indicators

to measure skills learning anxiety and analyze psychological calibration.

The project's chief results included the findings that application of QR code to multistage learning can reduce study load, and multistage learning is relatively well suited to newcomers. With regard to hybrid learning employing MOOC videos, it was found that learning results when the learner engages in practical training after watching the entire video are better than when the learner watches the video in stages supplemented by practical training. The project's results also support the effectiveness of anxiety scale use to assess learners' learning anxiety. Generally speaking, this project has paved the way for the application of physiological measurement instruments in a model for assessing learners' cognition, emotion, and skills learning effectiveness. The project also used QR code and an animated MOOC video in a hybrid skills learning model, which demonstrated a new approach to the use of forward-looking technology in skills learning.

(5) Reflecting on issues of end-of-life by approaching ventilator-dependent patients: An interdisciplinary educational action research

This project generated knowledge outputs through a three-stage process consisting of classic group discussion of instructional effectiveness assessment indicators, discussion of instructional effectiveness by a group of ventilator-dependent patients, and analysis of learning effectiveness and students with different characteristics.

The numerous discussions and specialists' meetings discussed the breadth, depth, and clinical practicality of various teaching plan designs. The three-stage research method achieved the following expected results: (a) Qualitative analysis via verbal analysis of group discussions: The researchers extracted 42 arguments supporting positive or negative decisions from 639 qualitative feedback items from 165 students. (b) Specialists' meetings and establishment of indicators: The project compared the responses of 16 groups of students and one group of specialists concerning ethical and humane issues involving severely-ill ventilator-dependent patients. This allowed the researchers to determine the differences between specialists and newcomers, and assess the students' learning performance. (c) Verification of learning effectiveness indicators: The researchers used a four-round Delphi method involving nine specialists to determine the verifiability of the students' qualitative feedback.

This three-stage approach can rely on specialists' consensus to assess students' convergent thinking when defining topical tests, and this process resulted in 42 instructional assessment indicators in this project. With regard to divergent thinking, it was found that there was a significant increase in the aspects considered by the students after taking the course. An assessment of the learning performance of the students with different characteristics in the two groups revealed that although there was a gap in performance after taking the course, effective learning occurred after the students reflected on their assignments, which indicated that instruction effectively helped the students to broaden their thinking.

(6) Medical governance and public understanding: Taking the culture of practice in health education as an example

"Technoscientific governance" and "public understanding of science and technology" are two important domains in the investigation of technological culture and the formation of mechanisms for the understanding of science and technology in the field of science, technology, and society studies (STS). In the context of the progression from policy to practice, and the transition from cognition to practice and understanding, these two domains can be seen two faces of the same subject: The former emphasizes the social processes by which policies, expertise, and knowledge systems are established, while the latter emphasizes the importance of sociocultural aspects and context in the public's understanding of and participation in science and technology. Taking knowledge accumulated by the researchers in past research as a foundation, this project explored technoscientific governance and the public's understanding of science and technology. On the basis of chronic disease clinical governance and practice, the project investigated how clinical health education establishes public understanding and implementation of practice in the formation of chronic disease governance systems through long-term tracking health education practice and in the processes, interactions, and changes that occur when patients receive health education. Among the three-year project's results, a survey of front-line clinical workplaces shed light on the diversified technological culture established in medical practice, and facilitated assessment of the discrepancies between standard medical knowledge and the general public's disease knowledge formation mechanisms in the context of current chronic disease prevention policies. This project has provided perceptive insights concerning medical communications, which is a subfield of scientific communications. Apart from serving as a

reference for the drafting of relevant policies, the project's findings can also provide a foundation for the development of even more possible medical communication strategies.

(7) Physics laboratory science, technology, engineering, and mathematics (STEM) education practice R&D in response to the twelve-year basic education system

This project chose to perform R&D concerning experiments in the areas of electricity and optics, which are of great relevance to contemporary high-tech industry. The project focused on high school physics, and employed mass production parts and technologies used in industrial testing or analysis to develop experiments. This approach had the advantages of allowing students to familiarize themselves with physics, enabling students to establish connections with technology and engineering, giving students with different aptitudes to motivation and experience, and reducing equipment budgets due to the low price of mass produced industrial elements. In addition, the standardization of specifications also helped enhance experiment quality.

The project's goal was to design instructional electricity and optics experiments using mass produced parts from contemporary high-tech and engineering industries. The project's results consisted of the completion of a diversified set of practical electricity and optics experimental components that can be used in physics instruction. These components can serve as basic instructional experiments or be used in advanced exploration and practice. Prototype production, assembly, and testing was completed during the first year of this project, and the prototype experiments were used in small-scale teaching activities and extension. The second year of the project will include the continued improvement of the finished products, as well as commercialization and large-scale extension.

Apart from experimental equipment R&D, the project invited students and teachers to jointly participate in an experiment testing science workshop. While providing an opportunity to test the equipment and collect information that could be used to make improvements, the workshop also served to extend the project's results, and provided the participating students and teachers with a superior summer vacation science education activity. The targets of extension are not limited to in-school students and teachers; the project members participated in several science education fairs and popular science activities during the project period, and hope to extend the experiment components to the general public.

Numbers of science education specific-topic research projects and funding, 2016

Units: NT$1 m

Item	Applications		Approved		Implemented	
	Projects	Funding	Projects	Funding	Projects	Funding
Science education	103	82.32	60	42.08	105	91.68
Mathematics education	118	85.33	72	45.67	96	69.22
Information education	184	180.65	95	79.46	168	165.68
Applied science education	174	137.88	79	55.44	124	97.80
Medical education	194	189.57	92	68.44	126	102.85
Diversity science education	26	25.58	14	11.26	21	18.15
Gender and science research	26	22.86	11	5.75	13	6.74
Popular science activities, popular science education projects, popular science communications industry-academic projects, and technology, society, and mass communication	77	294	41	104	86	141
Imagination research, practicum projects in science education	50	46.49	27	20.68	42	33.11
Mission-oriented projects, cutting-edge international research centers, S&T risk communication projects	5	180	5	120	22	149
Other[1]	42	68.99	0	0.00	24	32.57
Total	**999**	**1,313.67**	**496**	**552.78**	**827**	**907.8**

[1] Inccludes High-Scope Program, interdisciplinary engineering education, indigenous projects, and practice research projects.

Research manpower in science education specific-topic research projects, 2012-2016

Units: person-times

Item		2012	2013	2014	2015	2016[1]
Research personnel	Professors	779	772	786	844	728
	Associate professors	575	569	588	607	542
	Assistant professors	494	450	470	505	400
	Lecturers	39	0	21	38	41
	Other	162	150	175	236	230
Subtotal		2,049	1,941	2,040	2,230	1,941
Research assistants	Full-time assistants	416	378	414	386	353
	Part-time assistants	249	236	312	315	9
	Graduate students	2,509	2,211	2,282	2,236	2,249
Subtotal		3,174	2,825	3,008	2,937	2,611
Total		**5,223**	**4,766**	**5,048**	**5,167**	**4,552**

[1] 2016 data is to February 5, 2017.

Numbers and percentage of one- and multi-year specific-topic research projects in science education, 2012-2016

Year	Total projects	One-year projects (%)	Multi-year projects (%)
2012	896	346（38.62）	550（61.38）
2013	850	378（44.47）	472（55.53）
2014	905	377（41.66）	528（58.34）
2015	969	419（43.24）	550（56.76）
2016	**827**	**276（33.37）**	**551（66.63）**

B. National Science and Technology Programs

1. National Science and Technology Program-Energy

The second stage of the National Science and Technology Program-Energy is being jointly implemented by the Ministry of Economic Affairs, Ministry of Transportation and Communications, and Atomic Energy Council. Implementation began in 2014; the goals of this stage include (1) enhancement of energy efficiency and reduction in dependence on imported energy sources; (2) increased international competitiveness of alternative energy industries; (3) development of a smart grid technology industry and assisting with the establishment of smart grid systems in Taiwan; (4) development of an offshore wind power and marine energy industry and strengthening of offshore wind power development; (5) development of clean geothermal energy; (6) exploration of gas hydrates; and (7) establishment of a carbon dioxide capture, storage, and utilization (CCSU) and new combustion system industry.

Apart from basic research on energy, this stage of the program also emphasizes the energy industry's development, such as through verification of the possibility of industrializing energy technology and by steering research results to industry. To date, technology licensing cases resulting from this program have had a cumulative value of close to NT$600 million; licensed technologies were derived from such projects as "Use of 300 refrigerating ton class active magnetic bearing compressor technology to develop a 250RT-350RT active magnetic bearing compressor," "A low-price rechargeable aluminum-ion battery," "Development of high power grid-connected converters," "50 kW screw-expander organic Rankine cycle low-temperature thermal power generation system technology," "Key geothermal field development technology: Low-cost acid corrosion resistant materials technology," and "High-nutritive value astaxanthin microalgae." Furthermore, the program induced companies to invest more than NT$6.9 billion in relevant energy technology R&D and more than NT$3.7 billion in production, which has

facilitated the upgrading and transformation of the domestic energy industry. The following results were achieved in 2016:

(1) Energy conservation

a. Completion of mass production technology development and production management plans for maglev bearing elements to be used in commercial 200RT class maglev bearing compressors. This project determined a parts and drawing management plan and established part manufacturing and element assembly quality inspection methods at the element component and assembly level. By providing a basis for product quality management, the project's results will meet the future mass production management needs of domestic industry.

b. The new utility model patent "A thermally-insulating wall construction employing insulating building materials" was awarded the 2016 International Inventor Prize by the World Inventor Joint Certification and Awards Convention and the 11th Taiwan Top 10 Outstanding Inventors Award.

(2) Alternative energy

a. A project on high safety lithium ion battery (STOBA) materials performed trial mass production and established a retired battery reuse and energy storage system integration technology demonstration setting. At present, STOBA synthesis solution output has reached 0.4 ton/batch, and the project hopes to increase production to 1 ton/batch. In addition, the project has established a household power storage system in Kaohsiung's Riguang Xiaolin 2nd Village; apart from being able to control the times at which each household's power storage system feeds into the grid, and the amount of power feed, the system can also feed each household's excess power into a centralized community storage system for dispatching, which has improved the renewable energy supply and utilization rate.

b. At technology licensing press conferences held on June 22 and July 20 in 2016, MOST licensed key elements in solid oxide fuel cell (SOFC) power generation systems, including powder, elements, and the generating system, to Edison International Energy Co., Ltd. and Leatec Fine Ceramics Co., Ltd. This action integrated relevant domestic up-, mid-, and downstream industries chains, and encouraged companies to invest in commercial green energy production and sales.

(3) Smart grid

a. A project targeting photovoltaic renewable energy generation developed a smart inverter gateway based on an embedded system. This element can be used in conjunction with a 4G mobile network to ensure an optimal power factor and real power during photovoltaic power generation, which can reduce the impact of renewable power generation on the grid and increase renewable energy grid-connected capacity to over 30%. The project has also developed a smart current power drawing malfunction location system that can shorten the time needed to restore power in malfunctioning power distribution circuits, and completed steady operation analysis and transient operation analysis of the Qimei grid. The project assessed that the 355 peak kW (kWp) photovoltaic power system and planned 250 kW/300 kWh energy storage integrated control system can reduce Qimei's power generation costs by NT$5.0 million per year.

b. A project completed development and technology verification for a smart home/building power management system for the Xinglong Public Housing Building. This is Taiwan's first smart power management system to be linked with public housing policies. Working in conjunction with Taipei City Government and the Taiwan Power Company (Taipower), this project has integrated household energy conservation management, power usage analysis, a graphic interface, green energy system, energy storage system, electric vehicle recharging system, and automatic demand response technology. The project's successful operating results can serve as a reference for the central government, other city and county governments, and private enterprises, and can be extended to other industrial or residential areas to achieve even greater energy conservation benefits. A project completed physical verification and operational testing of the distributed power integrated dispatching system at the Taiwan Power Research Institute, Shulin, and helped the Taipower to operate this system and integrate it with Taipower's existing demand bidding mechanism; the system has successful won bids and achieved the goal of demand reduction. Researchers performed planning of a smart community power management system at the Beitou Shilin Science Park, and completed low-carbon green energy park power management system design work. Future plans call for expansion of system deployment and

the integration of smart power management systems at different levels, as well as the use of user integration technology in virtual power plant business model research and operational testing, which should lead to the development of a virtual power plant operating model for Taiwan's urban areas.

(4) Offshore wind power and marine energy

a. After performing R&D and numerical analysis of ocean current generation, a project conducted testing at sea using a tugboat in the waters near Xiaoliuqiu Island. Testing results indicated that an average power of 32.57 kW could be generated in a current with a stable velocity of 1.43 m/sec. The project also attached a 50 kW current power generating unit to a deep sea mooring, and conducted a four-day power generation test Kuroshio Current.

b. Researchers completed and performed testing of an experimental blade pitch angle control system for China Steel's 5 MW offshore wind turbines, and conducted simulation of whole turbine operating control. After performed analysis of wave force, aerodynamics, turbine system dynamics, and control system dynamics, the researchers innovatively integrated aerodynamics, turbine system dynamics, control system dynamics, and wave force analysis tools in performing whole-system dynamic simulation of China Steel's 5 MW offshore wind power generating units, which allowed the analysis of the wind generating units' movement under different wind conditions.

(5) Geothermal energy and gas hydrates

a. Drilling of exploratory geothermal wells: Shallow exploratory geothermal wells drilled in the Sikuangziping area (1,300 m, 134 ℃) yielded hot fluid with corrosive levels of acidity, and the project also performed R&D on acid-resistant plating materials. In a project drilling deep exploratory wells in the Hongchailin area of Yilan County, the no. 2 well found fluid at a temperature of 120℃ at a depth of 2,800 m, and preliminary verification made that the area has a heat reservoir at depths below 2,000 meters.

b. A project developed underwater probe equipment, including a deep-sea real-time image-guided instrument platform, a laser optical probe system, and grab bucket with a visual guidance system, and performed testing at sea.

(6) Reduced-carbon clean coal

a. MOST promoted investment in a 300-ton microalgae culture system at NCKU in order to encourage the development of microalgae biotechnology. A startup involved in this project was established in April 2016, and is promoting the commercial of CO_2 reuse technology.

b. MOST helped China Steel operate a demonstration CO_2 capture platform (0.27 tons CO_2/day), helped an engineering consulting company design a demonstration carbon dioxide absorption method plant for Formosa Chemical, and encouraged Tung Ho Steel and the Long Ding Wang Technology Co. to invest in the development of CO_2 post-combustion capture technology.

Major achievements of the National Science and Technology Program-Energy, 2016

Category	Item	Total
Academic papers	Conference papers	1,135
	Journal papers	520
Manpower training	Ph.D. students	297
	M.S. students	1,020
Patents	Received	446
	Pending	448
Technology licensing	Cases	376
	Licensing fees (NT$1,000)	248,099
	Royalties (NT$1,000)	65,112
	Signing fees (NT$1,000)	280,018
Promotion of corporate investment	Cases	297
	R&D (NT$1,000)	6,925,366
	Production (NT$1,000)	3,749,150
Startups	Companies	2
Employment	Persons	1,364

2. National Research Program for Biopharmaceuticals

The National Research Program for Biopharmaceuticals has the overall objective of strengthening mid-stream development work, employing pre-clinical trials or clinical trials to perform verification and add value, and promote the industrialization of R&D results. The following major results were achieved in 2016:

(1) Research teams: Mission-oriented research projects

a. The novel adenocarcinoma candidate drug DBPR112: After using EGFR as a molecular target and obtaining a series of compounds, researchers at the National Health Research Institute's Institute of Biotechnology and Pharmaceutical Research found that DBPR112 can inhibit EGFR's overactivation of cancer cell growth, and is also effective in the case of cancer cells resistant to Gefitinib and Erlotibnib. While Afatinib was shown in animal experiments involving mice to have a significant anti-cancer effect, DBPR112 possesses better pharmacokinetic characteristics, and consequently offers development potential. Kilogram-grade production of the active pharmaceutical ingredients for the quantity of this candidate drug needed for preclinical and clinical trials was completed in early 2016, and preparation of the drug for preclinical toxicology tests and preparation for clinical trials was also completed. The investigational new drug (IND) application passed review in Taiwan and the United States during 2016, and clinical trials are expected to get underway during the second quarter of 2017.

b. The novel diabetes candidate drug DBPR211: Apart from causing death, type 2 diabetes also induces many complications, including cardiovascular disease and neurological pathologies. The type 1 cannabinoid receptor (CB1) controls appetite via the central nervous system, and also regulates lipid and sugar metabolism and synthesis in peripheral tissue. As a consequence, peripheral CB1 is a potential target for treatment of type 2 diabetes. DBPR211 is a CB1 antagonist, can significantly improve insulin resistance in obese and diabetic rodents, and can reduce weight and alleviate fatty liver. Global patent protection for this drug is currently pending. Kilogram-grade production of the active pharmaceutical ingredients for this candidate drug was completed in early 2016, batches of the drug preparation to be used clinical toxicological tests and clinical trials have been produced, and the drug's US IND application has been approved.

c. The anti-cancer multi-target kinase inhibitor DBPR114: Conventional targeted therapy drugs typically have a single, specific molecule as a target, and block signal transmission pathways fostering the existence of tumor cells. Most drug resistance can be attributed to tumor cells' multiple proliferation mechanisms, which makes it difficult for a single targeted drug to effectively inhibit tumor growth. The multi-target kinase inhibitor DBPR114 can not only effectively inhibit at least 15 types of carcinogenic kinases, but also demonstrates significant efficacy against the growth of various types of tumors in animal models, including stomach cancer, colorectal cancer, pancreatic cancer, oral cancer, acute myelogenous leukemia, liver cancer, and bladder cancer. This candidate drug has obtained seven domestic and foreign patents, kilogram-grade production of the active pharmaceutical ingredients has been completed, and production of a preparation for preclinical toxicology tests and clinical trials is underway. It is expected that IND applications will be made in the US and Taiwan during the first half of 2017.

d. Use of an innovative subretinal biological scaffold in the treatment of human retinal diseases: The research team in this project developed and produced a "new multifunctional retinal biomimetic implantation scaffold" that can carry single-layer retinal pigment epithelial cells derived from stem cell differentiation, and also possesses the ability to inhibit abnormal blood vessel proliferation. This product, which can facilitate retinal repair and the treatment of ophthalmological diseases, has passed biosafety/compatibility testing administered by a third-party certification company, which indicates that it can be feasibly used in clinical research. The R&D team has also formed a strategic alliance involving domestic pharmaceutical and biotech firms. The team plans to apply this therapeutic model to the treatment of retinal maculopathy, which is prevalent among middle-aged and older persons and currently lacks effective treatment methods.

(2) Preclinical development group: New biomolecular target drug research and development

Institute of Biotechnology and Pharmaceutical Research, National Health Research Institutes produced many lead compounds and three novel candidate drugs between 2014 and 2016, which have entered the drug development or IND application stage. These candidate drugs consisted of the anti-cancer multiple-target kinase inhibitor DBPR114, the stem cell mobilizer DBPR215, and opioid receptor allosteric modifier DBPR116. The results of other

collaborative projects included the following:

a. Drugs to treat severe thalassemia and sickle cell anemia: In this collaboration project involving the National Health Research Institutes and Academia Sinica, drugs were used to induce red blood cells to produce fetal hemoglobin in adults, which may be a very effective approach of treating sickle cell anemia and severe thalassemia. The current stage of the project has already been completed, and lead compound optimization, animal pharmacodynamics experiments, and animal pharmacology and pharmacodynamics research are currently underway. Furthermore, the Academia Sinica has signed a licensing contract with the PharmaEssentia Co. giving this company an exclusive global license to the "second-generation sickle cell anemia small molecular drug candidate molecule" developed by the Academia Sinica's research team.

b. Drugs for treatment of Alzheimer's disease: This is a collaborative project involving National Health Research Institutes and Academia Sinica. Reports in the literature have indicated that glutaminyl cyclase depends on zinc ions for its enzymatic activity, and is responsible for catalyzing N-terminal pyroglutamate formation in many important proteins and polypeptides. This enzyme has been shown to be a new target for treatment of Alzheimer's disease. The project has entered the drug optimization stage, and it is expected that a candidate drug with development potential will be produced by the end of 2017.

