MOST 科技部
Ministry of Science and Technology

2018 ANNUAL REVIEW

Innovation and Technology

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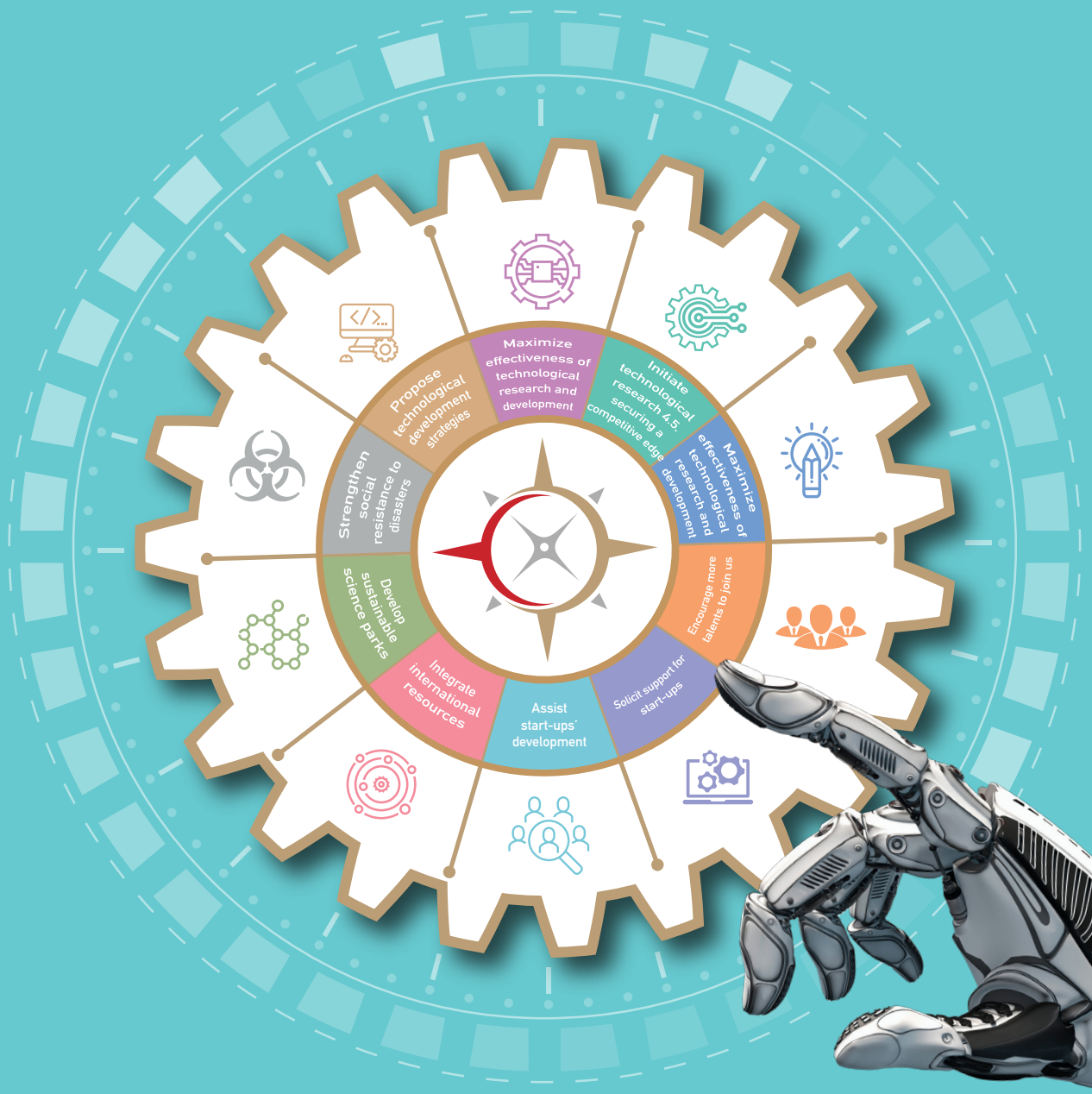
Growth Economy



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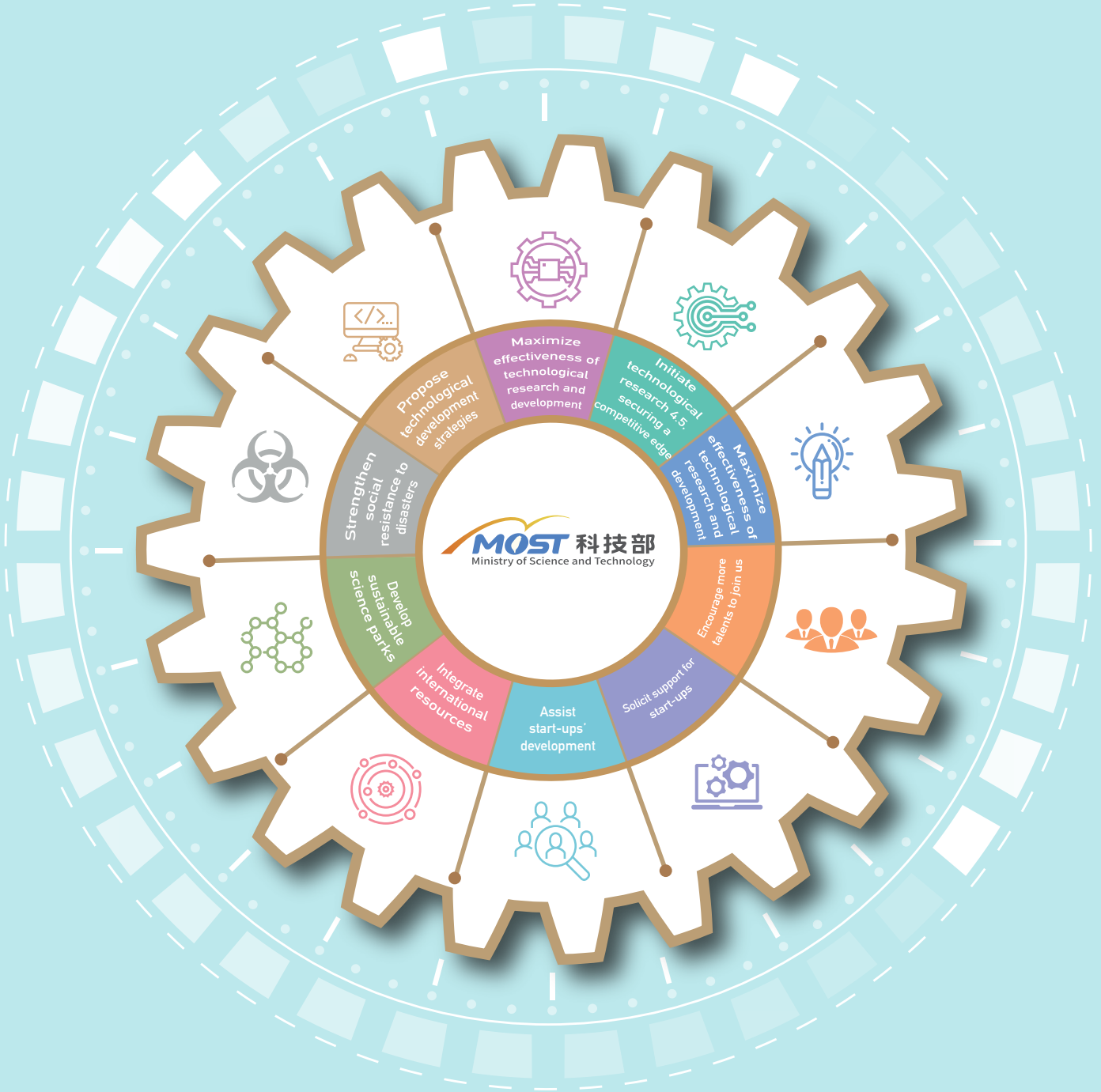

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Foreword

Minister

陳良基

Liang-Gee Chen

Science and technology are the greatest forces of progress in human society. In the face of intense worldwide competition and rapid environmental changes, in accordance with the "Small Economy, Smart Strategy" concept, the Ministry of Science and Technology (MOST) has focused its attention on areas in which the country has existing advantages. While continuing to lay the groundwork for basic research and promote scientific research innovation, MOST is also drawing on the R&D capabilities of international industry, universities, and research institutions, as well as cultural content, to train pragmatic and competent S&T personnel, vigorously create healthy innovation ecosystems, and thereby encourage linkage between advanced technologies and industry, while ensuring that science and technology drives the country's economic growth and progress.

MOST is striving to cultivate the scientific human resources needed in the future, accumulate innovative capabilities, and develop an ecosystem in which scientific research manpower can circulate freely, which is reflected in the three strategies of "creating an R&D-friendly environment," "active participation in global research," and "enhancement of Taiwan's international academic prestige." By nurturing an environment in which the country's scientific research manpower can thrive, MOST is ensuring that Taiwan has favorable conditions for scientific research.

With the revision of the *Fundamental Science* and *Technology Act* and subsidiary regulations, adjustments to regulations governing technology licensing and the holding of concurrent positions by research personnel, research integrity regulations, changes to the project review system, and loosening of project funding regulations will help encourage projects led by young scientists, artificial intelligence R&D and applications, and the Global Research & Industry Alliance (GloRIA) program. MOST has also drafted a roadmap for the development of Taiwan's science parks during the next ten years, strengthened the international mobility of scientific research personnel, and helped Taiwan attract and cultivate more next-generation research talent.

In order to boost science and technology as a force for national development, MOST has actively and continuously filled investment gaps in private basic research and development, and funds four types of basic research: "curiosity-driven exploratory research, directed research, core facilities and common-use resources, and basic scientific research personnel and international interchange," with the goals of creating an environment for free exploration and broadening and deepening basic research. Furthermore, in order to strengthen the service capabilities of universities and research institutions, MOST has been steadily building up national-level core experimental facilities and shared resources, which will increase the synergy of research resources.

In MOST's mission of nurturing innovative startups and creating S&T innovation ecosystems, apart from strongly promoting the Global Research & Industry Alliance, New Industry-university Cooperative Research Linking Program, large and small university-industry collaboration alliance projects, the Academic Research Results Industrialization and Values Enhancement (ARRIVE) program, and Innovative business model Development Enterprise-Academic collaboration projects (IDEA), MOST has also sought to reinforce the international linkage of industry and universities in Taiwan. MOST is further integrating universities' R&D capabilities, developing innovative service models, and encouraging the verification and industrial application of industry-academic R&D results in science parks, which will promote the development of industry-academic collaboration in science parks.

Because building the nation on a foundation of science and technology is a long-term project, MOST has taken the three concepts 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, building bridges to the world of the future" as its guiding principles in its promotion of major policies. While boosting the prestige and international visibility of Taiwan's academic research and scientific research results, MOST will also join forces with academic and research partners in Taiwan and abroad for the purpose of linking resources, maintaining a presence on the world stage, and establishing links to the world of the future.

Chapter 1
Overview

Chapter 1 / Overview

I. Science and Technology Development Policies

The arrival of the knowledge age will accelerate both scientific and technological progress and social changes, while also bringing new challenges and opportunities. Under these circumstances, the government must adopt a "Small Country, Big Strategy" way of thinking, and integrate resources from all parts of society in order to promote economic growth, maintain Taiwan's global creative leadership, and pursue a future vision of intelligence, health, and sustainability, while maintaining the country's leading status in the world of science and technology. According to the IMD's 2018 *World Competitiveness Yearbook*, apart from ranking 17th globally in terms of overall competitiveness, out of four major categories, Taiwan ranked best—12th place—in terms of "government efficiency," and 10th and 18th in the S&T-related categories of "scientific infrastructure" and "technological infrastructure." Furthermore, according to the *Global Competitiveness Report, 2018* issued by the World Economic Forum (WEF), Taiwan ranked 13th overall in terms of 12 indicators—ahead of South Korea and China—and also ranked 1st in the category of "macroeconomic stability." And while many countries fared poorly in the category of "innovation capability," Taiwan ranked 4th, and was included by the WEF in a select group of "Super Innovators," along with Germany, the United States, and Switzerland. However, in spite of the steady progress being made by science and technology in Taiwan, in view of the global situation and rapid development of S&T, there are still many problems and challenges that remain to be overcome.

A. Taiwan's S&T Development Challenges

1. R&D and innovation

Innovation is a driver of S&T development and economic growth, and is the key to maintaining national competitiveness. Due to rapid changes in the global environment and S&T, Taiwan must develop its competitive advantage by making the best use of its limited resources, selecting fields in which it will have the best opportunity and potential for success, and focusing on breakthroughs. Applying the "3D1C" framework, Taiwan must develop its basic scientific research capabilities (Discovery), uncover and deploy emerging science and technology (Development), respond to contemporary problems and future challenges (Delivery), and strive to promote socioeconomic development (Commercialization) in order to create an all-round scientific research and innovation ecosystem.

2. Manpower training and recruiting

Human resources are the cornerstone of national development, and are essential drivers of innovation in industry and scientific research. Although Taiwan must depend on superior human resources if it is to realize the UN's Sustainable Development Goals (SDGs), the active recruiting of professional manpower by many countries is exerting a magnet effect on personnel in Taiwan, leading to a situation of high manpower outflow and low influx. In addition, a gap still exists between industry and the educational system, and the trend toward smaller families has resulted in

insufficient manpower to meet industry's needs. Accordingly, Taiwan must continue to improve its human resources selection, training, and retention policies, create an environment suitable for living and working, and take other steps to enhance its human capital.

3. Industrial development and transformation

As new technologies such as the Internet of Things, artificial intelligence, and robotics reach maturity, they will initiate a fourth industrial revolution, and international trends, including "re-industrialization" and "manufacturing reshoring," are set to accelerate industry's shift to intelligent operations and higher value, which will transform global value chains and industry ecosystems. The government must monitor international S&T trends and lay a foundation for the innovation economy, such as by fine-tuning laws and regulations, training more manpower, and promoting innovation incentive policies, and must also integrate the resources of society, use science and technology to reinforce the nation's foundation, establish a model of economic sustainable development, and accelerate industrial upgrading and transformation.

4. Living and the environment

Because of global warming and climate change, as well as the effects of urbanization, environmental pollution has intensified, leading the UN to appeal to countries to include protections for the ecological environment in addition to promoting economic growth and enhancing social welfare when drafting national development policies. The government must consequently strengthen its disaster mitigation and resilience capabilities, accelerate the development of a circular economy, and put the recycling system on a sound footing. Furthermore, responding to demographic aging and food safety and information security threats, the government must make effective use of S&T to resolve related problems, improve the social support system, and create a safe and confidence-inspiring living environment.

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

In accordance with the *Fundamental Science and Technology Act*, the government must draft a National Science and Technology Development Plan once every four years to serve as a basis for the drafting of S&T policies and the promotion of S&T research and development, and must propose its science and technology development vision, strategies, and description of the current situation once every two years. While the Executive Yuan approved the most recent National Science and Technology Development Plan on September 7, 2017 (2017-2020), the rapid pace of S&T innovation and changes in the global environment has forced the government to perform a review and rolling revision of the National Science and Technology Development Plan on the basis of the "Strategic Blueprint for the Development of Science and Technology" (originally the White Paper on Science and Technology) two years after the drafting of the Development Plan in order to ensure the sustainability and appropriateness of policies.

Based on a human-centered perspective, the current Strategic Blueprint for the Development of Science and Technology (2019-2022) proposes the use of science and technology to respond to the needs of society, promote economic development, and resolve problems facing the public, and calls for the drafting of response strategies in the five areas of "health and social security," "industry and the economy," "energy, resources, and the environment," "education and culture" and "infrastructure" in order to achieve the goal of an intelligent, healthy, and sustainable society. The following is a summary of these strategies:

Health and social security

Strengthening of food safety and information security protection systems, protection of the public's everyday safety, integration of disease prevention, medical, and healthcare resources in order to upgrade the social support system, and enhancement of the public's media assessment capabilities in order to create an effective information ecosystem.

Industry and the economy

Fine-tuning relevant laws and regulations in order to more effectively accumulate human capital, promotion of the development of a circular economy, financial technology, and new types of business models, and use of intelligent technologies to stimulate industrial upgrading and the development of distinctive regional industrial ecosystems.

Energy, resources, and the environment

Perfecting the environmental monitoring and disaster prevention system, and strengthening energy conservation and the generation of diversified forms of energy in order to help create a livable, sustainable environment.

Education and culture

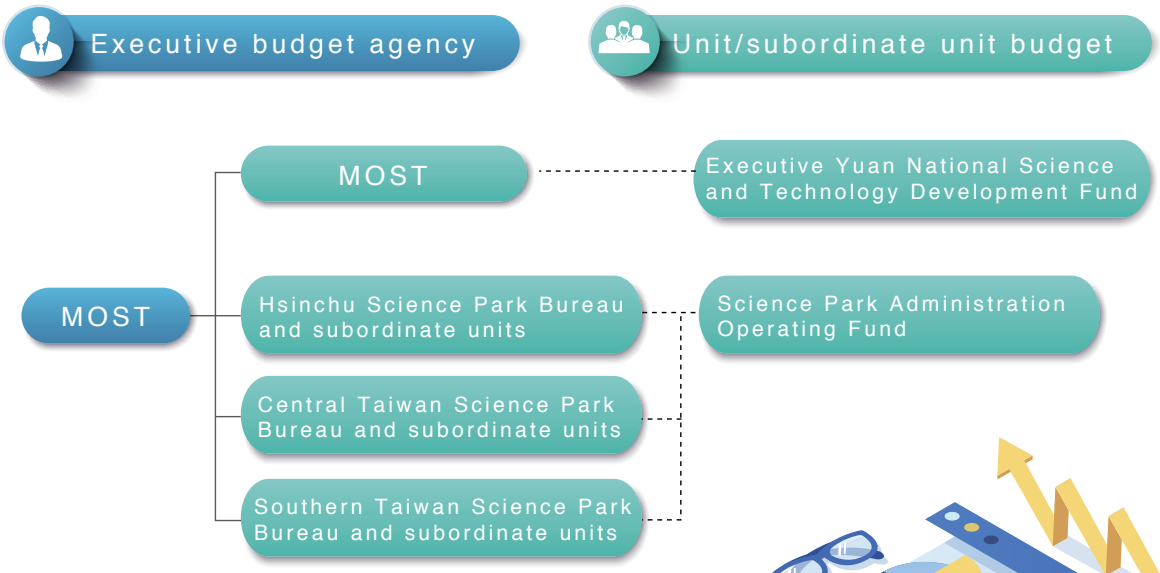
Promotion of a cultural S&T policy, creation of interdisciplinary, inclusive ecosystems, and strengthening of high-level manpower training and recruiting in order to strengthen scientific research and industrial innovation capabilities.

Infrastructure

Adjustment of S&T laws and regulations, shaping of a basic environment fostering innovation, and integration of cross-disciplinary capabilities and resources in order to strengthen the development of intelligent cites and stimulate regional development.

II. Funding

In 2018, 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. 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.



*1 Dotted lines indicate subordinate unit budgets.
*2 The three subordinate units consist of the Science Park Experimental High School, Central Taiwan Science Park Experimental High School, and Southern Science Park International High School.

MOST's executive income budget for 2018 was NT$130 million, which was an increase of NT$4 million (2.7%) from the NT$126 million income budget of the previous year. This income budget included fine and compensation income of NT$30 million, which included compensation for late vendor deliveries; fee income of NT$20 million, which included construction licenses and establishment and status change registration fees paid by science park companies; property income

of NT$20 million, which included royalty income from the commissioned operation of science park exhibition centers and the leasing of space in science park office buildings; and other income of NT$60 million, which included tuition and fees at science park experimental high schools.

Annual MOST executive income budgets, 2014-2018 Units: NT$100 m

Item	2014		2015		2016		2017		2018	
	Amount	Increase %	Amount	Increase %	Amount	Increase %	Amount	Increase %	Amount	Increase %
Fines and compensation	0.1	-37.5	0.2	33.3	0.3	45.0	0.3	-6.9	0.3	4.9
Fee income	0.4	-9.5	0.3	-26.3	0.2	-7.1	0.2	-11.5	0.2	-16.5
Property income	0.8	77.3	0.3	-52.6	0.4	13.5	0.2	-47.6	0.2	-5.2
Other income	0.5	-25.4	0.5	2.1	0.5	-2.1	0.6	14.9	0.6	13.0
Total	**1.8**	**2.9**	**1.3**	**-25.3**	**1.4**	**8.3**	**1.3**	**-12.5**	**1.3**	**2.7**

MOST's executive expense budget for 2017 was NT$39.6 billion, which was a decrease of NT$10.7 billion (21.2%) compared with the NT$50.2 billion budget of the previous year. Of this budget, the MOST expense budget accounted for NT$36.7 billion, and was mainly used to fund the National Synchrotron Radiation Research Center and National Applied Research Laboratories (NARLabs), and provide additional allocations from the national treasury to the National Science and Technology Development Fund for S&T project funding. The HSPB and subordinate unit budget was NT$1.44 billion, which was chiefly used for various science park services and the construction of a second biotech building at the Hsinchu Biomedical Science Park. The CTSPB and subordinate unit budget was NT$580 million, and was mainly used for park services. The STSPB and subordinate unit budget was NT$800 million, and was mainly used for park services.

Annual MOST executive expenditure budgets, 2014-2018 Units: NT$100 m

Item	2014		2015		2016		2017		2018	
	Amount	Increase %	Amount	Increase %	Amount	Increase %	Amount	Increase %	Amount	Increase %
MOST	405.5	-4.1	456.0	12.5	436.1	-4.4	477.5	9.5	367.3	-23.1
HSPB and subordinate units	11.8	-33.5	8.8	-25.1	9.2	4.3	10.7	15.7	14.4	34.2
CTSPB and subordinate units	12.0	4.0	14.1	16.9	13.2	-6.0	6.1	-53.4	5.8	-5.5
STSPB and subordinate units	11.1	19.9	11.2	0.7	8.0	-28.7	7.8	-1.9	8.0	2.6
Total	**440.4**	**-4.5**	**490.1**	**11.3**	**466.5**	**-4.8**	**502.1**	**7.6**	**395.5**	**-21.2**

The National Science and Technology Development Fund received NT$34.5 billion in 2018, which chiefly consisted of appropriations from the national treasury and R&D results income. The fund's disbursements of NT$40.6 billion were chiefly used for the promotion of overall S&T progress, the training, recruiting, and rewarding of S&T personnel, and projects to improve the research and development environment.

National Science and Technology Development Fund budget, 2014-2018 Units: NT$100 m

Item	2014		2015		2016		2017		2018	
	Amount	Increase %	Amount	Increase %	Amount	Increase %	Amount	Increase %	Amount	Increase %
Source of funds	343.6	-4.5	390.8	13.7	372.2	-4.8	422.8	13.6	344.6	-18.5
Government appropriations	327.4	-4.1	376.5	15.0	353.7	-6.1	406.0	14.8	327.4	-19.4
Other[1]	16.2	-10.7	14.3	-11.5	18.5	29.4	16.8	-9.3	17.2	2.1
Fund uses	369.1	0.1	428.7	16.1	383.7	-10.5	451.8	17.7	406.3	-10.1
Promotion of development	332.2	0.6	393.0	18.3	344.1	-12.4	408.1	18.6	362.7	-11.1
Manpower training	22.3	-6.6	22.0	-1.7	22.3	1.7	30.4	36.1	31.1	2.1
Environment improvements	14.0	-0.2	13.2	-6.2	16.7	26.6	12.7	-24.0	12.0	-5.6
Administration & management	0.6	1.8	0.5	-8.6	0.6	3.8	0.6	0.00	0.5	-1.2
Surplus/ shortfall for period（-）	**-25.5**		**-37.9**		**-11.5**		**-29.0**		**-61.7**	

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

MOST's final executive income figure for 2018 was NT$170 million, which represented an increase of NT$40 million compared with the budget number. This increase was chiefly attributable to larger-than-expected growth in breach of contract fine income used by NARLabs for funding procurement projects.

Annual MOST final income figures, 2014-2018 Units: NT$100 m

Item	2014		2015		2016		2017		2018	
	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	0.3	0.2	0.3	0.1	0.4	0.1	0.5	0.2	0.6	0.3
Fee income	0.2	-0.2	0.2	-0.1	0.1	-0.1	0.2	0.0	0.3	0.1
Property income	0.8	0.0	0.5	0.2	0.6	0.2	0.2	0.0	0.2	0.0
Other income	0.6	0.1	0.5	0.0	0.5	0.0	0.5	0.0	0.6	0.0
Total	**1.9**	**0.1**	**1.5**	**0.2**	**1.6**	**0.2**	**1.4**	**0.2**	**1.7**	**0.4**

MOST's final executive expenditure figure for 2018 was NT$39.4 billion, which represented a decrease of NT$130 million compared with the budget number. This decrease was chiefly attributable to surplus personnel funds and surplus funds from procurement cases.

Annual MOST executive final expenditure figures, 2014-2018 Units: NT$100 m

Item	2014		2015		2016		2017		2018	
	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	402.9	-2.6	455.5	-0.5	435.2	-0.9	476.6	-0.9	366.8	-0.5
HSPB and subordinate units	11.2	-0.6	8.5	-0.3	8.8	-0.4	10.5	-0.2	14.2	-0.2
CTSPB and subordinate units	11.5	-0.5	13.9	-0.2	12.8	-0.4	5.6	-0.5	5.3	-0.5
STSPB and subordinate units	11.0	-0.1	11.1	-0.1	7.8	-0.2	7.5	-0.3	7.9	-0.1
Total	**436.6**	**-3.8**	**489.0**	**-1.1**	**464.6**	**-1.9**	**500.2**	**-1.9**	**394.2**	**-1.3**

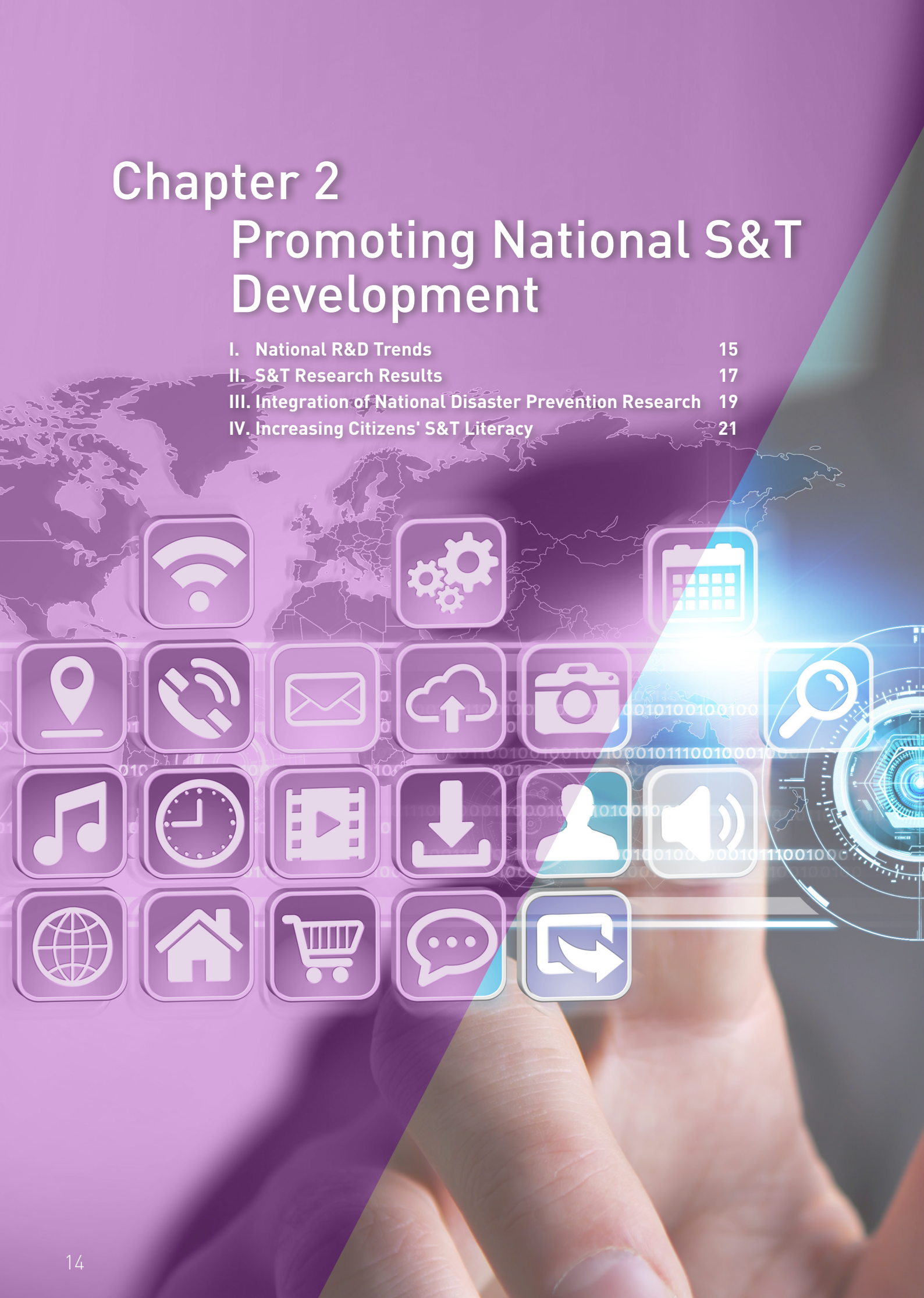
The Science and Technology Development Fund had a shortfall of NT$4.84 billion for 2018, which was a reduction of NT$1.33 billion compared with the budget shortfall of NT$6.17 billion. This difference was chiefly attributable to the fact that NT$1.03 billion in funding for the replacement of marine research vessels I, II, and III and the Taiwan Silicon Valley Technology Fund Investment Program was held over for continued processing until the following year due to service needs. In addition, there was an unexpectedly low number of funding applications for interagency S&T projects, and also a lower number of approved projects and lower funding amounts following proposal review.