(3) Clinical group: Translational medicine and clinical trial projects

a. In vitro diagnostic reagent for endometriosis: Endometriosis is common among women of childbearing age, and has a global prevalence of approximately 10%. Approximately 25-30% of infertile women have endometriosis. The research team designed a first-generation in vitro endometriosis diagnostic method employing one-step ELISA, collected approximately 300 new clinical serum samples, performed testing for the A1AT biological marker of endometriosis, and conducted validity assessment. The researchers also clarified the appearance of A1AT in other women's diseases (such as ovarian cancer) in order to determine whether the A1AT testing method might be confounded by the presence of other diseases, and assessed the specificity and accuracy of their diagnostic method. A US patent for relevant technology was obtained in November 2015, and a provisional patent application was completed in July 2016. Domestic and foreign companies are currently expressing interest in licensing the patented technology.

b. Design and synthesis of functional nanoparticles for multi-level targeted therapy: The use of nanocapsules in drug transmission systems has recently become a trend. This drug transmission technology can allow the extension of product patent protection, and its use can benefit the public by facilitating the development of new applications from old drugs. The development of nano-carriers combined with sub-cellular drug transmission strategies targeting the molecular pathways of specific diseases can achieve more precise clinical treatments, greater therapeutic effectiveness, and reduced side effects. This project's research team is currently able to stably produce nano-carriers with a high yield; apart from reducing drug and transport costs, the product is suitable for industrial production. The nano-carriers produced in this project can serve as functional nano-carriers after modification, promote phagocytosis by immune cells, and achieve the goal of highly-specific targeted therapy. This targeted therapy approach has demonstrated very low toxicity in both in vitro and animal experiments, and has no significant toxic side effects. It can be seen from biological distribution charts that the nano-carriers are retained in living organisms longer than in the case of the control group drug delivery method, and are more likely to be used by the human body, rather than being quickly excreted from the body. The research team has successfully applied for a patent, and is in the midst of technology licensing negotiations.

(4) Resource center: Providing technical services and consulting

The program resource center chiefly strives to help find and confirm disease targets, perform drug screening and design, synthesize lead drugs, establish animal models, perform animal experiments, offer legal consulting, and conduct clinical trials of candidate drugs. As of October 2016, the resource center had earned service income of NT$310 million from over 3,300 paying service cases, and provided a total of more than NT$570 million worth of services, including service funding subsidies and industrial service fees, in over 4,800 service cases.

This program established the Taiwan Clinical Trial Consortium (TCTC), which has accumulated the extensive implementation experience of Taiwan's medical centers. Many outstanding clinical trial-related

personnel helped found TCTC or have joined it. TCTC is effectively coordinating and integrating domestic clinical resources, collaborating in the implementation of multi-center trials, and cultivating clinical trial teams implementing international multi-center or domestic multi-hospital trials.

Thus far, TCTC has implemented 15 clinical trials cooperation alliances for specific diseases, and is currently managing 13 of these. According to a survey performed at the end of October 2016, 275 projects underway at that time had been commissioned by international pharmaceutical firms, 69 projects had been commissioned by domestic firms, and TCTC playing a leading role 80 of both types of projects. In order to enhance the quality and efficiency of clinical trials, this program also provides the bioinformatics, statistics, legal, and regulatory consulting services needed by clinical trials, and has established a joint ethics review and clinical trial contract signing acceleration mechanism. By ensuring that trials can be completed in as timely a manner as possible, the program will speed up the new drug R&D process.

(5) Industrialization promotion and international cooperation group

a. Industrialization promotion performance

This group completed 11 technology market assessment reports/case analysis reports, 17 patent retrieval reports/patent analysis reports, 13 patent/technical market consulting service reports, and assisted with 19 patent applications (including four Patent Cooperation Treaty patents and 14 US provisional patents, and one Taiwan patents) in 2016. Furthermore, the group used the iBM assessment model (IP, Business, Market) to perform an inventory of 150 results of the National Research Program for Biopharmaceuticals results, and found that 20 case sources possess continuing commercialization potential; the group will continue to perform tracking and assist the program in performing commercialization of technology.

The group further held two IPR committee meetings and three case R&D results recruiting and explanatory meetings, jointly promoted 38 industry-academic collaboration/technological collaboration/ technology transaction cases (including completion of contract signing for four technology licensing cases and two industry-academic collaboration cases), helped five companies to increase capital, and completed 39 commercial and legal service cases. These efforts induced about approximately NT$304.2 million in corporate investment and created 17 jobs in industry.

b. International cooperation and training

(a) A research team from National Taiwan University joined forces with R&D teams from Poland, Italy, and Spain in the multinational, multilateral Translational Cancer Research (TRANSCAN-2) campaign, which was approved by the EU's European Union Horizon 2020 Programme in October 2016. Domestic projects will implemented with funding support from MOST. Apart from showing the international community's respect for the translation cancer research being conducted in Taiwan, the implementation of TRANSCAN-2 projects is also an important milestone in Taiwan's international cooperation and diplomacy.

(b) The program hosted the 2nd Taiwan-Japan Bilateral Symposium, which was held May 27-28, 2016 and was on the topic of "Cancer Translational Research and Cancer Entry research". Both parties' speakers signed 13 bilateral confidentiality agreements, and speakers from Taiwan presented 11 papers, which will serve as references for subsequent R&D in relevant fields.

(c) In March 2016, the program received an invitation from Japan's Academic Research Organization (ARO) to participate in ARO's "Global Clinical Trial Consortium," which is conducting preliminary discussions with Asian countries (Japan, Korea, Singapore, Taiwan), European countries (France), and the US concerning "simultaneous worldwide marketing approval of drugs" as the goal of multinational, multi-center cooperation, and cooperation in the implementation of simultaneous clinical trials employing each country's funding approach.

(d) The program brought about collaboration between Takeda—Japan's largest multinational pharmaceutical company—and the Academia Sinica, and the two parties completed signing of a collaboration contract on August 26, 2016. This collaboration is Takeda's first early R&D collaboration case involving a research organization in Taiwan, and shows international industry's respect for the R&D technology of Taiwan's academic and research organizations, which is gradually reaching parity with international levels.

(e) The program brought about the joint implementation of a collaborative cancer research project

involving AstraZeneca (AZ) and AstraZeneca Taiwan (AZT). In this project, AZ and AZT provided research funding and compounds, and the three parties called for new indications or other preclinical research proposals involving innovative drugs against forms of cancer prevalent in Asia, such as lung cancer, breast cancer, stomach cancer, and liver cancer.

(f) The program arranged for the signing of an international technical service contract between the Japanese firm SAI and the Synchrotron Radiation Research Center in December 2016. Under this agreement, the Synchrotron Radiation Research Center began providing TPS machine experiment technical services to SAI during the latter part of December. Apart from establishing linkage between domestic academic and research organizations and international industry, this service cooperation will also enhance Taiwan's service capabilities as a whole through the accumulation of international market experience.

(6) Ethical, legal, and social implications (ELSI) group

a. This group is assisting TCTC in resolving technical and legal issues connected with trials at different stages, and continuing to implement joint ethical review mechanisms (NRPB-IRB), enhance the efficiency of multi-center clinical trial proposal review, reduce waste due to the redundant production of review documents, and lessen the time needed for transmission of review documents. As of the end of December 2016, 21 hospitals had joined NRPB-IRB, 29 NRPB-IRB applications had been received (12 from companies, 17 from principal investigators), 28 applications had been submitted to reviewing hospitals, and the reviewing hospitals had completed review of 25 cases. The average time needed to review each case was 14.6 days (from passing administrative review to completion of review). Because the National Research Program for Biopharmaceuticals will come to an end, relevant services have been handed over to the Center for Drug Evaluation (CDE).

b. After completing a sample "multicenter clinical trial contract" the group provided "contract-signing guides" to 30 hospitals in an effort to boost contract-signing performance, promote cooperation between hospitals, and boost the effectiveness of clinical trials.

c. The group revised the "Should I Participate in a Clinical Trial?" handbook, which explains to the public the implementation of clinical trials and IRB protection mechanisms in order to establish a basis of mutual trust.

d. The public participation group completed the "Public Attitude toward Human Specimen Studies" telephone survey and in-depth interviews. After interviewing biomedical researchers, IRB members, representatives of human rights group, legislators, and government decision-makers, the group completed 31 in-depth interviews. The group also conducted a nationwide telephone survey at the start of 2016, and held a panel discussion on public attitudes on November 26, 2016; the biomedical researchers, scholars, and members of patient groups and the general public invited to this event discussed this issue and shared their research results.

e. The group held three training classes, two next generation sequencing (NGS) round-table experts' conferences, and a public forum on the topic of "public attitudes toward human specimen research".

C. Research Results of the National Synchrotron Radiation Research Center

The Taiwan Photon Source (TPS) synchrotron accelerator successfully completed commissioning, and achieved a storage current with the design value, during 2016. President Tsai Ing-wen presided at the TPS' inaugural ceremony held on September 19, 2016, and took part in a push-button start-up ritual with various other dignitaries. Following the completion of commissioning, TPS' beamline experiment facilities were formally made available to users who completed application procedures, allowing domestic and foreign research teams to use TPS' advanced experimental facilities. TPS will lend new vitality to Taiwan's S&T development, and may develop into a world-class scientific research center. Apart from operating TPS and actively constructing beamline experimental facilities, the National Synchrotron Radiation Research Center (NSRRC) is also maintaining the high-efficiency operation of its existing Taiwan Light Source (TLS), and providing high-quality, advanced radiation services to domestic and foreign research teams engaging in basic and applied scientific research.

1. Accelerator Facility

The TLS and TPS accelerator light sources have continued to operate stably 24 hours a day. The accelerators had an operating efficiency of 98.2% (TLS) and 99.9% (TLS) in 2016, and were able to maintain an electron beam stability index ($\triangle I_0/I_0$, beam strength fluctuation ratio) of less than 0.2% for 99.9%

(TLS) and 99.8% (TPS) during the time periods when they were open to users. During the year, NSRRC continued to perform maintenance of the accelerators' power supply, beam power, high-frequency, instrumental control, magnet, vacuum, and precision mechanical subsystems and light source-related facilities, optimize the integration of subsystems, and provide domestic and foreign light source users with continuous, long-term, high-quality synchrotron radiation.

2. Beamline Experimental Facilities

NSRRC continued to operate, maintain, and upgrade its beamlines during 2016; beamline energies included infrared, UV, soft X-rays, and hard X-rays. During the year, the Center had 26 beamlines open to users (including 24 at the NSRRC site and two at Japan's SPring-8). To make full use of TPS's outstanding performance from the start, NSRRC began implementing the first phase of a beamline experimental facility construction project in 2011; this project encompassed seven experimental facilities: protein crystallography (TPS 05A), resonant soft X-ray scattering (TPS 41A), submicron soft X-ray spectrography (TPS 45A), coherent X-ray scattering (TPS 25A), X-ray nanoprobe experiments (TPS 23A), X-ray nanometer diffraction (TPS 21A), and temporally coherent X-ray spectroscopy (TPS 09A). Among these the TPS 05A, TPS 09A, TPS 21A, and TPS 25A beamlines were opened to users starting in September; optimization and experiment station expansion work is continuing. After the basic structure of the TPS 41A, TPS 45A, and TPS 23A beamlines has been completed, commissioning of the beamlines will begin. A second phase of experimental facility construction is currently getting underway.

3. User Extension and Scientific Research

A total of 1,636 research projects (12,619 person-times) used NSRRC's light source for cutting-edge experiments during 2016; these projects involved a cumulative total of 81 domestic and 58 foreign organizations. The scope of these projects encompassed atomic and molecular science, condensed state physics, materials science, soft materials, biological structures, nanometer fabrication, and industrial applications. As of the end of the year, users had published a total of 348 *SCI*-cited papers in prominent international scientific journals, including 166 papers published in prestigious journals with impact factors in the top 10%, and 90 papers published in journals with impact factors in the top 5%. Notable papers included "Structural basis of antizyme-mediated regulation of polyamine homeostasis," which used protein crystallography experiment stations at Japan's SPring-8 light source (experiment stations 15A1, 13B1, and SP12B2), and was published in *Proceedings of the National Academy of Sciences USA*; "Soft photo-piezoelectric smart materials," which used an X-ray powder diffraction experiment station, biological membrane scattering experiment station, and small-angle X-ray scattering experiment station (experiment stations 01C2, 13A1, and 23A1), and was published in *Advanced Materials*; "Growing high-efficiency perovskite heterogeneous interface thin film solar cells," which used a small-angle X-ray scattering experiment station (experiment station 23A1), and was published in *Energy Environmental Science*; "IrO_2-assisted surface plasma induction hot carriers," which used a soft X-ray absorption experiment station (experiment station 20A1), and was published in *Advanced Energy Materials*; and "Reasons for decay of capacitance in Li_2MnO_3 • LiMO_2 (M = Li, Ni, Co, Mn) anodic materials," which used transmission X-ray 3D microscopy experiment station (experiment station 01B1), and was published in the *Journal of the American Chemical Society*.

TPS combines advanced accelerator technology, precision electrical and mechanical equipment, automatic control, and high-precision measurements, and offers ultra-high brightness, ultra-small focus, and high coherence; it can be used to resolve 3D structures at the nanometer scale in an extremely short time, and can be used extensively in product R&D and process optimization by the green energy technology, biotech pharmaceuticals, and smart machinery industries. A research team at NSRRC used TPS' temporally coherent X-ray beamline experimental facility to design and test an X-ray single-mode interference monochromator, and their results have been published in an international journal, which has created some early publicity for scientific research at TPS.

NSRRC holds annual user conferences in order to strengthen communication with users and promote domestic and foreign academic interchange in research fields connected with synchrotron radiation. At the 2016 user conference, NSRRC invited Chiang Tai-chang, who is an Academia Sinica fellow and professor at the University of Illinois at Urbana–Champaign, to serve as the keynote speaker, and a TPS beamline commissioning discussion was held on the second day of the conference to introduce TPS' beamline construction plan, and the phase 1 experimental facilities and their preliminary commissioning results. At seminars on the topics of Soft X-ray SpectroNanoscopy and Its Emergent

Opportunities in Materials Science and Synchrotron for Industries held immediately afterwards, domestic and foreign scholars and experts were invited to introduce the most recent research advances in their areas of expertise. In addition, a number of synchrotron accelerator-related conferences and activities were held during the year, including the 2016 international symposium on Bragg coherent X-ray diffraction imaging, a TPS beamline commissioning conference, an academic interchange meeting on paleontology, the 2016 international conference on photoelectron microscopy, the 80th IUVSTA symposium on ultra-low beam divergence light source vacuum systems.

4. Collaboration with Industry

Apart from providing scientific research services, NSRRC also strives to promote the industrial applications of synchrotron radiation and help industry resolve problems. In 2016, in addition to continuing to deepen ties with key semiconductor industries and promote use of its advanced synchrotron light sources, NSRRC also actively collaborated with a domestic startup company to develop an optical chip microsensor able to create new industrial value and boost the company's international competitiveness. With regard to finding new users in industry, NSRRC is extending its services to potential new users in the steel and plastic industries, is in the midst of conducting a commissioned research project for the Metals Industry Development Center, and is performing initial commissioned research for Far Eastern New Century, and Cheng Shin Rubber. Furthermore, the Thai Ministry of Science and Technology's Synchrotron Light Research Institute (SLRI) signed an agreement with NSRRC on May 30, 2016, and provided funding to commission NSRRC to construct a key item of accelerator equipment (superconducting multipole wiggler) for the ASEAN beamline at Thailand's synchrotron accelerator light source, which represented a new milestone for Taiwan's ability to export its synchrotron accelerator technology.

5. Manpower Training

NSRRC teamed up with National Tsinghua University, National Chiao Tung University, and National Sun Yat-sen University to develop a light source curriculum and jointly train manpower. NSRRC also signed cooperation MOUs with over ten schools concerning the training of synchrotron accelerator manpower, promoted the integration and sharing of academic research resources, and recommended outstanding students to participate in foreign study. Furthermore, it also held occasional light source technology and applications training classes in an effort to create even more new light source talent through the integration of light source knowledge and experiments. NSRRC signed a bilateral cooperation agreement with National Cheng Kung University on April 27, 2016; this agreement calls for the expansion of the breadth and quantity of collaborative research, and the joint planning of an academic accelerator light source program aimed at systematically training the next generation of synchrotron radiation talent. National Cheng Kung University is one of the largest research universities in Taiwan, and will be better placed to attract personnel from southern Taiwan who are interested in various types of synchrotron accelerator research after establishing this linkage with NSRRC's superior light sources. In addition, NSRRC held several synchrotron accelerator light source classes in 2016, including a 4th advanced light source summer science workshop, a 7th X-ray science summer school, a 2016 winter class on free electron lasers, a 2016 protein crystallography training class, a 2016 X-ray absorption spectra data analysis workshop, and 2016 synchrotron accelerator application and practice summer classes.

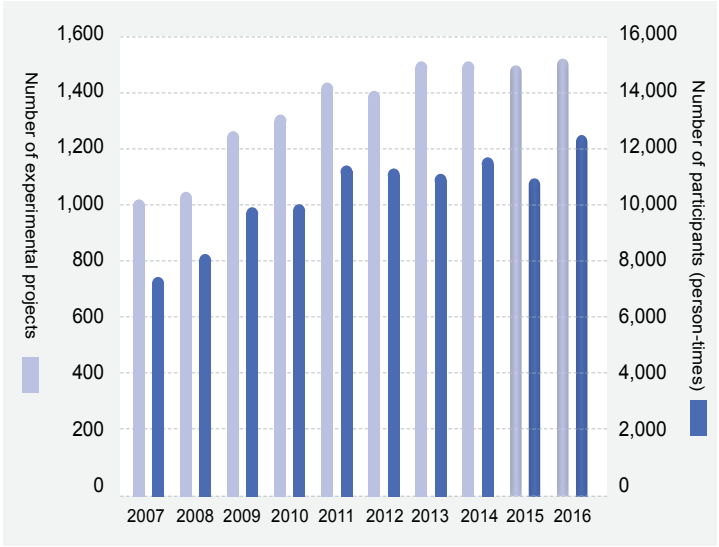
6. New Light Source and Prospects

TPS entered the operation and commissioning stage in March 2016, and the 14-week commissioning period extended from that time until June 28. This time was used to perform integrated commissioning of the accelerator and beamlines, and conduct trial experiments using the beamlines following integration. Thanks to the diligent efforts of the TPS accelerator team, the accelerator's storage ring achieved its goal of prolonged operation at a constant operating current of 300 mA. The TPS light source was formally made available for users' experiments on September 22, 2016; the storage ring currently has a constant current of 300 mA, and has passed testing for a current of 400 mA.

The result of many years of planning and construction, TPS is the first major scientific research facility to be opened for use after the new administration took office, and the four beamlines comprising the phase 1 experiment facilities began operation on time in September. TPS' scientific achievements have already attracted international interaction, and NSRRC was on the cover the American Chemical Society's August 2016 *Chemical & Engineering News* (C&EN); since this journal is an influential publication in the fields of chemistry and chemical engineering, this coverage provided TPS with great exposure.

President Tsai Ing-wen (6th from right) and other VIPs visit TPS for the accelerator's inaugural ceremony on September 19, 2016.

Beamline experiments and user person-times statistics, 2007-2016



D. Research Results of the National Applied Research Laboratories

Since it was established in 2003, the National Applied Research Laboratories (NARLabs) has relied on the development of R&D platforms to support academic research, promote forward-looking technologies, and train scientific and technological manpower. While pursuing global excellence, NARLabs plays the role of an R&D platform provider with a goal of fostering domestic S&T manpower and economic innovation and vision of creating local value.