Final Budget Numbers of the National Science and Technology Development Fund, 2014-2018 Units: NT$100 m

Item	2014		2015		2016		2017		2018	
	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	346.4	2.8	392.1	1.3	371.0	-1.2	429.1	6.3	351.6	7.0
Government appropriations	327.5	0.1	376.5	0.0	353.7	0.0	408.9	2.9	327.2	-0.2
Other[1]	18.9	2.7	15.6	1.3	17.3	-1.2	20.2	3.4	24.4	7.2
Fund uses	337.7	-31.4	391.4	-37.3	355.3	-28.3	412.7	-39.1	400.0	-6.3
Promotion of development	304.0	-28.2	355.6	-37.4	320.4	-23.7	372.3	-35.8	359.5	-3.2
Manpower training	21.9	-0.4	22.3	0.3	23.0	0.7	30.0	-0.4	29.8	-1.3
Environment improvements	11.2	-2.8	13.0	-0.2	11.4	-5.2	9.8	-2.9	10.2	-1.8
Administration & management	0.6	0.0	0.5	0.0	0.5	-0.1	0.6	0.0	0.5	0.0
Surplus/ shortfall for period (-)	**8.7**	**34.2**	**0.7**	**38.6**	**15.7**	**27.1**	**16.4**	**45.4**	**-48.4**	**13.3**

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

Chapter 2
Promoting National S&T Development



Chapter 2 / Promoting National S&T Development

I. National R&D Trends

A. National R&D Expenditures

Taiwan's total research and development expenditures increased steadily from NT$460 billion in 2013 to NT$577 billion in 2017, which had increased by 6.1% compared with 2016. The private sector's R&D expenditures totaled NT$421 billion during 2017, which represented growth of 8.2%, and the government had R&D expenditures of NT$115 billion, which represented a slight decrease of 1.7% compared with 2016. Private sector R&D expenditures as a share of the nation's total R&D expenditures increased from 78.4% in 2016 to 80.0% in 2017.

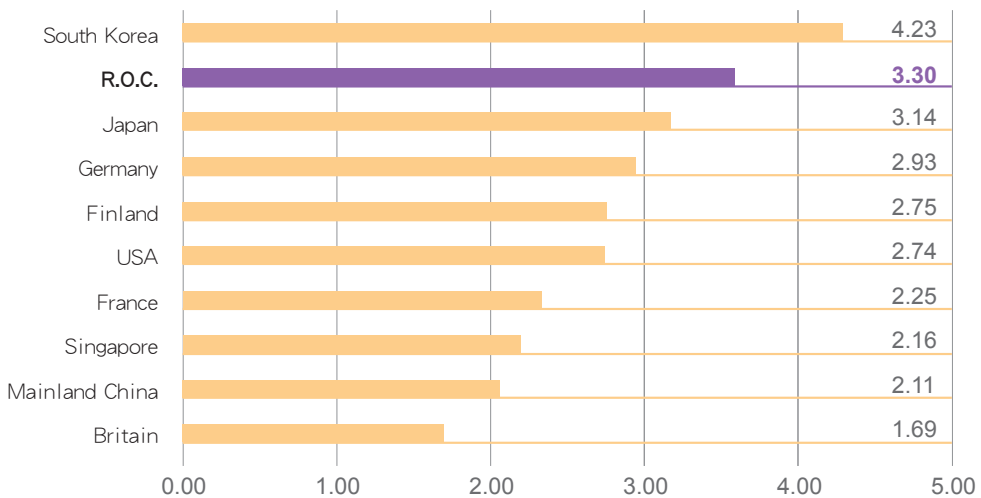
Taiwan's R&D expenditures as a share of GDP have increased steadily in recent years, and reached a historic high of 3.30% in 2017. Compared with other countries, in terms of R&D spending as a share of GDP, Taiwan lags behind South Korea, but is ahead of Japan, Germany, Finland, the US, France, Singapore, Mainland China, and Britain.

National R&D expenditures, 2013-2017

Item	2013	2014	2015	2016	2017
National R&D expenditures (NT$100 m)	**4,595**	**4,857**	**5,131**	**5,436**	**5,767**
As share of GDP (%)	3.02	3.01	3.06	3.16	3.30
By funding source (%)					
Government	23.6	22.0	21.4	21.6	20.0
Private sector	76.4	78.0	78.6	78.4	80.0

Source: *Indicators of Science and Technology*, ROC, 2018, MOST

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



Note: Apart from 2014 data for Singapore, the remaining data is for 2016.
Source: 1.Various countries: *Main Science and Technology Indicators*, 2018/1, OECD
2. Taiwan: *Indicators of Science and Technology*, ROC, 2018, 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 force over the years, and accounted for 58.8%-60.3% of R&D personnel during the most recent five years. The number of researchers grew over the most recent five years from 141,159 FTE (full-time equivalent) person-years in 2013 to 150,384 FTE person-years in 2017; the number of technicians grew from 80,909 FTE person-years in 2013 to 92,243 person-years in 2017; and the number of supporting staff grew from 12,180 FTE person-years in 2013 to 13,317 person-years in 2017.

The number of female researchers rose from 29,423 FTE in 2013 to 32,366 FTE in 2017, and the number of female researchers as a share of all researchers likewise rose from 20.8% in 2013 to 21.5% in 2017.

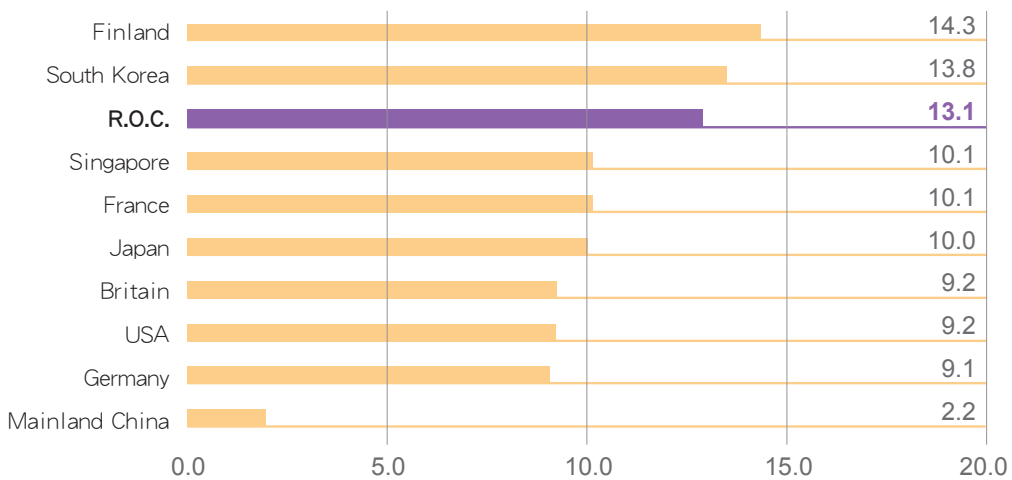
Compared with other countries, the number of FTE R&D personnel per 1,000 employed population in Taiwan was 13.2 person-years in 2017, which was lower than the equivalent figures for Finland and South Korea, but higher than the figures for Singapore, France, Japan, Britain, USA, Germany, and Mainland China during the 2014-2016 period.

R&D personnel in Taiwan, 2013-2017

Item	2013	2014	2015	2016	2017
FTE R&D manpower (person-years)	**234,248**	**240,528**	**245,941**	**251,042**	**255,943**
Researchers	141,159	142,983	145,381	147,710	150,384
Technicians	80,909	84,874	87,311	90,143	92,924
Supporting staff	12,180	12,671	13,249	13,189	13,317
FTE female research personnel (person-years)	**29,423**	**30,187**	**30,951**	**31,639**	**32,366**
Female research personnel as a share of all research personnel (%)	20.8	21.1	21.3	21.4	21.5
Number of researchers per 1,000 employment (person-years)	**12.9**	**12.9**	**13.0**	**13.1**	**13.2**

Source: *Indicators of Science and Technology, ROC*, 2018, MOST
Note: Because of effect of rounding, the sum of the given figures may not equal the total in some cases.

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



Note: Apart from 2014 data for Singapore, the remaining data is for 2016.
Source: *Main Science and Technology Indicators*, 2018/1, OECD

II. S&T Research Results

A total of 25,565 research papers by authors from Taiwan were contained in *Science Citation Index* (*SCI*) in 2017, giving Taiwan a global rank of 21st. A total of 16,652 research papers from Taiwan were cited in *Engineering Index* (*EI*) in 2017, giving Taiwan a world rank of 17th. To assess the quantity and quality of Taiwan's research output, the following is a comparison of Taiwan with eight major industrialized countries and leading Asian countries in terms of the three indicators of number of *SCI*-cited papers per million persons, impact factor of *SCI*-cited papers, and number of *EI* papers per million persons.

1. Number of *SCI*-cited papers per million persons

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 same period. Taiwan's 1,161 *SCI*-cited papers per million persons in 2017 put Taiwan behind Finland, Singapore, Britain, Germany, the USA, and France, but ahead of South Korea, Japan, and Mainland China. The best performer in this category, Finland, increased its output from 1,994 cited papers in 2013 to 2,534 in 2017. Although Mainland China's output still remains far behind most of the other countries, its cited papers have grown rapidly in number, increasing at average annual rate of 14.16% between 2013 and 2017.

2. 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 with Taiwan, Singapore, Finland, Germany, Britain, France, the USA, Japan, and Mainland China all had impact factors higher than 6 in 2017. Although Taiwan's impact factor rose from 4.78 in 2013 to 5.75 in 2017, it still lags behind Singapore and the leading European and North American countries, and has thus has room for improvement in terms of quality of academic papers.

Number of *SCI*-cited papers per million persons and five-year average growth rate in various countries, 2013-2017

Units: papers

Country	2013	2014	2015	2016	2017	Average growth rate, 2013 -2017
Finland	1,994	2,102	2,335	2,427	2,534	6.18%
Singapore	1,931	2,055	2,284	2,392	2,514	6.81%
Britain	1,594	1,651	1,884	1,939	2,021	6.10%
Germany	1,179	1,227	1,325	1,356	1,396	4.32%
USA	1,161	1,197	1,313	1,328	1,355	3.94%
France	1,032	1,058	1,122	1,147	1,175	3.30%
ROC	**1,130**	**1,163**	**1,190**	**1,180**	**1,161**	**0.67%**
South Korea	903	973	1,043	1,092	1,130	5.78%
Japan	604	609	628	633	642	1.55%
Mainland China	124	143	170	188	211	14.16%

Source: 1. *SCI*-cited papers: InCites™, Clarivate Analytics /date updated: 9/11/2018
2. Population figures: World Bank: http: //www.worldbank.org/
3. Population of Taiwan: Statistical Yearbook of the Ministry of the Interior: https: //www.moi.gov.tw/stat

SCI impact factors of various countries, 2013-2017

Country	2013	2014	2015	2016	2017
Singapore	7.64	8.45	9.11	9.90	10.14
Finland	7.50	7.83	7.87	8.23	8.48
Germany	7.53	7.77	7.94	8.15	8.26
Britain	7.38	7.52	7.60	7.84	8.02
France	7.16	7.43	7.61	7.83	8.01
USA	7.55	7.63	7.71	7.83	7.90
Japan	5.62	5.78	5.94	6.04	6.10
Mainland China	4.66	4.97	5.31	5.70	6.04
South Korea	4.74	5.07	5.34	5.66	5.85
ROC	**4.78**	**5.08**	**5.44**	**5.66**	**5.75**

Source: Web of Science, adapted by Science & Technology Policy Research and Information Center, date updated: 9/11/2018

3. 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 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 870 papers per million persons in 2017, and its *EI* citations per million persons has been in the range of 787-1,045 during the most recent five years.

Number of *EI* citations per million people and five-year average growth rate in various countries, 2013-2017

Units: papers

Country	2013	2014	2015	2016	2017	Av. growth rate 2013 -2017
Singapore	1922	1961	1974	1967	1954	0.41%
Finland	1323	1374	1405	1352	1356	0.62%
ROC	**1045**	**969**	**844**	**787**	**870**	**-4.48%**
Britain	750	782	785	793	787	1.21%
Germany	725	763	749	743	748	0.78%
South Korea	733	756	757	707	727	-0.21%
France	697	692	685	650	676	-0.76%
USA	600	584	579	560	581	-0.80%
Japan	462	439	422	395	423	-2.18%
Mainland China	206	222	196	230	207	0.12%

Source: 1. *EI*-cited papers: Web of Science, adapted by Science & Technology Policy Research and Information Center, date updated: 2018-07-23
2.Population figures: World Bank: http: //www.worldbank.org/
3.Population of Taiwan: Statistical Yearbook of the Ministry of the Interior: https: //www.moi.gov.tw/stat

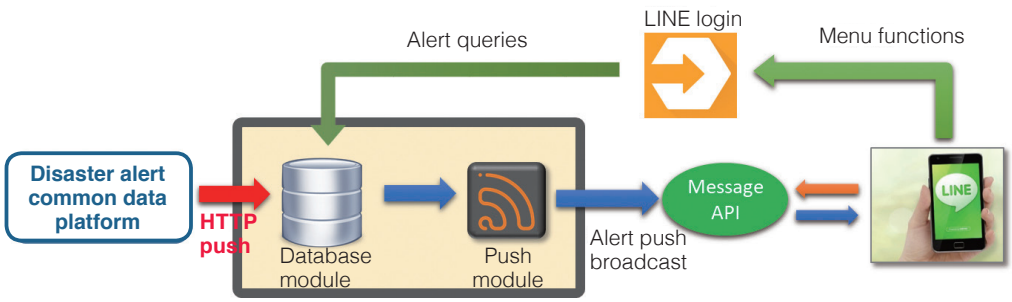
III. Integration of National Disaster Prevention Research

The National Science and Technology Center for Disaster Reduction (NCDR) has continued to promote and implement disaster prevention R&D, the integration, realization, and application of R&D results, and use of 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 technology. 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 periods. When a major natural disaster strikes, NCDR assists with scientific investigation and makes recommendations concerning countermeasures. Responding to natural disasters in 2017, NCDR personnel staffed the Central Disaster Emergency Operation Center (CDEOC), and assisted survey and assessment teams' to investigate disasters. In 2017, NCDR supported various response tasks at CDEOC six times; participation in these tasks involved over 383 person-hours and 472 person-times. NCDR further assisted CDEOC in holding 39 survey and assessment conferences, 44 working meetings, and three videoconferences with the president, which strengthened communication and the transmission of information concerning disaster situations.

In recent years, NCDR has worked with other agencies to make the government's disaster prevention information more open, such as by establishing a disaster warning platform providing users with real-time warning information through multiple channels, which has enhanced the effectiveness of disaster prevention and mitigation efforts. With the spread of smartphone apps, NCDR has been employing value-added apps to push warning information in real-time to the general public, which has made cell phones

the leading channel enabling citizens and the central government to simultaneously receive disaster prevention and relief information. Taking advantage of the fact that more than 19 million users in Taiwan have access to the LINE mobile communications software, NCDR sought to use this app's interface to quickly transmit information. As a consequence, NCDR reached a cooperative arrangement with Taiwan's LINE Corporation in March 2018 under which the NCDR account performs automatic push of disaster warning information, allowing users to quickly receive real-time disaster warning messages.

NCDR's official LINE account employs a real-time interactive model allowing users to make warning queries and sign up for warning subscriptions providing real-time push warning messages. The LINE account's data source consists of NCDR's open disaster warning data platform, which provides various types of warnings from all levels of government. These warnings are pushed to a receiving module server, which queries a database warning subscription list, and actively pushes warning messages to NCDR account subscribers.



Push disaster warning service

Members of the public using NCDR's official account service can query warnings throughout the Taiwan area in real-time, and can subscribe to receive warnings for areas of concern. Subscriptions can be classified on the basis of the four major attributes of "weather," "hydrology," "transportation," and "livelihood," and users can quickly complete subscription service sign-up.

Apart from providing 24 types of real-time warning information, NCDR's LINE account also provides disaster prevention and relief graphic cards and CDEOC's information assessment summary report graphic cards. As of December 31, 2018, NCDR's account had pushed warnings a total of 20,140,000 person-times, earthquakes, typhoons, and work/school cancellations were the three leading subscription types, and user acceptance exceeded 95%.

Looking ahead to the future, NCDR will continue to cooperate with the private sector and public agencies to provide even more real-time warning information connected with people's livelihoods, provide services employing the government's public data via various channels, strengthen the efficiency of disaster prevention and relief information, and increase the convenience of information service applications.

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 2018:

A. Popular Science Activities

MOST uses a wide range of channels to promote popular science activities, and has encouraged scholars at domestic universities, either by themselves or in partnership with businesses, foundations, academic groups, or associations, to use innovative, diverse, accessible, and interesting methods to hold workshops, hands-on activities, demonstrations, performances, and guided readings of popular science articles throughout the country, and also provide guided online popular science activities. A total of 2,500 popular science activities were held throughout 2018, attracting over 689,000 participants and resulting in the publication of 875 reports in news media, and the 67 websites and 62 Facebook fans pages established in conjunction with these activities provided free browsing and shared science resources with the public, and received more than 5.16 million visitors.

Furthermore, in order to promote the use of local resources by popular science activities and enable those activities to incorporate local features, MOST provided funding for the holding of National Science Week projects. The "Popular Science Train" activity was held around Taiwan from April 30 to May 4, 2018, and stopped at 19 cities and counties, which kicked off more National Science Week activities throughout Taiwan during May and June. Research organizations, private corporations, and even high school science clubs joined forces to plan and conduct innovative scientific experiments and hands-on activities on the Science Train, and each stop featured demonstrations and hands-on science experiences. A total of over 120 of these demonstrations and experiences were conducted, and more than 10,000 members of the public, students, and teachers participated.

Topical science media activities held during the year included the Science Day IC 60 activity series during the second half of the year. An IC 60 activity topic website was established during June, and an IC 60 press conference was held on June 13. IC Day visits to companies were held during July and August, permanent exhibitions held from July to December, IC audio broadcast visit programs conducted from August to December, and a master forum and online live broadcast held on September 5. A total of 36,750 persons took part in all activities; media contact (including radio, TV, and Internet) was made 7.7 million person-times, and over 70 media reports were made.

The "Sci-Tech Vista" website has been browsed a cumulative total of over 25 million person-times. After revision of the website in December 2018, over 4,600 selected articles and audiovisual resources from the previous five years providing correct, reliable scientific knowledge were included, and an interactive website format was designed in order to optimize smartphone users' experience. This upgrade has facilitated the public's ability to search for and view scientific and technological information. MOST is also using on science education social networking platforms to actively promote the Sci-Tech Vista site, and relies on a Facebook fans page and Google+ page to strengthen public interaction and promote the website's content. As of the end of 2018, Sci-Tech Vista's Facebook fans page had received over 47,000 "likes," and its YouTube channel had been viewed a cumulative total of more than 8.1 million times.

MOST held over 170 talks 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, and more than 35,000 students and members of the public listened to these events. In order to give students living in remote areas near-live access to these fascinating talks, videos of the talks have been placed on the "Sci-Tech Vista" website to enable viewers to watch at times and places of their choosing.

B. Industry-University Cooperative Research Project on Broadcasting Production and Promotion of Popular Science Products

In order to achieve the goal of promoting scientific literacy by providing citizens superior domestically-produced science programs, MOST is continuing to foster industry-academic collaboration between the media industry and domestic scientists.

MOST has provided funding to domestic scientists involved in industry-academic collaborative broadcasting production in order to promote the production and broadcast of popular science content. In 2018, funding was provided for the production of 68 popular science video programs in 10 series (1,902 minutes), one children's program, 7 online reports on popular science topics, one cell phone app, and 50 animated short video episodes totaling 150 minutes. New undertakings in 2018 included the commissioned production of two popular science videos (including one 3D animated video): "Taiwan's Aerospace Dreams come True," which was produced by TTV and the National

Geographic Channel, and took space science and technology as a topic, including Taiwan's satellite launches and linkage with the New Southbound Policy; and "Boundless Evolution," which was produced by Lytas Digital Co., Ltd. and the National Center for High-Performance Computing, and focused on artificial intelligence S&T, and introduced viewers to the future prospects of AI science and technology.

In the area of extension, in order to get the public in the habit of viewing, the "Science Discovery" popular science show continued to be broadcast every Saturday morning on FTV News, and 51 hours of programming was broadcast over the course of 2018. The program's highest viewing rate reached 0.6% (average: 0.35%), and each show was viewed approximately 300,000 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, and the show was publicized via 20 special reports in the media, 50 question and answer games with prizes, one educational talk, two manpower training talks, a Facebook community, and media exchanges, etc.

With regard to output quality, popular science programs produced with funding from MOST have earned a very favorable reception for many years, have included finalists in the Golden Bell Awards for 11 consecutive years, and have won this honor for seven consecutive years, with a cumulative total of 16 programs having won this prestigious award. In 2018, the program series "Lives of the Soil" was a finalist in the natural science documentary program category of the 53rd Golden Bell Awards. In addition, some programs, such as the series "VR 101," which concerns virtual reality, have been broadcast by the well-known National Geographic Channel, showing that they meet international standards.

Chapter 3
Support for Academic Research

Chapter 3 / Support for Academic Research

I. 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 research projects serves to improve the country's research and development standards. All professors and research personnel who meet MOST's research project funding application requirements may, within specified period of times, apply to MOST for research operation funding, equipment funding, or foreign travel funding based on the real needs of their research. Furthermore, to encourage long-term, in-depth research, MOST also promotes multi-year projects.

After a 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 or funding requirements that differ from those of the originally-approved project items or funding amounts, or if the project implementation period must be extended, change procedures may be performed in accordance with regulations. An online project results report and final expenditure report must be submitted via the MOST website within three months after the end of the implementation period.

B. Project Types

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 18,418 research projects were implemented during 2018 (including 13,204 newly-approved 2018 projects, 3,356 second-year projects of multi-year projects approved in 2017, 1,816 third-year projects of multi-year projects approved in 2016, 29 fourth-year project of multi-year projects approved in 2015, and 8 fifth-year projects of multi-year projects approved in 2014). Implemented expenditures totaled NT$25.05 billion, of which 62.64% went for research at public universities, 25.59% went for research at private universities, and 11.77% went for research at government research organizations and other units. Basic research projects accounted for 46.02% of the total, applied research projects accounted for 41.53%, and technology development projects accounted for 12.45%. By research field, natural science projects accounted for 14.03% of the total, engineering and applied science projects accounted for 31.40%, life science/medicine/agriculture research projects accounted for 23.69%, humanities and social science projects accounted for 29.07%, and other projects accounted for 1.81%. By length of research period, one-year projects accounted for 44.22% of the total, and multi-year projects accounted for 55.78%.

Numbers of specific-topic research projects and approval rate, 2014-2018

Item	2014	2015	2016	2017	2018
Applications	28,870	28,542	28,136	28,258	28,236
Approved	13,890	13,913	13,179	13,407	13,204
Approval rate	**48.11%**	**48.75%**	**48.76%**	**47.44%**	**46.76%**
Implemented projects	19,460	19,318	18,865	18,534	18,413[1]

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

[1]Projects implemented in 2018 included projects approved in 2018, second-year projects of multi-year projects approved in 2017, third-year projects of multi-year projects approved in 2016, fourth-year projects of multi-year projects approved in 2015, and fifth-year projects of multi-year projects approved in 2014.

Numbers of specific-topic research projects at different types of organizations and funding, 2014-2018

Units: NT$1 m

Item	2014		2015		2016		2017		2018	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
Public universities	12,008	14,552.39	11,904	14,357.43	11,720	14,426.03	11,569	14,616.15	11,535	17,173.62
Private universities	5,334	4,560.65	5,238	4,516.38	4,947	4,384.55	4,798	4,547.88	4,711	4,697.91
Military / police schools	229	203.34	239	241.83	240	235.53	227	227.16	249	230.79
Government research organization	907	1,532.61	924	1,483.5	926	1,449.93	918	1,530.79	884	1,521.85
Academic research organizations	325	822.11	334	770.74	360	696.79	325	642.45	296	587.87
Teaching hospitals	655	743.59	677	722.56	672	741.04	697	839.00	738	839.35
Other	2	3.19	2	47.39	0	0	0	0	0	0
Total	**19,460**	**22,417.91**	**19,318**	**22,139.83**	**18,865**	**21,933.87**	**18,534**	**22,403.43**	**18,413**	**25,051.39**

Numbers of funded basic research, applied research, and technology development projects and funding, 2014-2018

Units: NT$1 m

Item	2014			2015			2016			2017			2018		
	Projects	Funding	Funding %	Projects	Funding	Funding %	Projects	Funding	Funding %	Projects	Funding	Funding %	Projects	Funding	Funding %
Basic research	10,379	11,737.81	52.35%	10,534	11,794.94	53.27%	10,114	11,428.96	52.11%	10,003	11,319.03	50.52%	9,480	11,527.88	46.02%
Applied research	7,892	8,592.26	38.32%	7,610	8,203.49	37.05%	7,485	8,126.51	37.05%	7,287	8,404.10	37.51%	7,542	10,404.29	41.53%
Technology development	1,189	2,087.83	9.33%	1,174	2,141.39	9.68%	1,266	2,378.39	10.84%	1,244	2,680.30	11.97%	1,391	3,119.22	12.45%
Total	**19,460**	**22,417.91**	**100%**	**19,318**	**22,139.83**	**100%**	**18,865**	**21,933.87**	**100%**	**18,534**	**22,403.43**	**100%**	**18,413**	**25,051.39**	**100%**

Numbers of funded specific-topic research projects in each research area and funding, 2014-2018

Units: NT$1 m

Item	2014		2015		2016		2017		2018	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
Natural science	2,444	4,440.59	2,584	4,526.42	2,721	4,638.89	2,639	4,408.28	2,584	4,305.13
Engineering	6,740	7,343.21	6,390	6,898,6	6,231	6,999.39	5,963	6,901.74	5,782	7,573.88
Life science, medicine and agriculture	4,398	6,212.24	4,341	5,885.34	4,247	5,685.07	4,224	5,883.47	4,362	6,187.03
Humanities and social sciences	4,948	2,963.12	4,851	2,951.32	4,658	2,952.60	4,650	2,968.46	5,239	3,818.80
Science education[2]	905	1,122.22	969	1,058.54	827	907.08	864	925.95	-	-
Other	25	336.51	183	819.61	181	750.83	194	1,315.53	446	3,166.55
Total	**19,460**	**22,417.89**	**19,318**	**22,139.83**	**18,865**	**21,933.87**	**18,534**	**22,403.43**	**18,413**	**25,051.39**

[2]Science education was merged with the humanities and social sciences starting on June 1, 2018

Numbers of one-year and multi-year research projects and funding, 2014-2018

Units: NT$1 m

Item	2014		2015		2016		2017		2018	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
One-year projects										
Natural science	1,122	1,432.14	1,229	1,314.17	1,318	1,416.91	1,324	1,432.14	1,312	1,328.22
Engineering	3,673	2,946.22	3,418	2,581.66	3,393	2,751.80	3,107	2,377.92	2,688	2,141.68
Life science, medicine and agriculture	1,217	1,293.44	1,343	1,279.79	1,365	1,388.67	1,342	1,534.03	1,405	1,316.67
Humanities and social sciences	2,655	1,308.25	2,627	1,337.43	2,535	1,337.51	2,473	1,328.20	2,607	1,591.71
Science education[2]	379	248.93	419	305.57	276	167.51	317	275.78	-	-
Other	21	260.72	67	368.43	83	364.90	70	843.17	131	1,400.46
Subtotal	9,065	7,489.72	9,103	7,187.05	8,970	7,427.31	8,633	7,791.24	8,143	7,778.74
Multi-year projects										
Natural science	1,322	3,008.45	1,355	3,212.25	1,403	3,221.98	1,315	2,976.14	1,272	2,976.91
Engineering	3,067	4,396.98	2,972	4,316.94	2,838	4,247.59	2,856	4,523.82	3,094	5,432.20
Life science, medicine and agriculture	3,181	4,918.80	2,998	4,605.55	2,882	4,296.40	2,882	4,349.43	2,957	4,870.36
Humanities and social sciences	2,293	1,654.87	2,224	1,613.89	2,123	1,615.09	2,177	1,640.27	2,745	2,418.94
Science education[2]	528	873.29	550	752.97	551	739.57	547	650.17	-	-
Other	4	75.79	116	451.18	98	385.93	124	472.36	202	1,574.24
Subtotal	10,395	14,928.19	10,215	14,952.78	9,895	14,506.56	9,901	14,612.19	10,270	17,272.65
Total	**19,460**	**22,417.91**	**19,318**	**22,139.83**	**18,865**	**21,933.87**	**18,534**	**22,403.43**	**18,413**	**25,051.39**

[2]Science education was merged with the humanities and social sciences starting on June 1, 2018

Numbers of male and female principal investigators of specific-topic projects, 2014-2018

Item	2014		2015		2016		2017		2018	
	Person times	%	Person times	%	Person times	%	Person times	%	Person times	%
Female	4,488	23.06%	4,485	23.22%	4,473	23.71%	4,433	23.92%	4,542	24.67%
Male	14,972	76.94%	14,833	76.78%	14,392	76.29%	14,101	76.08%	13,871	75.33%
Total	**19,460**	**100%**	**19,318**	**100%**	**18,865**	**100%**	**18,534**	**100%**	**18,413**	**100%**

II. R&D Result in Different Fields

A. Ordinary Specific-Topic Research Projects

1. Natural Science

Basic research in natural science is the foundation of academic research and the training of scientific manpower. Natural scientific research encompasses the areas of mathematics, statistics, physics, chemistry, earth science, atmospheric science, and ocean science, as well as interdisciplinary research in sustainability, disaster prevention technology, and spatial information. Apart from continuing to support basic research and provide funding to innovative and important free research, MOST seeks to draft key projects, deepen and build on existing research results, solve scientific problems and issues affecting human survival, and train research manpower in the natural sciences and mathematical/statistical science. The following were among some of the most significant research results of the year:

(1) Lighting up Taiwan's beauty: Development of ultra-high-performance OLEDs employing a new diboron material

Commercial applications of organic light-emitting diode (OLED) technology are becoming increasingly mature, and include mobile device screens, high-resolution displays and various types of lamps and lighting. OLEDs possess the advantages of thinness, light weight, autoluminescence, planar illumination, and rich colors, and are especially suitable for use in flexible and transparent displays, which can allow the scrolling displays seen in science fiction movies and vehicle window smart displays to be realized. When used together with virtual reality (VR) and augmented reality (AR), OLEDs will ensure that the displays of the future are no longer unattainable. Now a research team consisting of personnel from the chemistry and materials science departments of National Tsinghua University has made a major breakthrough in the project "Elements Employing a New Type of Diboron Fluorescent Material," and has set the current world performance record for green light OLED elements. The results of this project have been published in the world's leading photonics journal—Nature Photonics—and the team has received patents in Taiwan and applied for patents in the US, Japan, and China.