Because the R&D platforms established by the ten experimental research units under NARLabs are usually larger and more costly than any single domestic university could undertake on its own, NARLabs is better able to provide academic researchers needed S&T research services, and enable research personnel at universities and research organizations to use superior, high-accuracy, high-efficiency instruments, facilities, and software modeling and analytical systems to develop forward-looking applied technologies. Furthermore, in order to enhance the effectiveness and industrialization value of S&T innovations, NARLabs has been actively promoting the application of R&D results. This takes the form of uncovering potential industry needs, and connecting industry with academic research units, which serves to boost industrial competitiveness. NARLabs also employs market analysis to harness the R&D capabilities of industry, academia, and research organizations in order to create key intellectual property portfolios and translate forward-looking R&D results into innovative industrial applications.

NARLabs' 2016 research results are summarized as follows in the four major areas of global environmental science, information and communications technology, biomedical technology platforms, and S&T policy:

1. Global Environmental Science

The National Center for Research on Earthquake Engineering's (NCREE) southern Taiwan experimental facility is expected to begin operation in 2017. This major, world-class research facility will have a mission of developing even better earthquake resistance and mitigation technologies, and gaining a better understanding of near-fault earthquake characteristics. NARLabs is currently employing the principles of buoyancy, connecting pipes, and flexible fiber optic gratings to construct a bridge fiber optic monitoring system suitable for long, multi-span bridges. Apart from use in bridge and elevated road safety monitoring, this system may also be used to monitor life support conduits and petroleum pipelines. NARLabs is applying experimental catchment area observation big data to develop a real-time flow automation estimation technique for rivers. This project is using microwave radar surface flow meter and radar water level meter data to accurately simulate and analyze downstream conditions, including whether flooding will occur, in real-time, which will assist in providing early warning. NARLabs is actively deploying an unmanned aircraft sounding system possessing automatic take-off, landing, and navigation control functions; the unmanned aircraft are able to complete long endurance (over 17 hours), long-distance (over 1,300 km) missions, and will be used in the future to collect meteorological data in

typhoons and strong convection centers, which will improve the accuracy of typhoon track forecasting and disaster relief decision-making. NARLabs has developed Lidar wind profiler measurement and data analysis technology that can be applied in the development of offshore wind power; this project using weather/sea condition observation tower data and environmental data in value-added interactive analysis, has completed observations during the northeast and southwest monsoons, and has analyzed wind speed profile and the characteristics of atmospheric turbulence, which will provide reference information needed in the assessment of wind power and drafting of wind turbine specifications. NARLabs' researchers are performing real-time monitoring of water temperature, salinity, depth, turbidity, pressure, and flow velocity, etc., using image analysis to observe marine organisms and environments, and are employing configurable carrier platforms to collect deep-sea water, which will facilitate real-time analysis of undersea data. The domestically-produced FORMOSAT-5 satellite includes an optical remote sensing payload, which is the first of its kind to be 100% manufactured in Taiwan through the joint efforts of industry, universities, and research units. After the satellite has entered orbit, it will acquire high-resolution images of the Earth that can be used in government and civilian applications spanning the areas of homeland security, environmental monitoring, disaster prevention and assessment, and scientific research.

2. Information and Communications Technology

NARLabs developed Internet protocol (IP) technology for CMOS (Complementary Metal-Oxide-Semiconductor) sensors. This technology can be used in flexible combinations of chips or system packaging, and can accelerate the realization of sensing system chips meeting the needs of wearable and Internet of Things devices. Energy management chips developed by NARLabs can acquire electric energy from energy sources as small as vibrations and as large as solar power; these chips can be incorporated in various green energy applications, and can be used in various kinds of wearable or Internet of Things systems. Researchers successfully developed a "subcutaneous blood clot imaging system" able to perform comprehensive, full-scale identification of subcutaneous blood clots during the initial period after an injury; a cooperating firm has realized a product based on this system that can be used to perform investigation and obtain evidence in criminal cases. NARLabs researchers working in conjunction with the Taiwan Semiconductor Manufacturing Co. (TSMC) successfully developed a 12" plasma-enhanced atomic layer deposition (PEALD) system able to boost plasma response efficiency and achieve superior film quality on 12" silicon wafers. The newly-developed cloud-based Cyber Defense Exercise Workshop is able to provide a setting for attack/defense exercises, and its ability to mimic a corporate network environment allows information security personnel to research attack and defense techniques. Researchers applying image analysis and machine learning have developed monitoring and big data integration technology, including automated traffic monitoring and identification and automated bad weather water situation image correction and flooding forecasting systems; the former can facilitate the collection of intersection vehicle traffic and type data, while the latter can assist monitoring of water conditions and forecast flooding, which will allow the two technologies to make contributions to smart transportation and smart disaster prevention applications.

3. Biomedical Technology Platforms

NARLabs established a laboratory animal facility quality improvement assistance team, obtained international quality standard certification standards and experience from the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC), helped domestic laboratory animal facilities to improve their animal care and testing quality, obtained international certification, and helped smooth the way for Taiwan's biomedical products to enter international markets. Researchers used 3D metal printing equipment to produce Taiwan's first 3D printed artificial joint products, which have passed strict ISO-10993 biocompatibility certification and entered the international market. A "mouse neurodegenerative disease behavior analysis platform" was used to observe and record the behavior of mice, and can be applied to the preclinical testing of new drugs for degenerative diseases of the central nervous system, such as Parkinson's disease and Alzheimer's disease. A project used advanced gene editing technology to produce lipoprotein gene knock-out mice, which can be used for preclinical testing of new drugs for cardiovascular disease induced by hyperlipidemia; this breakthrough will speed the ongoing development by industrial and academic researchers of new drugs against conditions that currently cannot be treated effectively with drugs, such as cardiovascular disease and stroke. In a global first, researchers using large-fragment BAC genetic recombinant technology discovered a new gene causing polycystic kidney disease—Wdr19, which will provide new opportunities to cure polycystic kidney disease, which is a familial hereditary condition.

4. S&T Policy

NARLabs has established the "Policy Research Indicators Database" (PRIDE), which contains statistics and competitiveness rankings in the areas of national demographics, economics, fiscal statistics, education, energy, environment, labor, government performance, quality of life, and science and technology, as well as academic capability statistics and data for different fields. Thanks to this database's large amounts of indicator data, users can truly "let data talk." NARLabs has established and publicized the Research Portal database, which contains links to groups concerned with S&T policy development in Taiwan and seeks to translate policy research into social influence. NARLabs' intellectual property creation and portfolio strategy service, which is based on NARLabs' patent portfolio intelligence, focuses on serving domestic academic research organizations. This service provides customized patent information to smart machinery R&D teams working at numerous domestic universities working in such areas as smart vehicles, applications of communications technology in medical care, and additive manufacturing. NARLabs established performance management mechanisms and procedures for the second phase of the National Science and Technology Program-Energy (NEP-II), refined the program's PDCA quality management cycle, and diffused R&D results. NARLabs' efforts to derive maximum benefit from energy technology innovation will encourage the government to devote more resources to energy S&T research and development. The following is an overview of major R&D results at each center in 2016:

(1) Chip Implementation Center

a. MorSensor wireless sensing building blocks

The MorSensor sensor building blocks, which were awarded NARLabs' 2016 Award for Outstanding Contributions in Science and Technology," constitute a set of reconfigurable modular electronic elements. These building blocks allow users to select elements meeting their specific needs and then assemble those elements into customized sensing systems, which can be used in conjunction with cell phone app software. Building blocks with seven new functions were added in 2016, including Wi-Fi communications, carbon dioxide, carbon monoxide, atmospheric pressure, ultrasonic distance sensing, infrared distance sensing, and infrared thermal imaging building blocks.

b. TN28HPM advanced process production services and training classes

In order to meet the design needs of high-performance, low-power-consumption chips, the Chip Implementation Center (CIC) added a 28nm CMOS high performance mobile (HPM) process in 2016, and provides a comprehensive iPDK design environment and chip production service. In order to promote use of its facilities and reduce time needed by designers, CIC has been holding 28nm process chip realization classes covering the topics of element simulation, circuit design, layout, and verification. These classes are strengthening students' practical skills and shrinking the gap between university education and practical knowledge needed by industry personnel.

c. CMOS sensing IP technology

CIC's R&D of CMOS sensing IP technology has led to the establishment of sensor and sensing system circuit IP, including motion, environment, and biomedical sensing and signal reading, analog/digital converters, wireless transmission, and power source management circuit IP. Single chips or system packaging can be used to create flexible combinations of these verified IPs, which can accelerate realization in the form of sensing system chips for use in wearable and Internet of Things devices.

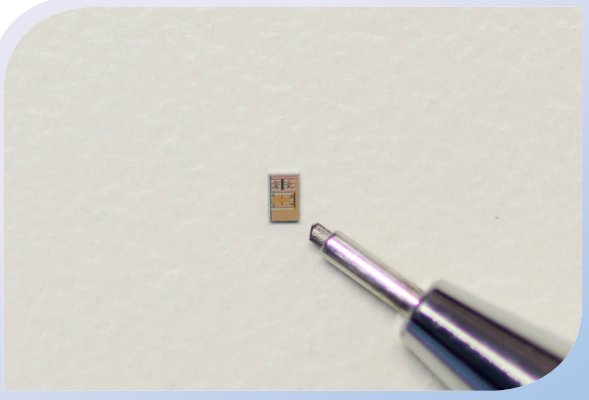
d. Millimeter band multi-channel transceiver measurement platform

CIC has developed Taiwan's first millimeter band multi-channel transceiver measurement platform, which is intended for use in academic applications. This platform integrates hardware and software, and generates of millimeter wave MIMO (multi-input multi-output) modulated signal. This platform can be used in conjunction with a high-end oscilloscope with multi-channel input to directly sample a millimeter wave MIMO modulated signal for use in signal demodulation and analysis. The integrated hardware and software resulting from this project can accelerate the development of multi-channel millimeter wave circuits and subsystems, and be used in system function verification and performance measurement services.

e. Energy harvesting management chip

CIC has developed a new energy management chip suitable for a wide range of applications. This chip, which measures only 1mm x 1mm in size, can

harvest the electricity produced by energy sources as small as vibrations and as large as solar panels, while also storing the energy obtained by the energy harvesting element on the same chip. As a result, the chip can be used in conjunction with various green energy systems, and is very suitable for application in many types of wearable or Internet of Things application systems.



1mm x 1mm size of energy harvesting management chip

f. 0.8-65GHz load-pull measurement system

Responding to wireless communications technology development trends, CIC has established a non-50 Ohm impedance matching measurement environment for GSM (900, 1800MHz), WiFi (2.4, 5GHz), 5G mobile communications (10-40GHz), and millimeter wave (60GHz) bands, and developed a measurement system combining nonlinear parameters (X-Parameter). By facilitating the establishment of linear and nonlinear models of high frequency power element and amplifier circuits, etc., and enabling the measurement and verification of characteristic parameters, and detection and measurement of impedance mismatch circuits, this measurement technology will enable greater technological innovation in domestic next-generation wireless communications service.

(2) Instrument Technology Research Center

a. Blood images that can talk: Subcutaneous blood clot imaging system

The Instrument Technology Research Center (ITRC) successfully developed a "subcutaneous blood clot imaging system" that can be used to detect and identify ordinarily-invisible subcutaneous blood clots during the initial period after an injury. This device overcomes the problem of the current blood oxygen concentration testing method in that it can only provide single-point information, and—in an international breakthrough—can detect the distribution of blood oxygen concentration over a large area (up to 8cm x 8cm) of skin. The device offers excellent sensitivity and usability, and can provide important supporting evidence when assessing the time of an injury. This system has been realized as a product by the cooperating firm Lumos Technology, has received a testimonial from the internationally well-known forensic scientist Dr. Henry Lee, and is being used by police in the United States. This is a powerful tool for assessment and acquisition of evidence in criminal cases, and we anticipate that it will be widely applied in criminal investigations in the future.

Fluorescence imaging system jointly developed by ITRC and a corporate collaborator

b. Successful development of a 12" plasma-enhanced atomic layer deposition

ITRC has collaborated with TSMC in the successful development of a 12" plasma-enhanced atomic layer deposition (PEALD) system. This system can quickly and evenly apply chemical precursors to the surface of 12" silicon wafers, while enhancing the evenness of chemical precursor application, avoiding the production of dust, and boosting film evenness. This design can enhance plasma reaction efficiency, reduce film damage, and achieve an even PEALD reaction. The system also allows the selection of film process methods via the replacement of elements, and is suitable for the reaction characteristics of various kinds of chemical precursors. It can achieve extremely high film quality on 12" silicon wafers.

c. Customized contact lens technology

ITRC relied on its optical element design and development, and integrated element manufacturing and testing capabilities to initiate the three-year international collaborative project "Ultra-

precision processing technology for contact lenses for Asians and Africans". This project, which is being conducted in collaboration with Prof. Khaled Abou-El-Hossein of the Republic of South Africa's Nelson Mandela Metropolitan University, has the objective of developing improved technology for the production of customized contact lenses suitable for different ethnic groups. Prof. Khaled Abou-El-Hossein has expressed his hope that this collaboration with ITRC will kickstart the development of an optoelectronics industry in South Africa. This collaborative project shows that ITRC's ultra-precision processing technology has earned the attention of first-rate international R&D teams.

d. ICG fluorescence onsite visualization and assessment system

With support from MOST's Germination Program, a fluorescence imaging team organized by ITRC, NTU Hospital, Computer Science and Information Engineering Department, National Taiwan University, and Wan Fang Hospital developed a prototype indocyanine green (ICG) onsite real-time surgical visualization and assessment system. This innovative instead uses projection to guide the marked fluorescent area, and resolves the difficulty affecting all current ICG fluorescence imaging methods in that they depend on a screen to indirectly judge the location of the fluorescent image. It therefore allows surgeons' actions to be more intuitive and continuous. The system received 12th National Innovation Award from the Institute for Biotechnology and Medicine Industry in 2016.

e. Taiwan's first 3D printed artificial joint enters international markets

With assistance from ITRC, Xinke New Materials, Taiwan's first biomedical grade 3D metal printing powder firm to pass preclinical animal experiments, teamed up with Tongtai Machine & Tool to develop 3D metal printing equipment, and has successfully printed a joint orthopedic medical device that has passed strict international ISO-10993 biocompatibility certification. Obtaining this ticket to enter the international market represents an important milestone for Taiwan's high-tech precision medicine.

f. ITRC helps traditional industry step up to advanced biomedical technology

Taiwan's biomedical technology is making a great leap forward, and the ability of traditional industry to transform itself should not be underestimated. In this context, with ITRC's encouragement and assistance, Xinke New Materials has become Taiwan's first biomedical grade 3D metal printing powder firm to pass preclinical animal experiments. Xinke has also joined forces with Tongtai Machine & Tool to develop 3D metal printing equipment, which represents a major advance in Taiwan's ability to develop and manufacture 3D printed medical devices. At the "Ceremony to mark the entry of Taiwan's biomedical technology into international markets" and the "Inaugural ceremony for the NARLabs/Tongtai Machine & Tool/China Steel/Xinke New Materials joint 3D printing laboratory" held on July 14, 2016, NARLabs proclaimed that it will actively participate in the promotion of Taiwan's biotech medical equipment in international markets.

(3) National Center for High-Performance Computing

a. TWAREN 100G research network begins operation

In the TaiWan Advanced Research and Education Network (TWAREN) 100G bandwidth expansion project jointly conducted by the National Center for High-Performance Computing (NCHC), Ministry of Education, and Academia Sinica, after over two years of implementation, transfer, adjustment, and testing, the new network system finally went online in 2016, and was formally opened to use in October. This event marks TWAREN's entry into the high-performance 100G age.

b. Laying the groundwork for petaflop computing power: Planning a next-generation high-performance computing platform meeting domestic scientific research needs

In order to lay the groundwork for a new-generation petaflop high-performance computer and green energy equipment room, NCHC continued to make plans for hardware and future operations during 2016, and the Executive Yuan Board of Science & Technology approved budget funding in 2017. Looking ahead to the future, the new petaflop supercomputer is expected to achieve a computing speed in excess of 1.4 petaflops, which is 7-8 times that of the existing Advanced Large-scale Parallel Supercluster (ALPS). NCHC hopes that the planned petaflop supercomputer will be able to handle large-scale computing applications, transcend existing computing dimension limits, and accelerate the output of results.

c. Providing value-added application services using a big data analytics platform

Braavos is NCHC's first big data analytics platform providing service to external users, and

began serving academic and research users in 2016. Braavos also serves as a dedicated analytics platform for confidential government data. Apart from use in seven major MOST projects, Braavos also was also used in health and welfare, biomedicine, environmental protection/disaster prevention, smart city, and tax applications during 2016. In addition, NCHC is also collaborating with Trend Micro in an arrangement under which Trend Micro is providing practical data, NCHC is providing a computing platform, and the academic sector is using the platform to develop deep learning technology and algorithms in the field of information security; this program is expected to achieve a win-win-win outcome for industry, academia, and research organizations.

d. Introduction of a new network security attack and defense platform

Researchers at NCHC have used cloud technology to establish the cloud-based Cyber Defense Exercise Workshop (https://cdx.nchc.org.tw) providing an environment for attack and defense exercises. This virtual platform allows multiple parties to simultaneously engage in attack and defense exercises involving multiple scenarios, and can simulate corporate network environments in order to facilitate research on attack and defense techniques by information security personnel. At present, a number of universities and government agencies are using this platform in their information security training classes.

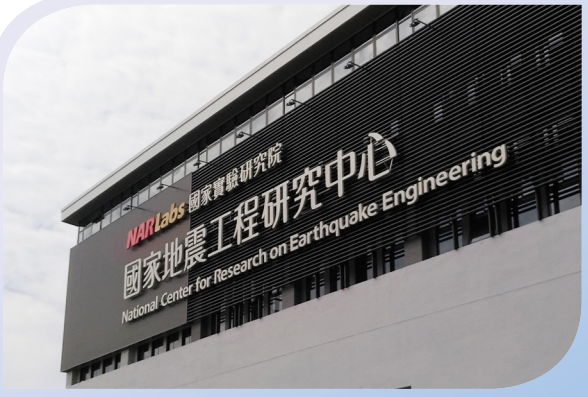
e. Monitoring and big data integration technology R&D

Responding to the needs of "smart city" R&D, NCHC is using image analysis and machine learning to develop monitoring and big data integration technology. The results of this research campaign include including automated traffic monitoring and identification and automated bad weather water situation image correction and flooding forecasting systems; the former can facilitate the collection of intersection vehicle traffic and type data, while the latter can assist monitoring of water conditions and forecast flooding, which will allow the two technologies to make contributions to smart transportation and smart disaster prevention applications.

(4) National Center for Research on Earthquake Engineering

a. Southern Taiwan experimental facility development plan

According to statistics, more than 8.6 million people in Taiwan live within 10 km of an active fault, and therefore face the threat of near-fault earthquakes. In order to develop even better earthquake warning and damage mitigation technology, and gain a better understanding of the characteristics of near-fault earthquakes, MOST, the National Development Council, NARLabs, and National Cheng Kung University have jointly provided NT$1.3 billion for the construction of the "National Center for Research on Earthquake Engineering Southern Taiwan Experimental Facility," which is located on National Cheng Kung University's Guiren campus, Tainan. Plans call for the facility to begin formal operation in 2017; this international-class flagship research facility will provide researchers in Taiwan with opportunities to make major breakthroughs in seismic engineering research.



Facade of the NCREE Southern Taiwan Experimental Facility

b. Tap water system earthquake simulation system

Because earthquake damage to Taiwan's tap water system would have a major impact on the economy and people's lives, the National Center for Research on Earthquake Engineering (NCREE) has joined forces with the Water Resources Agency, MOEA; Taiwan Water Corporation, and Taipei Water Department to develop the "Twater" tap water seismic risk analysis tool, which can model damage to pipelines and facilities in the event of an earthquake, and assess the extent of impact on public water supply and losses that may ensue. This system currently provides a nationwide notification service: When an earthquake occurs, the system immediately transmits projected pipeline damage to water companies and relevant personnel, which can facilitate assessment of damage and response actions.

c. Applying advanced technology to reduce earthquake damage

Since the 921 earthquake in 1999, NCREE has been cooperating with central and local government agencies in jointly promoting the "earthquake damage mitigation trilogy": (a) Building earthquake resistance assessment and reinforcing before an earthquake comes: A survey conducted after the February 6, 2016 Meinong earthquake in Kaohsiung discovered that 58 school buildings in Tainan that had undergone reinforcing were all free of structural damage. (b) Use of early warning technology during an earthquake: When an earthquake occurs, the earthquake early warning system will immediately be activated, and can provide early warning of 4-17 sec. even near the epicenter of earthquakes with magnitude 5 and above. (c) Use of early earthquake damage assessment to assist emergency response in the wake of an earthquake: After an earthquake has occurred, the Taiwan Earthquake Loss Estimation System developed at NCREE can be used immediately after an earthquake to complete loss assessment within 1 min. using data from the Central Weather Bureau, MOTC, and can send text messages to the cell phones of disaster relief personnel informing of them of possible deaths and injuries, and the locations of possible damage. This system can thus assist the central government and city and county governments in mounting emergency response efforts. The "earthquake damage mitigation trilogy" is expected to effectively achieve its goal of "applying advanced technology to reduce earthquake damage".

d. Rapid assessment technology for the seismic resistance of existing residential buildings

The "Street House Seismic Resistance Website" established by NCREE can enable the public to perform self-assessment of the seismic resistance ability of their own homes. The government has recently introduced full-scale seismic health checkups for old buildings, and expects to provide large amounts of funding for seismic resistance assessment work, but there are still no plans for substantial improvement of the seismic resistance of old residential buildings. People who have doubts about the seismic resistance ability of their private homes after using this website will be able to save significant assessment costs, and can use the saved funds for reinforcing work, which will help achieve the goal of an earthquake-resistant homeland.

e. Realizing applications of full fiber optic monitoring systems

Researchers at NCREE have relied on the principles of buoyancy, connecting pipes, and flexible fiber optic gratings to construct a bridge fiber optic monitoring system suitable for long, multi-span bridges. This system is already being used for safety monitoring on Taipei's Dazhi Bridge, some sections of the High Speed Rail line, the Wuyang elevated highway section, bridges along Highway 86, and three newly-constructed bridges along the West Coast Expressway. Apart from use on bridges and elevated roadways, application of the system will be expanded to life support conduits and oil pipelines in the future.

(5) National Nano Device Laboratories

a. Next-generation nanometer element technologies and innovation

Researchers at the National Nano Device Laboratories (NDL) have developed four types of smart gas sensing chips, which can be used to detect volatile organic compounds, carbon monoxide, carbon dioxide, and formaldehyde. NDL has teamed up with the Lite-On Group in an industry-academic collaborative project to apply the micro-electromechanical process used to make these chips, which offer the advantages of tiny dimensions, low energy consumption, easy integration, and ability to accurately identify gases, and make the vision of "everyone carrying their own gas sensors" a possibility.

b. Monolithic 3D image sensors

NDL researchers have successful combined large-area monolayer TMDCs and low thermal budget monolithic 3D ICs in the development a monolithic 3D image sensor. The middle and upper layers of this sensor consist of a monolayer molybdenum disulfide (MoS_2) optical sensor with a highly linear photoelectric current response to incident laser light (wavelength: 632nm), and the lower portion of the integrated 3D IC consists of a stackable 3D high-performance, low power consumption epitactic silicon nanowire transistor (subthreshold swing < 100mV/dec., driving current > 300uA/um) produced using a low thermal budget laser process (T_{sub} < 400℃).

c. Development of a rapid testing biochip diagnostic system

NDL developed a rapid testing biochip diagnostic system able to detect the dengue virus and other severe illnesses. Because this newly-developed chip technology requires very little blood (0.05ml), yields results quickly (within 30 min.), and is simple and earth to automate, it can be developed into products suitable for use in

health check-up stations, clinics, and fixed-location disease prevention work.

d. Miniaturized low energy consumption nanometer integrated sensors

The miniaturized low energy consumption nanometer integrated monitoring sensors developed at NDL can provide terminal applications with a smart sensing function. The sensors rely on electromagnetic induction induced by broadband oscillations in conjunction with integrated passive device back-end process technology to perform real-time monitoring of the vibrations of industrial machinery and check for abnormalities. They can therefore be used to help increase the intelligence of precision machinery and maintain machine reliability.

e. 10 nm 2D material transistor process

Two-dimensional transition metal chalcogenide compounds are novel substances with extensive potential applications in semiconductor elements. This technology, which involves the use of polysilicon source and drain, employs ion implantation and annealing processes, followed by etching and plasma oxidation to determine whether the gate structure is U-shaped or consists of a tri-gate structure. This approach can be used to incorporate novel structures during the mass production of elements in the future.

(6) National Laboratory Animal Center

a. Establishment of a mouse neurodegenerative disease behavior analysis platform

The causes of degenerative diseases of the central nervous system, such as Parkinson's disease and Alzheimer's disease, have not yet been elucidated, and the development of new drugs to fight these conditions commonly relies on the analysis and assessment of model animals' behavior. The "mouse neurodegenerative disease behavior analysis platform" developed at the National Laboratory Animal Center (NLAC) adopts Bussey-Saksida touch-control screen technology, which is consistent with human medical inspection techniques. The platform's integrated equipment and methods enable researchers to monitor and record mouse behavioral data, which can be used in the preclinical testing of new drugs.

b. Finding a new gene causing polycystic kidney disease

A polycystic kidney disease is a familial genetic disease for which the causative genes have not yet been discovered. In a global first, researchers at NLAC used novel large-fragment BAC genetic recombinant technology to knock out the gene Wdr19 from the epithelial cells of mouse kidneys, and found that mouse kidneys missing Wdr19 appeared swollen, were full of vesicles, and had severely reduced function, which are all characteristics of polycystic kidney disease. The discovery of the causative role of the gene Wdr19 in polycystic kidney disease by NLAC consequently represents a new opportunity to finds ways to treat this condition.

c. Production of ApoE knock-out mice with high application value

Hyperlipidemia is modern disease of civilization, causes hardening of the blood vessels, induces cardiovascular disease and stroke, and cannot be effectively treated using existing drugs. NLAC used the most advanced CRSIPR/Cas9 gene editing technology to produce Apolipoprotein E (ApoE) gene knock-out mice. These gene knock-out mice have hyperlipidemia, and may have atherosclerotic plaque in the arteries near the heart. These mice are suitable for use in preclinical testing of new drugs for cardiovascular disease induced by hyperlipidemia, and will accelerate new drug R&D in academia and industry.

d. Establishment of the NARLabs animals facility international certification assistance team

NLAC established the NARLabs animal facility quality improvement team, which has received animal facility quality certification standards and experience from the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC). The assistance team has gained animal facility improvement and new facility establishment certification experience, and members possess AAALAC international certification specialist reviewer qualifications. The team is helping domestic laboratory animal facilities to boost their animal care and experimentation quality, obtain international certification, and thereby establish a basis on which Taiwan's biomedical products can successfully enter international markets.

e. Optimized laboratory animal health monitoring technical service

NLAC provides a laboratory animal health monitoring technical service intended to ensure animal health and thereby enhance the reliability of experiments. The "IDEXX hematological analysis platform" developed at NLAC needs only 32μl blood samples to complete analysis of 20 blood test items, which meets the requirements of continuous analysis of the blood of small laboratory

animals. NLAC has further developed a molecular testing technique for mouse adenovirus (Mad) that can accurately distinguish Mad 1, Mad 2, and Mad 3 subtypes; this technique can resolve serum testing difficulties while boosting efficiency.

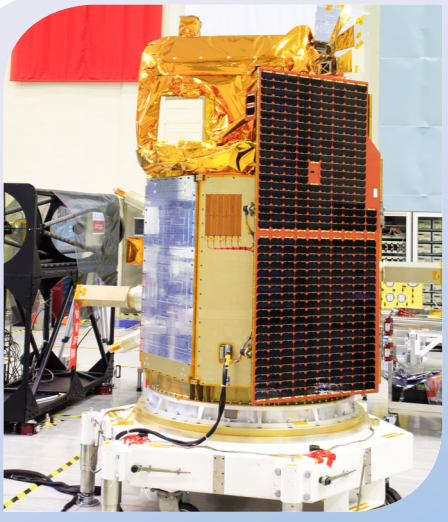
f. Establishment of pain assessment processes, enhancing laboratory animal welfare

It is difficult to assess how much pain laboratory animal feel. Because of this, it is important to use simple, clear-cut assessment methods to effectively manage laboratory animal pain. NLAC has therefore established its "TINT testing" technique, which takes advantage of the habit of mice to build nests by calculating the time needed by the mice to carry a certain number of pieces of nesting material back to their nest, and uses this information to assess the suffering of the mice after a surgical experiment. By assessing the discomfort experienced by animals during the process of disease-caused deterioration and the effect of treatment, and providing the animals with analgesics at suitable times, the technique can enhance the welfare of laboratory animals.

(7) National Space Organization

a. Completion of the Taiwan-made FORMOSAT-5 satellite system

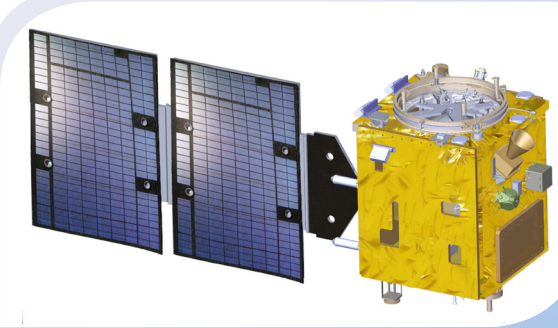
The FORMOSAT-5 satellite system was completed and readied for transport at the end of 2015. Although the satellite was originally expected to be launched during the second quarter of 2016, because the American contractor Space Exploration Technologies Corporation (SpaceX) encountered repeated explosions during rocket production and static testing, the launch time was postponed several times. However, the FORMOSAT-5 work team made use of this time by performing repeated testing and confirmation tasks, and conducted full-function launch site testing exercises, which enabled it to make improvements and ensure that the satellite performed as expected. All preparatory tasks have now been completed, and satellite transport operations can be initiated as soon as the launch date has been confirmed.



The FORMOSAT-5 satellite is ready for launch

b. The FORMOSAT-7 autonomous satellite enters the manufacturing and testing stage

The FORMOSAT-7 autonomous satellite is a 300kg-grade satellite, and will carry a global navigation satellite system (GNSS) reflected signal receiver developed by a domestic team. The sea level data collected by this satellite will facilitate understanding of typhoon structure, and will be useful in research on interaction of the air and sea. Production and testing of various elements was performed in 2016, and this work included such key elements as the satellite computer, power control unit, global positioning system navigation receiver, fiber optic gyroscope, and hydrogen peroxide (H_2O_2) propulsion module. The results of the various tests have verified the design baseline and completed the autonomous R&D objectives.



FORMOSAT-7 autonomous satellite

c. Development of key atmospheric satellite technologies

High-altitude long-endurance solar powered unmanned aircrafts are often termed "atmospheric satellites" by aerospace personnel. With a flight ceiling of approximately 20 km, atmospheric satellites offer the advantages of low manufacturing cost, recoverability, and reparability, and can perform remote sensing, communications, and meteorological observation functions. The National

Space Organization (NSO) has drawn on the capabilities of industry, government, academia, and research organizations to develop key technologies used in atmospheric satellites, including lightweight aircraft design and production, control system design, simulator development and production, high-efficiency solar panel development, regenerative hydrogen fuel cell development, high-torque motor development and production, carbon fiber high-pressure hydrogen storage tank technology development, and large, high-altitude propeller blade development and production. This project is currently performing aircraft assembly, ground testing, and flight verification. It is expected that the aircraft will reach an altitude of 10 km within one year, and it has an endurance goal of 8 hours. The research and development of so many key technologies in Taiwan will boost domestic renewable energy technology and industrial competitiveness.

d. A great leap forward in key synthetic aperture radar technology

Apart from requiring a high-gain antenna and high-power microwave amplifier, high-resolution synthetic aperture radar also requires a linear frequency modulation (chirp modulation) signal generator with high bandwidth. In the case of 1 m resolution, a chirp modulation signal generator with bandwidth of 300MHz is needed. NSO has therefore developed a 300MHz chirp modulation signal generator based on a field-programmable gate array (FPGA); this signal generator has features including a parallel architecture and easy expansion of bandwidth. NSO is continuing to research and development signal generators with an even higher 600MHz bandwidth in order to meet the needs of future 0.5 m ultra-high resolution synthetic aperture radar satellite missions.

e. Verification of advanced optical remote sensing payload experiment

The optical system of the advanced optical remote sensing payload of the FORMOSAT-5 was upgraded from a Cassegrain telescope to a Korsch telescope with off-axis optics. Various technologies for the optical remote sensing payload experiment with a 300 mm aperture Korsch telescope were developed performed in 2016, and completed tasks included optical design, optical mechanism design, experiment production and integration, and off-axis optical system correction technology development and verification. In the future, NSO will develop the 300 mm optical remote sensing payload experiment into a lightweight, compact optical remote sensing payload that can be carried on 100kg-grade satellites. In addition, NSO will continue to develop advanced optical systems with apertures of as large as 550 mm, which will provide a technological foundation for the development of next-generation sub-meter optical remote sensing satellite payloads.

f. FORMOSAT-2 is decommissioned with honors

The FORMOSAT-2 satellite was launched from California's Vandenberg Air Force Base on May 21, 2004. After continuing to implement its mission for 12 years and 2 months (longer than the original mission life of 7 years and 2 months), the FORMOSAT-2 was formally decommissioned on August 19, 2016, ending its honorable service. During its 12 years of operation, the FORMOSAT-2 support domestic and foreign disaster assessment work on 343 occasions, and took a total of 2,555,643 photographs of the ground. Images taken by the satellite have been widely applied in numerous government and private uses, including homeland security, environmental monitoring, disaster prevention and disaster surveys, scientific diplomacy, and scientific research. The Imager of Sprites and Upper Atmospheric Lightings (ISUAL) payload recorded more than 41,863 observation data items, which formed the basis of over 300 academic papers, including several reports published in *Nature*. NSO is currently striving to ensure that the FORMOSAT-5 satellite mission can pick up where the FORMOSAT-2 left off, and continue to protect Taiwan and watch the world.

(8) Science & Technology Policy Research and Information Center

a. Helping hold the National Science and Technology Conference

The Science & Technology Policy Research and Information Center (STPI) played the role of a think tank in helping MOST to organize and hold the 10th National Science and Technology Conference. Establishing two-way linkage between "top-down" policy guidance and "bottom-up" issue analysis, STPI assembled long-term, forward-looking, focal issues associated with the three major aspects of "infrastructure environment," "smart living," and "economic development," and gathered the views of scholars, citizens, and experts affiliated with industry, government, academia, and the research community. This enabled STPI to map out a national science and technology development blueprint for the coming four years, which will provide government agencies

basis for the drafting of S&T policies and promotion S&T development.

b. Planning of S&T R&D inputs

STPI has mapped out Taiwan's needs and applications on the basis of the current situation and technology development trends, while taking the important issues facing Taiwan into consideration. At the same time, STPI has also determined potential key technologies that can satisfy the needs of Taiwan's society, represent future global technological development focal points, and reflect survey findings concerning Taiwan's most important and feasibly-met local needs. Following analysis of domestic research and development capabilities (including such items as distribution of research project inputs, professional human resources, and the current state of industries, etc.), STPI has located areas of technology where Taiwan possesses a comparative advantage, and is relying on multifaceted, objective evidence to help direct Taiwan's research inputs toward areas of potential advantage, and provide a reference to guide the planning of future applied science and technology developmental directions.

c. Patent intelligence service: Trend monitoring and portfolio planning

STPI has applied systematic patent analysis tools to analyze technological development and industrial competition trends in key areas of development, which has provided reference information to guide the formulation of S&T policy decisions, resource allocation plans, and R&D items. STPI's intellectual property creation and portfolio strategy service, which is based on patent portfolio intelligence, is intended to help academic research organizations to plan strategies for R&D and the practical utilization of R&D results. During 2016, this service provided systematic analysis of patent information chiefly in the areas of smart vehicles, applications of communications technology in medical care, and additive manufacturing, and provided customized patent information to smart machinery R&D teams working at numerous domestic universities.

d. Employing energy technology to protect Taiwan; building a sustainable future

MOST has integrated the resources of different government agencies in implementing the National Science and Technology Program-Energy, and is relying on collaboration with industry, academia, and research organizations to establish linkage with international R&D resources. By accelerating the industrialization of R&D results, this approach has developed energy conservation and carbon dioxide emissions reduction technology and leading Taiwan toward sustainability by meeting Taiwan's energy security, S&T development, and environmental sustainability needs. STPI is helping MOST to establish performance management mechanisms and procedures for the second phase of the National Science and Technology Program-Energy (NEP-II), including a PDCA (Plan-Do-Check-Action) quality management cycle, and is employing a more public-friendly approach to disseminate R&D results, spread the benefits of energy S&T innovation, and help achieve vertical accountability in government inputs used for energy S&T research and development.

e. Use of quantitative methods to analyze Taiwan's scientific research and technological development capabilities

STPI has long relied on academic papers and patents to monitor Taiwan's S&T research and development capabilities. The quantity and quality of Taiwan's scientific papers have continued to rise in recent years, and the quantity and quality of papers in the fields of computer science, engineering, materials science, and physics have reached especially high levels, making these areas in which Taiwan enjoys a competitive advantage. Taiwan ranks 5th worldwide in terms of the number of approved US patents, and ranks 12th in terms of patent influence.

f. New tools for the review and assessment of S&T projects

In order to provide an even better review environment and make available more information to assist review, apart from continuing to improve and operate the "Government S&T Project Information Website," STPI is also continuing to perform advanced analysis of the content of S&T projects. The "S&T Project Input Statistics and Content Analysis System" is a new subsystem added to the "Government S&T Project Information Website" during 2016, and employs interactive Web methods to visualize S&T project statistics and the results of analysis for the period from 2014 to 2017. The content of this subsystem includes government agency funding application statistics, analysis of government agency research topics, and analysis of major interagency policies and issues. This subsystem is expected to become a new tool assisting project review.

g. Reliance on Taiwan-American cooperation to train high-level policy planning personnel

After signing a MOU calling for cooperation with Stanford University in the training of new-generation biomedical manpower for Taiwan, STPI again engaged in cooperation with Stanford University in late May for the purpose of training prestigious high-level policy research scholars. Starting in 2017, STPI will select one scholar each year to perform visiting research at the Center for Advanced Study in the Behavioral Sciences at Stanford University, which will serve to train Taiwan's high-level policy research and planning personnel. This instance of cooperation will help Taiwan's humanities and social science scholars to engage in interchange with top international figures, which is expected to stimulate new perspectives and yield empirical research results concerning some of the key social issues currently faced by Taiwan.

h. Taiwan-Japan cooperation: Long-term friendship

As instructed by MOST, the Supra Integration and Incubation Center (Si2C) and STPI are jointly implementing the "SPARK Taiwan Biomedical Translation Value-Added Manpower Training Project" (SPARK Taiwan). During the period of March 7-11, Chuang Yu-tze, the project's principal investigator and STPI director, led faculty advisors from six anchor universities, namely National Taiwan University, National Cheng Kung University, Taipei Medical University, National Yang Ming University, China Medical University, and National Tsinghua University, on interchange visits to key universities in Japan. These visits had the purpose of sharing the biomedical R&D results translation and commercialization experience of Taiwan and Japan, discussing future topics and directions for cooperation between the two parties, and strengthening online contact between domestic anchor universities and foreign biomedical firms, which will facilitate the expansion of product sales channels.