The emissive layer in commercial OLEDs is composed of either first-generation fluorescent materials, have a luminous efficiency of roughly 5%, or second-generation phosphor material, which have an efficiency of 20%. Due to the cost of commercial light-emitting materials, current OLED panels are typically quite costly, and because phosphor materials must use precious metals—either iridium or platinum—many laboratories have taken up the challenge of developing third-generation light-emitting materials.

Thermally activated delayed fluorescence (TADF) materials currently represent the mainstream of new-generation materials research, and offer the advantages of employing low-cost purely organic materials, and providing performance overcoming the efficiency restrictions of conventional fluorescent materials and rivalling that of high-efficiency phosphor elements. However, TADF also suffer from a dramatic drop in efficiency at high brightness.

The new type of diboron material designed and synthesized by the research team possesses third-generation TADF characteristics, and the rod-shaped molecules give the material a tendency to assume a horizontal arrangement during thermal evaporation, while also enhancing light-emitting efficiency. In addition, the structure of the elements designed by Dr. Lin Chih-chun overcomes the external quantum efficiency restrictions of conventional fluorescent and phosphor layer OLEDs. Furthermore, the team's element process technology and skill at variable angle spectroscopic measurements have enabled it to produce ultra-high performance green

light OLED elements with an external quantum efficiency of as high as 38%, and the efficiency of the elements decreases by only 0.3% at a brightness of 1,000cd/m^2. These elements have set the current world performance record, and represent a huge step forward in the development of practical new-generation purely-organic light-emitting materials.

As external competition grows, Taiwan's LCD panel industry currently faces a technological turning point. Major foreign manufacturers have acquired amounts of patented OLED technology during the past decade, and Chinese firms have actively expanded their OLED panel production lines in recent years. As a result, the development of OLED panels in Taiwan lags severely behind Japan and Korea.

Because the diboron material developed in this project is composed of the common elements carbon, hydrogen, boron, and nitrogen, there is no need to use noble metals as raw materials, synthesis is simple and easy, and gram-level or larger quantities can readily be produced in the laboratory, greatly reducing the cost of key light-emitting materials. Taiwan's panel and lighting firms are currently establishing a global patent portfolio, and the industry can look forward to upgrading supported by the domestic production of high-performance materials.

The research team's results build on the findings of the "Frontier Research Center on Fundamental and Applied Sciences of Matters" project, and the team seeks to develop new materials and practical OLED life testing methods; it is expected that the commercialization of new materials will be completed within two years. The research results will be diffused to industry in the future, and will enable Taiwan's OLED industry to pursue new directors. The results of this research campaign were published online in the March 6, 2018 edition of Nature Photonics (DOI: 10.1038/s41566-018-0112-9).

A high-performance OLED made using a new type of diboron material
source: Prof. Cheng Chien-hung, Dept. of Chemistry, National Tsinghua University

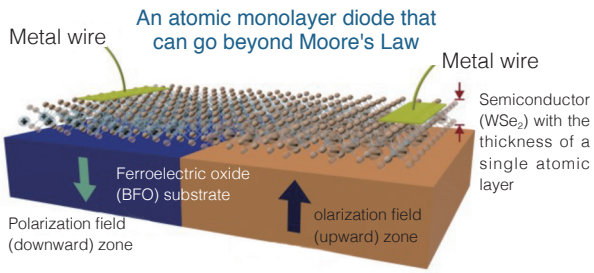
(2) Single atomic layer diodes transcending Moore's Law

The shrinking of conventional semiconductor processes is expected to end at a line width of 3 nm. When that time comes, finding an alternative route to the miniaturization of integrated circuits to atomic size will be the key to the future development of technology. A research team working in the field of condensed matter physics has now overcome the past limitation of only being able to use external electrodes or elemental doping to control the electrical properties of two-dimensional materials by successfully producing a tungsten diselenide (WSe_2) diode with the thickness of a single atomic layer on a ferroelectric oxide substrate using a nanometer-scale electric field for control. This diode possesses outstanding physical characteristics, including reversible read/write and persistent memory. Apart from leaping over Moore's Law, providing a basis for the development of the next generation of electronic elements, and pursuing the optimization of element cost/power consumption/speed, this type of two-dimensional single atomic layer diode will satisfy the electronic element needs of future artificial intelligence chips and machine learning applications. The results of this project were published in the journal *Nature Communications*.

For close to half a century, the number of transistors integrated circuits has increased in pace with Moore's Law, which specifies that that speed will approximately double every two years. Nevertheless, the miniaturization of integrated circuits will ultimately result in transistor circuits with excessively fine and densely-arranged lines, which will cause electrons to escape the circuits and engage in mutual interference. When this

occurs, transistors will have run into the barrier of quantum physical limits. Transition metal dichalcogenides (TMDs), which like graphene can be produced a two-dimensional layers a single atom in thickness, have offer outstanding semiconductor transmission characteristics, and will be better able to meet the thinness, miniaturization, and speed needs of next-generation integrated circuits than conventional silicon semiconductor materials.

In recent years, researchers have gained the ability to stack two-dimensional materials with similar structures like building blocks in order to create heterogeneous stacked structures possessing different types of electronic transmission behavior. Nevertheless, because the creation of a three-dimensional structure via stacking can reduce the fast planar electron transmission provided by two-dimensional materials, the ability control the number of electrons in different subareas, and thereby create a planar homogeneous two-dimensional semiconductor structure, is essential to further progress. Breaking with the past practice of using complex electrodes to control the electrical properties of two-dimensional materials, this project applied a single-atom layer of the semiconductor material tungsten diselenide (WSe_2)—which is a single-compound atomic film with a structure consisting of a layer of tungsten atoms sandwiched between two layers of selenium atoms—to a substrate consisting of ferroelectric bismuth ferrite ($BiFeO_3$) with surface electric field switching characteristics. And giving up the conventional reliance on doping with chemical elements to control the number of electrons, the researchers used the surface electric field switching of the ferroelectric oxide alone to successfully increase the number of electrons (n-type doping) or reduce the number of electrons (p-type doping) within different areas of a tungsten diselenide semiconductor layer a single atom in thickness. This allowed the researchers to alter the electrical properties of the two-dimensional semiconductor in different areas at different times, which is something that conventional semiconductor electrical property control methods cannot achieve. Apart from demonstrating a new method of controlling the number of electrons in a two-dimensional material and creating a single atomic layer diode with extreme control freedom and outstanding rectification characteristics, because this revolutionary method of controlling electrical properties does not require the creation of metal gates, it can sharply reduce the complexity of circuit design and semiconductor processes, while avoiding the problems of short circuits, current leakage, and noise caused by mutual inductance.



Source: Prof. Wu Chung-lin, Dept. of Physics, National Cheng Kung University

(3) Innovative e-bike technology announcement conference: Realizing low-carbon intelligent living with e-bikes + Internet of Things + artificial intelligence

Members of the public who like cycling will soon have even more intelligent choices in the future. National Chungshing University SwiCity intelligent e-bike R&D team has announced two innovative technologies: The "Infinity Bike" and "Swi-Lock." Apart from giving users an all-new public transportation "mobility as a service" (MaaS), the project has also demonstrated a new type of low energy consumption power generation technology, a powerful online search function enabled by the Internet of Things (IoT) incorporated into the bicycle frame, and support for multiple types of payment mechanisms.

The successful development of e-bike technology in Taiwan will depend on MOST's recent interdisciplinary integrated research

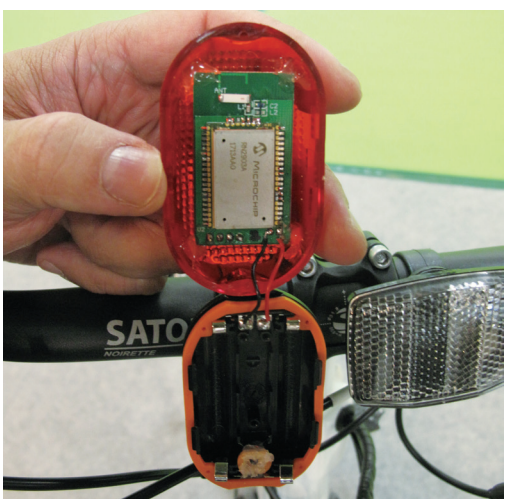
project "Blueprint for Technological Innovation Targeting the Needs of Society." In contrast with ordinary research projects geared to the needs of industry, this project has taken the needs of society as its central focus, invited experts and scholars in the area of technology, industry, economics, management, humanities, and social sciences to form an interdisciplinary research team jointly tasked with tackling the problems currently facing domestic society and the world, and embarked on the drafting of a long-term blueprint for technological innovation in Taiwan based on holistic thinking. Starting out from the issue of battery technology, the research team gradually integrated 24 cooperating units and enterprises representing industry, academia, and research organizations, formed a horizontal alliance spanning domestic industry chains, IoT companies, telecommunications enterprises, and cell phone payment system companies, and developed numerous patented technologies. The results of this project will give Taiwan's "bicycle kingdom" an opportunity to transform itself into an innovative industry employing IoT and artificial intelligence, and stimulate the developmental potential of domestic and foreign markets.

(4) Infinity Bike – Leisurely cycling while charging and maintaining an Internet connection

The Infinity Bike is not only custom-tailored for people who love outdoors activity, but is also a mobile device designed to let people realize life's boundless possibilities. The bicycle frame is made from lightweight carbon fiber, and the bike is equipped with an automatic generator with co-rotational generating technology. The generator is mounted on the chain axle, and will not affect cycling speed. This approach not only provides power to drive the bicycle and operate the IoT chip, but can also charge the user's mobile devices. The Swi-IoT low power consumption IoT chip enables tracking of the bicycle's location and status, searches for nearby food and attractions, and match-up with fellow cyclists nearby. The new personal experiences enabled by this e-bike will change people's definition of bicycles.

The "Swi-Lock" is a shared bicycle 4.0 rental device featuring compact size, low cost, and the ability to resolve the problem of payment without an Internet connection. Swi-Lock's safety lock function has already passed the United States' highest safety certification, and the highly compact lock can be hidden in the bicycle frame. In conjunction with the widely accepted Pass2U, it is expected that the Swi-Lock will become the world's first dockless electronic payment lock supporting the international barcode standard and an open wallet framework, and will be able to create an all-new up-to-date infrastructure for the rental of shared bicycles. Within this framework, not only can payments be made using Easy Card or a smartphone, but users can also just press a button on their smartphone payment app to lock a bicycle, which will automatically unlock itself when the owner approaches the bicycle. In comparison with QR code and safety password methods, there is now no need to perform scanning or input a password, making the system even more convenient.

In comparison with UBike and oBike shared bicycles, etc., SwiCity e-bikes allow users to ride even farther (5-30 kilometers), and provide more convenient payment and unlocking mechanisms. In addition, the low power consumption IoT chip recessed inside the frame enables the bicycle to



The tiny Swi-IoT chip
Source: Prof. Lin Kuan-chu, Dept. of Chemistry, National Chungshing University

be precisely located and dispatched in real-time, greatly enhancing bicycle set-out management efficiency. Relevant technologies were used on a trial basis during the 2018 Taichung World Flora Exposition, which began during November 2018, and induced a high level of interest from relevant domestic and foreign companies. The power of this project lies in its integration of some of Taiwan's most mature technological capabilities, and it will also channel technology to Taiwan's manufacturers and gradually realize a new vision of bicycle IoT.

The SwiCity e-bike project's results were displayed by invitation at the 2018 Taipei International Cycle Show, and the project's exhibitions included an e-bike experience area, Infinity Bike riding area, and a Swi-Lock area.

Research manpower in natural science specific-topic research projects, 2014-2018

Item		2014	2015	2016	2017	2018
Research personnel	Professors	1,433	1,532	1,632	1,594	1,597
	Associate professors	763	835	886	884	784
	Assistant professors	689	711	758	701	634
	Lecturers	-	-	7	4	2
	Other	701	791	909	886	820
Subtotal		3,586	3,869	4,192	4,069	3,837
Research assistants	Full-time assistants	892	947	1,035	1,016	879
	Part-time assistants	30	45	62	45	27
	Graduate students	9,086	9,688	9,708	8,876	8,146
Subtotal		10,008	10,680	10,805	9,937	9,052
Total		**13,594**	**14,549**	**14,997**	**14,006**	**12,889**

Note: Data for 2018 extends to 1/5/2019.

Numbers of one-year and multi-year specific-topic research projects in natural science, 2014-2018

Year	All projects	One-year projects (%)	Multi-year Projects (%)
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）
2017	2,639	1,324（50.17）	1,315（49.83）
2018	**2,584**	**1,312（50.77）**	**1,272（49.23）**

Natural science and mathematics specific-topic research projects and funding, 2018 Units: NT$1 m

Item	Applications		Approved		Implemented projects	
	Projects	Funding	Projects	Funding	Projects	Funding
Physics	541	3,198.00	292	558.43	535	1,014.55
Chemistry	722	3,107.59	414	697.18	550	1,006.93
Mathematics & statistics	647	561.38	359	204.44	494	300.89
Earth science, atmospheric science, ocean science	684	2,055.49	379	571.84	426	670.99
Sustainable development research	134	562.03	75	101.98	112	146.96
Interdisciplinary research[1]	147	1,637.72	100	199.36	100	199.36
Disaster prevention and mitigation S&T	389	865.56	206	208.85	219	222.20
Technology and Industry Upgrading Program	56	538.89	22	74.75	22	74.75
National Science and Technology Program-Energy	11	1,131.27	9	128.53	9	128.53
Science Vanguard Program	28	643.53	23	139.06	23	139.06
Instrument centers	3	4.40	3	1.47	3	1.47
Spatial information science	138	218.45	64	49.33	74	56.45
Academic Summit Program	4	84.09	4	56.98	4	56.98
Novel materials	16	207.45	10	48.01	23	76.94
Nanotechnology	39	859.89	28	238.62	28	238.62
MOST / EPA air pollution prevention technology	7	183.68	7	47.00	7	47.00
Food-Water-Energy Nexus and Urbanization in Development	9	88.44	9	21.00	9	21.00
Other	5	240.23	1	5.60	1	5.60
Total	**3,580**	**16,188.09**	**2,005**	**3,352.43**	**2,639**	**4,408.28**

[1]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.

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. The chief mission of this discipline is to promote relevant research and development in engineering fields, ensure that R&D funding is used effectively, construct a superior R&D environment, train cutting-edge R&D manpower and research teams, and rely on the extension and realization of R&D results to stimulate the upgrading of domestic industrial technology and improve people's lives and welfare. The following were some of most important research results achieved during the year:

(1) Virtual machine tool and visualization (AR/VR) technology

Major technologies needed in the development of cyber-physical systems (CPS) and "digital twin" systems—which is a global technological trends—include visualization employing interface systems with enhanced 3D geometric data, integrated sensing data, network technologies, optimized cutting and processing parameters based on mechanical and physical models, and CAD/CAM systems. This project began by focusing on 3D geometric visualization technology for 3-axis machine tools, and employed computer-aided design (CAD) to develop interactive geometric machine modeling and virtual reality technology. The team established a static operating simulation system to serve as a basis for the 3D user interface of a cyber-physical system; the system included a linear motion axis and platform, main rotating axis, and tool axis, employed intelligent "Internet of Machines" technology to access sensor data, and used algorithms to analyze and integrate this data. In the future, the project will apply the results of its computer-aided analysis technology development work to 5-axis machine tool and 7-axis mill-turn machines with advanced functions, and development of these machines will stimulate the growth of Taiwan's smart machinery industry.

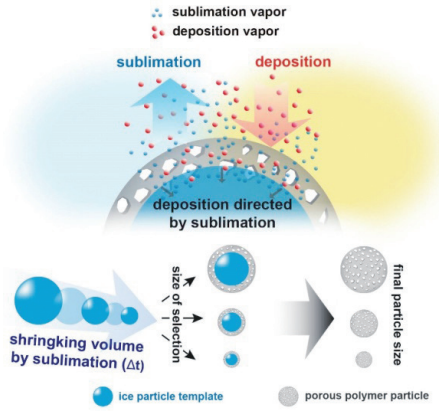
The immersive virtual reality simulation system used in human-robot collaboration systems enabling virtual/physical integration of multiple machines can be divided into two main components: a virtual reality system and its motion module and configuration system, and whole-machine hardware and whole line peripheral equipment networking technology, which includes both equipment with network-supported functions and equipment without network-supported functions. The team has thus far completed configuration of the immersive virtual reality simulation system for a 3-axis milling processing center and upright 5-axis milling processing center and assembly of a prototype system, which was displayed at the Taiwan pavilion of the METALEX metal processing trade show held in Thailand during November 2018. In the future, the team plans to develop integrated hardware and software in order to incorporate the functions of its human-robot collaboration system enabling virtual/physical integration of multiple machines in an immersive virtual reality environment and networking system.

(2) Creating nanoparticles in a gaseous environment

The scientific exploration of the nanometer realm has been making steady progress. The materials created on a nanometer scale include inorganic materials, organic materials, magnetic materials, energy materials, and porous materials, etc., and these nanomaterials' special surface interface phenomena, physical and chemical characteristics, and biological functions give them a vast array of potential applications. Nanomaterials currently have important applications in such areas as biomedicine, optics, electrical machinery and electronics, energy technology, and materials science.

The research team in this project discovered that control of the thermodynamic properties of

gas molecules in a gaseous environment can enable the molecules' sublimation and deposition pathways to be controlled, and used this approach to create new nanomaterials. The innovative process developed in this project does not require advanced equipment, involves fast, simple steps, and can potentially be used for large-scale production. Most importantly, the process readily allows the size of the nanomaterials to be controlled. The team used this new process to demonstrate the production of special polymer nanoparticles (that could not be produced using past technology), and showed that magnetic and metallic materials can easily be combined with polymers to produce composite multifunctional nanomaterials with magnetic, metallic, and polymer chemical properties. The team is currently actively researching the possible important applications of the nanomaterials made using this technology, and hopes to create nanomaterials with even more novel functions in the future.



Creation of nanomaterials in a gaseous environment: Control of the sublimation and deposition of gas molecules can create nanoscale materials, and the size of the nanoparticles can be readily controlled.
Source: Prof. Chen Hsien-ye, Dept. of Chemical Engineering, National Taiwan University

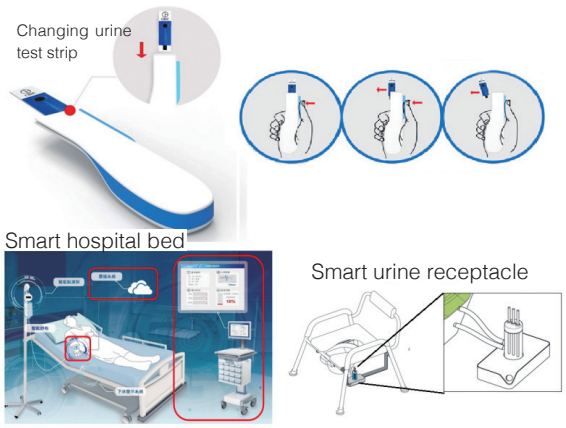
(3) A portable wireless system and platform for urine analysis and cardiovascular disease prevention

According to a survey performed by the WHO, cerebrovascular and cardiovascular disease topped the list of the ten leading causes of death worldwide in 2016, at which time ischemic heart disease and stroke accounted for 31% of all deaths, which is equivalent to one death attributable to cardiovascular disease out of every three deaths. Cardiovascular disease has remained the leading cause of death throughout the past decade, and has remained among the top three causes of death in Taiwan during the same period. This indicates that cardiovascular disease remains an intractable illness without effective means of prevention or control.

The "portable wireless system and platform for urine analysis and cardiovascular disease prevention" developed by the research team in this project employs an integrated electrochemical system chip, microelectrodes, and a microfluidic channel chip to sense the concentration of cardiovascular disease biomarkers in urine, and transmits data wirelessly to the system platform. The system combines the results of clinical medical research with artificial intelligence, and uses multiple types of cardiovascular disease biomarkers to assess users' risk of cardiovascular disease in real-time. In addition, personnel at medical institutions cooperating with the platform can then give users professional medical recommendations to help them prevent the occurrence or worsening of cardiovascular disease.

This system can be applied to prevention, monitoring, home care, and community screening for cardiovascular disease; both ordinary people and members of high-risk groups can use the platform to assess whether they have cardiovascular disease risk factors and prevent the occurrence of the disease through professional medical recommendations. In addition, patients with cardiovascular disease can monitor their condition at home, saving the time needed to go to a hospital and wait for their report. Because cardiovascular disease has a very high death rate, by helping patients understand their condition in real-time, this system platform can achieve the goals of prevention and letting patients monitor the effectiveness of their treatment, and thereby reduce health insurance costs.

Patients' personal guardian angel—Urinalysis device



Source: Prof. Lee Shun-yu, Dept. of Electrical Engineering, National Cheng Kung University

Because the urine analysis device providing convenient cardiovascular disease risk screening developed by this team is chip-based and highly compact, it can be used in conjunction with toilets, urinals, diapers, hospital beds, and other medical equipment in the future, and can enable the prevention and monitoring of cardiovascular disease to be incorporated in everyday life in many ways, which will reduce the incidence of cardiovascular disease and its death rate.

(4) Intelligent disease risk early detection system

Precision medicine promises to provide more effective medical diagnosis and treatment, and preventive healthcare can ensure that more people are able to escape the ravages of disease. This project is combining innovative deep learning and big data analysis with medicine in the development of a high-accuracy real-time early health risk detection and warning system; this system, which employs biomarkers and risk models, can be used to detect pathologies at an early date, greatly reducing death rate and medical costs.

The research team (1) used deep learning and high-performance prediction technology to develop an early pathology and sudden health risk forecasting model using patient records and physiological signals; (2) employed deep learning involving a convolutional neural network to analyze ultrasound and PET images of developing cases of cancer. Together with the patients' clinical data, this system provided information helping doctors to predict recurrence, assess the effectiveness of treatment, determine cancer stage, and forecast metastasis; (3) used intelligent algorithms and machine learning technology to develop a high-dimensional biomarker detection method involving tissue samples from patients with major illnesses, enabling doctors to analyze cancer patients' lesions in detail and achieving the goal of precision medicine; (4) relied on deep learning to improve on the problems affecting text mining extraction models, used deep learning to directly obtain extract style and rules from large bodies of data in the medical literature, and performed optimization of identification results, allowing the detection of early signs of chronic diseases (such as obstructive pneumonia, rheumatoid arthritis, and kidney disease, etc.) through the mining of electronic medical records.

The research team employed deep learning and data analysis in conjunction with methods including image processing, multivariate time series data mining, and text mining to development innovative intelligent disease risk detection and forecasting technology. This technology can be used to detect and analyze signs of disease in medical images, predict sudden diseases such as epilepsy and heart disease, and forecast the health risk of chronic diseases.

In terms of analytical accuracy and speed, this technology is significantly better than existing international interpretive and predictive methods, and it represents an innovative breakthrough in the field of smart medicine. In particular, the use of computer-aided diagnosis with a deep neural network (DNN-CAD) to determine the tumor progression of colorectal polyps from endoscopic images has achieved predictive sensitivity of over 96%, and can make assessments in only 0.5 sec. An article concerning the technology has been published in *Gastroenterology*—one of the world's leading journals of digestive internal medicine—and the research team has been interviewed by

Research manpower in specific-topic research projects, 2014-2018

Item		2014	2015	2016	2017	2018
Research personnel	Professors	4,883	4,793	4,846	4,883	4,790
	Associate professors	2,595	2,510	2,354	2,187	2,068
	Assistant professors	2,047	1,805	1,691	1,470	1,404
	Lecturers	25	28	18	17	9
	Other	760	776	845	842	850
Subtotal		10,310	9,912	9,754	9,399	9,121
Research assistants	Full-time assistants	708	661	708	759	762
	Part-time assistants	52	37	67	67	53
	Graduate students	23,179	22,103	21,686	20,461	19,630
Subtotal		23,939	22,801	22,461	21,287	20,445
Total		**34,249**	**32,713**	**32,215**	**30,686**	**29,566**

America's Reuters, which expressed admiration for the project's technological breakthroughs and clinical potential.

(5) Development of technology for controlling the "exchange bias" of spintronic elements

With the miniaturization of semiconductor elements, electron spin has begun to be exploited as a new degree of freedom in electronic elements, and magnetoresistive random access memory (MRAM) has recently become an attention-getting type of spintronic product. The production of MRAM takes advantage of different electron spin directions to create ferromagnetic layers with magnetic moments in different directions (N pole or S pole), which constitute memory bits in "0" and "1" states. This memory retains its state even when there is no power, and thus constitutes non-volatile memory. MRAM possesses the advantages of fast read and write and low power consumption, and is expected to replace or be used in tandem with existing types of semiconductor memory in the future.

Apart from controlling the direction of the ferromagnetic layers' magnetic moments, the "exchange bias" resulting from the interaction of the ferromagnetic and anti-ferromagnetic layers has always been a major challenge in spintronic element R&D. Now a team led by Prof. Lai Chih-huang, Dept. of Materials Science, National Tsinghua University and Prof. Lin Hsiu-hao, Dept. of Physics, National Tsinghua University has proposed the use of electron spin current to control exchange bias. This approach not only changes the direction of magnetization in the ferromagnetic layer, but also reverses the direction of exchange bias, which overcomes the past need to use magnetic annealing. This breakthrough will have a profound effect on spintronic elements and MRAM. Related research results ("Manipulating exchange bias by spin-orbit torque") were published in Nature Materials.

A current focal point of research on spintronic elements is how to not depend on a magnetic field to change the direction of the magnetic moment of the ferromagnetic layer, which is the so-called "write" mechanism. Spin orbit torque has been recently been developed as a means of changing the direction of the magnetic moment, and employs the following principle: When a current flows through a structure consisting of a ferromagnetic

layer/heavy metal layer (such as Pt, Ta, W), because of the spin Hall effect, among the electrons flowing through the heavy metal layer, electrons with different spin directions will move in opposite directions. And the fact that adjacent ferromagnetic layers can sense the entry of electron spin currents causes the magnetic moments of the ferromagnetic layers to reverse. This research project was the first to discover that the spin orbit torque induced by spin currents can be used control exchange bias in an element. Because the creation of a spin current does not require a magnetic field, but only requires a current pulse, a spin current can be used independently to control the reversal of the magnetic moment and exchange bias in spintronic elements. This finding provides a brand-new approach to the design of spintronic elements,

Numbers and of one- and multi-year specific-topic research projects in engineering, 2014-2018

Year	All projects	One-year projects (%)	Multi-year Projects (%)
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）
2017	5,963	3,107（52.10）	2,856（47.90）
2018	**5,782**	**2,688（46.49）**	**3,094（53.51）**

Numbers of engineering specific-topic research projects and funding, 2018 Units: NT$1 m

Item	Applications		Approved		Approved projects	
	Projects	Funding	Projects	Funding	Projects	Funding
Electrical / mechanical / energy group[1]	2,904	4,479.07	1,447	1,161.29	1,848	1,552.06
Chemical / materials / consumer applications group[2]	2,678	5,604.98	1,248	1,194.80	1,772	1,794.82
Electronics / information / communications group[3]	2,872	5,828.08	1,401	1,185.77	1,931	1,752.94
Atomic energy and applied radiation technology	39	55.02	24	22.40	24	22.40
National Science and Technology Program-Energy	79	1,321.10	54	452.73	54	452.73
Gender mainstreaming technology projects	13	20.70	6	3.00	6	3.00
Special projects	715	7,618.23	296	1,273.00	304	1,281.90
Interdisciplinary research	16	234.70	4	23.90	4	23.90
Other	44	67.86	20	17.99	20	17.99
Total	**9,360**	**25,229.74**	**4,500**	**5,334.88**	**5,963**	**6,901.74**

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

[2]Includes materials and applied chemistry, chemical engineering, materials engineering, food engineering, civil and hydraulic engineering, environmental engineering, medical engineering, and polymer and fiber technology.

[3]Includes electronic and information systems, telecommunications engineering, microelectronic engineering, optoelectronic engineering, and information system/intelligent computing.

and boosts Taiwan's domestically-controlled MRAM technology.

3. Life Science

Life science encompasses 18 fields within the three main disciplines of biology and agriculture, basic medical science, and clinical medicine. MOST's primary mission in life science consists of planning and promoting of research and development projects in the areas of biology, agriculture, and medicine, improvement of research quality and R&D capabilities in life science, training outstanding research talent, and promoting the formation of research teams, with the goal of creating an outstanding academic environment and effectively providing research funding, pursuing academic excellence, fostering S&T interchange and collaboration, and advancing life science.

(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 2018 included the following:

The inflammatory response induced by the accumulation of large amounts of beta-amyloid in the brain is an important causal factor in Alzheimer's disease, and researchers have discovered that imbalances in the gut microbiota can induce an inflammatory response in the brain. New research employing a fruit fly model of Alzheimer's disease has found that communication between the brain and intestinal tract is an important control mechanism in the neurodegenerative effects of Alzheimer's disease. During the expression of genes, all such processes as RNA transcription, splicing, and transport out of the cellular nucleus have precise control processes. Researchers successfully developed a new yeast extracellular system that can be used to study RNA transcription and splicing, which promises to shed much light on RNA transcription and splicing integration mechanisms. Relying on analysis of information from a bioinformation database, researchers studied information about and the function of novel highly-conserved genes present in humans in organisms ranging from zebra fish to humans. The project employed the phenotypes of gene knockout zebra fish and their impact on the development of various organs to obtain a detailed account of the biological function of various novel singleton genes. The complexity of the visual systems and brain structure of cephalopods is second only to those of vertebrates, and cephalopods' ability to quickly change their color enables them to effectively camouflage themselves and communicate with others of their species. Research on the structure of neurons in the visual lobe of the brain of cuttlefish and giant squid has verified that the reproductive choices of female cuttlefish will influence the mating strategies of male cuttlefish. This type of neurobehavioral research can further enhance our understanding of the laws governing the functioning of cephalopods' sensorimotor integration and visual cognitive systems.

Observations of cooperative behavior among old carrion beetles found that behavioral differences exist among beetles with different ages, and an experiment revealed that two old female beetles exhibited a greater ratio of individual cooperation than two young female beetles; when two young male beetles were paired with two old female beetles, the male beetles exhibited greater cooperation than when paired with two young female beetles. A research project revealed the diversity and evolutionary origins of giant chloroplasts for the first time. This project found that that giant chloroplasts are diverse in terms of shape (cup-shaped, bifid, or disk-shaped), location (epidermal cell type or mesophyll cell type), and microstructure (whether bizonoplasts are present), and are present solely in plants that are adapted to growth in deep shade." A project on the use of heterogeneous protein expression methods to identify enzyme functions found that the changing colors of the leaves of the Formosan gum (*Liquidambar formosana*) are controlled by microRNA. The modification of clay with non-ionic surfactants was found to reduce the impact of biological toxins on human health via the

food chain. Researchers found that care for young among female *Kurixalus eiffingeri* tree frogs can reduce predation and infection by exotic predatory snails.

Researchers showed that microbial fertilizer can help reduce the use of chemical fertilizers and establish an environmentally-friendly crop production system. The photosynthetic bacteria *Rhodopseudomonas palustris*, which is found in paddy fields in Taiwan, is an effective promoter of crop growth, and can also increase crops' ability to metabolize chemical fertilizers; this study established fermentation conditions for the mass culture of the PS3 photosynthetic bacterial strain and the amount, optimal concentration, and packaging method of protective agent, confirmed the formulation and storage life of a liquid agent that can be developed as a microbial fertilizer. A research project used enoki mushrooms to develop a multiple-antigen oral vaccine platform against P protein in Taiwanese norovirus strains; the results of this research can facilitate the development of different types of edible fungal vaccines, including vaccines against hepatitis B, EV71 enterovirus, and norovirus. Japanese encephalitis is an important infectious, insect-borne disease of humans and animals in Taiwan: A research project on the molecular epidemiology of Japanese encephalitis discovered transformations between the different molecular subtypes of the virus, and investigated the possibility that the molecular mechanisms behind differences in replication ability can assist the development of vaccines and prevention of the disease. Researchers relied on cross-species analysis of multiple fish species in different ocean areas to investigate the effect of ocean warming and fishing pressure on the size structure of fish schools; the findings of this study can be applied to management of catch strategies for the fishing industry in the future. Lymphocystivirus is a major infectious virus of fish, and affects the aquaculture industry in Taiwan and abroad; research on the mechanism by which cell lines from fish infected with this virus induce apoptosis and the role of major viral genes in pathogenesis will facilitate the future development of effective preventive strategies. Research involving a mouse model used natural substances from the aster *Bidens pilosa* to develop a novel, superior poultry feed; in the future, this feed can potentially be used to boost chickens' feed conversion rate and improve their gut microbiota, and can be used in research on the breeding of low-fat chickens.

(2) Basic medicine

The field of basic medicine includes morphological and physiological medicine, biochemistry and pharmacology, microbiology, immunity, and testing, pharmacy science, traditional Chinese pharmacology, and food and nutrition. The following major research results were obtained in 2018:

Research investigating the molecular mechanisms of Parkinson's disease prepared mice bearing the VPS35D620N/+ gene expressing Parkinson's disease for the first time in order to investigate the molecular mechanisms of Parkinson's disease. A research project found that the fibroblast growth factor gene FGF9 can enhance the proliferation and mobility of prostate cancer cells and neuroglial cells, has the ability to act as a sex determining gene, and possesses potential in the treatment of neural lineage cells. Researchers found that the ability of growth-associated protein GAP43 to regulate protein homeostasis enables it to prevent molecular mechanisms leading to erroneous protein folding, and this protein can be applied in therapeutic strategies for mild hypoxic-ischemic encephalopathy of newborns. A study found that the Cisd3 gene may be able to regulate the lifespan of mammals; Cisd3 was also found to participate in liver function, and the absence of Cisd3 may promote the emergence of liver cancer. It was discovered that abnormalities in the SUPT4H gene are connected with type 3 spinocerebellar atrophy, and the inhibition or knock-out of SUPT4H may mitigate pathogenic gene expression and reduce the death of neurons in the brain. Other research found that the degradation of the PML gene caused by the WDR4 gene can promote the metastasis and invasiveness of lung cancer cells, which will facilitate

the development of new strategies for inhibiting metastasis in cases of lung cancer.

A project establishing a FPR1 (formyl peptide receptor1) drug development platform successfully performed screening for FPR1 inhibitors, and obtained patents in several countries for its work; the results of this project can potentially be used to develop drugs for the treatment of psoriasis and lung injuries and disorders. Electro-acupuncture of the neiguan acupoints of mice was shown to induce the release of endocannabinoids, achieving a pain-killing effect, and the researchers also discovered that the mechanism behind this pain-killing effect was unconnected with endorphins, and instead involved an all-new analgesic mechanism; because this study's findings elucidated the neurophysiological changes caused by acupuncture, and showed that acupoints can be used as new targets in the development of analgesic drugs, it received a high level of interest from international scholars and media. Research on lingzhi fungus (Ganoderma) and Cordyceps discovered that the high molecular weight saccharides in these two substances can induce the proliferation of the intestinal bacteria *Parabacteroides goldsteinii* in animals; this study verified that the use of this bacteria alone can achieve significant weight reduction and a metabolic syndrome prevention effect; further human trials and research can shed more light on the biochemical and immune regulations mechanisms of these substances, and lay the groundwork for commercialization.

A study investigating the role of group 2 innate lymphoid cells and the short-chain fatty acids created by bacteria living on the skin in atopic dermatitis found that the skin damage of mice treated with a mixture of acetone and ether can simulate atopic dermatitis, which enabled the project to establish a mouse model of atopic dermatitis. Not only will skin damage cause the activation of group 2 innate lymphoid cell (ILC2s) on the skin, but the resulting skin damage will increase activation of the ILC2 cell population, and the project also discovered that IL-33 plays an important role in this process. These findings will facilitate future efforts to develop drugs to treat atopic dermatitis. A different study found that the mechanisms by which chitosan and chitin oligosaccharides improve blood lipid levels are different, which may be because the high molecular weight chitosan can improve fatty liver caused by the accumulation of fat in the liver. Researchers found that substances in the small bitter melon can serve as selective androgen receptor modulators (SARMs), and can improve poor skin quality, mitochondrial function and mobility caused by castration, which indicates that the small bitter melon possesses potential applications in the prevention of skin loss. A research project found that Lycium barbarum polysaccharides can reduce damage to the mucous membrane of the stomach caused by aspirin, and can prevent damage to the gastric mucosa caused by non-steroidal anti-inflammatory drugs (NSAIDs). Phycocyanin can improve oxidation and gastric microbiota in rats with gastric ulcers induced by aspirin, and the use of phycocyanin together with lycium barbarum polysaccharides can increase the stomach's protective factors and improve oxidative stress and the stomach's microbiome.

(3) Clinical medicine

The field of clinical medicine includes community medicine, biomedical engineering, digestive medicine, cardiovascular 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 2018:

Globally, non-alcoholic fatty liver disease is the most common cause of abnormalities in liver function. A study of chronic hepatitis B carriers 40-65 years of age found that that risk factors for metabolic syndrome also imply increased risk of liver cancer, and smoking plays an important role in this relationship. The implementation of tobacco control laws was found to have resulted in significant decreases in risk of premature birth and low-birth-weight newborns, and has therefore promoted the health of pregnant women and newborn infants.

Researchers showed that the early detection of oral health indicators and implementation of oral health promotion measures can improve cardiovascular and metabolic risk factors and the oral health situation of persons with metabolic syndrome. The clinical experiment "Multi-domain Attention Training" showed that this training model can improve attention, executive attention, and spatial orienting attention in elderly persons with mild cognitive impairments.

A project developing delivery carriers for glaucoma drugs investigated the drug release control behavior of polymeric gels and hollow nanoparticles, and also examined the effect of functionally modified medical materials on drug delivery systems. The results of analysis of the physical and chemical properties of these materials verified the characteristics of the various modified drug carriers that have been prepared. This findings of this research project indicated that optimization of hollow nanoparticles and degradable in situ gels is an important factor that can influence carrier drug delivery performance. The results of this project are expected to supercharge the development of novel therapeutic agents in the future.

A project studying lung cancer performed in-depth research on lung cancer diagnosis, treatment, and new mechanisms of metastasis and drug resistance. The project found that multiple genetic and cellular signal transmission pathways are connected with the epithelial-mesenchymal transition, the metastasis of cancer cells, and the drug resistance of cancer stem cells in lung cancer, and its findings may provide new therapeutic targets. Researchers employing a synthetic lethal screen involving the EGFR signal transmission pathway performed screening for miRNA participating in resistance targeted drugs, and obtained information concerning novel genes and signal transmission pathways connected with mutated tumors. The use of targeted therapy and anti-angiogenic antibodies was found to increase the number of cytotoxic T-cells. All of these results can facilitate the development of new lung cancer treatment strategies.

Research involving animal models and clinical specimens revealed that the greater the expression of the ALDH1 gene in patients with esophageal cancer, the later the patients' clinical stage and the lower their survival rate. The use of an anti-inflammatory drug (COX-2 inhibitor) was found to inhibit IL-6 signal transmission, reduce myeloid-derived suppressor cell count, and reduce the invasiveness of tumors with high ALDH1 expression. These research findings can facilitate the development of new treatment protocols for esophageal cancer. Research investigating the relationship between miR-106b and programmed cell death 1 ligand 1 (PD-L1) shed light on the mechanism of the progression of liver cancer resistant to treatment with sorafenib; the results

of this project will help reduce deaths from liver cancer and facilitate the development of new liver cancer treatment strategies, and the project itself has enhanced Taiwan's biotech and clinical trials capabilities, while developing potential methods of treating late stage liver cancer.

Using trigeminal nerve cells and dental pulp cells from mice, a research project investigated neural growth and interaction with stem cells, along with related growth factors, in order to elucidate tooth regeneration and neural regeneration mechanisms. As a precursor to clinical application in humans, this project also employed the placement dental pulp stem cells and nerve growth factor in a 3D printed root canal prosthesis in attempt to achieve tooth regeneration with nerve growth in dogs. The results of the experiment included the discovery of local calcification of the tooth roots, which indicated that neural development and pulp stem cells are connected with the mutual attraction of nerves during the process of tooth regeneration, and dental pulp stem cells can potentially be used to induce tooth regeneration.

Liver cancer patients who also have fatty liver in the non-cancerous portion of their liver tend to have a high body mass index and low adiponectin value. In chronic hepatitis B patients, probably does not play an important role in the progression of the disease. Furthermore, a research project created transgenic mice containing the hepatitis B virus; this animal model is expected to shed light on the pathogenic mechanism by which the hepatitis B virus causes liver cancer.

Research on the brains of possible early-stage Alzheimer's disease patients observed structural degenerative changes linked with brain areas, and found that the accumulation of amyloid is linked with the spatial distribution of atrophy in the cerebral cortex. A study found that DNA demethylation may participate in the development of chronic pain via expression of nociception genes. Melatonin was found to reverse the demethylation of target genes via type 2 melatonin receptors, and effectively ease behavioral signs of pain.

Researchers applying ultrasound contrast agent with microbubbles in a new approach to the delivery of delivering drugs to the cochlea achieved a higher drug concentration in the inner ear, which will enable greater effectiveness in drug treatment of diseases of the inner ear. A study employing blood specimens developed a smear test able to perform the early detection of nasopharyngeal

Research manpower in life science specific-topic research projects, 2014-2018

Item		2014	2015	2016	2017	2018
Research personnel	Professors	2,965	3,001	2,897	2,965	3,078
	Associate professors	1,635	1,517	1,494	1,520	1,506
	Assistant professors	1,439	1,383	1,352	1,384	1,394
	Lecturers	62	48	39	38	43
	Other	3,088	3,223	3,278	3,406	3,613
Subtotal		9,189	9,172	9,060	9,313	9,634
Research assistants	Full-time assistants	2,937	2,789	2,830	3,051	2,765
	Part-time assistants	23	16	14	9	6
	Graduate students	5,393	4,956	4,568	4,370	4,869
Subtotal		8,353	7,761	7,412	7,430	7,640
Total		**17,542**	**16,933**	**16,472**	**16,743**	**17,274**

Numbers and percentages of one-year and multi-year specific-topic research projects in life science, 2014-2018

Year	All projects	One-year projects (%)	Multi-year Projects (%)
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）
2017	4,224	1,342（31.77）	2,882（68.23）
2018	**4,362**	**1,405（32.21）**	**2,957（67.79）**

Numbers of life science specific-topic research projects and funding, 2018 Units: NT

Item	Applications		Approved		Implemented	
	Projects	Funding	Projects	Funding	Projects	Funding
Medicine	4,585	19,353.61	2,021	2,599.01	3,300	4,183.75
Biology	380	1,923.90	173	256.46	295	431.50
Agricultural science	643	2,387.09	288	398.88	463	623.99
Special projects and other	318	6,244.91	165	643.23	166	644.23
Total	**5,926**	**29,909.51**	**2,647**	**3,897.58**	**4,224**	**5,883.47**

cancer in individuals with a family history of multiple nasopharyngeal cancer. This method will achieve early diagnosis of nasopharyngeal cancer in both the members of families with multiple nasopharyngeal cancer and ordinary individuals. Specific immune receptor genotypes in B lymphocytes were found to be linked with allergic reactions to non-steroidal anti-inflammatory drugs (NSAIDs). These findings can be used to reduce severe allergic reactions to drugs through the screening of patients before they receive treatment.

4. Humanities and Social Sciences (including Science Education)

The humanities and social sciences comprise 25 disciplines in the four major areas of the humanities (literature I, literature II, linguistics, history, philosophy, and art), the social sciences (law, political science, anthropology and ethnology, sociology (including mass communications), education (including physical education and library information), psychology, and economics), management (management I, management II, finance and accounting, regional studies, and geography), and science education (mathematics education, science education, information education, applied science education, medical education, multicultural science education, technological society and mass communications, and science education practice). The following is an overview of the results of projects during 2018:

(1) Establishment of a Taiwan Empirical Database

MOST believes that Taiwan's developmental experience, including its politics, economics, society, and education, should be systematically organized and preserved as a resource for scholars in relevant fields. In recent years, MOST has established the Taiwan Social Change Survey Database, Election and Democratization Study Database, Taiwan Database for Empirical Legal Studies, Taiwan Communication Survey, Kids in Taiwan: National Longitudinal Study of Child Development and Care database, and Survey Research Data Archive, etc. These databases provide researchers multifaceted

long-term tracking data, help pass on experience, and serve as the shared assets of academic researchers and policy-drafting agencies.

(2) Major Cognitive and Mind Science Research Equipment Joint Use Service

Research on human cognitive function through the observation of brain activity has become a major international research trend in the humanities and social sciences. In order to keep up with international trends, MOST has supported the acquisition and installation of functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG) equipment, and has established three Taiwan Mind & Brain Imaging Centers, which perform instrument maintenance & operation, training, research consulting, and encouragement of research. This project is providing the following benefits to the humanities and social sciences: (1) provision of more objective measurements, (2) expansion of research topics, (3) encouragement of interdisciplinary dialogue, (4) promotion of international cooperative research, and (5) facilitation of recruiting and training. Various research projects on such different aspects as "understanding the self," "interpersonal interaction," "humans and the environment," and "people and culture" have gotten underway, including projects on the topics of cognitive control and prediction of brain age, the brain during social interactions, benefits of natural scenery, neural mechanisms of children's mathematics learning, language differences between autistic and healthy children, use of mindfulness training to improve pain, and research on aging. Relevant research projects have begun cooperation with prominent universities overseas, and research talent has been recruited. In addition, the fMRI unit has been connected with the Internet in order to facilitate research on social interaction, and also to allow scholars to remotely use fMRI to investigate the characteristics of brain activities during interpersonal interactions.

(3) High school camp and high school classic reading camp program

The participants in this camp consist of 200 high school freshmen from throughout the country who had a high level of interest in the humanities and social sciences, and vocational high school participants have also been recruited in recent years. The camp relies on lively instruction to increase young scholars' interest in the humanities and social sciences, and a total of 22 general knowledge class sessions were held during a two-week period in students' summer vacation. Professional lecturers in various academic fields were engaged to teach the basic ideas and concepts of various subjects, and the classes also included field trips and presentation of group results, as well as opportunities for participation in research and analysis. Fourteen outstanding Ph.D. students in different fields served as camp advisors, and encouraged the participants to think about the subjects of the classes through group discussions.

(4) Stanford-Taiwan Social Science Fellowship Program

Stanford University's Center for Advanced Study in the Behavioral Sciences at Stanford University (CASBS) was established in 1954, and has had a profound impact on the social sciences. A total of over 2,500 scholars have served as in-residence researchers at CASBS over the past 60 years, including 25 Nobel laureates, 23 Pulitzer Prize winners, and 146 members of the US National Academy of Sciences. To encourage domestic scholars in the humanities and social sciences to participate in CASBS' interdisciplinary dialogue and interchange, and increase high-level research manpower in the humanities and social sciences, this program sent one outstanding domestic humanities and social science scholar to CASBS in 2018 for academic interchange activities.

(5) Projects for Book Writing in Humanities and Social Sciences

These projects are intended to enhance the quality of scholarly books in the humanities and social sciences, and ensure that academic books more comprehensively present scholars' research results and perspectives, have greater academic depth and breath, present both local and

international outlooks, and are highly influential in their fields. MOST makes an open call for proposals and provides funding for a maximum of 6 projects each year. A total of 19 projects received funding from 2013 to 2018. The following two books have completed review and been published thus far: (1) *Establishing a Foundation for Operatic Music*, which is a major work on opera containing over 300,000 words and presenting the milestone achievements of the author and other scholars, and (2) *Raising Global Families: Parenting, Immigration, and Class in Taiwan and the US*, which was published by the Stanford University Press, and compares the parenting of families in Taiwan and immigrants from Taiwan/China living in the United States, and analyzes how two-way cultural networks and circuits are formed between the mother country and country of origin, and between global society and the locale.

(6) Innovative Emerging Technology Business Operating Model Program (Flagship Program)

The goal of this program is to establish bridges between the humanities and technology and increase the value of technology in the humanities and social sciences. In conjunction with the "5+2 Industrial Innovation Plan," local links with the New Southbound Policy, and emerging technological media issues, MOST hopes to establish at least 5 innovative business and emerging technology media research centers, and provided funding to 8 projects in 2018. The results of implementation included the following:

a. At MOST's urging, National Taiwan University, National Tsinghua University, National Chengchi University, National Sun Yat-sen University, Feng Chia University, and National Chungshing University organized 8 inter-organizational/departmental cooperative teams to propose new industrial innovation business models and emerging technology media research projects in the areas of smart machinery, digital economy, biotech medicine, new agriculture, and Asia Silicon Valley.

b. MOST has encouraged academic researchers and industry groups to engage in cooperation, such as through establishment of the "Taiwan Intelligent Manufacturing Innovation Consortium," and establish platforms to bring together partners to exploit cross-domain business opportunities.

c. To encourage the investigation of innovative business models in connection with efforts to enter New Southbound Policy markets and analyze case content, MOST sponsored the publication of *Collected Innovative Business Model Cases: Smart Cities*, performed matchmaking of inter-domain business opportunities, and held a number of conferences and workshops for industry and academia.

d. MOST has established an expert and media online database, and conducted a development risk inventory for the fields of green energy, biomedicine, and intelligent machinery industries. In the case of the intelligent machinery industry, for example, this inventory included an examination of impacts on employment and social ethics, and information security worries about Internet of Things systems and products.

(7) Humane Innovation and Social Practice

This program's second stage (2016-2019) is currently being conducted at three schools: Taipei

Medical University, National Chi-Nan University, and National Cheng Kung University, and its third stage (2018-2022) will be conducted at National Sun Yat-sen University and Tunghai University. Each school is employing a different operating model, and is providing other schools reference information concerning innovation and social practice in the humanities via school-wide projects. This project's results have included:

a. Taipei Medical University conducted a cultural knowledge preservation and seed conservation project involving the millet culture of the Atayal indigenous residents of the mountainous areas around Jianshi, Hsinchu, and initiated a cultural care exploratory activity. In recognition of the fact that elders and women have become the driving force of village culture revival and the local sharing economy, the project team expanded its attention from preservation of the millet culture under the "Elder Millet Field" focal point to the "Yaya's Food" production and marketing program organized by village women.

b. National Chi-Nan University empowered youths at Meixi Village, Nantou through training in reporting, writing, and activism addressing major local issues. The project also developed a user-friendly air quality instrument measuring PM2.5 air pollution within the local area, and encouraged local residents to use websites or cell phone apps to monitor air quality. In this project, scientific instrument R&D triggered changes in human behavior and pushed the government to quickly draft a total air pollutant control plan and establish an inter-city/county air pollution reduction committee. The project team is continuing to work with the Puli Self-Help Association to jointly promote environmental education and awareness, establish consciousness of air pollution, and encourage the public to engage in further activism.

c. National Cheng Kung University supported aging in place among the elderly residents of Tainan's Yintong Community, and employed diversified, small-scale, focused (emphasizing community relationships) community activities and spatial environment construction measures to encourage low-participation residents of community margins and mobility-impaired residents to participate in activism and express concern for local community issues. The university also promoted the concept of "University Community Supported Agriculture" (UCSA) in the Dadongyuan area of Tainan as a core element of social practice and means of restoring the partnership between humans and nature.

(8) Cooperation between Universities and Local Governments in Promoting Local Cultural Development and Interregional Governance Plan

This project has sought to cultivate interregional cultural development cooperation mechanisms involving public-private collaboration and synthesis reflecting a perspective of humane concern and value innovation through cooperation between universities and local governments. The project is also encouraging universities to dedicate research and practical problem-solving efforts to real issues facing Taiwan, and explore the cultural development and interregional governance problems encountered in isolated townships and cities throughout Taiwan. The project cooperated with the governments of Hsinchu, Miaoli County, Nantou County, Penghu County, and Pingtung County in 2018. Major results have included the organization of a community empowerment task force by National Penghu University of Science and Technology and the introduction of the concept of "citizen review" in the isolated communities of Penghu County; the promotion of the "Moses Parts the Sea" new travel attraction community construction activity, which has sought to promote local development and establish a sustainable social development model for Taiwan's offshore islands; and National Chi Nan University's assistance with the establishment of a Nantou County food bank network through specific recommendations, which led to the development of an innovative model that the Nantou County government can use to promote the establishment of food banks.

(9) Humanities Salon

In order to guide the practical applications of humanities and social science research, and thereby generate greater benefit for society, MOST has held "Humanities Salon" talks in northern, central, southern, and eastern Taiwan. MOST hopes that these crowd-pleasing talks will spread awareness of the universal value of research on culture, the arts, and the social sciences. Twelve talks were held in 2018, attracting more than 1,500 participants.

(10) Indigenous Science Education Program

Based on respect for the existing culture of Taiwan's indigenous citizens, a wish to enhance indigenous children's science and mathematics interest and skills, and in compliance with the UN's education for sustainable development indicator and spirit, MOST has developed a science and mathematics education environment reflecting indigenous knowledge systems. Funding was provided to 21 project teams this year, and research efforts focused on the Tsou, Atayal, Paiwan, Bunun, Amis, Rukai, Tao, and Seediq ethnic groups, as well as the urban indigenous population. Implementation results in 2018 included: (1) An indigenous science fair in Hualien's Dongdamen Night Market featured 19 activity booths containing interesting science activities with tribal cultural elements, and attracted numerous members of the public of all ages while displaying the traditional scientific knowledge of indigenous of Taiwan's peoples. (2) The "2018 Symposium of Indigenous Knowledge & Quality of Education" featured discussion of the "sustainable development of indigenous education" between domestic researchers and 10 invited experts from nine countries. (3) A teaching strategy combining Atayal culture with collaborative problem solving was used to establish a mathematical spatial concepts course teaching and assessment platform, and several teacher workshops were held to increase promotion of this teaching method.

(11) Science Education Dragon Training Program (phase II)

This program consisted of a long-term joint research project employing an action research method in elementary and middle schools and seeking to address the growing gap in individual science and mathematics achievement among elementary and middle school students. Working from a theoretical foundation, this program developed practical teaching materials and methods intended to boost the science and mathematics interest and ability of young students who had previously displayed low to moderate scholastic

Research manpower in humanities and social science specific-topic research projects, 2014-2018

Item		2014	2015	2016	2017	2018
Research personnel	Professors	2,664	2,661	2,686	2,732	2,752
	Associate professors	2,329	2,392	2,321	2,264	2,085
	Assistant professors	2,081	1,948	1,867	1,703	1,583
	Lecturers	42	52	50	43	36
	Other	558	618	696	740	766
Subtotal		7,674	7,671	7,620	7,482	7,222
Research assistants	Full-time assistants	925	936	937	884	811
	Part-time assistants	377	384	336	213	191
	Graduate students	11,491	11,573	10,878	10,463	9,801
Subtotal		12,793	12,893	12,151	11,560	10,803
Total		**20,467**	**20,564**	**19,771**	**19,042**	**18,025**

achievement. Eight integrated projects are receiving funding under phase II of this program, and chiefly seek enhance students' learning performance using the following three approaches: (1) Use of explorative activities involving hands-on activities, e-books, and tabletop games to enhance learning interest and motivation; (2) use of computer simulations to assist understanding of abstract scientific concepts; and (3) establishment of online social networking platforms or holding of teachers' workshops to help teachers learn interdisciplinary integrated teaching skills and use of technology. A total of 191 teachers and 3,685 students at 61 elementary and middle schools participated in this program during 2017. In the use of computer simulations to aid the understanding of abstract scientific concepts, the program has developed more than 80 science simulations for use by teachers and students, including 17 mini science simulation games aimed at elementary and middle school science classes and encompassing the concepts of kinematics, dynamics, optics, electricity, and heat. These simulations will provide teachers a new science demonstration resource, and offer students opportunities to acquire science inquiry skills through exploration and hands-on experience. Apart from cooperation with the Spanish scholar Francisco (Paco) Esquembre, the program will continue to improve its online simulation platform website, and also cooperate with the EU Framework Programme in the introduction of 32 science simulations via the Next-Lab project. This will not only increase the platform's international visibility and reach, but also open the door to more future international cooperation opportunities.