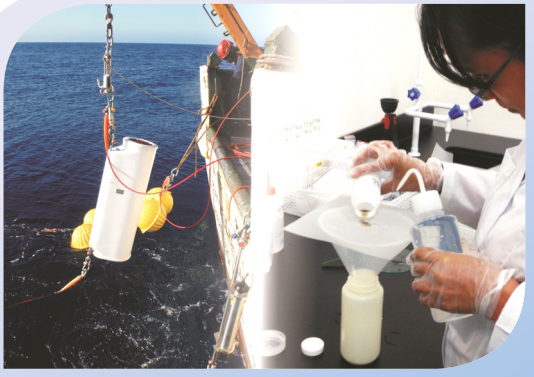
(9) Taiwan Ocean Research Institute

a. Long-term South China Sea biological/geological/chemical observation at SEATS

The Taiwan Ocean Research Institute (TORI) has been monitoring the impact of extreme climate conditions on the South China Sea—the world's largest marginal sea—at the South East Asia Time-Series Station (SEATS). Apart from performing physical oceanography, chemistry and isotope ratio, and bioinformation analysis of sediment composition and sources, this project is also using anchored sediment particle collectors to perform continuous, long-term specimen collection.

b. Inshore marine organism long-term ecological observation network

The inshore marine organism long-term ecological observation network seeks to investigate the effect of various environmental parameters on organisms and the ecology through the integration of biological and water quality data. The focus of current work is on the waters around the island of Xiao Liuqiu. Preliminary results have included the fact that the inshore water temperature near Xiao Liuqiu decreases as the tide rises; although there were many reports of coral bleaching worldwide during 2016, the coral reefs around Xiao Liuqiu have remained unscathed, which may be due to this cooling phenomenon.



An anchored collector is prepared on the deck of SEATS

The coral reefs near Little Liuqiu have experienced only sporadic bleaching

c. Development of a small ROV

TORI began developing a small remotely operated underwater vehicle (ROV) in 2015. The ROV's chief functions include real-time monitoring of water temperature, salinity, depth, turbidity, pressure, and flow velocity, and it allows observation of aquatic organisms and the marine environment through image analysis. The ROV can be equipped with a carrying platform used to sample deep sea water, which facilitates real-time analysis of undersea information. Current able to descend to a maximum depth of 200 m, the ROV relies on a coaxial cable to transmit signals and receive power. Thanks to its control module and four propulsion devices, which were developed in Taiwan, the ROV is self-stabilizing, and can explore at a constant depth. In the future, the addition of a virtual reality system will enable users to vividly experience the undersea world.

d. Lidar wind field measurement and application to offshore wind power applications

TORI has applied Lidar wind profiler measurement and data analysis techniques developed in-house to the development of offshore wind power. The "marine weather observation tower integrated monitoring data application and environmental data value-added cross-analysis project" conducted by TORI under the "National Energy Program—Offshore wind power industrial/academic collaboration project" has performed wind field measurements in the Hanbau intertidal zone of the Fuhai wind field, Fangyuan, Changhua County. The resulting data was used to verify weather research and forecasting models and computational fluid dynamics numerical modeling results, and was compared with measurements from marine anemometer towers to confirm the accuracy of marine data. TORI has completed observations during the northeast and southwest monsoons, and has analyzed wind speed profile and the characteristics of atmospheric turbulence, which has verified theoretical models and provided a reference for assessment of wind energy and determination of wind turbines specifications.

e. Small drifting buoy applications

The correction of the antenna patterns of the Taiwan Ocean Radar Observing System (TOROS), which has been conducted at 20 stations each year, is an important task needed to maintain this system's ocean current measurement precision. The measurement line (a curved line) used in antenna pattern measurements in accordance with standard operating requirements can affect the correctness of correction. As a consequence, in order to enhance ship operators' navigation accuracy, a radar research team has used a basic architecture consisting of a global positioning system with an embedded microcontroller and very high frequency signals, along with a user interface developed in house, as an antenna pattern correction tool. This framework can be developed into various maritime observation applications, and offers the advantage of enabling low-cost, long-distance transmissions.

f. Establishment of the Marine Environmental Databank

The Marine Environmental Databank collects, stores, processes, and manages data produced by observation platforms operated by TORI and ROVs and scientific research projects implemented by research vessels. This database serves as a data integration platform providing shipboard measurement data, inshore and far sea observation data, satellite remote sensing data, numerical modeling forecasts, and marine rock core data, and provides value-added application services. The Marine Environmental Databank website (http://med.tori.NARLabs.org.tw) has been revised in order to increase the effectiveness of data presentation, and now features updated design elements and a user-friendly interface providing near real-time marine observation data.

g. Cooperative deployment of undersea seismometers by TORI and Korea's Pusan National University

According to the cooperation MOU signed by TORI and the South Korea's Pusan National University in 2016, TORI personnel will deploy "Yardbird" undersea seismometers developed in Taiwan in the waters off the east coast of South Korea, where they will provide seismic data enhancing earthquake positioning accuracy, while also assessing risk of geological hazards. The technology resulting from this project is being publicized internationally.

(10) Taiwan Typhoon and Flood Research Institute

a. Establishment of experimental watersheds

In order to model and record changes Taiwan's local hydrology and topography, the Taiwan Typhoon and Flood Research Institute (TTFRI) has been cooperating with the Institute of Planning and Hydraulic Research, Water Resources Agency, Ministry of Economic Affairs to establish Taiwan's first experimental watersheds. Experimental watersheds have been established

in the basins of the Yilan River and Kaohsiung's Tianbao River, and more than 88 million total pieces of data have been accumulated. Apart from helping government service units to enhance the quality of their observation data and better plan watershed management and flood early warning operations, TTFRI has used this large body of observation data to develop value-added watershed disaster prevention applications and technology.

b. Development of real-time automated flow estimation technology

TTFRI has been cooperating with the Institute of Planning and Hydraulic Research, Water Resources Agency, Ministry of Economic Affairs in the development of "real-time automated river flow estimation technology" employing the large body of observation data derived from Taiwan's experimental watersheds. This approach relies on the use of comparison of different types of measurements, seeks to establish correspondences, and then relies on measurement data from microwave radar surface flow meter and radar water level gauges to automatically, accurately estimate river flow in real-time. The system further analyzes whether downstream areas may have flooding, and assists in providing early warning.

c. Establishment of an unmanned aircraft sounding squadron

TTFRI has established an unmanned aircraft sounding system able to enhance Taiwan's ability to directly observe extreme weather conditions. This system possesses automatic take-off, landing, and navigation control functions; the unmanned aircraft has completed long endurance (over 17 hours) and long-distance (over 1,300 km) test missions. In the future, these unmanned aircraft will enter typhoons and strong convection centers to collect important meteorological data, which it is hoped can improve the accuracy of typhoon track forecasting and disaster mitigation and relief decisions.

d. Establishment of an MPAS global model

TTFRI uses an MPAS (Model for Prediction Across Scales) model to perform daily forecasting experiments providing a forecast for the next 10 days, and assess the stability and predictability of extended forecasts when typhoons strike Taiwan. Preliminary results indicate that extended forecasts made using MPAS can generally pinpoint typhoon movements. In the future, TTFRI will continue to R&D use the MPAS model in providing 5-10 day extended rainfall forecasts for reservoir watershed areas.

e. Development of forward-looking observation technology

TTFRI has relied on observations using dual polarimetric radar that it has deployed in a mountainous area of Kaohsiung together with disdrometer data to improve radar rainfall estimation formulas. Preliminary results display that the accuracy of the improved dual polarimetric radar rainfall estimation formula is at least 10% better than that of the traditional radar rainfall estimation formula. The results of this project will be provided to the Central Weather Bureau as a reference for future regional rainfall radar observations and flood forecasts.

TTFRI's unmanned aircraft prepared for a runway take off

III Human Resources Recruiting and Training

A. Recruiting of S&T Personnel

Scientific and technological personnel are the driving force behind S&T advancement and national development, and all leading countries are competing to recruit S&T personnel. MOST employs generous subsidy measures to recruit outstanding domestic and foreign high-tech personnel in order to strengthen research and development at academic research organizations and universities. The following subsidy measures were employed during 2016:

1. Effective Mechanisms for Recruiting S&T Manpower

(1) Establishment of bottom-up subsidy platforms for the recruiting of S&T manpower: MOST has drafted various subsidized recruiting measures, provides generous subsidy terms, and helps academic research organizations to recruit overseas technical manpower for work in Taiwan. For instance, in 2016, a total of 2,520 guest personnel and post-doctoral researchers were recruited to participate in S&T research projects, and 140 research scientists were recruited to implement major mid-/long-term research projects.

(2) Assisting the professional development of post-doctoral researchers: In order to cultivate talented S&T manpower MOST has continued to provide stable research funding and independent research opportunities, and encourages early planning of research careers by promising young post-doctoral researchers.

(3) Top-down creation of an excellent R&D environment: MOST promotes Academic Summit Program projects, Science Vanguard Research Program projects, Frontier Research Program projects, and national science and technology programs linked with key areas of scientific and technological development in Taiwan, and relies on major research projects to create an excellent environment and attract outstanding S&T manpower overseas to participate in research in Taiwan.

2. Promotion of Measures for the Recruiting of Special Outstanding Manpower and the Granting of Academic Work Awards to Post-doctoral Researchers

(1) The *Subsidy Measures for the Recruiting of Special Outstanding Manpower by Universities* provide funding support for the competitive recruiting of foreign elite S&T manpower by universities, and allow universities to put S&T personnel on their regular payrolls as full-time teaching and research personnel with monthly salaries. This encourages outstanding international S&T personnel to accept employment in Taiwan, and will induce such persons to pursue long-term S&T research in Taiwan. A total of 35 applicant organizations obtained subsidies for this purpose in 2016.

(2) MOST provides the Post-doctoral Researcher Academic Work Award in order to encourage post-doctoral researchers to publish superior, innovative, and important academic works, and provide incentives for the country's future academic elite to engage in long-term, in-depth S&T research. A total of 40 post-doctoral research personnel received this award in 2016.

3. In order to establish conditions and an environment facilitating the recruiting of academic and S&T manpower, MOST assisted implementation of such policies as the Executive Yuan's "Contact Taiwan—Global Recruiting Program" and "Integrated Cultivation, Retention, and Recruiting Program."

MOST-funded S&T personnel recruiting statistics, 2012-2016

Units: person times

Item	2012	2013	2014	2015	2016
Guest personnel	134	133	136	118	115
Post-doctoral researchers	2,206	2,201	2,223	2,261	2,405
Research scientists	82	59	76	109	140
Total	**2,422**	**2,393**	**2,435**	**2,488**	**2,660**

B. Training of S&T Personnel

In order to broaden the qualifications and international perspectives of domestic teaching and research personnel, and acquire the newest S&T knowledge from the world's leading nations, since 1960 the National Science Council—MOST's predecessor—has provided subsidies to S&T personnel wishing to study at foreign universities or perform research at foreign research organizations. Furthermore, to acquire new technology and knowledge from the leading nations, and in response to a drop in university and college students studying abroad, apart from encouraging outstanding young Ph.D.-holders in Taiwan to engage in post-doctoral research abroad, MOST has also instituted the "Graduate Student Study Abroad Program" to provide funding to in-school Ph.D. students wishing to participate in 7-12 month short-term research and study programs at prominent foreign universities and research organizations.

In order to send selected outstanding domestic individuals to world-class public and private research organizations overseas, where they can study areas of science and technology urgently needed in Taiwan and receive training to become the human resources needed for Taiwan's future development, subsidies have been provided to mission-oriented teams seeking to study abroad since 2009, and guidelines for the granting of such subsidies were drafted in 2012. These subsidies have been issued to 87 projects since the program was initiated on a trial basis in 2009, and MOST provided such subsidies to 19 teams (involving 78 individuals) studying, performing research, and receiving training at 18 organizations in six countries, including the United States, in 2016.

In addition, to encourage young persons of Taiwanese descent overseas to visit Taiwan and learn about the country's development, MOST and the Ministry of Foreign Affairs; Overseas Compatriot Affairs Commission; Ministry of Health and Welfare; Environmental Protection Administration; Council of Agriculture; National Youth Commission, Ministry of Education; Academia Sinica; NARLabs; and the Taiwan Foundation for Democracy have jointly implemented the "Taiwan Tech Trek" program. This program sponsors summer trips to Taiwan by youths of Taiwanese ancestry living abroad for the purpose of participating in internships at public and private organizations and enterprises. Twelve sessions of the Taiwan Tech Trek have been implemented from 2005 to 2016, and a total of over 3,000 trainees have participated.

Manpower training statistics, 2011-2016

Units: person times

Item	S&T personnel engaging in short-term research overseas	Graduate Student Study Abroad Program		Taiwan Tech Trek
		Ph.D. students	Post-doctoral researchers	
2011	273	185	66	254
2012	253	134	82	298
2013	257	160	65	289
2014	228	147	77	276
2015	236	143	95	282
2016	**235**	**102**	**101**	**246**

IV. Research Awards

A. MOST Awards

1. Outstanding Research Award

MOST established the Outstanding Research Award in order to encourage S&T personnel with outstanding research results to engage in long-term academic or academic-industrial research, and thereby enhance the country's academic research standards and industrial technology R&D capabilities. Starting in 2015, the number of annual recipients of the Outstanding Research Award has been limited to 77, and the academic research and industry-academic research categories are limited to 70 and 7 recipients respectively. Apart from receiving a certificate from MOST, recipients receive an award of NT$900,000. A total of 74 persons received this award in 2015, and the 2015 academic research awards ceremony was held on April 27, 2016. Applications for the 2016 award are currently in the midst of review, and it is expected that the list of award-winners will be announced in March 2017.

2. Ta-You Wu Memorial Award

The Ta-You Wu Memorial Award was established in order to cultivate young researchers, encourage the academic elite of tomorrow to commit themselves to long-term academic research, and commemorate the contributions of Ta-You Wu to the development of science and technology. The number of recipients is limited 40 annually, and recipients receive a medal and NT$200,000 from MOST. A total of 40 persons received this award in 2016.

Winners of the award received their awards from the Minister of Science and Technology at the academic research awards ceremony held on April 27, 2016.

B. Other Awards

Executive Yuan Award for Outstanding Science and Technology Contribution

The Executive Yuan drafted the *Implementation Guidelines for Recognition of Persons Making Outstanding Contributions in Science and Technology* and established the Outstanding Achievement in Science and Technology Award in order to encourage technological R&D and recognize the country's outstanding S&T personnel. The award was renamed the "Executive Yuan Award for Outstanding Science and Technology Contribution" in 2006, at which time the relevant regulations were revised as the *Executive Yuan Award for Outstanding Science and Technology Contribution Implementation Regulations, Executive Yuan Award for Outstanding Science and Technology Contribution Review Committee Establishment Regulations, and National Science Council, Executive Yuan Selection Operating Guidelines for the Executive Yuan Award for Outstanding Science and Technology Contribution*, and the amount of the award was increased from the original NT$600,000 to NT$1 million. All citizens engaged in science and technology in the natural sciences, engineering, life science/medicine/agriculture, or the humanities and social sciences whose R&D results lead to outstanding inventions or innovations, and thereby make significant, groundbreaking, and original contributions to society may be nominated to receive this award. After experts and scholars engaged by MOST perform a preliminary assessment, a review committee consisting of the heads of government agencies, schools, and academic research organizations, plus experts and scholars affiliated with these units, performs a review, and the results are sent to the Executive Yuan for approval and conferral of awards.

In 2015, 42 nominations were received for the Executive Yuan Award for Outstanding Science and Technology Contribution, and the award was granted to three persons following the selection process. The winners were Mr. Chuang Pen-chi and Mr. Chien Chen-fu in the natural science and engineering category, and Mr. Yeh Hsi-tung in the life science/medicine/agriculture category. The Executive Yuan held the awards ceremony on December 29, 2016, and the awards were bestowed by Executive Yuan Premier Lin Chuan.

Research awards, 2012-2016

Item	2012	2013	2014	2015	2016
Outstanding Research Award (persons)	73	72	72	74	**In-review**
Ta-You Wu Memorial Award (persons)	40	40	40	40	**40**
Executive Yuan Award for Outstanding Science and Technology Contribution (persons)	1	4	2	4	**3**

This photograph of the 2016 Executive Yuan Award for Outstanding Science and Technology Contribution awards ceremony, which was held at the Executive Yuan on December 29, 2016, shown are Executive Yuan Premier Lin Chuan (4th from right), Executive Yuan Secretary-general Chen Mei-ling (3rd from left), spokesperson Hsu Kuo-yong (2nd from left, former MOST Vice Minister Chiu Cheng-chien (1st on left), former MOST Vice Minister Tsai Ming-chi (2nd from right), and the three award-winners: Mr. Yeh Hsi-tung (3rd from right) in the life science/medicine/agriculture category and Mr. Chuang Pen-chi (1st on right) and Mr. Chien Chen-fu (4th from left) in the natural science and engineering category.

C. Technology Transfer Incentives

In order recognize research personnel and research teams that have made significant contributions to the transfer of R&D results and have demonstrated excellent performance, project-implementing organizations may apply to MOST for the Outstanding Technology Transfer Contribution Award when technology transfer of the results of MOST-funded R&D projects has been completed, and total licensing fees and derivative benefits have exceeded NT$1 million. This award may be received only once for each R&D result. After MOST performs a selection process, awards of up to a maximum of NT$150,000 may be granted in each case, along with a medal to each research personnel. Applications for 2016 are currently being reviewed.

V International Cooperation in Science and Technology

Apart from sharing research results and enhancing the country's R&D capabilities through international activities including joint research projects and conferences, joint use of major research facilities, reciprocal visits of personnel, and the exchange of information, MOST is also maintaining the balanced development of Taiwan's S&T development strategies by continuing to strengthen cooperation and interchange with technologically-advanced countries, while employing S&T assistance to further the government's diplomatic policies.

A. Promotion of Bilateral S&T Cooperation

In order to strengthen bilateral collaborative relationships and establish bilateral platforms for S&T interchange, apart from signing scientific and technical cooperation agreements and MOUs with foreign S&T organizations, MOST is also strengthening outreach to new partners and exploring potential areas of cooperation. A total of 115 cooperation agreements, MOUs, and other cooperation documents had been signed with 43 countries and three international organizations as of the end of 2016.

MOST signed the following bilateral S&T cooperation agreements during 2016 (including extended agreements): (1) A new Taiwan-United States cooperation agreement concerning frequency coordination of the FORMOSAT-3 satellite galaxy system; (2) a strategic partnership agreement between Taiwan and the United States concerning digital RF cavity controllers; (3) an MOU with Canada concerning a cooperation program in communications technology; (4) an MOU with Japan's National Institute of Advanced Industrial Science and Technology; (5) MOST and the Estonian Research Council (ETAg) added a second annex (concerning exchanges and visits of personnel) to their scientific cooperation agreement; (6) MOST and the Czech Academy of Sciences (CAS) renewed a scientific cooperation agreement; (7) MOST signed a cooperation letter of intent concerning battery development with the German Federal Ministry of Education and Research (BMBF). MOST hopes that the establishment of a cooperation framework between the parties in these agreements will help Taiwan's scientific research personnel participate in international S&T cooperation and boost Taiwan's S&T research standards and international influence.

B. Participation in Major International S&T Organizations

This year MOST continued to promote Taiwan's participation in the activities of major international S&T organizations, and encouraged international scientific and technological interchange and collaboration.