(12) Gender in Science and Technology Program

In order to promote gender research in science and technology, and publicize past result for the purpose of stimulating even more diverse and innovative developments, MOST approved

Numbers and percentage of one-and multi-year specific-topics research in humanities and social science, 2014-2018

Year	Total projects	One-year projects(%)	Multi-year projects(%)
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）
2017	4,650	2,473（53.18）	2,177（46.82）
2018	**5,227**	**2,512（48.06）**	**2,715（51.94）**

Numbers of humanities and social sciences specific-topic (including science education) research projects and funding, 2018

Units: NT$1 m

Item	Applications		Approved		Implemented projects	
	Projects	Funding	Projects	Funding	Projects	Funding
Humanities	1,623	1,211.56	784	441.60	1,056	618.33
Social sciences	2,290	2,607.65	1,108	803.67	1,535	1,175.30
Management	2,287	1,966.93	1,096	695.06	1,416	966.81
Science education	755	1,661.19	381	281.88	663	576.80
Emerging / other fields	70	10.60	15	9.93	15	9.93
Projects and other	1,063	4,206.53	305	266.55	554	471.62
Total	**8,088**	**11,664.46**	**3,689**	**2,498.69**	**5,239**	**3,818.80**

the "Gender in Science and Technology (GIST) Program" in 2018 after a public request for proposals and review process. This three-year program is being implemented by a team in the Graduate Institute of Gender Education, National Kaohsiung Normal University, will receive total funding of NT$10.4 million, and is focusing on six major topics. Apart from providing MOST with gender-related service promotion direction and policy recommendations, the program will also actively promote gendered innovations in various fields of science and technology, and seeks to encourage research personnel to incorporate physiological gender and social gender analysis in their research process, which will lead to the proposal of innovative S&T research with gender-related content. The aforementioned six major topics include: (1) promotion of innovative research in interdisciplinary gender medicine, (2) development of gender-friendly hiring strategies in science and engineering, (3) analysis of gender and S&T policies in Europe, Canada, Asia, and Australia, (4) analysis and extension of past gender and S&T project results, (5) application of extension and administrative cooperation, and (6) gender and the extension of new tech media.

B. National Science and Technology Program-Energy

The second phase of the National Science and Technology Program-Energy (2014-2018) has been jointly implemented by MOST, the Ministry of Economic Affairs, Ministry of Transportation and Communications, and Atomic Energy Council. The goals of this stage included: (1) enhancement of energy efficiency and lessening of dependence on imported energy sources; (2) increasing the international competitiveness of the alternative energy industry; (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) prospecting and 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 development of an energy industry, such as via the verification of energy technology industrialization and by steering research results to industry. To date, technology licensing cases resulting from this program have had a cumulative value of more than NT$2.29 billion, and the licensed technologies were derived from such projects as "Development of microgrid feed voltage control technology," "Wind farm operating and monitoring technologies," "Development of mass production technology for perovskite solar cells," "Infrared sensor film sputtering," and "Development of a virtual power plant power supply service system." Furthermore, the program induced companies to invest more than NT$3.53 billion in relevant energy technology R&D and more than NT$7.34 billion in production, which has facilitated the upgrading and transformation of the domestic energy industry. The following results were achieved in 2018:

1. Energy creation

(1) Solar energy

a. Autonomous development of mass production processes for the calcium titanate material perovskite, which is widely used in solar cells, along with related machinery: The product had a photoelectric efficiency of 13%; the Shang Yi company invested in this technology, with a technology licensing fee of NT$3 million, and the program also performed NT$720,000 worth of technical service for the CPC Corporation.

b. The program developed a low carbon footprint photovoltaic module: The product had a photoelectric efficiency of over 35%, and 90% of the materials in the module can be recycled, which can dramatically reduce damage to the environment.

(2) Biomass energy

a. Researchers confirmed process technology for different biomass sources, and obtained ton-grade full process know-how for carbohydrate fermentation and lactic acid manufacturing technologies, which have received international patents.

b. The combination of unique biomass technology with a regional business model can accelerate the conversion of biomass into clean zero-carbon energy in the form of biofuel and high-unit-price byproducts. This approach can support the New Southbound Policy by using Southeast Asia's plentiful biomass as a source of biomass energy for Taiwan.

c. Technology from the program has been licensed to the domestic firm Hai Sen Wei Broadband and the Malaysia-based Taiwanese firm Han Sen, which will establish a production enterprise. The program is also working with Taiwan's representative office in India to promote licensing of the technology by India's new energy companies.

(3) Offshore wind power

a. Referring to international design standard IEC61400-3 and technical guidance GL, the program completed ultimate strength analysis and fatigue damage assessment for a series of offshore support structures. Based on assessment results, the program submitted load calculation procedures for the preliminary design stage to the China Steel company. This work will accelerate wind farm planning and preparatory efforts. China Steel has chosen to establish an offshore wind farm with 300MW of installed capacity during the first stage of construction work, and is the leading wind farm development company in Taiwan.

b. The program provided China Steel comprehensive load calculation procedures, and relied on industry-academic collaboration to license offshore wind turbine support structure design analysis technology. This technology will fill China Steel's technological gap, and enable it to establish autonomous domestic design analysis capabilities. China Steel has recently invested NT$6.5 billion in an offshore wind turbine fixed underwater structure production line located at Kaohsiung's Xingda Harbor.

(4) Marine energy

a. The program completed anchoring of an ocean current generating unit test platform in the seas off Cape Eluanbi, and tested the 50kW generating unit at sea.

b. Completion of development of an 800W floating generating unit and boat-towed experimental unit in the Kuroshio current; this generating unit was jointly designed and manufactured in Taiwan by domestic industry, universities, and research organizations.

(5) Geothermal energy

a. The construction of a series of dispersed geothermal power plants will be completed during the period of 2018-2020, and will have total installed capacity of 7MWe. If foreign technical models can be acquired and developed, Taiwan's geothermal power installed capacity can reach 10MW within 5-10 years.

b. The establishment of geothermal generating plants can promote the development of Taiwan's power industry, and geothermal generating unit R&D and the development of anti-acidic corrosion and anti-scaling technologies—both of which are important in the operation of geothermal generating stations—can stimulate the development of related industries. Furthermore, cogeneration technology can use the excess heat from geothermal power for secondary power generation, or used in greenhouse agriculture or fish-farming, which can boost energy use efficiency.

2. Energy conservation

(1) Development of innovative external rotor permanent magnet brushless motors:

a. Taiwan's first semi-automated, quality engineering-based production line for external rotor BLDC motors and control modules has been established, and the product quality attainment rate exceeds 99%.

b. An alliance of domestic and foreign domestic motor and motor controller supply system firms (ITRI + RichTek + Dyna Rechi) and domestic and foreign module vendors (Jia Long + HonnShin + Chun Tai) has established a demonstration production line in Shalun, and is promoting its motors in in the international brand market; orders for 7,000 motors have been received thus far.

(2) Development of aerogel building materials technology and applications:

a. The properties of aerogel powders (thermal conductivity coefficient of <0.04 W/m-K, specific surface area >700 m^2/g) developed in this program rival those of the international benchmark product (Carbot). If produced in large-scale quantities, production cost can be reduced to under NT$1,500/kg.

b. It has been verified that energy-saving roofs and aerogel-insulated multi-layer glass can reduce air conditioning power consumption by 30% compared with conventional sheet metal roofs and single-layer glass. The use of building materials such as aerogel glass and aerogel phase-change coatings can improve the insulating properties of cargo container buildings, and thereby reduce annual power consumption by 35%.

c. The Ya Bi Si Energy Conservation Tech. Co., Ltd., which was founded to produce and sell an aluminum foil aerogel phenolic foam board product, developed high insulating performance aerogel powder, aerogel fireproofing materials, and integrated energy consisted of building materials and renewal energy applications. The company has also been actively developing commercial applications of aerogel technology in multi-layer glass, coatings, and fireproof functional fabrics, etc.

(3) Establishment of a magnetic bearing centrifuge industry supply chain: By coupling international sources of technology with industrial upgrading in the domestic supply chain, the program has made Taiwan the world's second largest magnetic bearing centrifuge supplier.

(4) Development of a soft printed circuit board process with ultra-fine line width: The program has fostered the establishment of Taiwan's first contract printed electronics firm, which is expected to create NT$120 million in value annually during the initial period.

(5) New combustion systems: Completion of Taiwan's first industrial pilot scale demonstration of pulverized coal/biomass stack gas co-combustion with pure oxygen reflow, which achieved a stack gas CO_2 concentration of 94%. In addition, the program also established a clean combustion research facility, which includes pilot-level experimental 280kW solid/liquid fuel, 100kW gaseous fuel, and 200kW fluidized bed furnaces. The Institute of Nuclear Energy Research's gasification technology, National Cheng Kung University's oxygen enriched combustion technology, ITRI's chemical looping process, and National Central University's integrated gasification fuel cell technology were used to establish a kilowatt-grade demonstration platform.

3. Energy storage

(1) The development of non-platinum key catalyst materials will reduce fuel cell battery cost and accelerate industrialization and product marketing.

(2) The development of a solid electrolyte interface modified lithium batteries resolved the problem of short battery life cycle in electric vehicles due to damage by organic solvents, and boosted number of battery charging cycles. Lithium batteries using this technology can be charged as many as 1,400 times, which is equivalent to the extension of battery life by roughly 70% compared with unmodified batteries.

(3) Aluminum ion batteries developed under this program have received over 50 domestic and foreign patents, and account for over 35% of all aluminum battery patents worldwide, making Taiwan the global leader in this technology. To accelerate the industrialization of aluminum batteries, the program is cooperating with the largest domestic battery module producer, promoting the establishment of a materials supply company, and has licensed technology to a Shalun materials plant.

4. Systems integration

(1) Smart grid

a. Smart metering technology: Following the installation of smart meters at 24,000 high-voltage users by 2013, the installation of smart meters at 200,000 low-voltage users got underway in 2017, and it is expected that 3 million users will have smart meters by 2024. In addition, smart meters have been exported to Japan, Korea, Ireland, Thailand, Vietnam, Indonesia, the Philippines, Malaysia, and the Middle East.

b. Advanced power distribution automation: The program's researchers worked with the Tatung Company and Ablerex Electronics to develop a smart inverter monitoring system, which was verified and adopted by the Taiwan Power Company's high-penetration renewable energy grid connection system; this technology will continue to be developed and promoted to Malaysia in the future.

c. Micro-grid technology: Micro-grid technology developed in this program is being applied in Pingtung's Guancai Wetlands, new Taipei Fushan elementary schools, Dongjiyu and Qimei islands, Penghu, Kaohsiung's Yongan salt flats, Myanmar, Indonesia, the Philippines, China, and Japan.

d. Virtual power plant technology: Application to phases I and II of Taipei's Xinglong Public Housing development, with over 300 households integrated into the system (trial users of the Xinglong Public Housing Phase I smart grid can save 11% in power costs). Relevant technology has been licensed to Tatung and Delta Electronics, and will be extended to representative projects by Taiwan Power Company's user base, ASE's plant, Beitou Shilin Science Park, Shalun Smart Green Energy Science City, and in Malaysia.

e. Smart power distribution system monitoring technology: Auvus Technology has continued to sell its PMU (μPMU) technology and products to the Taiwan Power Co. and other domestic companies with high power quality needs, has completed development of a wide area data processing (WADP) system, and has embarked on the development of an automatic intelligent electronic device malfunction handling system platform.

(2) Application of microalgae to carbon fixation:

a. The program constructed East Asia's largest microalgae culture pond, and established a startup company (GreenFeel Biotechnology, capital of approximately NT$25 million). Many existing products enjoy steady sales, and the program has founded the Asian Microalgae Biotech Alliance together Korea's largest microalgae biomass energy R&D team and a team from Kobe University—Japan's leading group in the field of biomass energy.

b. Development of high value microalgae products (including high astaxanthin microalgae, high xanthophyll microalgae, high protein microalgae, and alkaline wastewater tolerant microalgae): These microalgae products can be used in products with high economic value, such as nutriceutical foods, cosmetics and skin care products, and additives for aquaculture and animal feed.

c. It was shown that a semi-continuous microalgae culture system with reuse of recovered microalgae culture fluid can reduce the cost of microalgae nutrient medium from NT$160 per ton to NT$95 per ton.

Undersea exploration and underwater sampling engineering platform: The first platform of its kind to be autonomously developed and assembled in Taiwan, this underwater exploration and sampling system includes a deep-sea real-time imaging-

Major achievements of the National Science and Technology Program-Energy, 2018

Item	Item	Total
Academic papers	Conference papers	**715**
	Journal papers	**355**
Manpower training	Ph.D. students	**148**
	M.S. students	**616**
Patents	Received	**229**
	Pending	**232**
Technology licensing	Cases	**221**
	Licensing fees (NT$1,000)	**166,720**
	Royalties (NT$1,000)	**31,950**
	Signing fees (NT$1,000)	**228,381**
Promotion of corporate investment	Cases	**238**
	R&D (NT$1,000)	**3,435,590**
	Production (NT$1,000)	**32,509,978**
Startups	Companies	**2**
Employment	Persons	**512**

guided instrument platform, visually-guided rock core sampling system, and visually-guided grab bucket system.

C. Research Results of the National Synchrotron Radiation Research Center

National Synchrotron Radiation Research Center (NSRRC) continued to stably operate the 1.5 GeV Taiwan Light Source (TLS) synchrotron accelerator and its experimental facilities, and the newly-completed 3.0 GeV Taiwan Photon Source (TPS) synchrotron accelerator and its experimental facilities, while continuing to install and operate the TPS's beamline facilities. NSRRC's synchrotron accelerators provide users nationwide with powerful tools supporting advanced scientific and applications research, and NSRRC is also continuing to promote research on forward-looking topics in the fields of biomedicine, nanotechnology, and green energy, train high-tech talent, encourage international cooperation, and strengthen industry's R&D capabilities. In addition, NSRRC has taken on operating and maintenance duties for the Taiwan-Australian neutron facility, and is helping domestic users to perform experiments and accumulate the specialized knowledge and technical skills needed for neutron experiments.

1. Accelerator facilities

The TLS and TPS accelerator light sources continued to operate stably 24 hours a day in 2018, had operating times of 6,375 hours (TLS) and 5,831 hours (TPS) during the year, and had an electron beam stability index (△I0/I0, beam strength fluctuation ratio) of less than 0.2% for 99.5% (TLS) and 97.4% (TPS) of times when in use by users. Throughout the year, NSRRC continued to perform maintenance of the accelerators' power supplies, beam dynamics, 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 24 hours a day.

2. Beamline experimental facilities

Beamlines at NSRRC's accelerators encompass the infrared, UV, soft X-ray, and hard X-ray spectral ranges. In 2018, apart from continuing to operate, maintain, and upgrade the 24 TLS beamlines and two beamlines for use by Taiwan at Japan's SPring-8 facility, NSRRC also opened to users the first protein crystallography (TPS 05A) facility, temporal coherence X-ray diffraction facility (TPS 09A) X-ray nanometer diffraction (TPS 21A), X-ray nanometer probe (TPS 23A), and coherent X-ray scattering (TPS 25A) beamlines at TPS, along with TPS's second-phase quick X-ray absorption spectroscopy beamline (TPS 44A). These beamlines will help users to perform advanced scientific research in such fields as natural science, biomedicine, and nanotechnology. During 2018, use of beamlines at the TLS, TPS, and the dedicated Taiwan beamlines at Japan's SPring-8 in experimental projects totaled 112,620 hours, 11,664 hours, and 8,052 hours. Plans call for TPS to have 25 beamline experimental facilities, which will be constructed in three phases. The seven phase-one facilities were completed in 2018, and construction of the nine phase-two beamline facilities is currently underway.

3. User extension and scientific research

A total of 1,965 research projects (12,033 person-times) used NSRRC's TLS and TPS beamlines, and the Taiwan beamlines at SPring-8, for cutting-edge experiments during 2018, and 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 313 SCI-cited papers in prominent international scientific journals, including 139 papers published in prestigious journals with impact factors in the top 10%, and 86 papers published in journals with impact factors in the top 5%. Notable papers included "Actin-binding proteins from Asgard archaea can bind to and regulate eukaryotic actin," which used

TPS's protein crystallography experiment station (experiment station TPS 05A) and was published in *Nature*; "Phase orientation of Eu^{2+} in the $K_2BaCa(PO_4)_2$ polycation blue light material system and its thermally stable emission characteristics," which used TPS's temporal coherence X-ray diffraction experiment station (experiment station TPS 09A) and was published in *Journal of the American Chemical Society*; " Bioinspired solid state gyroid icositetrahedral microstructures and their trapping of structural coloration," which used TPS's coherent X-ray scattering experiment station (experiment station TPS 25A) and was published in *ACS Nano*); "Active sites in the electrocatalytic reduction of carbon dioxide by nickel (I) dispersed as single atoms," which used the biostructure and materials research experiment station at Japan's SPring-8 light source and TLS's high energy SGM experiment station (experiment station SP12B and 20A1) and was published in *Nature Energy*; "A high efficiency fully-hydrolyzed catalyst: Co_3O_4 with added phosphorus," which used TLS's X-ray absorption spectroscopy experiment station (experiment station 17C1) and was published in *Energy & Environmental Science*; " Highly efficient mixed 2D/3D hybrid perovskite solar cells via low-pressure vapor-assisted solution process," which used TLS small-angle X-ray scattering experiment station (experiment station 23A1) and was published in *Advanced Materials*; "Use of the cationic dislocation effect to enhance the emission efficiency and thermal stability of phosphor powder," which used TLS's high-energy X-ray diffraction experiment station (experiment station 01C2) and was published in the *Journal of the American Chemical Society*; and "Use of protein crystal structure to explain the mechanism of bacterial cell wall remodeling," which used TLS's biomedical technology protein crystallography experiment station (experiment station 15A1) and was published in *Nature Communications*.

In order to promote academic interchange and results sharing in the field of synchrotron accelerator research and development, NSRRC invites domestic and foreign scholars and all users to annual user conferences and seminars. The 24th user conference was held September 11-13, 2018, Dr. Liu Fu-Tong, vice president of the Academia Sinica, served as keynote speaker. This event include four symposiums on the subjects of the "Applications of modern spectroscopic methods of inorganic chemistry to biology and chemistry using synchrotron radiation," "VUV experiments in molecular and aerosol sciences," "Full-field hard X-ray microscopy and its applications," and "Complementary applications of X-rays and neutrons," which gave the participants opportunities for sharing novel research results in relevant fields.

The 13th International Conference on Synchrotron Radiation Instrumentation (SRI 2018) was held June 10 - 15 and hosted by NSRRC at the Taipei International Convention Center; more than 800 scientists involved with synchrotron radiation from 25 countries attended this event. SRI is held by turns in Europe, the Americas, and Asia every three years, and is the world's largest international conference focusing on synchrotron radiation research; apart from academic and technological interchange, the event also makes a great contribution to the promotion of cooperation among scientific and research personnel. Furthermore, NSRRC also held several synchrotron light source conferences and activities during 2018, including the Science Advisory Committee (SAC) and 10th Continuous Wave and High Average Power RF Workshop (CWRF

2018), International Workshop on X-ray Optics and Metrology (IWXM 2018), 18th Taiwan-Japan-Korea Symposium on Strongly Correlated Electron Systems (TJK18), and the 12th International Workshop on Personal Computers and Particle Accelerator Controls (PCaPAC).

4. Collaboration with industry

NSRRC is making continuous efforts to deepen and broaden the industrial applications of synchrotron radiation. Apart from the NSRRC's efforts to strengthen ties with key members of the semiconductor industry and increase beamline time available for industrial research, there has been steady growth in R&D users from the plastics industry and biomedical pharmaceutical industry. In 2018, a microspectrometer startup company project completed technology licensing procedures with NSRRC, and the startup has proposed an incubation plan, which calls for the pilot production of products, in 2019. As for plastic industry applications, NSRRC has continued to implement the "High-value ultra-strong fiber R&D" 5-year collaborative project with a major domestic manufacturer, and is also helping a manufacturer to develop plastic graphitization 3C product applications in the second phase of a commissioned research project. With regard to technical services to the biopharmaceutical industry, NSRRC introduced a protein drug integrated analytical service program in 2018, and provides service packages including synchrotron radiation circular dichroism (SRCD), biological small-angle scattering, and protein diffraction analysis. As a consequence, NSRRC has successfully attracted key new drug companies in Taiwan to use synchrotron radiation for pharmacokinetics research and structural analysis of drugs consisting of large biomolecules. In order to promote the development of industrial applications of core synchrotron radiation technologies, NSRRC established an industrial applications strategy office in 2018, and has been relying on innovative industrial strategies, bridging and cooperation, horizontal and vertical coordination, and the draft of industrial laws and regulations to expand and deepen the industrial applications of synchrotron radiation technology.

5. Manpower training

Apart from helping to train synchrotron radiation talent by jointly conducting synchrotron radiation classes with National Tsinghua University, National Chiao Tung University, and National Sun Yat-sen University to offer light source classes, promoting the integration and sharing of its research resources, and recommending outstanding young trainees to participate in foreign classes, NSRRC has sought to boost Taiwan's synchrotron accelerator light source manpower be recommending outstanding young personnel to take classes overseas. NSRRC has also held numerous light source technology and applications training classes and seminars, including a seminar on synchrotron radiation microscopy and microscopic image analysis, a winter class on free electron lasers, a seminar on X-ray nanometer diffraction data acquisition and analysis, accelerator class for the 10th convention of the Organization of Chinese Physicists and Astronomers (OCPA 2018), the 9th X-ray summer school, an explanatory meeting on quick X-ray absorption spectroscopy experiment techniques, a summer training camp on X-ray absorption spectroscopy, a training class on protein crystallography, a high-resolution X-ray powder diffraction training class, a summer synchrotron radiation application and internship program, and the 6th advanced light source summer science internships.

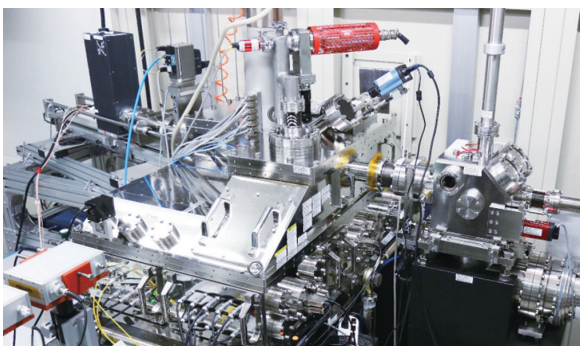
6. New light source facilities and prospects

During the year since the TPS was opened for use, a paper on Asgard archaea based on research conducted using a TPS beamline was published in the prestigious journal *Nature*, and another five papers based on research using NSRRC's experimental facilities were featured on the front or back covers of major scientific journals. These high-quality research results are

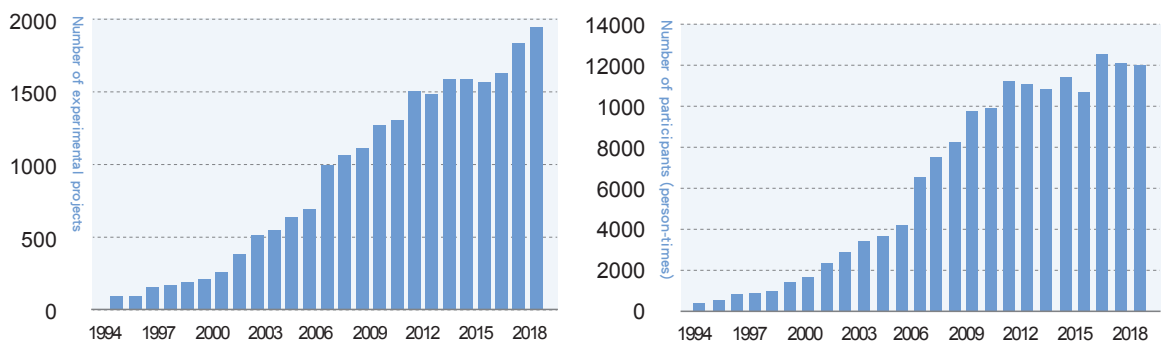
successfully boosting the international visibility of Taiwan's scientific research acts. Germany's Max Planck Institute established the Center for Complex Phase Materials in Hsinchu in 2017, and the Center has been expanding its research cooperation and personnel interchange with NSRRC, National Tsinghua University, and National Chiao Tung University. By taking advantage of the strengths of Taiwan's first-rate universities, the Center for Complex Phase Materials has not only continued the 20 years of Taiwan-German bilateral cooperation in the field of synchrotron radiation, but also enlarged the two countries' scientific research cooperation network through its operation, which is providing new kinetic energy for Taiwan's future technological development.

The soft X-ray tomography beamline (TPS 24A) experimental facility was the first of TPS's second-phase experimental facilities to operate, and senior users were invited to perform trial use in 2018; this beamline was used to successfully obtain the first image of a tungsten needle at room temperature. In addition, the basic construction of the second-phase quick X-ray absorption spectroscopy beamline (TPS 44A) was completed in February 2018, and is currently able to acquire high-quality X-ray absorb spectra and in situ measurement data. Following pilot operation tasks such as the optimization of optical element parameters and system adjustments, some time slots at second-phase synchrotron radiation facilities were released for users' experiments during 2018.

To enable even more citizens to understand Taiwan's development of advanced light source technologies and related scientific achievements, NSRRC has teamed up with the Golden Bell Award-winning animation team Studio2 to produce the superior popular science animated film "Aka's Adventure: The Secret of Photons," which took three years to complete, and combines new scientific knowledge with entertainment. Science and technology Minister Liang-Gee Chen personally attended a test screening of this film at the August 18 "TPS 2018 Popular Science Activity," along with Golden Bell Award-winning director Chiu Li-wei and close to 600 members of the public. This popular science animated film, which is suitable for viewers of all ages, is scheduled to be shown by Public Television on February 8, 2019. In addition, when the "2018 Future Technology Show" was held in Taipei World Trade Center Hall 3 on



TPS X-ray nanometer probe experiment station (TPS 23A) was opened to user experiments after TPS's first phase began operation in 2018, and is used for scientific research in such areas as nanometer semiconductor elements, nanomaterials, low-dimensional materials, energy materials, light-emitting elements, nanometer biomedical materials, and environmental science, etc. (Source: National Synchrotron Radiation Research Center)



Beamline experiments and user statistics, 1994-2018 (Source: National Synchrotron Radiation Research Center)

December 13-15, NSRRC took advantage of this event to demonstrate synchrotron radiation-related advanced technologies and industrial applications, including results concerning "aluminum alloy ultra-high vacuum system clean process," "magnetic field design and applications," "high-energy particle RF power," and "application of synchrotron radiation in advanced semiconductor technology." NSRRC also showcased the technologies used to unravel the mysteries of novel material structures, including scanning soft X-ray transmission microscopy, nanometer focus angle resolution photoelectron spectroscopy, nanometer probe technology, and nanometer diffraction technology, and provided an easy-to-understand overview to NSRRC's impressive long-term scientific research results.

Responding to the government's green energy policy, NSRRC has completed a rooftop solar power generating project, and the installation of solar panels on the roofs of buildings has provided a new source of power, beautified NSRRC's facilities, and saved energy costs. The system can produce 1.15 million kWh annually, which can enable the tangible reduction in carbon dioxide emissions by more than 600 tons each year, and the solar panels also sharply reduce indoor air conditioning costs by blocking sunlight. Using an energy monitoring and management system developed in-house, NSRRC can monitor power quality and usage throughout the Center in real-time, which has enabled the implementation of energy conservation improvement measures.

D. Research Results of the National Applied Research Laboratories

Since it was established in 2003, the National Applied Research Laboratories (NARLabs) has responded to future S&T research needs by boosting tech research standards and applications, and effectively transferring upstream R&D results to downstream government working units and industry applications. The R&D platforms established by the ten experimental research units under NARLabs are usually larger and more costly than what any single domestic university could maintain on its own, and these major R&D platforms chiefly provide to S&T research services to academic users. NARLabs helps users at universities and research organizations to use high-accuracy, high-efficiency instrument facilities and software modeling and analysis systems to create pioneering applied technologies, help government train superior, innovative manpower, and assist in raising international competitiveness.