1. European Union

The EU's 8th Framework Program-entitled "Horizon 2020"-will extend from 2014 to 2020. Responding to the Horizon 2020 framework, MOST has encouraged researchers in Taiwan to actively participate in multinational, multilateral projects, and has established an interagency National Contact Point in Taiwan steering committee in conjunction with the Ministry of Economic Affairs. Vice ministers from MOST and the MOEA serve as the chairs of this committee, and a Ministry of Foreign Affairs vice minister, Ministry of Education vice minister, and the Board of Science & Technology, Executive Yuan serve as members. This steering committee has establish four subgroups in charge of industrial technology, academic R&D, manpower training, and four international links respectively, and provides an interagency platform for communication, coordination, and the preparation of manpower and resources needed for the implementation of EU projects. At the same time, MOST has established National Contact Point (NCP) offices at NARLabs and the Industrial Technology Research Institute (ITRI), which have provided citizens with consulting services and assistance with project application procedures through strengthened awareness and match-up activities. MOST has further assigned its five overseas science and technology divisions in Europe to serve as Taiwan NCPs directly participating in Europe's NCP network, which will expand Taiwan's network of European contacts and provide a better understanding of the Horizon 2020's newest trends. MOST has also been actively participating in numerous EU ERA.NET projects, and has been assisting with the issuance of calls for multinational research project proposals in conjunction with multinational research-funding organizations in Europe, which has helped R&D teams from Taiwan to participate in EU projects.

2. APEC

MOST actively participates in Asia Pacific Economic Cooperation (APEC) activities, and took

part in the 2016 7th and 8th APEC Policy Partnership on Science, Technology and Innovation (PPSTI) conferences, which were held in Peru. At these conferences, Taiwan's two proposals—"2016 APEC Typhoon Symposium" and "Simple Human Resources to Symbiotic Green Makers-An Education Platform for STI to SMEs"—were approved.

C. Major Joint S&T Activities with International Partners

1. European Area

The deputy director of the German Federal Ministry of Education and Research (Bundesministerium fur Bildung und Forschung, BMBF) visited Taiwan to participate in the "2016 Green Together" sustainability summit, and signed a MOU concerning cooperative battery development by Taiwan and Germany. The 4th Taiwan-Czech S&T Day activity was held in the Czech capital of Prague, and MOST signed an extended scientific cooperation agreement with the Academy of Sciences of Czech Republic. MOST participated in the 15th Taiwan-Latvian S&T cooperation convention with the Latvian Ministry of Education and Science.

2. The Americas

MOST signed MOUs concerning the Partnerships for International Research and Education (PIRE) and cooperation in the earth sciences with the National Science Foundation (NSF), and jointly promoted projects and sought joint research proposals. MOST held a joint bilateral S&T cooperation conference with the NSF in Taiwan, and the two parties provided joint funding for a bilateral symposium. MOST strengthened cooperation with the US National Cancer Institute (NCI) and the US National Institutes of Health (NIH), and the signing of a Taiwan-American cancer research MOU (revised version) by the Academia Sinica and the NIH made Taiwan one of the international members of the US "National Cancer Moonshot." In cooperation with Canada, MOST continued to fund bilateral cooperative S&T projects with Canadian agencies (NRC, NSERC, CRC, CIHR), and held an annual advisory conference with the NRC.

3. Asia Area

MOST signed an MOU with Japan's National Institute of Advanced Industrial Science and Technology (AIST). The 5th Taiwan-Philippines Ministerial S&T Conference, which was held in Taipei on December 9, 2016, approved the three-year VOTE (Volcano, Ocean, Typhoon, and Earthquake) project, and Taiwan expanded cooperation and interchange in the areas of agriculture, medicine and human resources training with the Philippines in conjunction with the New Southward Policy.

4. Africa Area

MOST participated in the 3rd meeting of the Taiwan-Republic of South Africa S&T cooperation committee together with the South African Ministry of Science and Technology in Pretoria, and bilateral symposia were held on the topics of "Innovation Enablers" and "E-learning."

D. Funding International Academic Interchange Activities

In order to enhance Taiwan's visibility in the international academic world, MOST has striven to promote participation of domestic teams in the activities of international scientific and technological organizations and international academic organizations, and continues to support S&T research cooperation via attendance at international academic conferences, the holding of international academic conferences, and the invitation of foreign figures to Taiwan. Furthermore, to encourage young scientists to enter the international academic sphere at an early date, MOST provides funding to domestic graduate students for participation at international conferences allowing them to present their research results. This participation also expands graduate students' international perspectives, sharpens their research skills, and fosters collaborative international research relationships.

In order to promote the internationalization of academic research, encourage domestic experts and scientists to aspire to international academic leadership circles, and enhance the international influence of relevant domestic academic communities, MOST drafted the *Operating Guidelines for Subsidies for Scientists to Enhance International Influence*. In accordance with these Guidelines, MOST provides subsidies to domestic scientists serving in important academic positions, such as the directors, supervisors, or executive members of major international academic organizations, or the chief editors or deputy chief editors of international academic journals, in order to fund participation in relevant academic activities. MOST continues to fund participation in the activities of the Global Biodiversity Information Facility (GBIF).

Furthermore, to support the development of science and technology in developing nations, MOST held 12 international training workshops for trainees from Southeast Asian countries in 2016. The topics of these workshops included public health, earthquakes, disaster prevention, sustainable development,

environmental protection/energy, atmospheric radar, space remote sensing, biotechnology, food safety, and earth science. A total of 350 trainees from Southeast Asia, the Asia-Pacific, and Latin America area came to Taiwan to participate in these events.

Funding for international academic interchange activities, 2011-2016

Item	Joint international research (projects)	Invited visits by foreign S&T personnel (person times)	Attendance at international academic conferences (Dept. of International Cooperation & Science Education projects/specific-topic research projects) (person times)	Graduate student attendance at international conferences (person times)	International conferences held in Taiwan	Participation by teams in international academic organization conferences (teams/ person times)	Assistance in enhancing the international influence of domestic scientists (cases)
2011	164	767	872 / 10,968	2,589	273	35 / 178	41
2012	198	833	925 / 11,898	3,221	295	38 / 209	29
2013	138	856	982 / 12,290	3,314	345	42 / 223	34
2014	114	839	953 / 12,607	3,300	345	49 / 313	27
2015	250	758	934 / 12,774	3,375	327	42 / 224	25
2016	**282**	**730**	**1,009 / 12,288**	**3,545**	**315**	**42 / 243**	**25**

E. Overseas Science Divisions

Apart from assisting in the promotion of bilateral and multilateral S&T interchange and cooperation, MOST's science and technology divisions abroad also actively maintain contact with and serve overseas Chinese S&T personnel and academic associations in their service areas, and occasionally hold seminars to serve overseas Chinese scholars and exchange students. Eleven overseas symposia held in North America during 2016 discussed topics including biomedical engineering, biotechnology, advanced medical device technology, the Internet of Things, and smart cities.

VI S&T Interchange with China

Complying with the government's China policy of "taking Taiwan's interests foremost and ensuring benefit to society," MOST has been actively promoting steady, in-depth cross-Strait academic interchange and collaboration. While prioritizing technological interchange and cooperation benefiting Taiwan, China, and their people, MOST relies on contact at different levels to strengthen the development of systematic, routine cross-Strait S&T interchange mechanisms based on mutual trust. MOST's chief approach to interchange is to recruit scientists and technical specialists in China who wish to perform research in Taiwan, support cross-Strait research projects on topics of common importance, and provide funding for relevant technical forums. The following is an overview of the cross-Strait interchange regulations drafted in conjunction with government policy and the results of their implementation during 2016:

1. Based on the *Regulations Governing the Recruitment of Visiting Science and Technology Personnel with Subsidies from the Ministry of Science and Technology*, MOST provided subsidies to research organizations for the recruiting of S&T personnel from China for participation in scientific research in Taiwan; such subsidies were provided 85 person-times in 2016.

2. Based on the *Operating Guidelines for Subsidies for the Holding of Cross-straits Academic and Sci-tech Conferences*, MOST encouraged and supported the holding of cross-Strait S&T and academic conferences by academic or S&T organizations and universities. Support was provided for 47 conferences in 2016.
3. Based on the *Guidelines for Subsidies for the Invitation of S&T Personnel from the Mainland China Area, Hong Kong, and Macao to Taiwan for Short-term Visits*, MOST provided subsidies to academic and research organizations for invitation to Taiwan of individuals from the Mainland China Area, Hong Kong, and Macao who possess special skills and can benefit the host organization's research or S&T development; funding was provided for 83 such visits in 2016, which were chiefly for the purpose of public lectures and participation in discussions.
4. In 2016, after review of cases in which applications were made to let academic and S&T personnel from the Mainland China Area come to Taiwan for long- or short-term academic or S&T activities, MOST approved 547 such applications.
5. In order to promote positive cross-Strait academic interchange, MOST continued to fund its share of bilaterally-funded joint research projects with China on specific issues concerning public welfare. This year's joint topics consisted of "From near-earth objects to the evolution of galaxies" and "Applications of disaster prevention technology". Furthermore, MOST supported the 6th "Cross-Strait Science Communication Forum," which was held October 25-26, 2016 in Chengdu, China.

Apart from continuing to promote research cooperation on common issues with the National Natural Science Foundation of China, MOST has been holding regularly scheduled working conferences with the Chinese Ministry of Science and Technology, and is also conducting interchange with relevant academic units in Mainland China, promoting cross-Strait S&T forums, and continuing to sponsor reciprocal high-level visits of high-level S&T officials as part of efforts to establish stable interchange mechanisms.

S&T interchange with China and permit review statistics, 2012-2016

Item	2012	2013	2014	2015	2016
Recruited S&T personnel from China (person times)	110	109	121	108	**85**
Cross-strait academic conferences	67	59	64	73	**47**
S&T personnel from the Mainland China Area, Hong Kong, and Macao invited to Taiwan (person times)	48	82	89	67	**83**
Professional S&T activity permits reviewed (person times)	1,613	2,089	464	433	**547**

VII Improving the Research and Development Environment

A. Online Services

MOST revised its online application systems for domestic experts and scientists wishing to attend international conferences and teams wishing to attend conferences of international academic organizations in 2016 in order to provide applicants online application, expense reimbursement, report submission, and agency compilation, and online review by reviewers functions, while improving compatibility with leading browser versions.

With regard to paperless online application for academic research grants and funding, after many years of paperless online submission for review, the system has effectively reduced paper and postage costs, shortened processing time, and boosted administrative efficiency. In order to seek further improvement, MOST began use of paperless academic review fee receipts on a trial basis in 2013, and paperless receipts were used to request funding reimbursements approximately 107,400 times during 2016, and effectiveness has been excellent.

Paperless online application statistics, 2014-2016

Item	2014	2015	2016
Specific-topic project funding	107,897	103,592	**102,576**
International collaboration	19,356	18,663	**18,757**
Manpower recruiting	15,468	15,842	**15,893**
Industry-academic collaboration	4,651	5,885	**5,940**

Note: Includes online applications, contract signing requests for funds, production and change of contracts, report of expenses for reimbursement, and report submission.

Paperless online review cases and person-times, 2014-2016

Item	2014		2015		2016	
	Cases	Person times	Cases	Person times	**Cases**	**Person times**
Specific-topic project funding	27,331	86,933	28,443	88,049	**28,233**	**87,205**
International collaboration	8,578	11,661	8,123	11,034	**8,516**	**10,900**
Manpower recruiting	1,690	3,146	1,609	2,804	**1,692**	**3,087**
Industry-academic collaboration	1,406	4,291	1,680	5,638	**1,638**	**6,208**

Note: Statistics are based on online application cases submitted via the online review system.

B. Major Instrument Common Use Service

MOST's major instrument common use service program provides needed equipment to researchers in academia and industry. During 2016, subsidies were provided to the following 21 schools participating in the program: National Taiwan University, National Taiwan Normal University, National Central University, National Tsinghua University, National Chiao Tung University, National Chungshing University, National Chung Cheng University, National Cheng Kung University, National Sun Yat-sen University, National Taiwan University of Science and Technology, National Dong Hua University, Taipei Medical University, National Taiwan Ocean University, Chung Yuan Christian University, Feng Chia University, Kaohsiung Medical University, National Pingtung University of Science and Technology, National Taipei Institute of Technology, Tunghai University, National Changhua University of Education and National Chi Nan University. Facilities at these universities housed 195 in-service instruments during the year. The major instrument centers provided services 409,557 times in 2016, and service time totaled 390,973 hours. The aggregate value of instrument services amounted to over NT$529.3 million.

Major instrument use center service statistics, 2016

School name	Number of instruments	Number of cases	Service hours
National Taiwan University	23	59,654	58,343
National Taiwan Normal University	6	11,419	14,383
National Central University	12	20,307	19,146
National Tsinghua University	28	87,276	65,851
National Chiao Tung University	25	46,867	60,228
National Chungshing University	19	50,055	41,327
National Chung Cheng University	11	13,394	18,050
National Cheng Kung University	23	58,655	49,151
National Sun Yat-sen University	17	28,424	34,682
Non-major instrument centers (12 schools)	31	33,506	29,814
Total	**195**	**409,557**	**390,973**

Source: Major information management system.

VIII Management and Extension of R&D Results

In conjunction with the implementation of the Fundamental Science and Technology Act, after January 22, 1999, the right to manage and extend the results of MOST-funded specific-topic research projects, such as through patent application and technology licensing, has, as a rule, been granted to the implementing organization.

In view of the important role played by academic research organizations in the development and application of knowledge, MOST drafted the *Guidelines for the Funding of the Management and Extension of Academic Research and Development Results* in order to help implementing organizations boost the effectiveness of R&D results management and extension, and has adopted many performance-oriented funding and award measures since 2003. In the case of R&D results resulting from MOST-funded projects, when the implementing organization applies for an invention patent, subsidies during the application stage will cover 40% of expenses, and subsidies covering additional 40% of application expenses and 80% of maintenance expenses during the first 3 years can be obtained after the patent has been received.

In order to further boost the industrial application of academic research organizations' invention patents, the *Guidelines* were revised on June 5, 2015 in order to adjust funding ratios. Funding is now provided for 60% of patent application expenses, and for 50% of patent certificate acquisition and maintenance expenses during the first three years. All academic research organizations that have instituted sound management mechanisms are now eligible to initiate invention patent application, maintenance, and extension cases, which will induce research organizations to strengthen their internal management mechanisms and make their performance management more rigorous. Subsidies covering invention patent expenses were provided in 6,600 cases involving the results of funded projects during 2016.

Furthermore, to encourage technological diffusion, project-implementing organizations need pay only a certain percentage of income from R&D results to the funding agency (these payments are included in the Science and Technology Development Fund in accordance with budget procedures); this percentage is 20% in the case of schools and government research organizations, and 40% in the case of companies and other research organizations. MOST's royalty income from R&D results was approximately NT$52 million in 2016.

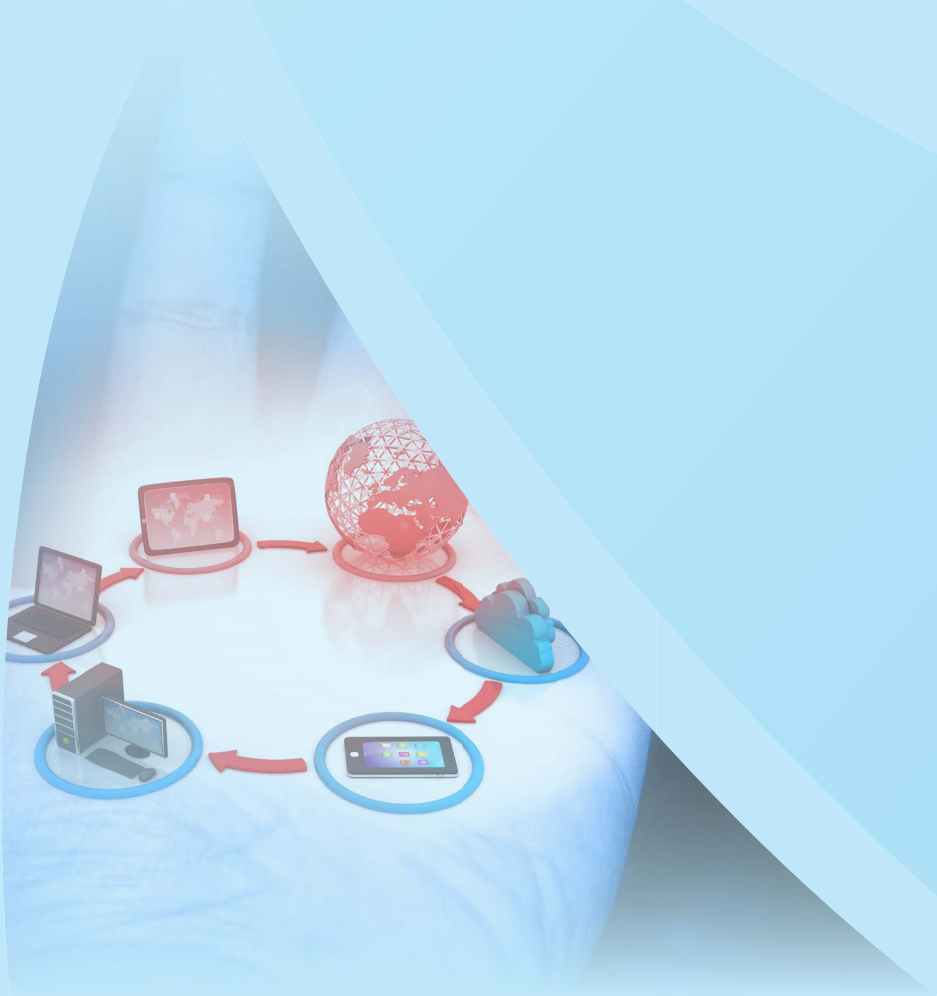
IX Publications

Ministry of Science and Technology Annual Review	Published online in Chinese and English versions, the MOST Annual Review reports on MOST's key undertakings and results during the year, enabling citizens and overseas individuals who are interested in scientific and technological affairs to find out about MOST's promotion of S&T development and its achievements.
Indicators of Science and Technology, R.O.C. (2016 edition)	The *Indicators of Science and Technology* has been published annually since 1990 in order to publicize the results of the "Survey of National Science and Technology Activity." The 2016 edition contained four major sections: The first section, "Summary Analysis," compared trends in the R&D input and output indicators of Taiwan and other major nations during the most recent five years; apart from explanatory text, charts and graphs help readers to clearly understand the significance of major indicators and the current state of R&D in Taiwan and other countries. The second section, "International Comparison of S&T Activity," contained relevant data concerning major S&T indicators in various countries. The third section, "S&T Activity in Taiwan," included a breakdown of R&D funding and R&D manpower across the business enterprise, government, higher education, and private nonprofit sectors, the government's S&T budget and R&D budget, S&T results, and science park R&D data. The fourth section consisted of appendices explaining the survey, defining terms, and providing the survey questionnaire and comparisons of OECD and Taiwan industry classifications.
Science Development	First published in 1973, the monthly *Science Development* originally served as a government policy publication. It was changed into a general popular science magazine in January 2002, and has striven to make science and technology accessible and relevant to the public since that time. Well-illustrated reports enable general readers to understand scientific developments and trends in Taiwan and around the world, promote stronger links between science and the humanities, and increase the public's understanding of science. This magazine won the Executive Yuan's Outstanding Government Publication Award from 2002 to 2007, and also won the 2nd and 3rd National Publication Award in 2009 and 2010.