In conjunction with the state of national S&T development and government policies, NARLabs works together with university technology transfer centers to find academic S&T teams with high potential technology licensing value, and helps bring about the value-added transfer of academic R&D results to industry. By pairing the creative, forward-looking research results obtained by outstanding domestic research teams with the practical integration capabilities of research organizations, NARLabs is coupling upstream academic research energies with the needs of downstream industries, strengthening cooperation between industry, academia, and research organizations, promoting manpower training, enhancing the integration of Taiwan's S&T and industry value chains, while accelerating the development of value-added applications and promoting a shift from "innovation" to "value creation." NARLabs' 2018 research results in the four major areas of global environmental science, information and communications technology, biomedical technology platforms, and S&T policy are summarized as follows:

1. Global environmental science

(1) In orbital testing of the Formosat-5 satellite, the satellite operating system went online on September 21, 2018, and the cumulative image data reception success rate has been over 96%. The remote sensing payload has completed acquisition of 13,200 black-and-white/color images of the Earth, and will continue to protect Taiwan and keep a watchful eye over the world. Held in April 2018, the 4th International

Conference on GPS Radio Occultation provided global occultation data users with a forum for the sharing of research results and discussion of data verification and calibration and scientific cooperation matters after the launch of the Formosat-7 satellite; 150 research personnel from 14 countries attended this event, and more than 60 papers were presented.

(2) In compliance with national green energy S&T policy, the National Center for Research on Earthquake Engineering completed the establishment of a "large multi-axis soil shear test box with soft boundaries," which it has been using for earthquake engineering research on near-fault seismic effects in an effort to increase Taiwan's resilience in the face of earthquakes.

(3) Taiwan Long-Offset Multichannel Seismic System was operated in conjunction with the research vessel Legend in 2018, and successfully used to collect undersea seismic data from the area to the southwest of Taiwan; this system can be applied to marine energy and hazard potential surveys, and will give the country significant new geophysical prospecting capabilities.

(4) The Southwest Monsoon Experiment, which got underway in 2014, established an intensive observation network in southwestern Taiwan during May and June of 2018, and the analysis of actual observation data is facilitating the acquisition of parameters illuminating the chance of disastrous torrential rains in southwestern Taiwan, and will provide weather forecasting and disaster relief personnel with reference information.

2. Information and communications technology

(1) Taiwan's first petascale high-performance computer— "Taiwania"—was opened to users, and will serve as a leading facility for big data and artificial intelligence research. The Taiwan-developed and produced supercomputer Taiwania 2 set a new record as the world's 20th-ranked high-performance computer, and this AI cloud computing platform is expected to promote the adoption of AI by domestic industry.

(2) A newly-developed system employing 1" plasma-enhancement and 4" atomic layer deposition technologies demonstrated autonomous instrument development capabilities meeting international standards, and can create high aspect ratio microstructures via an ultra-low-temperature ALD process, while offering highly competitive performance and prices.

(3)The completion of a high-speed digital communications two-channel modulated signal measurement environment will assist in boosting domestic wireless communications R&D capabilities and stimulate the further development of relevant domestic industries. The autonomously-developed "Plug and Measure smart sensing device" can protect personal safety through the real-time use of environmental information monitored using a cell phone app.

(4) In the field of sub-5 nm element technology R&D and verification technology development, researchers in Taiwan used surface science methods for the first time in the world to investigate stress distribution in ferroelectric interface layers; the results of this research will be highly applicable to the development of 3 nm technology in the future, and can facilitate the development portable electronic products and low-energy-consumption elements for use in Internet of Things applications.

3. Biomedical technology platforms

(1) The "biological 3D printed bone reconstruction system" jointly developed by NARLabs and a biotech company can produce artificial replacement bone enabling the patients' facial appearance to remain unchanged. The "NARLabs Medical Materials Value Creation Alliance" helped Taiwan's dental grinding machines to quickly obtain approval for sale in

the US and European Union.

(2) A nephrotoxicity detection platform developed using gene modification and bioluminescence testing technology employs non-invasive methods to detect kidney toxicity in foods and pharmaceuticals, and can maintain food health and safety by reducing people's risk of exposure to nephrotoxic substances.

(3) Advanced severe immunodeficient (ASID) mice developed in 2017 were used successfully to grow patient-derived tumors, and CRISPR/Cas9 technology was used in 2018 to create hairless ASID mice able to ensure more precise observations and measurements of subcutaneous transplanted tumors in the mice; it is expected that the mice can be supplied to research personnel nationwide for use in 2019.

4. S&T policy

(1) A survey project gathering and listing the top 100 social issues eliciting the most concern from the public used scientific methods to rank these major social issues, and also determined differences in level of concern between different generations. In order to meet local needs, satisfy the expectations of different generations, and create a technological society, the project will attempt to find solutions to the problems from the perspective of science and technology development, ponder how to use new technology to respond to society's needs and expectations, and propose response strategies in pace with the development of technology.

(2) A project performing the long-term tracking of Taiwan's academic research performance from an international perspective issues annual reports on Taiwan's scientific research performance as a reference for efforts to boost Taiwan's scientific research capabilities. This project held a press conference and international symposium in April 2018 in order to announce the qualitative and quantitative performance of Taiwan's research papers, and made comparisons with such other hotbeds of innovation as the US, Switzerland, the Netherlands, Sweden, and Israel.

(3) NARLabs helped MOST to draft the *Strategic Blueprint for the Development of Science and Technology* (originally the *White Paper on Science and Technology*), which presents key issues and challenges in Taiwan's current socioeconomic development, formulates all-round S&T research and development deployment strategies, and seeks to promote Taiwan's socioeconomic development.

The following is an overview of major R&D results at each NARLabs center in 2018:

1. Chip Implementation Center

(1) PaS: Plug and Sense—Smart Sensing Device

Since existing sensing devices are typically bulky and not easily portable, and may require inconvenience power supplies, the Chip Implementation Center (CIC) has autonomously developed a "Plug and Sense (PaS) Smart Sensing Device," which can effectively resolve sensing devices' power supply and portability issues. This device has built-in humidity, UV radiation index, and alcohol concentration sensors, and can rely on a cell phone app to transfer data in real-time. It combines computation and display functions, is easy to operate, is compact and easy to carry, and can readily monitor environmental information and help protect personal safety at any time or place.

PaS-Plug and Sense Smart Sensing Device in use

(2) AI SoC Design Platform

In conjunction with MOST's "Semiconductor Moonshot Project, CIC began the development of an artificial intelligence (AI) system on chip (AI SoC) design platform in 2017, and began discussing R&D needs with research teams from around the world in 2018, along with establishment planning. CIC has already acquired a commercial AI acceleration circuit, high-performance cup, and other peripheral silicon intellectual property from a major international firm, and has chosen to establish an open AI SoC design platform with the Synopsys ARC HS34 processor as its core. Academic research teams will be able to use this platform as a basis for the design of AI SoC architectures, which will accelerate the collaborative design and optimization of circuit and AI model hardware and software, enable the establishment of rapid prototyping platforms and chip system design processes, and facilitate the establishment of an AI system development lab. Design and tape-out work for the first chip—a "genetic testing application AI system chip"—was completed in April 2018.

(3) Green energy chip integrated certification system

In light of the fact that power conversion circuits are a mainstream part of the high-voltage chip market, CIC provides academic researchers a 0.25μm CMOS 60V high-voltage process and 0.5μm CMOS 800V ultra-high -voltage process, and also provides autonomously-developed power transistor element (power cell), electrostatic discharge protection element library (ESD I/O library), and gate driver circuit silicon intellectual property. By helping researchers focus on high-voltage element structure, power conversion circuit, and LED driver circuit design research, CIC has accelerated the green energy high-voltage chip R&D process and shorted the learning curve. CIC plans to focus on integrated gallium nitride (GaN) power transistor elements in the future, and hopes to provide power supply application design solutions with an even higher degree of integration.

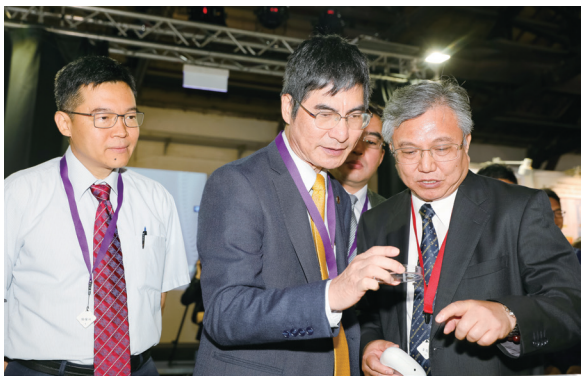
(4) A digital high-frequency and high-speed chip system measurement environment

The rapidly emerging domestic 5G and AI industries have induced industrial and academic researchers to focus on the development of high-speed, high-bandwidth systems (such as 802.11ad systems, 5G mobile communications systems, and radar for use in intelligent vehicles, etc.), CIC developed digital high-frequency waveform generators and oscilloscopes supporting 128Gbps in 2017, and completed the establishment of a measurement environment for dual-channel 64-Gbaud patterns and high-speed 1024-QAM/2GHz bandwidth modulated signals in high-speed communications in 2018. This will help boost Taiwan's wireless communications R&D capabilities, and further stimulate the development of relevant domestic industries.

2. Instrument Technology Research Center

(1) Facilitating the signing of a cooperation MOU between NARLabs and Belgium's Interuniversity Microelectronics Center

The Instrument Technology Research Center (ITRC) has engaged in joint R&D with the Taiwan laboratory of Belgium's Interuniversity Microelectronics Center (Imec) since 2014, and has obtained impressive results in numerous cooperation projects. In order to build on this collaborative experience, ITRC encouraged NARLabs to sign a cooperation MOU with Imec, which is a prominent player in advanced technologies such as nanotechnology and microstructures, and has an excellent reputation among Taiwan's high-tech industries. Looking ahead to the future, ITRC hopes to jointly develop applied technologies such as hyperspectral technology and wearable devices with Imec, which will expand Taiwan's recognition and influence in the field of instrument technology.



Science and Technology Minister Chen Liang-gee visits the joint results exhibition for the "Internet of Things Sensor Service Platform" and "Forward-looking Intelligent Robot Module Development and Systems Integration" projects on May 9, 2018, and inspects the project teams' R&D results.

(2) Joint final results exhibition for industry-academic collaborative projects

In order to introduce new-generation AI-enabled smarting living in Taiwan, MOST has commissioned NARLabs and the Department of Mechanical Engineering at National Taiwan University to implement the "Internet of Things Sensor Service Platform," "Network Platform for Intelligent Machinery," and "Forward-looking Intelligent Robot Module Development and Systems Integration" projects, and held a joint results exhibition on May 9, 2018. ITRC bears responsibility for the planning office's operational management duties in the case of the two former projects. The "Internet of Things Sensor Service Platform" project involves 44 teams at 17 schools; the project has obtained approval for clinical trials of four sensor modules developed by the wearable device and personal care project at teaching hospitals and long-term care organizations, and it is expected that mass production and marketing in Taiwan will begin within two years. The "Network Platform for Intelligent Machinery" project involves 8 teams at 11 schools, and seeks achieve the goals of collaborative service and sharing of manufacturing information for processing equipment developed by academic researchers via the platform; this project will help the domestic machinery manufacturing industry to achieve even greater benefit by changing its operating model.

Biological 3D printed bone reconstruction system

(3) Joint development of the "biological 3D printed bone reconstruction system" with 3D Global Biotech

Conventional mandibular reconstruction surgery following oral cancer usually involves the removal of a piece of bone from the fibula of the leg or radius of the arm matching the size of the mandibular defect to fill the gap. This surgery is not only time-consuming, but also often fails to completely restore the patient's facial appearance due to the differing shapes of the fibula/radius and the missing portion of the mandible. ITRC has teamed up with 3D Global Biotech to jointly develop a "biological 3D printed bone reconstruction system," which does not require the removal of a piece of the patient's fibula or radius, and can shorten operating time by one-half. Because the 3D printing process can produce a piece of artificial replacement bone snugly fitting the gap in a patient's mandible, the patient's facial appearance can be maintained unchanged.

(4) Helping Taiwan's dental grinding machines to quickly obtain approval for sale in the US and European Union

ITRC bears chief responsibility for the "NARLabs Medical Materials Value Creation Alliance," and has helped the startup MicroP Technology to obtain ISO 13485:2016 quality certification for medical devices, the European Union's CE Mark, and US FDA 510(k) marketing approval within two years. This has enabled MicroP to pass these three international approvals within the shortest period of time of any company

in Taiwan, and it has also obtained purchase orders from the well-known North American dental equipment vendor AG Neovo Dental, allowing it to enter the North American market. This has made MicroP Technology another successful startup assisted by NARLabs Medical Materials Value Creation Alliance, and highlights the contribution made by the Value Creation Alliance to Taiwan's medical device industry. NARLabs urges interested manufacturers to take advantage of the Alliance's platform to accelerate the commercialization process and further promote Taiwan's brand on the global market.

(5) Holographic projection technology is combined with art in the innovative "holographic projection display system" developed at ITRC.

This system allows the projection of virtual images in the air, allowing images to coexist with real objects in the real physical world, and realizing the goal of making a mixture of real and virtual images visible to the naked eye. The system consists of an image light source, polarizer, computer, and floating glass particles with a precise interwoven structure; imaging signals are reflected among the floating glass particles after they are illuminated by the light source, and the light is then focused in the air, creating holographic images. This technology and art from National Chiao Tung University was displayed at the "Chatter of Bamboo and Fox: National Palace Museum x National Chiao Tung University" and MOST's Future Tech Expo activities, where it not only amazed visitors, but also won the Future Tech Expo's "Most Appealing Technology Award."

(6) Development of a spherical main mirror for microsatellites, facilitating the domestic development of microsatellite optical payloads

ITRC has relied on its more than 40 years of experience to overcome bottlenecks in large aperture aspherical lens technology, and is the sole R&D unit in Taiwan able to produce satellite lenses. ITRC's R&D team completed production of main and secondary lenses for the Formosat-5 satellite in 2013, and continues to support the development of precision satellite mirrors needed in domestic space technology. ITRC's optical technology has also been applied by the domestic semiconductor and precision optics industries. Microsatellite mirror processes, including weight reduction of the glass raw materials, acid washing, curve shaping, polishing, and testing, can all be performed by domestic firms and ITRC, which will sharply decrease Taiwan's dependence on foreign technology.

(7) Development of 1" plasma enhanced ALD technology meeting international standards and a 4" ALD system with a low-temperature process

Atomic layer deposition (ALD) can produce coatings with thicknesses precise to the level of atoms, and also has excellent ability to fill voids in tiny circuit structures. ITRC has developed 1" plasma enhanced ALD technology with 100% high step coverage, high thickness uniformity (<1% variation in thickness), and atomic-level control of film thickness growth (0.1nm), which meets international standards. Following improvement of the chamber and program, ITRC has also realized a 4" ultra-low-temperature ALD process system that can produce structures with a high aspect ratio; this system's excellent performance and reasonable price give it great market competitiveness.

3. National Center for High-Performance Computing

(1) Providing Taiwan's first public-use petascale high-performance computer—the Taiwania—for use by academic users

Taiwan's first public-use petascale high-performance computer, the Taiwania, which was deployed by the National Center for High-Performance Computing (NCHC), comprises 630 pure central processor (CPU) computing nodes and 64 CPUs plus graphic processor (GPU) accelerator nodes. The CPUs have a maximum computing capability of 1.325 petaflops, which is approximately 7.5 times the speed of NCHC's Advanced Large-scale Parallel Supercluster

(ALPS). In addition, the overall performance of the GPUs exceeds 1.7 petaflops. This new supercomputer will form the new core of Taiwan's research and development infrastructure, and promote overall industrial and economic development. Apart from large-scale computing in key areas of science and technology, the Taiwania can provide an effective tool for artificial intelligence and big data research, and enable major domestic breakthroughs in science and technology. This computer will therefore support the continued growth of domestic scientific research capabilities and help accelerate industrial development.

(2) The Taiwan-developed and produced AI supercomputer "Taiwania 2" sets a new record

NCHC is implementing MOST's "Forward-looking Infrastructure Development Program: Establishment of a Cloud Service and Big Data Computing Platform," and has formed a national team with Quanta, ASUS, and Taiwan Cellular to create the AI cloud mainframe "Taiwania 2." Taiwania 2 is Taiwan's first domestically developed and produced AI supercomputer. After seven months of continuous optimization, debugging, and testing, this supercomputer has achieved superb performance (9 petaflops). It is ranked 20th on the Top 500 list of the world's fastest computers and 10th on the Green 500 list of the most energy efficient computers—and it has risen higher on these two rankings than other computer in Taiwan. This AI cloud computing platform is expected to make major contributions to the adoption of AI by industry and the industrialization of AI, and will provide quicker and more convenient AI development service to industry, academia, and research organizations.

The Taiwania 2 supercomputer is promoting a major leap forward in domestic AI technology

(3) Initiating a data market platform service

NCHC began provided an online "Data Market platform" service in April 2018, and the platform contained more than 40,000 data sets (including open and non-open data sets) by the end of December. Data categories include government administration, living, the environment, scientific research, medical, voice, and information security, and the data sets enable users of various types to tap the value of data and develop innovative data applications and services. In addition, NCHC is also helping National Taiwan University, Taipei Veterans General Hospital, and Taipei Medical University Hospital to conduct a medical imaging project, and has established a medical imaging management platform to serve as a domestic pathology annotation database. In the future, apart from application of this platform in high-tech industrial competition, the data sets will be placed on commercial platforms, and made available for use in collaborative applications research.

The Data Market platform possesses an extensive collection of data sets

(4) Development of a "neural image tracking algorithm" propelling Taiwan's brain research to a higher level

This joint project involving NCHC and the Academia Sinica, National Tsinghua University's

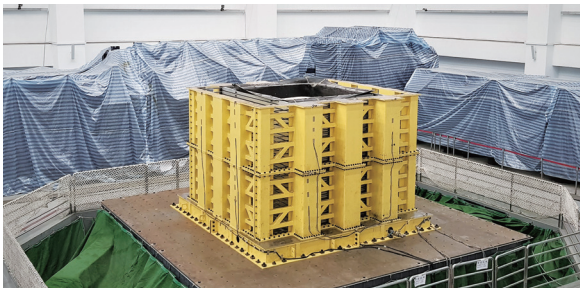
brain science center, and the Synchrotron Radiation Research Center, has implemented the "Massive Biomedical Image Data Processing Tool and Value-added Platform Development Plan." In this project, NCHC bore responsibility for providing the research team computing facilities, an imaging big data management environment, parallel display technology, and assistance in imaging big data processing. In addition, the analytical algorithms developed in cooperation with the research team can quickly mark neural images, image acquisition and analysis much more effective. In particular, the "NeuroRetriever" neural image tracking algorithms developed in-house at NCHC can perform computer tracking of the complex three-dimensional neural structures, and reduce the time needed for the segmentation of images of neurons in the brain from 5 years to only 7.5 hours (30,000 neurons, 1,000 cores @ ALPS).[Note 1] This algorithm has received patents in Taiwan and the US. NCHC has also developed a visualization tool for the processing of large amounts of data; this tool can quickly present several thousand or even more than 10,000 neural images for easy browsing by scientists—The results of this work have been published in the prominent international journal *Neuroinformatics*.

Note 1: Based on the time needed by NCHC's ALPS supercomputer to process 30,000 neurons using 1,000 cores

4. National Center for Research on Earthquake Engineering

(1) Development of a "large soil shear test box with soft boundaries"

In order to comply with the country's green energy technology policy, National Center for Research on Earthquake Engineering (NCREE) completed installation of a "large multi-axis soil shear test box with soft boundaries" in August 2018. This test box has a unique motion mechanism, and can cause the soil samples placed in it to undergo horizontal movement without torsion, while sharply reducing the influence of boundaries. This facility can be

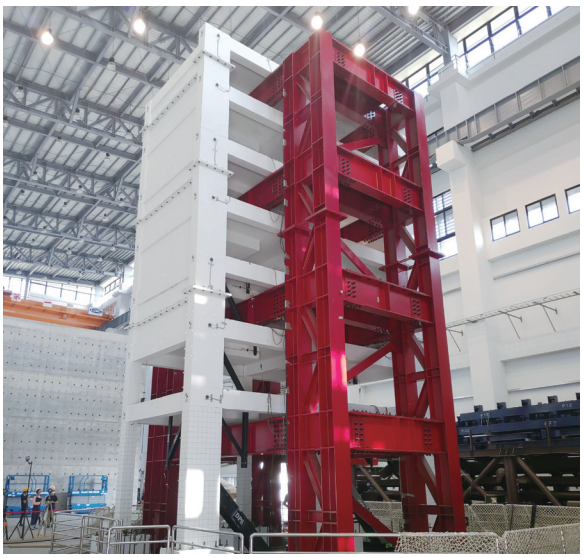


Performance testing of shear test box

used to perform physical model testing of the undersea foundations of offshore wind turbines, as well as research on other geotechnical and earthquake engineering questions involving near-fault earthquake effects in conjunction with the earthquake simulation shaking table at NCREE's Tainan laboratory. By promoting the development of leading-edge geotechnical and earthquake engineering, this new facility will accelerate Taiwan's evolution into an earthquake-resilient country.

(2) "Experiment on the collapse of buildings with a weak first story due to near fault effects"

Near fault earthquakes are characterized by high-speed pulses and large surface displacement; because of these effects, the impact of earthquakes on buildings located near faults is more severe than in the case of ordinary earthquakes, and these effects are a major



Weak first story building collapse experiment

reason that buildings with weak first stories often collapse in earthquakes. The "long stroke, high-velocity vibration system" that NCREE built at its new Tainan laboratory was completed in 2017; this vibration platform is designed to imitate the effects of near fault earthquakes. The vibration platform has been used in a series of collapse experiments involving large structures in an effort to investigate the effect of near fault earthquakes on the seismic performance of buildings with weak first stories and formulate prevention strategies able to protect citizens' safety.

(3) Development of a "Life-Cycle Based Bridge Management System"

Because Taiwan's bridges face the threat of earthquakes, typhoon, floods, and slow deterioration from corrosion, effective disaster mitigation management systems must be put in place in order to protect the public's safety. Because of this, NCREE has developed a "Life-Cycle Based Bridge Management System" from the perspective of human healthcare management. This system can perform automated bridge hazard analysis, assessment, and ranking on the basis of test data, its advanced automated monitoring system can remind bridge management units in real-time of potential threat before disasters occur. The development of this system represents a new milestone in bridge health and safety in Taiwan.

5. National Nano Device Laboratories

(1) Development of "sub-5nm element technology exploration and verification technology"

The National Nano Device Laboratories (NDL) has been investigating sub-5nm stacked ferroelectric gate transistors in conjunction with National Chiao Tung University and National Cheng Kung University, and has examined the relationship between environmental stress and scale effect behavior in these transistors. This NDL-led project achieved the world's first demonstration of the stacking of ferroelectric ultra-thin 2nm-HfZrOx gates and interface stress distribution, and was also the first use of surface science methods to investigate stress description in a ferroelectric interface layer. The results of this project were presented at the 2018 Symposia on VLSI Technology and Circuits, which was held in Hawaii, as "A Comprehensive Study of Polymorphic Phase Distribution of Ferroelectric-Dielectrics and Interfacial Layer Effects on Negative Capacitance FETs for Sub-5 nm Node." The findings of this research have great applicability to the future development of 3nm technology, which will better meet the needs of low energy consumption elements used in portable electronics products and Internet of Things applications.

(2) Development of integration techniques for monolithic 3D integrated circuits

In order to improve the characteristics of monolithic 3D integrated circuits, NDL has developed a laser crystallization method that can control the crystal growth, and has used the single silicon crystals developed at NDL for use in fin field-effect transistors (FinFET) to inhibit variation in elements' electrical characteristics caused by poly-si grain boundaries. NDL has recently used different base etched patterns and the corresponding laser processes to complete 3D stackable silicon channels that can control crystal growth. The results of this project were presented at the 2018 International Electron Devices Meeting (IEDM) as "Location-controlled-grain Technique for Monolithic 3D BEOL FinFET Circuits." NDL plans to use this technology to produce high-quality single-crystal FinFETs and related applications circuits in conjunction with National Chiao Tung University, and expects this work to greatly increase the feasibility of monolithic 3D integrated circuit commercialization.

In addition, in a project on monolithic 3D integrated circuit integration technology with Prof. Chang Meng-fan of National Tsinghua University and Prof. Vijaykrishnan of the University of Pennsylvania, NDL developed an in memory computing SRAM circuit with computing and storage functions. The use of negative capacitance elements and advanced

circuit manufacturing techniques to achieve the integration of ultra-low-energy-consumption in memory computing elements can reduce element switching and conductor-end energy transmission losses at both the element and circuit ends. The results of this work were presented at the 2018 International Electron Devices Meeting (IEDM) as "Ultra-Low Power 3D NC-FinFET-based Monolithic 3D+-IC with Computing-in-Memory for Intelligent IoT Devices," and the project's findings can be applied to the development of AI and to intelligent Internet of Things chips.

(3) Groundbreaking ceremony for Nano Device Laboratory's Tainan site

In order to strengthen interdisciplinary science and boost Taiwan's nanotechnology R&D and energy, NDL joined forces with National Cheng Kung University to jointly establish the Nano Device Laboratory's Tainan site. The two parties will integrate their resources in order to make the best use of their respective advantages, and the site will focus on technology and applications development in the areas of semiconductors, nanomaterials, biotechnology, and medical devices. The site's goals are to train the high-level human resources needed by industry and academic research institutions, increase linkage between industry, academia, and research organizations in northern and southern Taiwan, and guide the establishment of new economic models in Taiwan.

A groundbreaking ceremony was held for the Nano Device Laboratory's Tainan site on September 27, 2018. Here NARLabs Director Wang Yung-ho (right) and NCKU President Su Hui-chen (left) break ground for the new center.

With a total area of close to 3,000m2, NDL's Tainan site contains a semiconductor clean room meeting high industry standards, a biomedical chip laboratory, and green technology exhibition area. The site will promote the development of technology service platforms for forward-looking, low-energy-consumption fast sensing chips, next generation semiconductor process, advanced heterogeneous integrated chip packaging, and advanced biomedical microfluidic chips.

(4) Development of an "antimicrobial susceptibility test chip"

Working in cooperation with Taichung Veterans General Hospital, researchers at NDL have used integrated optoelectronic chip technology to develop an "antimicrobial susceptibility test chip" able to quickly identify bacterial type. This chip can shorten testing time to 51 hours, which saves 2 days compared with current medical testing technology, and this shorter identification time is expected to have pivotal significance when patients' lives hang in the balance.

As far as testing costs are concerned, the chip currently being developed has a cost of approximately US$1 (approximately NT$30), and it is expected that the cost can be reduced significantly if the chip is commercialized. While the retail prices of existing automated microbial analysis systems approaching NT$3 million, NDL's antimicrobial susceptibility test chip instrument will have a projected retail price of only one-twentieth of this amount.

After the chip was used in 36 clinical cases at Taichung Veterans General Hospital, the hospital's clinical test reports indicated that the agreement rate was 88.2%. It is projected that the chip can be commercialized in 3 years; when that time comes, we can look forward to the chip reducing testing costs and deaths from septic shock, which will benefit patients, doctors, family members, and the entire medical system.

Apart from testing for septicemia, the

antimicrobial susceptibility test chip can also be applied to other infectious bacterial diseases, such as urethritis, peritonitis, and pyogenic arthritis. In addition, the chip promises to have a broad range of further applications in such areas as foods, livestock raising, and aquaculture, including, for example, the identification of bacteria in dairy cattle and farmed fish. The application of nanotechnology to biomedicine is one of the focal points of national development, and the results of this project are a fine example of successful cooperation between medicine and research.

(5) A novel next-generation energy-saving transistor element

The famous "Moore's law," which specifies that the number of transistors per unit area in integrated circuits doubles with every generation of semiconductor process technology, has provided a roadmap to guide the semiconductor industry's development for at least half a century. But as the number of elements on a chip doubles, the chip's energy consumption also doubles, each new generation of transistors should ideally have less than one-half the power consumption of the previous generation, which will ensure that there is not a sharp increase in energy demand with each new generation. Fortunately, when the size of a transistor element is shrunk, the transistor's power consumption will also decrease, but unfortunately, this decrease is not necessarily proportional to the decrease in size. This is why each new generation of computers, tablets, and cell phones has a steadily increasing demand for power, and also has an increasing need for cooling.

NDL has recently developed "negative capacitance field effect transistors" in a collaborative project involving domestic and foreign research teams. The development of these transistors required only the use of simple ferroelectric materials in a fin field-effect transistor, and the transistors, which can reduce power consumption by around 30%, can be applied in each new generation of transistor element. This technology attracted considerable attention from industry at the 2015 and 2018 International Electron Devices Meeting (IEDM), which will provide opportunities for cooperative development.

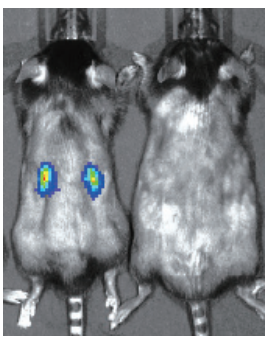
(6) Establishment of advanced semiconductor etching process module verification technology

NDL is cooperating with ITRC to promote semiconductor equipment process module verification technology, and has established msec self-feedback monitoring and control systems for vacuum chamber, reaction precursor, and etching plasma modules, including the ability to handle large numbers of data-based, high-speed dynamic, real-time semiconductor process parameters. These systems will facilitate the conceptual design of key modules for atomic layer etching (ALE) equipment. NDL's tests of the ALE etching of various high-density Si FinFETs on 8" wafers have yielded 3D wafer-level integration with a fin size of 16nm and fin height of 100nm, and researchers have also used temporary laser bonding technology to perform the 3D vertical stacking of wafers with a thickness of 50 μm.

6. National Laboratory Animal Center

(1) Development of a nephrotoxicity detection platform employing bioluminescence

Food safety problems have been an issue of great public concern during the last few years. More than 60,000 people in Taiwan have suffered kidney failure, and the fact that Taiwan has the world's highest incidence and prevalence of kidney failure indicates that the sensitivity of tests for nephrotoxicity should be improved in order to reduce people's exposure to nephrotoxicity risks.



A bioluminescent signal (blue) can be seen from the kidneys of Shen-Nong transgenic mice

The National Laboratory Animal Center (NLAC) has used genetic engineering and bioluminescence testing technology to express a chemilluminescent protein in the kidney tissue of mice; the bioluminescent signal from this protein can be detected in the animals' blood or urine whenever kidney tissue suffers damage. This testing platform can enable the use of non-invasive methods to detect nephrotoxicity in foods or pharmaceuticals, which will benefit citizens' health.

(2) Establishment of a mouse model for the metastasis of human in situ colon cancer

Colon cancer has had the highest incidence of any type of cancer in Taiwan for 9 years in a row, and the death rate from colon cancer has also remained quite high. The occurrence of colon cancer is associated with a multi-step genetic chain reaction, which has a first step consisting of carcinogenesis triggered by a mutation in the APC gene. In the second step, a mutation in the RAS gene accelerates cellular proliferation, forming an adenoma, and a mutation in the P53 gene finally causes the proliferating cells to transform into cancer cells, which may metastasize to other organs. While conventional genetic engineering cannot reconstruct these genetic changes triggered in a temporal sequence, the genome integrating technology developed at NLAC has been used to sequentially alter these three genes in the intestinal tract, and thereby create a mouse model of colon cancer. This project has achieved preliminary results, and it is expected that verification will be completed during 2019.

(3) Development of highly immunodeficient nude mice

While laboratory rodents are important platforms for the testing of cancer drugs, conventional rodent models are less than ideal for experiments involving the transplant of tumors from humans. In order to optimize this testing platform, NLAC successfully developed "advanced severe immunodeficiency (ASID) mice" in 2017; thanks to the removal of T-cells, B-cells, and killer cells

Highly immunodeficient nude mouse

from these mice, as well as their low numbers of macrophages and dendritic cells, human-derived tumors can grow readily in the mice. Researchers at NLAC used CRISPR/Cas9 technology in 2018 to cause mutations in the mice's Foxn1 gene, which brought about the development of hairless ASID mice. These mice facilitate the observation and more precise measurement of subcutaneous transplanted tumors; it is expected that they can supplied for use in research nationwide in 2019.

7. National Space Organization

(1) Normal operation of the Formosat-5 satellite's dual payload

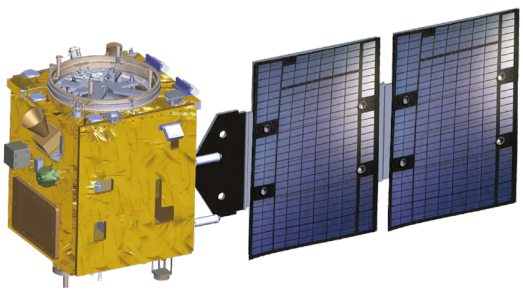
Verification of the orbital performance of the Formosat-5 satellite has been completed. The satellite's remote sensing payload has taken more than 13,200 black-and-white/color images of the earth, and the cumulative image data reception success has exceeded 96%. The satellite operating system went online on September 21, 2018, and the image processing center was opened to visitors on the same day. The satellite's scientific payload collects over 100MB of high-quality ionospheric parameter data every day, and this data is processed and provided to domestic and foreign data users by the advanced ionospheric probe science data center. An asynchronous imaging function has been fully integrated with the satellite's flight software and ground image processing system, and orbital verification of the software upgrade to version 7.1.6 has been successfully completed.

(2) Formosat-7 weather satellite galaxy

The US-Taiwan Formosat-7 satellite project is a joint effort to establish an operational weather satellite galaxy system, and it is expected that the 6 satellites forming this galaxy will be launched during 2019. The 4th International Conference on GPS Radio Occultation in 2018, which was held at the Howard Civil Service International House in Taipei during the period of April 18-20, 2018, provided global occultation data users with the project's research results, and discussed issues such as scientific cooperation and the verification and calibration of data after the launch of the Formosat-7. A total of 150 research personnel from 14 countries attended this event, and presented over 60 papers.

(3) Flight test verification of Triton satellite mission payload using an unmanned fixed-wing aircraft

The 300kg class Triton satellite will carry an advanced global navigation satellite system-reflectometry (GNSS-R) payload developed and produced by a team in Taiwan; this system will be used of the measure wind speeds at sea level after the satellite is launched. Ten key elements and technologies developed in Taiwan were verified during the year. Assembly, testing, and first end-to-end testing of most satellite elements was completed during 2018, and plans call for full-function testing and electromagnetic compatibility testing during early 2019. The GNSS-R payload has completed unmanned fixed-wing aircraft flight testing and data verification, and GNSS-R observation data has been obtained from NASA's CYGNSS satellite for use in verification of the Triton satellite's data processing software.



The Triton satellite

(4) Airborne hyperspectral imaging system completes 12 imaging missions

The NSO's airborne hyperspectral imaging system conducted 6 flight tests and 12 remote sensing missions in 2018, and has successfully acquired large amounts of aerial hyperspectral imaging data. The project also conducted hyperspectral data analysis and research, and established various hyperspectral analysis techniques, including determination of atmospheric correctness coefficients. The along-track scanning image data obtained by the project in the future will be used by researchers in the areas of agriculture, forestry, fisheries, mining, and disaster mitigation.

(5) Design of a synthetic aperture radar architecture

The goal of NSO's synthetic aperture radar (SAR) project is to design a lightweight, multifunctional X-band synthetic aperture radar satellite galaxy. During 2018, the project completed ground and flight testing of an airborne synthetic aperture radar payload prototype, and performed design of a block floating point quantitative data compressor, processing and control units, RF transceiver, high-speed high-capacity solid-state recorder, and high-power amplifier power supply module, which represents a new milestone in Taiwan's SAR R&D program.

8. Science & Technology Policy Research and Information Center

(1) Major social issues of public concern

The Science & Technology Policy Research and Information Center (STPI) has relied on online public opinion surveys to collect and list the top 100 social issues of greatest concern to the public. Apart from using scientific methods to rank major social issues in Taiwan, this project has also shed light on differences in the perceived importance of issues among different generations. In the future, in order to respond to local needs, ease generational differences, and create a technological society benefiting the public, STPI

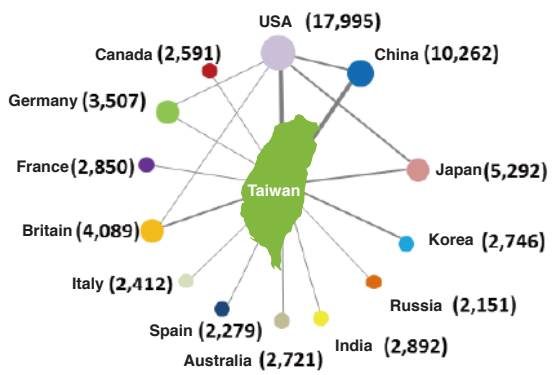
will search for solutions to social problems from the perspective of the development of science and technology, think about how to use new science and technology to respond to the needs and expectations of society, and propose response strategies reflecting technological progress.

(2) Establishment of a multi-perspective decision-making model, optimizing S&T decision-making

STPI has used a multi-perspective decision-making model (including technological, economic, social, and environmental aspects) developed in-house to analyze 119 key innovative areas in 13 industries. The results of this project provide an even-more comprehensive comparison and assessment of technologies, and will facilitate the future assessment of Taiwan's technologies with developmental potential from a national policy perspective. The project's findings can also serve as a reference for decision-makers' selection of strategic innovative fields suitable for future development.

(3) Looking Taiwan's research performance from a global perspective

Academic research is the cornerstone of a nation's innovation. STPI has conducted the long-term tracking of Taiwan's academic research performance from an international perspective, and announced the quantitative and qualitative performance of Taiwan's academic research papers at a press conference held on April 16. As the volume of international cooperative academic papers involving Taiwan increases, the number of international collaborators and their locations has also been increasing. STPI therefore cooperatively held the "Seeing Taiwan—Forward-looking Scientific Research" symposium in conjunction with the prominent global publishing company John Wiley & Sons, and took opportunity to share knowledge about academic publishing in Taiwan, and boost Taiwan's scientific research capabilities through the exchange of ideas among the top-flight international scientific personnel at this event.



Chief countries collaborating in the writing of Taiwan's academic papers

(4) S&T Innovation Supernova — Neuroscience

Neuroscience is the study of how the nervous system functions, and spans the fields of basic science, engineering, and medicine. Apart from possessing translational potential of many types, neuroscience also encompasses the industrialization and applications of drugs, medical devices, and assistive equipment, and is capable of addressing many still-unsatisfied medical needs. STPI has performed an analytical assessment of neuroscience, inventoried the content and funding of domestic and foreign projects, and relied on the Essential Science Indicators (ESI) and Web of Science (WOS) databases to perform literature clustering and topic analysis, which provided a better understanding of the current state of research in neuroscience and emerging research directions. STPI also conducted interviews with domestic experts and scholars concerning the future development of neuroscience, and organized their comments and recommendations into a form suitable for the reference of decision-makers.

(5) Focal S&T development strategies, filling out Taiwan's innovative R&D portfolio

In order to achieve a consensus among industry, academia, and the research community concerning Taiwan's science development strategies and innovative technology R&D portfolio, STPI assisted MOST in holding the Science Development Strategy Conference on October 1, 2018, along with four pre-conference meetings during September. Apart from providing "innovative research and development portfolios

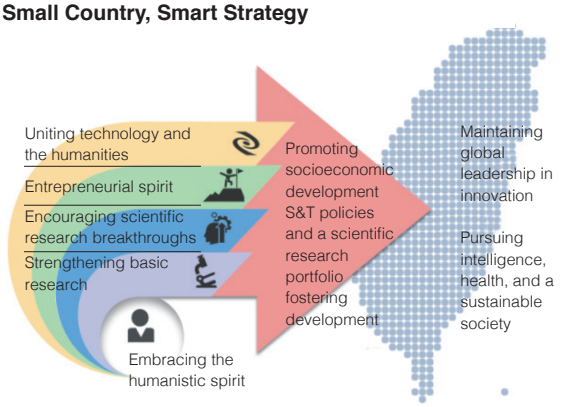
Vice President Chien-Jen Chen delivers the opening speech at the "2018 Science Development Strategy Conference" held on October 1.

in the humanities/life science/engineering/natural science" and "comprehensive high-level scientific research manpower training and development" information before the conference, STPI also compiled the participating scholars' proposed recommendations after the conference in its role as MOST's staff organization.

(6) Drafting of the "Strategic Blueprint for the Development of Science and Technology"

While maintaining a humane orientation and "Small Country, Smart Strategy" thinking, STPI has assisted in the drafting of the *Strategic Blueprint for the Development of Science and Technology* (originally the *White Paper White Paper on Science and Technology*), which presents the key issues and challenges facing Taiwan's current socioeconomic development. With goals of "maintaining global leadership in innovation, pursuing intelligence, health, and sustainability" promoting and Taiwan's socioeconomic development, the *Blueprint* seeks to monitor world S&T development trends, strengthen Taiwan's scientific research advantages, and offer an all-round scientific R&D deployment strategy consolidating basic research, and encouraging scientific research breakthroughs, the entrepreneurial spirit, and fusion of science, technology.

Small Country, Smart Strategy



Pursuing an intelligent, healthy, and sustainable society

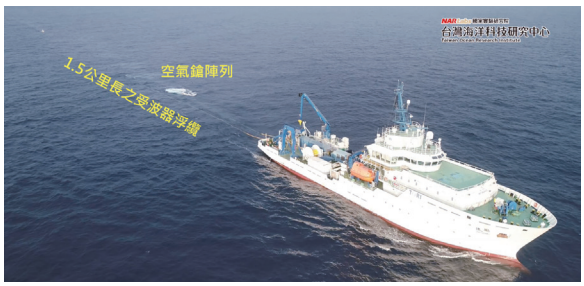
(7) Providing superior academic information resource services, creating a robust S&T innovation development environment

Having celebrated its 20th anniversary, the "CONsortium on Core Electronic Resources in Taiwan" (CONCERT) boasts members including over 200 academic and research organizations nationwide. To mark this event, STPI held a celebration and international conference with the theme of "Commitment, Enthusiasm, and Joint Attainment of 20 Years" on November 12, 2018. This event re-affirmed CONCERT's dedication to acquiring information resources needed for academic R&D on behalf of Taiwan's academic research organizations, and creating a favorable environment for the nation's S&T innovation and development. Furthermore, in order to meet the needs of readers at academic research organizations, STPI unveiled an all-new online version of the Nationwide Document Delivery System (NDDS) interlibrary loan platform in 2018, which is expected to greatly improve literature transmission service quality in Taiwan.

9. Taiwan Ocean Research Institute

(1) Using a long-offset multichannel seismic system to explore undersea geology

The Taiwan Ocean Research Institute (TORI) acquired Taiwan's first industry-grade long-offset multichannel seismic system in 2018, and is operating the system from the research vessel "Legend." The system has employed a 1,060 in^3 air gun (maximum capacity of 3,000 in^3) and 1.5km floating geophone cable (maximum length of 6km) to successfully collect seismic survey data from the waters to the southwest of Taiwan, and the compiled images clearly display the fault structure



The long-offset multichannel seismic system in use at sea

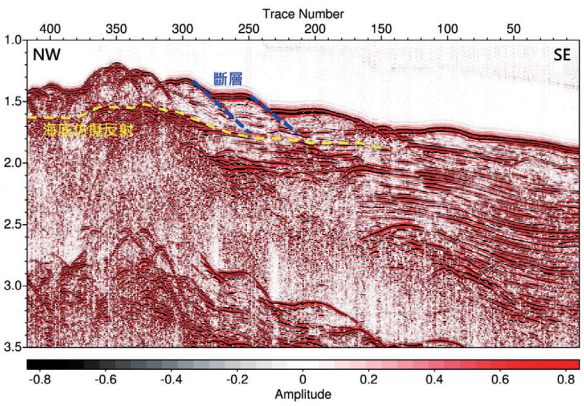
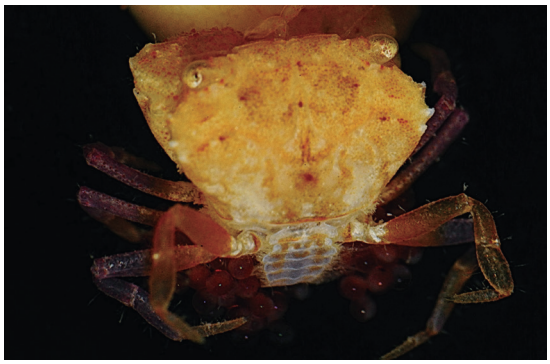
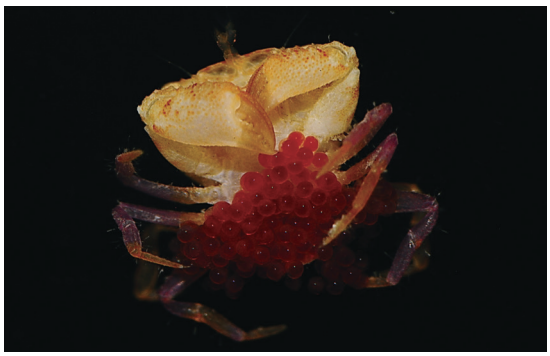


Image and preliminary interpretation of marine deposit structures to the southwest of Taiwan



Dorsal surface of newly-discovered crab



Ventral surface of crab and red eggs

beneath the seabed and bottom simulating reflectors. Looking ahead to the future, the system can be used in marine energy and hazard potential surveys (such as petroleum, natural gas, potentially-catastrophic fault, and seabed landslide investigations), and will lend new energy to the country's marine geophysical exploration.

(2) A tiny pixie from the sea: New crab species record made near Liuqiu Island

Liuqiu Island is the sole coral island among Taiwan's offshore islands, and has been a long-term monitoring and sampling location for the Marine Organic Biogeochemistry Lab, Taiwan Ocean Research Institute. A routine survey conducted in October 2018 discovered a tiny crab only 0.5cm in size in a sample of undersea sand. Although research personnel initially thought that the creature, which was hiding in the sand to avoid predators, was an immature crab, they noticed that a cluster of eggs was hanging from its abdomen, indicating that it was a mature female crab. Further comparison and assessment revealed that this was the first time that this species of crab—*Nanocassiope tridentate*—had been recorded in Taiwan, and the crab was the 801st species on the originally 800-species *Taiwanese Crab List* jointly issued by domestic and foreign scholars in 2017.

(3) 20th anniversary of the establishment of the South East Asia Time Series Study international monitoring station

The South East Asia Time Series Study (SEATS), which was founded in 1998 by oceanographers in Taiwan, is part of the international Joint Global Ocean Flux Study (JGOFS). TORI has performed long-term collection of settling particles using an anchored system at the SEATS station in a study of marine mass flux. TORI has held responsibility for the important task of SEATS operation since 2013, and celebrated SEATS' 20th anniversary in 2018. To mark the occasion, TORI has issued the longest and most complete time series data for settling particles; this data indicates that when the Kuroshio current intrudes into the South China Sea, it will reduce marine productivity and settling particle failure. This phenomenon promises to shed light on long-term

Deployment of an anchored string of deposit collector

rises and falls in biological activity in the area.

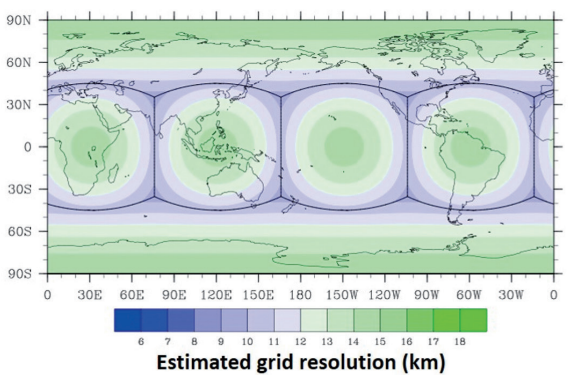
(4) Application of ocean radar in the measurement of waves in offshore wind farms

TORI has established the Taiwan Ocean Radar Observing System in order to monitor sea surface currents. Because this ocean radar system can observe large swaths of the ocean, as opposed to the point locations observed by conventional anchored or moored observation system, it can provide data that is more representative of individual areas. Responding to the need for wave data from Taiwan's developing offshore wind power industry, TORI installed a radar unit in waters included in the Southwest Offshore Wind Power Project; radar reflection data from this radar is being used in a wave measurement R&D project, which is comparing the resulting information with data from a nearby buoy operated by the Central Weather Bureau, MOTC. The results of this project indicate that while the 24MHz radar system used in this project offers a certain degree of accuracy and reliability in the observation of all but the largest waves, further research must be performed on the radar inversion method's parameter settings and performance in different types of wave climate must be performed in order to enhance the radar's wave measurement reliability.

10. Taiwan Typhoon and Flood Research Institute

(1) Establishment and testing of an FV3 global model

The FV3 model (FiniteVolume Cubed-Sphere Dynamical Core) US National Centers for Environmental Prediction's (NCEP) next-generation advanced global atmospheric simulation system. The Taiwan Typhoon and Flood Research Institute (TTFRI) has joined forces with the Central Weather Bureau, MOTC and researchers at domestic universities to test the FV3 model, and used the FV3 model and the physical process module of NCEP's global forecasting system to model the global atmosphere with spatial resolution of 13km. The results showed that for a period from August 15 to September 30 in 2017, the FV3 model's 5th-day forecasts for Asia at a height equivalent to 500hPA achieved a correlation coefficient of approximately 0.88, which indicates excellent forecasting ability.



The global grid setting chart for the FV3 model displays a resolution of approximately 13 kilometers

(2) Development of physical watershed water and sediment transport modeling technology

TTFRI coupled a topographical hydrological model, landslide volume estimation model, river channel mobile bed model, and a dynamic scouring algorithm for flood-control structures in the preliminary development of physical water and stored transport modeling technology. Taking the watershed areas in Zhongzhi Borough, Wulai District, New Taipei as a demonstration area, TTFRI further tested this model by simulating

short-term river bed erosion during the 2015 Typhoon Soudelor; the results of this simulation indicated that the mobile bed model can perform successful modeling for areas with steep slopes. Furthermore, in simulations of floods with different recurrence intervals, TTFRI generated flux and scouring bed height curves for the Guishan Bridge on the Nanshi River, which allowed the quick estimation of degree of bridge foundation scouring hazard during floods. This will allow TTFRI to provide reference information needed by the Directorate General of Highways when considering emergency bridge closure strategies.

(3) Southwest Monsoon Experiment

Starting in 2014, TTFRI has used its existing equipment and technology in conjunction with domestic academic researchers, the military, and weather forecasting units to conduct the Southwest Monsoon Experiment. The Southwest Monsoon Experiment's observation period during 2018 was from May 22 to June 8, and an existing dual polarimetric radar in a mountainous area of Kaohsiung served as the chief observation instrument. TTFRI established an intensive observation network in southwestern Taiwan, and hoped that the analysis of actual observation data would enable the acquisition of meteorological parameter thresholds for potentially catastrophic torrential rain in southwestern Taiwan, which could be provided to forecasting and disaster relief personnel for use as a reference. In addition, in order to gain a better understanding of the upstream characteristics of air flow during the southwestern monsoon, TTFRI used a wind profiler and multichannel microwave radiometer to again perform observations on Nansha Taiping Island.

III. Human Resources Recruiting and Training

A. Recruiting of S&T Personnel

Scientific and technological personnel are a driving force behind S&T advancement and national development, and all leading countries are competing to recruit S&T talent. In order to strengthen research and development at academic research organizations and universities, MOST employs generous subsidy measures to recruit outstanding domestic and foreign high-tech personnel. The following subsidy measures were employed during 2018:

1. Comprehensive 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. In 2018, a total of 2,045 visiting S&T personnel and post-doctoral researchers were recruited to participate in S&T research projects, and 93 research scientists were recruited to implement major mid-/long-term research projects.

(2) Assisting the professional development of postdoctoral researchers: In order to cultivate promising young domestic postdoctoral researchers, MOST has continued to provide stable research funding and independent research opportunities, and encourages early planning of research careers in order to

Wind profiling radar and multichannel microwave radiometer installed on a wharf at Nansha Taiping Island

cultivate high-level domestic academic S&T personnel.

(3) Top-down creation of an excellent R&D environment: By providing resources to various types of research projects in areas aligned with the country's S&T development focal points, MOST is creating an excellent research environment, providing research personnel with opportunities to show their talents, and attracting outstanding S&T manpower overseas to participate in research in Taiwan.

2. The Post-doctoral Researcher Academic Work Award

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 an incentive 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 2017, and 2018 candidates are currently in the midst of the review process.

3. Establishment of superior conditions and an effective environment for recruiting academic S&T manpower in conjunction with the Executive Yuan's "Effective Talent Retention Environment Program" and other policies.

MOST-funded S&T personnel recruiting statistics, 2018-2018 Units: person-times

Item	2014	2015	2016	2017	2018
Visiting personnel	136	118	115	82	92
Post-doctoral research	2,223	2,261	2,405	2,285	1,953
Research scholars	76	109	140	104	93
Total	**2 ,435**	**2,488**	**2,660**	**2,471**	**2,138**

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 basic or applied research, and thereby enhance the country's academic research levels and international academic status. Apart from receiving a certificate from MOST, recipients receive an award of NT$900,000. A total of 78 persons received this award in 2017, and the 2017 academic research awards ceremony was held on May 28, 2018, at which Science and Technology Minister Liang-Gee Chen personally conferred this award.

In order to fundamentally transform the scientific research ecology, reinforce basic research, and also strengthen the many forms of value and academic influence of research results, MOST changed award categories to "basic research" and "applied research" starting in 2017, and a total of 80 persons may receive the awards in both categories. This award is intended to encourage scientific breakthroughs and the practical application of academic research, and emphasizes the tangible contribution of research results to society, the economy, people's livelihoods, the environment, and industry. The list of 2018 award-winners will be announced in late March 2019.

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. A total of 45 persons received this award in 2018, and the awards ceremony was held on November 2, 2018.

B. Other Awards

1. Presidential Science Prize

The Presidential Science Prize has been granted once every two years since 2001, and represents the country's highest academic research honor. According to the *Presidential Science Prize of Taiwan Eligibility and Selection Process*, the selection process begins with the Academia Sinica calling together the heads of relevant agencies, who establish a "Presidential Science Prize Committee" consisting of 15 experts and scholars. This committee will select academic researchers who have made outstanding, innovative contributions through international academic research in the areas of physical science, life science, social science, and applied science, and who have made major contributions to society in Taiwan.

The final selection of recipients of the Presidential Science Prize is made at a joint conference of the Presidential Science Prize Committee after review by selection subcommittees. Winners of this award receive a trophy, certificate, and NT$2 million in prize money. Nominations for the 2018-2019 Presidential Science Prize have been accepted since October

Research awards, 2014-2018

Item	2014	2015	2016	2017	2018
Outstanding Research Award (persons)	72	74	73	78	80
Ta-You Wu Memorial Award (persons)	40	40	40	44	45
Presidential Science Prize	-	3	-	3	-
Executive Yuan Award for Outstanding Science and Technology Contribution (cases)	2	4	3	2	2

29, 2018, and the selection process and public awards ceremony will be completed by the end of 2019.

2. 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 recognize the country's outstanding S&T personnel. The award was renamed the "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 to NT$1 million. All citizens engaged in S&T work in the fields of the natural sciences, engineering, life science/medicine/agriculture, and the humanities and social sciences whose R&D results lead to outstanding inventions or innovations, and thereby make significant, groundbreaking, and original contributions to the country and society may be nominated to receive this award and participate in the selection process. 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 organizations, performs a review, the results are sent to the Executive Yuan for approval and conferral of awards.

In 2018, 28 nominations for the award were received, and the award was granted to two persons in two cases following the selection process. The winners were Deputy Section Chief Hung Huan-yi, Material and Chemical Research Laboratories, ITRI, and Researcher Wu Han-chung, Institute of Cellular and Organismic Biology, Academia Sinica. The Executive Yuan held the awards ceremony on December 25, 2018, and the awards were bestowed by Executive Yuan Premier Lai Ching-teh.

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 licensing 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 researcher. Nine persons in 13 cases received this award in 2017, and applications for 2018 are currently being reviewed.

V. International Cooperation in Science and Technology

A. Establishment of International Cooperation Networks

MOST and foreign funding agencies are relying on agreements and memoranda of understanding to establish bilateral cooperation frameworks, within which both parties will provide funding for bilateral projects on priority areas, two-way visits of research personnel, and jointly holding of topical conferences to perform matchmaking for bilateral joint research projects. Apart from reliance on international ties to strengthen R&D capabilities and manpower training, MOST also strives to encourage emerging areas of technological R&D in order to support the development of key industries, and thereby promote the goals of innovation and entrepreneurship. Beyond deepening bilateral and multilateral S&T

cooperation with the leading countries, MOST is also expanding in-depth S&T cooperation and interchange with key countries in Southeast Asia in conjunction with the government's New Southbound Policy.

MOST has signed 121 cooperation agreements, MOUs, and other cooperation documents with 43 countries and 3 international organizations. New agreements during 2018 included the "Implementing Arrangement Number 3 to the Guidelines for a Cooperative Program in Physical Sciences between the Taipei Economic and Cultural Representative Office in the United States and the American Institute in Taiwan" and "Amendment of the Agreement between the Taipei Economic and Cultural Representative Office in the United States and the American Institute in Taiwan for Cooperation in the Global Learning and Observations to Benefit the Environment Program," which were signed with the Taipei Economic and Cultural Representative Office in the United States (TECRO) and the American Institute in Taiwan (AIT). In Asia, apart from renewing an S&T cooperation agreement with the Vietnamese Ministry of Science and Technology, MOST also signed a cooperation MOU with National Institute of Information and Communications Technology's (NICT). In addition, in Europe, MOST also signed S&T cooperation documents with Britain's Natural Environment Research Council (NERC), France's Academie des Sciences (Ads), and France's French National Institute of Health and Medical Research (INSERM).