Journal of Biomedical Science	This international academic periodical is edited by domestic scientists, and the editorial committee consists of domestic and foreign experts and scholars. There is a strict review system, and the journal is published in English by a prominent international publishing company. First published in 1994, the Journal of Biomedical Science was originally a quarterly, but was changed to a bimonthly in 1996. In order to disseminate academic research results faster and more widely, this journal was changed to open access in 2009; any user can use papers free of charge via the Internet, and research personnel can freely share resources from the journal, promoting academic development. The *Journal* had an *SCI* impact factor of 2.935 according to the 2015 *Journal Citation Reports (JCR),* and is one of the most representative biomedical journals in Asia.
International Journal of Science and Mathematics Education	First published in 2003, this quarterly international academic periodical was changed to a bimonthly in 2009. It is edited by domestic scholars with the help of an editorial committee consisting of prominent domestic and foreign experts in relevant areas, and is published by a well-known international publishing company. The journal employs a strict double-blind peer review system. Manuscripts are received from many countries worldwide, and roughly 73% of manuscripts are from non-English-speaking countries, which makes it a very representative educational research journal presenting viewpoints from non-English-speaking countries. According to the 2015 *Journal Citation Reports (JCR),* this journal had an *SSCI* impact factor of 1.104.
East Asian Science, Technology and Society: an International Journal	First issued in 2007, this quarterly is published in cooperation with a prominent international publishing company, and contains articles, book reviews, and short communications concerning science, technology and society (STS). MOST hopes that the studies of East Asia experiences and phenomena and comparative research in this journal will enable the emergence of STS perspectives differing from those in the West, which will highlight Taiwan's contribution to the international STS academic community. Apart from a domestic chief editor, the journal has invited experts and scholars from Taiwan, Japan, Korea, Britain, the US, and Australia to form the editorial committee. The journal relies on its rigorous review system to continuously improve the quality of articles.

All of the foregoing publications can be viewed via the MOST website. (https://www.most.gov.tw)

ACADEMIA
INDUSTRY
SCIENCE
TECHNOLOGY



Chapter 4 Strengthening Industry-Academic Linkage and Innovation

Industry-Academic Collaborative Research Projects

PIONEER Grants for Frontier Technologies Development by Academia-Industry Cooperation

Academia-Industry Technology Alliance Projects

From IP to IPO Program

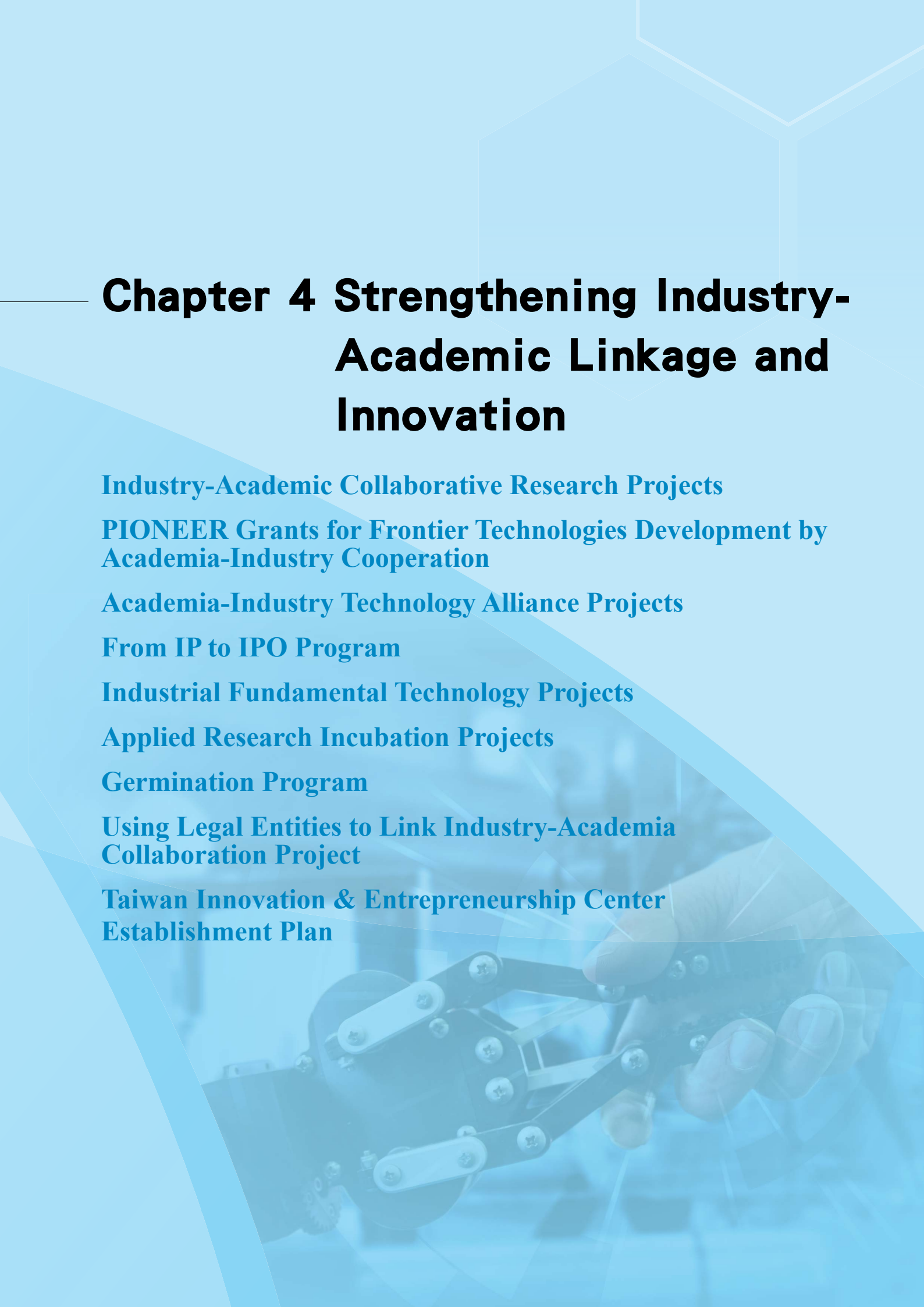
Industrial Fundamental Technology Projects

Applied Research Incubation Projects

Germination Program

Using Legal Entities to Link Industry-Academia Collaboration Project

Taiwan Innovation & Entrepreneurship Center Establishment Plan



Industry-Academic Collaborative Research Projects

MOST actively promotes industry-academic collaborative research projects in order to harness the abundant R&D resources of Taiwan's academic sector and train S&T personnel with practical experience. The model of mutually-beneficial cooperation employed in these projects over the course of many years has supported and boosted the R&D capabilities of domestic companies, and the advanced technologies developed in these projects have made major contributions to domestic industrial competitiveness.

In order to make even greater use of the results of academic research and further accelerate Taiwan's S&T innovation, starting in 2013 MOST has promoted industry-oriented industry-academic collaboration models including university-industry collaboration projects (large alliance), academia-industry technology development alliance projects (small alliance), industrial fundamental technology projects, and the Applied Research Program for Start-ups.

Industry-academic collaborative research project application forms were simplified starting on April 18, 2016; apart from eliminating redundant proposal fields and fields for information not needed for review, application data submission requirements have been simplified, companies no longer need to submit a CPA-attested profit and loss statement and asset balance sheet for the most recent year, and proposal writing requirements have been simplified. These changes have eased the clerical work burden of academic applicants.

Industry-academic collaborative research project statistics, 2012-2016

Item	2012	2013	2014	2015	2016
Number of projects	863	842	813	808	840
Funding (NT$1 m)	793	816	894	993	889
Participating companies	883	829	852	829	867
Corporate contribution (NT$1 m)	347	306	328	380	348
Manpower training (graduate students)	2,179	2,081	2,095	2,078	2,178
Patents received	130	130	110	108	86

Source: MOST's service statistics database and S&T R&D results information system.

II. PIONEER Grants for Frontier Technologies Development by Academia-Industry Cooperation

In order to direct academic R&D capabilities and resources to the industrial sector, strengthen Taiwan's industrial technology innovation ability, and gain an advantage in international markets, MOST and MOEA joined forces in November 2012 to propose "PIONEER Grants for Frontier Technologies Development by Academia-Industry Cooperation (PIONEER Grants for AIC)," which call for an interagency industry-academic collaboration model based on the novel format of "academic solution for industrial problems". MOST serves as the program's unified application acceptance window, and the academic participants are responsible for submitting project proposals for review.

These projects channel academic R&D capabilities to industry by pairing Taiwan's finest scientists and researchers with internationally competitive companies. The beneficial results of this approach include shrinking the gap between academia and industry, fostering the development of cutting-edge industrial technologies, strengthening the key technological capabilities and patent portfolios of Taiwan's high-tech firms, and training scientific and technological manpower of the highest caliber.

A total of 6 large alliance projects were implemented in 2016, and the participating companies consisted of 16 well-known domestic firms, including companies in the fields of semiconductors, green chemical engineering technology, wireless/broadband network technology, and mobile communications technology. The projects have attracted a cumulative total of approximately NT$1.5 billion in R&D funding, have resulted in more than 200 patent applications, and have yielded results including the development of an analog-digital converter with bandwidth of as high as 1 GHz, and speed and performance respectively 60% faster and three times better than those of prominent competing brands overseas. By harnessing the R&D capabilities of universities and industry, and promoting joint R&D efforts in forward-looking and basic technologies, this program seeks to bring about a full-scale improvement in Taiwan's industrial competitiveness and product added value.

III. Academia-Industrial Technology Alliance Projects

The abundant research capabilities of Taiwan's academic research sector are not directed solely to the publication of papers in journals; apart from strengthening linkage with domestic industry, Taiwan's research capabilities are also being applied to the training of human resources meeting industry's needs. In view of the major role played by SMEs in Taiwan's industries, and their urgent need for the R&D resources and capabilities of academia, MOST began funding "academia-industry technology alliance projects" ("Minor Alliance Projects") in 2012. These projects take technologies developed by the academic sector as their subject, and employ an industry-academic alliance format to fund "technical service laboratories" spanning various industries. This novel form of industry-academic collaboration can systematically diffuse the technological capabilities of the academic sector, which will strengthen industry-academic technological linkage, enhance the practical experience of research personnel, and shrink the gap between industry and academia by promoting better interaction between universities and companies.

Implementation of the first batch of minor alliance projects got underway in February 2013; 75 projects received funding during the first year, 92 projects received funding in 2014, 106 projects received funding during 2015, and 91 such projects received funding in 2016. Project implementing organizations included 37 public and private universities and research organizations during 2016. As of the end of December 2016, 1,522 companies were participating in minor alliance projects. This program has achieved its preliminary goal of establishing a platform for academic-industry collaboration, and alliances are currently being encouraged to expand their membership and thereby further expand the diffusion of academic technologies to industry.

IV From IP to IPO Program

While Taiwan's scientific and technological expertise and achievements have won extensive recognition in the international sphere, a gap has emerged between these achievements and the value following corresponding industrial applications. The reason for this gap is chiefly the fact that Taiwan's concept of industry-academic collaboration, entrepreneurship policy, culture, environment, and resources have not yet reached a state of maturity, which has caused obstacles along the pathway from innovation to startup. Hoping to overcome this situation, MOST began implementation of the "From Invention to Innovation" (FITI) program (also known as the "From IP to IPO" program) in March 2013 in an effort to establish regular entrepreneurship promotion mechanisms able to help research teams who wish to transform their S&T R&D results or creative ideas into startup companies apply their innovative R&D capabilities to the establishment of budding enterprises and achievement of market value, adding to Taiwan's economic momentum.

This program conducts an innovative startup team selection process twice annually, and teams may focus on areas including biotech medicine, innovative technologies and design, and information applications and services. In this process, startup teams consisting of students, professors, and researchers write startup pre-proposals, and the selected finalist teams receive training. Apart from helping the teams with their proposals, the program, also provides key resources at each stage, including assistance with verification of technology, business model guidance, contact with key individuals, professional consulting services (concerning market demand, patents, finance, and marketing channels, etc.), and referral to prototype production and startup funding seed funds, which ensures that the teams receive much-needed startup assistance.

During the training period, in order to enhance their business management ability and briefing technique, the entrepreneurial teams receive monthly in-person or online classes and two monthly entrepreneurship immersion training boot camp sessions. And in order to enhance the teams' international outlook and core functions, the program invites successful domestic and foreign Chinese entrepreneurs and venture capitalists to serve as instructors and impart their entrepreneurial knowledge and experience directly to the teams. To provide the teams with concept verification and prototype production assistance and guidance during the initial stage, NARLabs and the three science park bureaus offer supporting equipment, experimental facilities, operating space, and referral to resources.

With regard to private participation, since this program was introduced, it has garnered support from 14 leading companies, which include Acer, Hiwin Technologies, Ernst & Young, the Fubon Group, Far Eastern Group, and the Lite-On Electronic Group. Stan Shih, founder of Acer, serves as honorary dean of studies. Apart from providing startup funds for the teams, these industry partners also provide entrepreneurship coaches offering general manager-level insights. Since 2013, the program has gathered 1,385 startup proposals, provided in-depth training to 321 startup teams, assisted 1,795 entrepreneurs, and helped 105 teams accelerate the establishment of startups. Apart from directly creating 450 employment opportunities, these startups had also cumulatively raised more than NT$995 million in funds and had a total of NT$1.04 billion in paid-in capital as of the end of December 2016.

V Industrial Fundamental Technology Projects

MOST promotes "Industrial Fundamental Technology Projects" in order to enhance basic industrial standards in Taiwan and unite the R&D capabilities of academia and industry. This program chiefly provides funding to universities to establish basic technology R&D centers charged with

developing fundamental industrial technologies that will have high applicability by manufacturers, pose high technological hurdles, have high expected economic influence, and offer broad application markets ("three highs and one broad"). The projects' industry-academic collaborative format attracts R&D resources from industry, and is intended to leverage the government budget, take advantage of universities' abundant resources, help industry boost its competitive ability, and train personnel possessing practical experience.

MOST provides funding of up to NT$20 million to each project, and companies must contribute no less than 20% of the applied-for funding. Projects are conducted in four-year stages; implementation performance is evaluated on an annual basis, and funding to poorly-performing projects may be cut off. While government contributions initially constitute the lion's share of project funding, corporate contributions and university resources are expected to gradually increase, and it is hoped that projects can attain long-term self-sufficiency. The program was initiated in September 2012; as of December 2016, 32 basic technology R&D centers were operating, and implementation results included the acquisition of 177 domestic and 57 foreign patents, completion of 123 technology licensing cases, NT$88.61 million in technology licensing fees, 16,258 hours of on-campus university classes taught by instructors from industry, 143 exhibitions and announcements of physical results attended by 20,928 persons, and the holding of 64 open competitions attended by 7,084 persons. The participating companies contributed approximately NT$236.11 million in project funding and 1,662 hardware and equipment items valued at NT$445.63 million. The 427 derivative industry-academic collaborative projects received NT$458.52 million in funding, and 1,608 persons received technical licenses.

VI Applied Research Incubation Projects

MOST drafted the "Provisional Guidelines for Funding of Applied Research Incubation Projects" in 2013 in order to promote industrial utilization of academic research results and nurture high-tech startups. These projects seek to promote product-oriented, forward-looking, original early research with application potential; proposals are reviewed when received, subjected to quick review, funding is provided in stages divided by milestones, and projects receive assistance and incubation management. This approach can help boost the proportion of promising cases finding their way to the marketplace, and facilitate startup incubation.

Although Taiwan's academic institutions and research units have achieved considerable promise and good results in the areas of biotech pharmaceuticals and medical equipment, most relevant academic research results still remain at the front end of industry value chains, and have made insufficient progress toward commercialization. These projects are consequently intended to promote early R&D in the fields of pharmaceuticals and medical equipment. As of the end of 2016, more than 230 promising proposals in the fields of pharmaceuticals and medical equipment had passed the initial screening process, and 69 of these had been subjected to in-depth assessment. After rigorous review and selection by an advisory team consisting of domestic and foreign experts, 24 projects were approved to receive MOST funding and full-scale incubation assistance. The program has assisted the establishment of 11 new startups, and has helped research results in the medical equipment-related areas of customized maxillofacial reconstruction, neural conduits, new drug release systems, bone screw positioning, and 3-D microscopy equipment, leukocyte reduction filter technology, and an automated blood testing system to advance to commercialization. The cumulative paid-in capital of the startups exceeded NT$430 million, which indicates that this program has successfully facilitated the transformation of R&D results into products, and ensured that citizens can enjoy the fruits of the commercialization of domestic biotech R&D.

VII Germination Program

Acting in accordance with the recommendations of the 25th Executive Yuan Science and Technology Advisory Group conference, since 2007, MOST has sought to uncover research organizations' groundbreaking academic research results possessing industrial value via the planning of projects and drafting of appropriate mechanisms. Following collection of assessment recommendations during the first stage, which lasted from 2007 to 2010, the Germination Program got underway in 2011. This program seeks to systematically promote the commercialization of promising scientific discoveries, and has the following objectives:

1. To strengthen academic research organizations' capacity and mechanisms for investigating early R&D results with potential commercial applications, and simultaneously encouraging promising projects to train manpower and embark on startups.
2. To connect upstream scientific research with downstream industry, encourage the use of academic research results as a basis for startups, and foster linkage between scientific advances and commercial applications.

This program has provided funding for the establishment of nine germination centers, which are located at National Taiwan University, National Yang Ming University, National Tsinghua University, National Cheng Kung University, National Chung Hsing University, National Sun Yat-sen University, National Central University, Chung Yuan Christian University, and Taipei Medical University. Targeting original technologies developed at universities and research organizations, these germination centers seek to uncover the commercial applications of these technologies when their potential is still unclear, and assist teams with innovative, technical, and early ideas to establish startups. As of the end of 2016, this program had brought about the establishment of nine germination centers and 20 startups, with the latter having total paid-in capital of NT$202.84 million.

VIII Using Legal Entities to Link Industry-Academia Collaboration Project

In order to strengthen linkage between academia, industry, and society, MOST has actively promoted "Using Legal Entities to Link Industry-Academia Collaboration Project," which rely on the research capabilities and industrial experience of research institutions to uncover promising academic R&D results, assist with value-adding and extension, and accelerate the industrialization of university R&D results. This program is expected to strengthen industry-academic linkage, create a self-reinforcing ecosystem involving university R&D results and industrial application, shrink the gap between universities and industry, ensure that industry makes effective use of academic research capabilities, and thereby give a significant boost to Taiwan's industrial competitiveness and capacity for S&T innovation.

This program was initiated on a trial basis during 2015, and its applicable industrial areas were expanded to include biotech medicine, sustainable energy, machine materials, and civil engineering in addition to the original electronics/information/communications in 2016. At the same time, the program has also sought to promote the Executive Yuan's "5+2" areas of industrial innovation—biotech medicine, green energy technology, smart machinery, Asian Silicon Valley, defense & aerospace, new agriculture, and circular economy. The chief features of this program are as follows:

1. Reliance on the capabilities of research institutions to accelerate the industrialization of academic R&D results: The program seeks to uncover promising academic R&D findings and accelerate the industrialization of those results via the capacity and experience of research institutions, which will nurture a new model of collaboration among industry, academia, and research institutions.

2. Enhancing the output benefits of universities' R&D results: In order to boost industrialization capacity, the program is providing training in intellectual property practice to university personnel, and helping universities to establish professional intellectual property and market assessment capabilities.
3. Boosting universities' intellectual property skills: This program's professional training classes in intellectual property practice are helping universities to establish intellectual property and market assessment expertise, increasing their industrialization capacity.
4. Raising universities' international visibility: By encouraging universities to enter their R&D results in Singapore's Tech Innovation exhibition, the program has been helping universities establish international links and enhance their international perspectives.
5. Boosting the positive impact of academic R&D results on the innovative ability of industry in Taiwan: By linking the capacities of research institutions with industry and universities, the program is encouraging academic researchers to engage in high-value product R&D meeting industry's needs.

With regard to the results of the Using Research Institutions to Link Industry-Academia Collaboration Projects during 2016, an inventory of R&D results not involving information and communications technologies found 2,502 results with industrialization potential, training in intellectual property knowledge and industrialization skills was provided to 181 university personnel, and a survey was performed of 104 companies' industrial technology needs. To harness the capabilities of five research institutions, the program established an industry-academic matchmaking service team in March 2016, which has thus far visited 150 university departments, provided consulting services in 200 cases, conducted 41 demonstration cases, and brought about NT$170 million in derivative technology licensing cases. It is projected that the benefits of R&D result industrialization derived from this program will reach NT$4.7 billion during the next five years.

IX Taiwan Innovation & Entrepreneurship Center Establishment Plan

The mission of the Taiwan Innovation & Entrepreneurship Center Establishment Plan is to rely on the Taiwan Innovation and Entrepreneurship Center in Silicon Valley to link startup teams in Taiwan with Silicon Valley's entrepreneurial resources, such as by helping Taiwan's startup teams to occupy Silicon Valley's famous startup accelerators, immersion of startup teams in Silicon Valley's innovative startup ecosystem, and fostering interchange with entrepreneurs from around the world. At the same time, the plan will help Taiwan's startup teams to enhance their international profile and expand their international markets.

Since the Taiwan Innovation and Entrepreneurship Center in Silicon Valley was established on June 19, 2015, it has conducted six rounds of selection procedures, and has selected 55 startup teams to continue their business development in Silicon Valley. These teams have received a cumulative total of more than US$38.0 million in funds raised internationally. In addition, 23 other teams have entered Silicon Valley's most prominent accelerators.

Looking ahead to the future, in line with Taiwan's "Asian Silicon Valley" policy direction, MOST will continue to take the establishment of links to Silicon Valley's innovative entrepreneurial resources as an important objective, and hopes to gradually steer Silicon Valley's entrepreneurial manpower, technology, and funds back to Taiwan. MOST also hopes to transplant some of Silicon Valley's entrepreneurial culture, and hopes that young entrepreneurs in Taiwan will gradually be infected by the Silicon Valley spirit of bold adventure and lack of fear of failure.

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Chapter 5 Development of Taiwan's Science Parks

Hsinchu Science Park

Southern Taiwan Science Park

Central Taiwan Science Park

Taiwan's science parks were established for the purpose of attracting high-tech industries and manpower, encouraging domestic technological innovation, promoting industrial upgrading, balancing regional development, and achieving nationwide economic growth. Among the three science parks, the Hsinchu Science Park (HSP) is a hotbed of the semiconductor and optoelectronics industries; the Central Taiwan Science Park (CTSP) specializes in optoelectronics, aerospace, and precision machinery; and the Southern Taiwan Science Park (STSP) is a stronghold of the optoelectronics industry. These three science parks provide key industries with advantageous home bases, form a high-tech corridor extending from north to south in western Taiwan, and are in the forefront of creating new opportunities for the nation's economic development.

Hsinchu Science Park

Hsinchu Science Park (HSP) is widely acclaimed as one of the world's most successful science parks. Its formidable industry clusters possess unique competitive advantages, and its tenant firms have achieved many successes in product R&D and international market competition. Many products made in HSP have leading global market shares, and its semiconductor industry has become a crucial supply chain member in the global market.

The Hsinchu Science Park comprises six sites, which include the fully-developed 653-hectare Hsinchu site, 123-hectare Zhunan site, the 38-hectare Hsinchu Biomedical Science Park, and the 71-hectare Yilan site, as well as the under-development Tongluo site (308 ha already developed, 42 ha still being developed) and Longtan site (76.2 ha already developed, 30.8 ha still being developed). As of the end of 2016, a total of 147,624 persons were employed at the park (excluding persons working in industrial and commercial services), and the 487 companies operating in the park had cumulative paid-in capital of NT$1.993 trillion and total operating revenue of NT$1.04 trillion. In 2016, 30 companies made new investments totaling NT$5.32 billion, and training was provided 8,446 person times.

The Hsinchu Science Park Bureau (HSPB) has a vision of "creating an innovative, entrepreneurial, pioneering science park," and strives to promote innovation and upgrading of industry. Apart from steadily acquiring flagship, innovative domestic and foreign innovative companies, HSPB established the "Bamboo Dragonfly" (Young Entrepreneur's Studio, YES) on December 24, 2015 in conjunction with MOST's "From IP to IPO" program to provide innovative startup teams with an attractive, thoughtful working environment. As of December 2016, a total of 205 entrepreneurial teams had set up operations in the park or received HSP assistance, and 89 teams had established companies, of which 76 companies are still operating. If these companies can quickly grow and achieve positions of strength, this will inevitably spur a renewed surge in entrepreneurial activity, which will help drive the innovative transformation of Taiwan's industries. Furthermore, HSPB received the "Service Planning Agency" award in the Executive Yuan 8th Government Service Quality Awards on the strength of its "Finding Opportunities for Young Entrepreneurs—Nesting High-tech Venture Startups at the Hsinchu Science Park" project.

The Hsinchu Biomedical Science Park has already accepted 40 tenant firms, which have made investments totaling NT$15.19 billion, and another 23 firms at the incubation stage are also operating inside the park. The Biomedical Science Park has a total area of 38.1 ha, of which 24.1 ha is available for assignment or leasing. A total of 16.8 ha have already been leased out (for a 69.7% leasing rate). Amaran Biotechnology and Medigen Vaccine Biologics have begun operations in self-built buildings, and Gwoxi Stem Cell, ACE Solution, and EirGenix broke ground on buildings in May, July, and December respectively. Furthermore, TaiMed Biologics, Liverage Biomedical, and Chinan Biomedical Technology are applying for land in the park, which underscores the fact that new drug and high-end medical device industry clusters are gradually forming in the park.

Overview of Hsinchu Science Park Industries, 2016

Item	Companies	Number of employees[1]	Capital (NT$100 m)	Revenue (NT$100 m)	Revenue growth (%)
Integrated circuits	185	87,608	6,445	8,009.38	-5.15
Computers and peripherals	51	9,870	849	373.83	-2.87
Telecommunications	45	7,001	237	305.44	-29
Optoelectronics	88	37,902	3,144	1,894.51	-0.12
Precision machinery	40	3,132	87	276.6	5.27
Biotechnology	73	3,307	202	91.29	9.74
Other	5	280	25	61.32	2.32
Total	**487**	**149,100**	**10,989**	**11,012.37**	**-5.34**

[1]Number of employees does not include industrial and commercial service personnel.

Growth of the Hsinchu Science Park, 2011-2016

Item	2011	2012	2013	2014	2015	**2016**
Revenue (NT$100 m)	10,346	10,588	11,125	11,633	11,012	**10,395**
Increase or decrease (%)	-13	2	5	4.57	-5.34	**-5.94**
Number of companies	477	485	481	489	478	**487**
Increase or decrease (%)	2	6	2	-1	-2	**1**
Number of employees[1] (person times)	145,537	148,104	148,608	149,116	149,100	**147,624**
Increase or decrease (%)	7	2	1	1	0	**-1**

[1]Number of employees does not include industrial and commercial service personnel.

Hsinchu Biomedical Science Park from the air

11 Southern Taiwan Science Park

The Southern Taiwan Science Park (STSP), which includes Tainan and Kaohsiung sites, has successfully stimulated industrial development in southern Taiwan since its establishment in 1997. Twenty-one more firms (including four startups) were approved to occupy the park's Tainan and Kaohsiung sites in 2016, and the park now has a cumulative total of 210 tenant companies, of which 185 have already occupied sites and begun operations. The revenue earned by park companies during the year totaled NT$829.6 billion, which represented growth of 16% compared with 2015. As of the end of 2016, 576.7 hectares of land in the park had been leased out, and the leasing rate had reached 88.92%.

The establishment of this science park has boosted the regional economy, stimulated peripheral industries, and promoted cultural development. MOST hopes that Taiwan's science parks will lift Taiwan's product and technological standards, and catalyze the formation of numerous high-tech industry clusters. STSP is expected to gradually develop into a multifunctional park featuring both R&D and production, and serve as production site for existing high-tech industries. In addition, to ensure that the park's technological personnel and other employees settle and work in the area, the peripheral area has been designated a special district, which will contain high-quality, low-density residential communities suitable for high-tech personnel. MOST hopes that STSP and the adjacent special zone will form a high-tech garden city combining production, research, and living. STSP's industrial development features include the following:

A. Gradual Transformation into An Innovative, Entrepreneurial Park

In conjunction with MOST's "From IP to IPO" (FITI) program, STSP has established links with the entrepreneurship resources of relevant agencies and local governments, the equipment of R&D organizations, and the resources of park companies, and provides prototype production, small-scale trial production, funding infusions, and entrepreneurship assistance services, as well as the "Southern Taiwan Innovative Startup Service Platform". From 2013 to the end of 2016, STSP has helped 91 teams occupied startup spaces in the park, of which 32 teams have been promoted to the top-10 best startups among their cohorts in the FITI program, 16 teams obtained NT$2 million in startup funds, and 37 teams completed company registration (with total capital of NT$919.5 million); 6 startups have become tenant firms, and 8 startups have occupied the park's incubation center.

B. The World's Foremost Dedicated Foundry Site

STSP currently contains 18 semiconductor plants. The Taiwan Semiconductor Manufacturing Co. (TSMC) has invested a cumulative total of more than NT$500 billion in the Tainan site, and its No. 14 plant is currently using sub-20 nm advanced semiconductor processes (the No. 14 plant's phase I-VII and advanced packaging plant are in mass production). The United Microelectronics Corp. (UMC) has invested a cumulative total of more than NT$240 billion in the Tainan site, and phase I-VI of its No. 12A plant are all in mass production. With these two leading foundries both continuing to boost their investment, the semiconductor industry will continue to develop in STSP, maintaining STSP's role as a key international wafer foundry site.

C. Taiwan's Most Complete Optoelectronic Industry Cluster

Mildex Optical has built a new touch-control panel plant at the Kaohsiung site, and Innolux has invested NT$80 billion in construction of a low-temperature polysilicon (LTPS) panel plant in addition to its existing 8.5th-generation and new 8.6th panel plants. The Kaohsiung site has become the location of an advanced panel industry cluster, and new panel plants are expected to add 3,000 jobs.

D. Biotech/Device Equipment Industry Cluster Goes International

STSP has successfully established an integrated biotech/medical device industry cluster service platform establishing linkage between industry, academia, research, and medical organizations, and performing KOL (key opinion leader) marketing, which has established an innovative medical device development environment. STSP has further initiated a funding program fostering clinical innovation and has established an experience sharing and diagnostic hotline aimed at boosting the reliability and market share of medical devices. As of the end of 2016, the medical device cluster contained 51 firms, which had made investments totaling NT$9.6 billion. The cluster's output has grown steadily during recent years, and revenue reached NT$2.71 billion in 2016, which represented an increase of 35% compared with the NT$2.01 billion figure for 2015. Four STSP firms have passed the Ministry of Health and Welfare's artificial tooth root inspection registration, 29 firms have passed GMP (Good Manufacturing Practice) certification, six firms have passed qualifications

review under the Biotech and New Pharmaceutical Development Statute, 31 firms have received sales permits from the Taiwan Food and Drug Administration (TFDA), 10 firms have received sales permits from the US Food and Drug Administration, and 18 firms have received European Union certification, which shows that the medical device industry cluster is poised for success.

Overview of Southern Taiwan Science Park Industries, 2016

Item	Approved companies	Employment	Capital (NT$100 m)	Revenue (NT$100 m)	Revenue growth rate (%)
Integrated circuits	18	22,650	9,765.64	5,067.85	36.98
Optoelectronics	54	42,296	2,375.56	2,657.23	-10.01
Computers & peripherals	2	291	30	16.54	2.97
Telecommunications	11	1,351	77.05	56.76	-24.14
Precision machinery	52	7,244	207. 34	380.40	23.63
Biotechnology	66	2,226	260.73	91.26	19.84
Other[1]	7	2,374	33.2	25.60	5.53
Total	**210**	**78,432**	**12,749.52**	**8,295.63**	**16.00**

[1] Other industries include other scientific industries and other park enterprises.

Growth of the Southern Taiwan Science Park, 2012-2016

Item	2012	2013	2014	2015	**2016**
Revenue (NT$100 m)	6,219.63	6,151.21	6,394.38	7,151.37	**8,295.63**
Increase or decrease (%)	7.34%	-1.1%	3.95%	11.84%	**16%**
Number of companies	186	185	196	204	**210**
Increase or decrease (%)	4%	-0.5%	6%	4%	**3%**
Employment (persons)	64,887	70,896	78,992	79,877	**78,432**
Increase or decrease (%)	4%	8%	10%	1%	**-2%**
Manpower training [1] (person times)	1,606	1,369	1,315	1,318	**1,361**
Increase or decrease (%)	-8%	-15%	-4%	0.2%	**0.7%**

[1] Manpower training figures do not include participation in advanced technical lectures or talks by benchmark corporate leaders.

Central Taiwan Science Park

Established in 2003, the Central Taiwan Science Park (CTSP) seeks to gather high-tech companies and manpower, encourage domestic innovation, promote industrial upgrading and balanced regional development, and contribute to the country's economic growth. CTSP has continuously striven to maintain an international outlook and combine the four functions of production, living, the ecology, and life in one superior industrial and research park.

Twenty more companies received approval to occupy sites in the park during 2016, giving it a cumulative total of 189 firms, of which 136 have

already registered to occupy sites in park. Tenant firms had revenue of NT$507.4 billion in 2016, which represented growth of 3.10% compared with 2015.

A. Park Firms Enjoy Steady Revenue Growth

CTSP's tenant firms had revenue of NT$507.4 billion in 2016, and this figure was up by 3.10% compared with 2015. This growth was largely fueled by rising demand for smart handheld mobile devices, which caused orders to increase throughout the semiconductor industry supply chain, including the wafer fab and packaging and testing segments. As a consequence, 28 nm foundries in the park were operating at full capacity, and enjoyed growing sales.

B. Outstanding Recruiting Results

CTSP has successfully acquired numerous domestic and foreign high-tech tenant companies in recent years. As of the end of 2016, the park had approved occupancy by 189 companies, which included 38 optoelectronics firms, 70 precision machinery firms, 40 biotech firms, 8 integrated circuits firms, 16 computer and peripheral firms, 2 communications and digital content firm, and 15 other enterprises. Industry clusters are forming rapidly, and achieving a strong competitive advantage. In addition, CTSP has bolstered its R&D capabilities through the acquisition of 14 research organizations and incubation centers. Advanced research within CTSP is exemplified by the Institute for Information Industry's "Emerging Smart Technology Research Center," the Industrial Technology Research Institute's "Central Taiwan Industrial Innovation R&D Zone," and companies such as Allion Computer, Taiwan Mother Cosmo, Hsinnjy Nonwoven, Gain Science Technology, Taiwan Mother Cosmo, and CH Biotech. In addition, CH Biotech also broke ground on a new R&D laboratory in September 2016. Twenty more enterprises entered the park during 2016, of which six were biotech firms, five were precision machinery firms, two each were optoelectronics, integrated circuits, and computer and peripheral firms, and three were park enterprises. These companies plan to make new investments worth NT$3.94 billion. Furthermore, another seven companies increase their capital by approximately NT$1.6 billion. Newcomer enterprises in 2016 included nine startups, among which was Sunder Biomedical. Foreign enterprises making new investments in the park included the American firm Jabil Green Point and the French firm Balaisi Asia. It is evident that CTSP is enjoying robust growth, and it has also made a significant contribution to the Greater Taichung area's economic growth and employment in Taiwan as a whole.

C. Expansion of The Taichung Park

Following the initiation of a Taichung park expansion project in 2015, a prioritized flood detention pond also used for water conservation was completed at the start of this round of development. Furthermore, in order to accelerate implementation of the project as a whole, it is being conducting concurrently with construction work by a park firm (TSMC). Thanks to excellent communication and coordination between the two parties, difficulties concerning the construction interface and entry/exit routes have been overcome. The water conservation facility for the first stage of development was completed and inspected on the eve of the 2016 Lunar New Year holiday, and drainage, flood detention, and sedimentation facilities for the first stage of expansion have been constructed.

The first stage of public construction work was completed in September 2016. TSMC has concurrently completed its first stage of plant expansion work, and has acquired production equipment and operating personnel. As a result, the expansion area has already been gradually providing employment opportunities and economic benefits, and will make a tangible contribution to the development of Taiwan's integrated circuits industry.

The second stage of public construction work is proceeding rapidly, and CTSP is making use of the experience gained with concurrent private development during the first stage. It is expected that water conservation facilities, a tap water treatment and pressurization facility, and pipelines for the second stage of expansion will be completed during 2017, and will increase the water supply capacity in the expansion area. TSMC plans to implement plant construction concurrently with expansion work, and a second company (Giant Bicycles) plans to build its global headquarters in the area. This project is one of the examples of the Science Park Bureau working with park enterprises to fulfill its vision of a flourishing CTSP.

D. Building A Smarter Park; Continuing Improvement of Services

Various smart park projects have been underway since 2016, and a smart parking system has already been completed. In order to build the infrastructure for a smart park, CTSP has installed 163 wireless broadband hotspots and a system management server, which enables the public to use the Internet quickly and conveniently throughout the park. With regard to smart disaster prevention, CTSP has completed the establishment of an autonomous, intelligent water status system, and has installed sensors at key locations at the Huwei site to provide real-time monitoring of water levels. The information from these systems will be used to remind enterprises to adopt response measures aimed at minimizing losses in the event of possible flooding.

Looking ahead to the future, even more smart facilities will be established at CTSP, such as a demand responsive transit system employing

electric buses, and smart water and power usage systems, which will ensure that CTSP has a superior investment environment. CTSP will also continue to promote various innovative services in conjunction with the implementation of smart park projects. The Science Park Bureau will strive to strengthen the competitiveness of the park's recruiting and services as it works to meet the service needs of park companies and boost the livability of the park and surrounding areas, and will continue efforts to fulfill its vision of a smart park with even better services.

E. Completion of The Erlin Site through The Xiangsiliao Sale Project

With respect to the Xiangsiliao sale project at the Erlin site, which is being conducted under the oversight of the Executive Yuan, although the project has encountered certain difficulties and issues, government agencies have managed to jointly resolve outstanding problems after numerous instances of interagency coordination. As a result, the project's goal of preservation of Xiangsiliao Village at its original site, residents' retention of farmland at a different location, and the Nongchang Lane sale were successfully achieved in November 2016. This has allowed those Xiangsiliao residents who engage in agriculture to continue farming, displayed the government's commitment to farmers and fulfillment of its pledge to let residents stay in their homes, maintained the right of rural residents to live in their homes and engage in agriculture, and created an example of the coexistence of economic development and agriculture.

Overview of Central Taiwan Science Park industries, 2016

Item	Companies	Employment	Capital (NT$100 m)	Revenue (NT$100 m)	Revenue growth rate (%)
Integrated circuits (semiconductors)	7	13,625	1,120	3,003.44	8.69
Computer and peripherals	12	1,299	17.87	34.53	11.43
Telecommunications	1	111	0	0.76	-31.12
Optoelectronics	32	17,476	572.13	1,751.75	-5.48
Precision machinery	44	5,180	102.83	238.22	1.09
Biotechnology	27	1,796	61.08	31.25	30.28
Other[1]	13	469	9.30	13.72	7.37
Total	**136**	**39,956**	**1,883.21**	**5,073.67**	**3.10**

[1] Other" industries include other scientific industries and other park enterprises.

As of the end of 2016, the park had approved occupancy by 189 companies and 14 research organizations and incubation centers, and cumulative investment had reached NT$2.48 trillion—which showed the outstanding results of CTSP's recruiting efforts.

Growth of the Central Taiwan Science Park, 2012-2016

Item	2012	2013	2014	2015	**2016**
Revenue (NT$100 m)	3,233.26	4599.08	5,220.70	4,921.17	**5,073.67**
Increase or decrease (%)	11.07	42.24	13.52	-5.74	**3.10**
Number of companies	140	158	174	180	**189**
Increase or decrease (%)	12	13	10	3.45	**5**
Research organizations & incubation centers	14	14	14	14	**14**
Increase or decrease (%)	7.7	0	0	0	**0**
Number of employees	28,751	31,242	32,260	33,018	**39,956**
Increase or decrease (%)	7.35	8.66	3.26	2.35	**21.01**
Manpower training[1] (person times)	837	645	635	631	**706**
Increase or decrease (%)	-38.04	-22.94	-1.57	-0.63	**11.89**

[1] For persons employed in the park.

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