B. State of International Cooperation and Interchange

In order to leverage international academic cooperation, MOST has launched the MOST Add-on Grants for International Cooperation (MAGIC) program, and is actively providing funding for principal investigator's fees to encourage research project principal investigators to plan international cooperative projects and promote closer international ties. In addition, to boost the international visibility of Taiwan's scientific research results, MOST has established the Center for Global Affairs and Science Engagement (GASE), which is responsible for linking inter-school organizations and promoting the integration of teams and resources, which will make it a strong supporter of MOST's scientific development and international interchange.

Science and Technology Minister Chen Liang-gee (left) and Kuo Ta-wei (right) jointly host the inauguration of the Center for Global Affairs and Science Engagement (GASE) on November 14, 2018.

1. North America

In 2018, MOST expanded the scope of cooperation with the US National Science Foundation (NSF), which apart from cooperation in the Future Air Traffic Management Concepts Evaluation Tool (FACET) project, will also include participation in the NSF's Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) program for the first time, which will promote an international outlook among young research personnel and deepen international linkage and continued interchange concerning the topic of how to strengthen ecological sustainability. MOST is also actively participating in the National Cancer Moonshot led by the US National Institutes of Health (NIH) and National Cancer Institute (NCI), which has also broadened bilateral S&T between Taiwan and the United States. In addition, Taiwan's National Space Organization (NSO) is jointly implementing the Formosat-7 satellite program with the United States' National Oceanic and Atmospheric Administration (NOAA); in this program, MOST has assisted in sending the satellite to the US by diplomatic parcel, and launch has been scheduled for 2019.

MOST is continuing to promote Taiwan-Canadian bilateral research projects and encourage reciprocal visits and the joint holding of bilateral conferences in conjunction with Canada's Tri-Council, which has been established by three Canadian federal research funding organizations, namely the Natural Sciences and Engineering Research Council (NSERC), Canadian Institutes of Health (CIHR), and Social Sciences and Humanities Research Council (SSHRC). Apart from this, in order to pave the way for future internship and cooperation opportunities involving Taiwanese-Canadian academic organizations and industry, MOST has further promoted contact and interchange with Canada's Global Research & Industry Alliance (GLORIA) and Mathematics of Information Technology and Complex Systems (MITACS). The Canadian Technology Accelerators Initiative headed by the Trade Commissioner Service, Global Affairs Canada has announced that it will establish a new location in Taiwan, which will be closely linked with MOST's newly-established Taiwan Tech Arena (TTA), integrate resources from Canadian accelerators, companies, and venture funds, and strengthen Taiwan's tech startup ecosystem.

To encourage young Taiwanese talent currently overseas to return home to work in Taiwan, MOST has joined forces with the Ministry of Education and 11 university presidents, vice presidents, and R&D heads to hold explanatory meetings aimed at recruiting talented young

A 20-person delegation headed by Science and Technology Minister Chen Liang-gee (6th from the left, front row) and Education Vice Minister Yao Li-teh, and including the presidents, vice presidents, and R&D heads of 11 universities, visited New York and Boston to encourage young S&T workers to return to Taiwan to contribute their talents.

involve from Taiwan working and studying overseas and, specifically, promoting the Einstein Program and Yushan (Young) Scholar Program.

2. Europe and the EU

The European Union's Horizon 2020 Framework Programme is currently the world's largest innovative technology platform. In order to embrace international norms, focus R&D capabilities, and avoid redundant investment of resources, MOST is actively encouraging domestic R&D teams to participate in the Horizon 2020 scientific research program, which will boost Taiwan's innovative R&D capabilities and broadening international personal connections and outlook by enabling Taiwan's researchers to take part in large multinational, multilateral research projects. Statistics from the European Union's Community Research and Development Information Service (CORDIS) website indicates that as of the end of November 2018, Taiwan had participated in 35 Horizon 2020 projects, and 29 other team had received MOST funding to participate in multinational, multi-year European projects, with project topics including nanomaterials, nano-medicine, translational cancer research, cardiovascular disease, water resources, agricultural economics, and information and communications. The European Commission's Directorate-General for Research and Innovation (DG RTD) took advantage of the June "Horizon

At the France-Taiwan Science Festival, Science and Technology Minister Chen Liang-gee (3rd from right) and MOST Department of International Cooperation and Science Education head Huang Hsin-ya (first on right) arranged for Academie des Sciences head Sébastien Candel (5th from left) and French National Research Agency head Thierry Damerval to visit Vice President Chen Chien-jen (5th from right).

The RFBR-MOST Anniversary of Partnership in Taipei, which was held on November 6, 2018, celebrated 20 years of partnership between MOST and the Russian Foundation for Basic Research

Shown from right to left in this photo taken at the 20th anniversary of the Franco-Taiwanese Scientific Grand Prize are Representative Wu, Taiwan Representative Office in France, Academie des Sciences (Ads) head Sébastien Candel, Science and Technology Minister Chen Liang-gee, Institut de France head Darcos, and Jean-François Bach, Permanent Secretary of the French Academy of Sciences.

2020 Info Day in Taiwan" to hold Horizon 2020 awareness activities in Taipei and Tainan in conjunction with MOST and NARLabs' National Contact Point (NCP) offices.

As for bilateral S&T cooperation with European countries, MOST and Germany's Federal Ministry of Education and Research (BMBF) jointly provided funding for the first year of the Taiwan-Germany Joint Research on Battery Technology, which has successfully established a joint Taiwan-German research mechanism, and is working to develop high-energy negative and positive electrode materials. At least 11 domestic battery companies are currently participating in industry-academic collaboration and performing technology verification, and the project has sponsored the exchange of research students. The Taiwan-Germany Joint Workshop on Lithium Ion Battery Technology Cooperation was held in December 2018 at National Taiwan University of Science and Technology; 26 German officials and research personnel came to Taiwan to take part in this event, which discussed collaboration items during the project's second year.

In order to celebrate the 10th anniversary of cooperation between MOST and the French National Research Agency (ANR) and the 20th anniversary of the Franco-Taiwanese Scientific Grand Prize, MOST held the France-Taiwan Science Festival in Taipei during September. In conjunction with this event, ANR head Thierry Damerval and Academie des Sciences (Ads) head Sébastien Candel led a delegation to Taiwan, where they met with Vice President Chen Chien-jen.

In order to celebrate 20 years of bilateral cooperation with the Russian Foundation for Basic Research (RFBR), MOST and RFBR jointly held the RFBR-MOST Anniversary of Partnership in Taipei during November. Representative Sergei Petrov of the Representative Office in Taipei for the Moscow-Taipei Coordination Commission on Economic and Cultural Cooperation visited Taiwan to participate in this event.

3. Asia

MOST has signed bilateral S&T cooperation agreements with the ministries of science and technology in India, the Philippines, and Vietnam, and regularly holds joint bilateral S&T conferences with these countries to discuss cooperative projects of joint interest. In the wake of the 5th Taiwan-Philippines Ministerial Conference on Science and Technology, the three 3-year research projects constituting the Volcano, Ocean, Typhoon, and Earthquake (VOTE) program has promoted regional S&T research cooperation between Taiwan and the Philippines. The two parties held the 6th Taiwan-Philippines Ministerial Conference on Science and Technology in Manila during September 2018, which kicked off the four 3-year research projects comprising the Health, Agriculture and Training Initiative (HAT). Two bilateral Taiwan-Philippines projects were approved at the event, and funding was provided to 17 persons participating in the Taiwan-Philippines Sandwich Program (under which Filipino students participate in internships in Taiwan).

At the 6th Taiwan-Philippines Ministerial Conference, which was held in Manila on September 24, 2018, shown are Science and Technology Vice Minister Hsieh Ta-pin (1st on right in front row), Hsu Pei-yung (2nd from right in front row), Taiwan representative in the Philippines, Science and Technology Minister Chen Liang-gee (3rd from right in front row), Philippines Secretary of Science and Technology Fortunato Dela Peña (3rd from left in front row), Angelito Banayo (2nd from left in front row), chairman of the Manila Economic and Cultural Office in Taipei, and Rowena Guevara Vice Minister (1st on left in front row), Undersecretary for Research and Development of the Philippines Department of Science and Technology.

With regard to cooperation with India, MOST approval nine multi-year bilateral research projects in 2018, and sent personnel to attend the Indo-Taiwan Joint Workshop on Artificial Intelligence, which was held by the Indian Institute of Technology, Madras during November; apart from planning the 10th Meeting of the India-Taiwan Joint Committee in Cooperation in Science & Technology, which will be held in India during 2019, the workshop also contained two bilateral seminars on the topics of smart cities and the bamboo industry. In cooperation with Vietnam, MOST and Vietnam's Ministry of Science and Technology held the 6th Taiwan-Vietnam Joint Conference on Science and Technology in December, at which decisions were made to extend the VOTE program to Vietnam and promote Vietnam-Taiwan smart disaster mitigation cooperative research.

In conjunction with regional initiatives under the government's New Southbound Policy, MOST has relied on promotion of the Overseas Science and Technology Innovation Center program to encourage domestic universities and research organizations to jointly establish "science and technology innovation centers" New Southbound Policy countries in conjunction with local organizations. By serving as overseas hub-centers and offices for MOST, These research centers will exert Taiwan's S&T influence while cultivating outstanding seed personnel in the host countries. In 2018, the government approved the establishment of 6 three-year overseas S&T innovation center projects; these centers will be located in the Philippines, Malaysia, India, Indonesia, Sri Lanka, and Myanmar, and will focus on topics in the humanities, medicine, natural science, agriculture, and engineering.

In order to promote interchange with high-level personnel, MOST is targeting government officials and S&T personnel in the New Southbound Policy countries under the "Southeast Asia International Joint-Research and Training Program," which provides for 1- to 2-week training

classes, takes common regional problems and social challenges as its main theme, and spans the fields of disaster mitigation, earth science, climate change, emerging regional infectious diseases, biodiversity, agricultural biotechnology, science education, engineering & applied technology, humanities & social sciences, and S&T policy. The eight S&T workshops held under the program in 2018 trained over 200 S&T personnel from the region (including New Southbound Policy countries) and strengthened regional cooperation networks.

With regard to cooperation with South Asia, in order to further strengthen links with Taiwan's Science Parks and the New Southbound Policy, the Central Taiwan Science Park and Hsinchu Science Park signed a three-way cooperation MOU with India's Karnataka Innovation and Technology Society (KITS) in July 2018.

In cooperation with Northeast Asia, held an international symposium with Japan's National Institute of Information and Communication Technology (NICT) and Israel on the subject of artificial intelligence. In addition, MOST held the "ICT for Hyper Aged Society" conference in Tainan with the Japan Science and Technology Agency (JST), and also held the "Taiwan-Israel Innotech Forum" in Taipei with Israel in order to encourage linkage between innovative enterprises in Taiwan and Israel.

C. Participation in Major International S&T Organizations

1. Asia Pacific Economic Cooperation (APEC)

MOST actively participates actively in APEC's multinational cooperation and activities promoted by the Policy Partnership on Science, Technology and Innovation (PPSTI) working groups via APEC's annual senior officials' meetings and APEC Chief Science Advisors and Equivalents Meetings, and MOST's Department of International Cooperation and Science Education and the Department of Industrial Technology, Ministry of Economic Affairs are jointly listed as Taiwan's APEC PPSTI contact windows. In 2018, the 11th and 12th APEC PPSTI conferences were held in Papua New Guinea. Eight research centers have been established under the PPSTI working group, of which the APEC Center for Typhoon and Society (ACTS) and APEC Center for Advanced Biohydrogen Technology (ACABT) have been implemented by NARLabs and Green Energy and Biotechnology Industry Research Center, Feng Chia University with funding from MOST. ACTS held the 2018 APEC Typhoon Symposium in May at the GIS Convention Center, NTU; 250 government officials, scientists, and young scholars from 10 APEC economies attended this event, which had the topic of Sustainable Development with Digital Innovation for Weather-related Disasters. ACABT holds annual international conferences and engage in technology and manpower interchange

Funding for international academic interchange activities, 2014-2018

Item	Joint international research projects under bilateral agreements (projects approved during year)	Invited visits by international S&T personnel (person-times)	Attendance at international academic conferences (Dept. of International Cooperation & Science Education projects / 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)	Enhancing the international influence of domestic scientists (cases)
2014	114	839	953 / 12,607	3,300	345	49 / 313	34
2015	130	758	934 / 12,774	3,375	327	42 / 224	27
2016	128	730	1,009 / 12,288	3,545	315	42 / 243	25
2017	128	800	1,110 / 12,504	2,805	285	37 / 227	25
2018	**127**	**532**	**970/12,290**	**2,466**	**318**	**42/283**	**33**

with APEC member states, and seeks to boost Taiwan's degree of international participation and visibility in the field of scientific research. MOST held the YES Challenge Symposium in Bangkok, Thailand during August; the topic of this event was Smart Power Management for Self-Sustained Green Community in APEC Region, and it attracted over 70 experts and scientists from 10 APEC economies.

2. European Molecular Biology Conference/ European Molecular Biology Organization (EMBC/EMBO)

Established in 1964, the European Molecular Biology Organization (EMBO) relies on cooperation and interchange between top-notch international research personnel, and seeks to extend molecular biology to important areas in the fields of medicine, plant cultivation, and agriculture, while promoting the development of life science in Europe and other parts of the world. EMBO currently has over 100 foreign fellows, most of who come from the United States, and Asian fellows are very few in number. To date, more than 85 EMBO fellows have received Nobel prizes, showing the international prestige of this body and its members. EMBC is an international body jointly organized by government agencies in the 29 EU member states. EMBC provides a bridge for collaboration in basic research in molecular biology and related fields among member states, and agreements with EMBC permit cooperation with external organizations and non-member states.

Representing Taiwan, MOST and Academia Sinica jointly signed academic cooperation agreements with EMBO and EMBC in November 2012, which will provide opportunities for Taiwan's scientists in life science and reinforce ties between Taiwan and Europe in molecular biology. MOST's provision of EMBO sponsorship funds in keeping with these agreements gives Taiwan's scientists and researchers enjoy the same eligibility as European scientists to apply for EMBO-funded projects and activities, including (1) EMBO guest scholar scholarships, (2) EMBO classes and seminars, (3) travel expense funding, (4) funded lecture and activities, (5) EMBO young research scholar projects, and (6) EMBO members' recommendations.

D. Funding of International Academic Interchange Activities

In order to create an international S&T collaboration environment and enhance Taiwan's visibility in the international academic world, MOST has vigorously promoted participation in the activities of international scientific and technological organizations, and provides support for attendance at international academic conferences, the holding of international academic conferences, and the invitation of foreign figures to Taiwan for interchange and collaboration. This work is strengthening Taiwan's international collaboration human resources and creating a more international scientific research environment.

To help young scholars broaden their international perspectives and gain international academic experience, MOST provides funding to domestic master's and Ph.D. students for participation at international conferences allowing them to present their research results. This participation also enhances graduate students' international outlooks, sharpens their research skills, and fosters international collaborative research relationships.

To 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*, which calls for encouragement and support of 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.

E. Promotion of Overseas Science Division affairs

Apart from assisting in the promotion of bilateral and multilateral S&T interchange and cooperation, MOST's overseas science divisions also actively maintain contact with overseas Chinese S&T personnel and professional associations in their service areas. The science divisions also rely on academic conferences to promote the sharing of new S&T development knowledge and information via networking, and maintain contact with overseas research personnel. The 15 overseas conferences held in 2018 discussed topics including translational cancer biology, biomedical engineering, reliance on innovation and education to realize sustainability, big data technology development and applications, natural disaster prevention engineering, biotech medicine, circular economy, innovative biotechnology, and future medicine, etc.

On March 27, 2018, a MOST press conference announced that a new overseas science division would be stationed in Israel. Shown are MOST Department of International Cooperation and Science Education head Huang Hsin-ya (first on left), Science and Technology Minister Chen Liang-gee (2nd from left), Yarden Asher (2nd from right), representative at the Israel Economic and Cultural Office in Taipei, and Wang Ting-an (first on right), division chief of the overseas science division in Israel.

In order to establish a "strategic complementarity, mutual prosperity" collaboration platform between Taiwan and Israel, and strengthen future ties, MOST joined forces with the Israel Economic and Cultural Office in Taipei on March 27, 2018 to announce the establishment of a MOST overseas science division in Israel. In addition, in order to establish linkage with the Boston area's biotech industry cluster and strengthen S&T collaboration, MOST established a new science division in the Taipei Economic & Cultural Office in Boston.

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 stable, in-depth cross-Strait academic interchange and collaboration. While prioritizing technological interchange and cooperation benefiting Taiwan, China, and their people's livelihoods, 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 cross-Strait interchange regulations and the results of their implementation during 2018:

S&T interchange with China and permit review statistics, 2014-2018

Item	2014	2015	2016	2017	2018
Recruiting S&T personnel from China (person-times)	121	108	85	79	63
Cross-strait academic conferences	64	73	47	55	52
Invitation of S&T personnel from the Mainland China Area, Hong Kong, and Macao to Taiwan (person-times)	89	67	83	77	67
Professional S&T activity permits reviewed (person-times)	464	433	547	395	740

1. Based on the *Regulations Governing the Recruitment of Visiting Science and Technology Personnel with Subsidies from the Ministry of Science and Technology*, MOST provides subsidies to research organizations for the recruiting of S&T personnel from China for participation in scientific research in Taiwan; such subsidies were provided 63 person-times in 2018.

2. Based on the *Operating Guidelines for Subsidies for the Holding of Cross-straits Academic and Sci-tech Conferences*, MOST encourages and supports the holding of cross-Strait S&T and academic conferences by academic or S&T organizations and universities. Support was provided for 52 conferences in 2018.

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 67 such visits in 2018, which were chiefly for the purpose of public lectures and participation in discussions.

4. In 2018, 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 740 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 issues concerning public welfare. The topics of this year's joint issue of investigation was "Ecological Agricultural Technology."

In the future, MOST will continue to construct and implement stable interchange mechanisms on the foundation established by both parties in the past.

VII. Improving the Research and Development Environment

A. Online Services

MOST's international website, which received AA grade certification under the Website Barrier-Free Mark 2.0 in October 2018, provides an even more convenient and user-friendly browsing experience. The content framework of the website's English version was also adjusted in August, allowing foreign readers to browse and understand MOST's policies with greater convenience. In the future, in conjunction with the government's "Blueprint for Developing Taiwan into a Bilingual Nation by 2030," MOST will continue to enrich and enlarge the English content of its international website.

With regard to online information service improvements, MOST completed improved online application system updates for "bilateral and short-term visits through the Department of International Cooperation and Science Education," "human resources training research projects," "recruiting of S&T manpower and cross-Strait S&T interchange," "incentives for advanced & outstanding personnel," "Executive Yuan Award for Outstanding Science and Technology Contribution," and the "Scientific & Technological Resources, Information, and Knowledge Exchange (STRIKE)" system. The replacement of old application systems has made online application, agency compilation, funds use reporting, report submission, and online review more convenient, and strengthened compatibility with major browsers.

After several years of implementation, paperless online application and review of MOST academic research grants and funding has effectively reduced project application paper and postage costs, shortened processing

Paperless online application statistics, 2016-2018

Item	2016	2017	2018
Project funding	102,576	101,136	103,657
International cooperation	18,757	22,092	20,041
Manpower recruiting	15,893	15,716	13,622
Industrial / academic collaboration	5,940	5,692	5,739
Total	**143,166**	**144,636**	**143,059**

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

Paperless online review statistics, 2016-2018

Item	2016		2017		2018	
	Cases	Person- times	Cases	Person- times	Cases	Person- times
Project funding	40,194	98,656	37,935	95,887	40,432	105,893
International cooperation	8,516	10,900	9,000	12,222	8,778	11,573
Manpower recruiting	1,692	3,087	1,608	3,042	1,371	2,744
Industry-academic collaboration	2,320	6,462	1,456	3,985	2,211	5,881
Total	**52,722**	**119,105**	**49,999**	**115,136**	**52,792**	**126,091**

Note: Online review tasks include review of application cases, appeal cases, and results reports.

time, and boosted administrative efficiency. Taking conservation of paper as an example, throughout the process from initial application to final review and approval, application cases in 2018 conserved close to 40 million sheets of paper, which is equivalent to saving 4,700 trees and demonstrated significant energy and paper conservation.

B. Major Instrument Common Use Service

MOST's major instrument common use service program provides needed equipment to researchers in academia and industry. During 2018, major instrument common use program subsidies were provided to the following 23 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 Dong Hua University, National Taiwan Ocean University, National Changhua University of Education, National Taiwan University of Science and Technology, National Pingtung University of Science and Technology, Tunghai University, Chung Yuan Christian University, Feng Chia University, Taipei Medical University, Kaohsiung Medical University, National Chi Nan University, National Taipei University of Technology, National Chin-Yi University of Technology, Yuan Ze University, and National Yunlin University of Science and Technology. Facilities at these universities housed 206 in-service instruments during the year, and the major instrument centers provided services 427,631 times in 2018, and service time totaled 384,374 hours. The aggregate value of instrument services amounted to over NT$585.2 million.

Major instrument use center service statistics, 2018

School name	Number of instruments	Cases	Service hours
National Taiwan University	24	76,989	69,254
National Taiwan Normal University	7	13,735	18,589
National Central University	13	17,015	21,613
National Tsinghua University	27	83,432	58,176
National Chiao Tung University	27	50,542	58,421
National Chungshing University	21	46,810	33,401
National Chung Cheng University	11	13,947	16,962
National Cheng Kung University	25	57,401	45,858
National Sun Yat-sen University	18	25,611	29,475
Non-major instrument centers (15 schools)	33	42,149	32,626
Total	**206**	**427,631**	**384,374**

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 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 industrialization of academic research organizations' invention patents, the foregoing *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 3,813 cases during 2018.

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. The amount of cash royalty income from R&D results paid into the Science and Technology Development Fund was approximately NT$60 million in 2018.

IX. Publications

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 sought to make science and technology accessible and relevant to the public since that time. 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 scientific knowledge. This publication 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.

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, Taiwan (2017 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 2017 edition contained four major sections: The first section, "Summary Analysis," compared trends in the R&D inputs and outputs of Taiwan and other major nations during the most recent five years; apart from text explanation, charts and graphs help readers to clearly understand the significance of major input and output indicators and their status 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, "Appendices," explains the survey, defines terms, and provides the survey questionnaire and comparisons of OECD and Taiwan industry classifications.

Journal of Biomedical Science

A domestic scientist serves as the chief editor of this international academic periodical, 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 3.466 according to the 2017 *Journal Citation Reports* (*JCR*), and is one of the most representative biomedical journals in Asia.

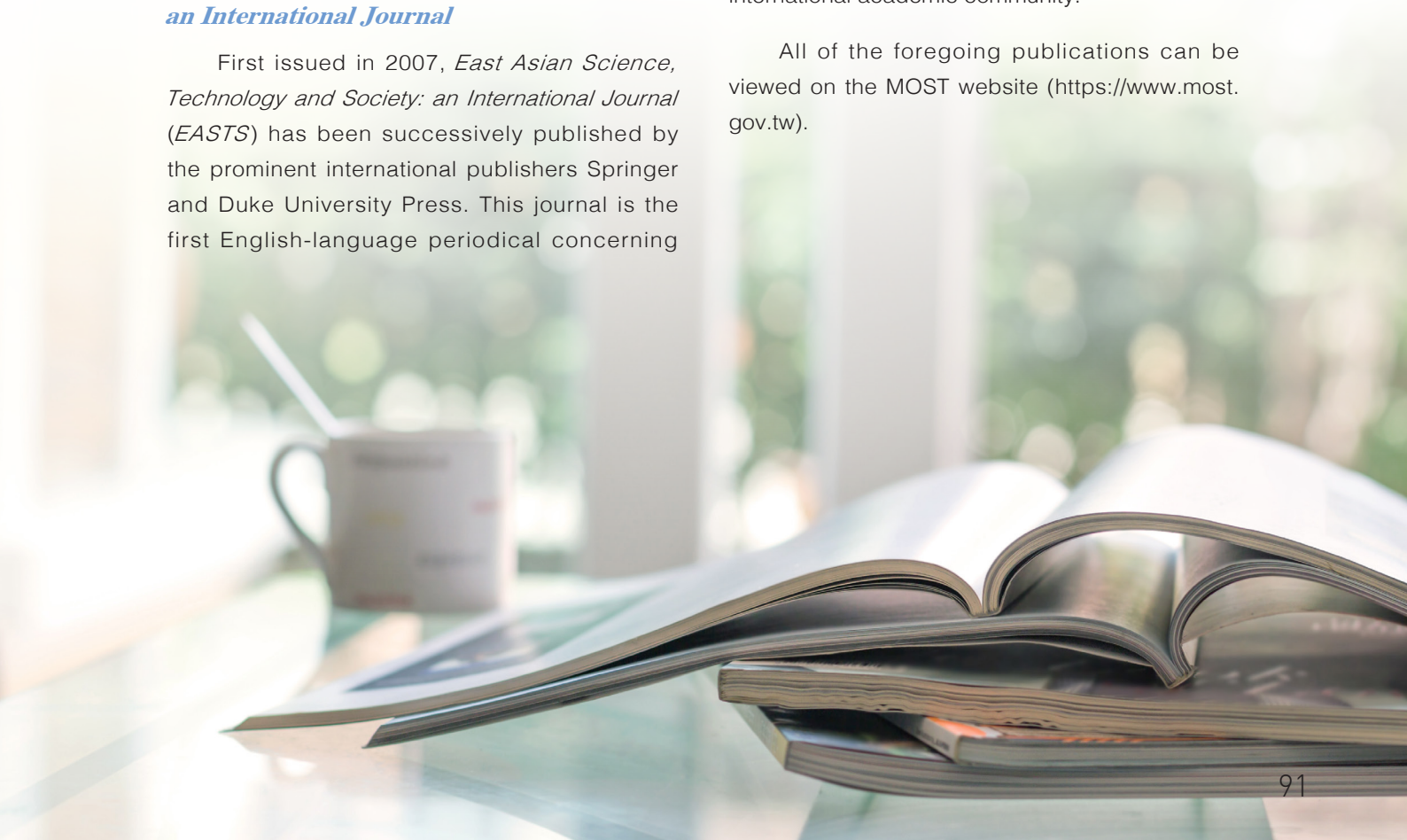
International Journal of Science and Mathematics Education

First published in 2003, this quarterly international academic periodical was changed to a bimonthly in 2009. A domestic scientist serves as the chief editor, and prominent international scholars have been invited to serve on the editorial committee. The journal is published by a well-known international publishing company, and 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 this a very representative educational research journal presenting viewpoints from non-English-speaking countries. According to the 2016 *Journal Citation Reports* (*JCR*), this journal had an SSCI impact factor of 1.086.

East Asian Science, Technology and Society: an International Journal

First issued in 2007, *East Asian Science, Technology and Society: an International Journal* (*EASTS*) has been successively published by the prominent international publishers Springer and Duke University Press. This journal is the first English-language periodical concerning science, technology and society (STS) and taking East Asia with its area of focus. *EASTS* seeks to explore the interplay between local contexts and the development of analytical technologies, and chiefly contains articles, research records, forums, short communications, and book reviews. This journal hopes that exposure to solid experiential and comparative research will inspire perspectives diverging from the mainstream view. Apart from a domestic chief editor and executive editor, the journal has invited experts and scholars from Southeast Asia, Australia, US, and Europe to form the editorial committee. The journal relies on its rigorous review system and interdisciplinary spirit to continuously improve the quality of articles. Articles published in *EASTS* have won awards from the International Conference on the History of Science in East Asia (ICHSEA), Society for the Social Studies of Science (4S), and Society for the History of Technology (SHOT), and the journal has also won the 4S Infrastructure Award and been included in the *SSCI* and *A&HCI* academic index database. This not only reveals the excellent results of the editorial team's long-term efforts, but also highlights Taiwan's contributions to the international academic community.

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



Chapter 4
Strengthening Industry-Academic Linkage and Innovation

Chapter 4 / Strengthening Industry-Academic Linkage and Innovation

I. Industry-Academic Collaborative Research Projects

In order to establish a supportive environment for industry-academic collaboration, encourage enterprises to participate extensively in applied academic research, and encourage the exchange of human resources and joint industry-academic participation in innovative R&D, MOST promotes pace-setting, developmental, and applications-type industry-academic collaborative projects. Among these project types, pace-setting projects consist of industry-academic collaborative projects involving forward-looking technologies or knowledge needed for industrial development, seek to increase future industrial competitiveness, and constitute high-risk, high-innovation early-stage research or initiatives requiring long-term R&D. Developmental projects focus on helping industry develop core innovative applied technologies, and include industry-academic collaborative projects in which the cooperating enterprise wishes to engage in the joint innovative development of specific technologies or products. Application-type industry-academic collaborative projects seek to train personnel at the implementing organization in basic applications research skills; projects of this type focus on the needs of private corporations, and may establish corporate business models, enhance management ability, increase product added value, or generate digital content.

A total of 1,259 project applications were accepted in 2018, of which 787 were approved to receive funding, and the total funding amount was NT$824.3 million. The projects provided training to 1,917 graduate students, attracted NT$324.6 million in corporate R&D funding, and involved 817 participating enterprises. In view of the commercial time-sensitivity of industry-academic collaboration, regulations have been eased to allow acceptance of industry-academic collaborative projects at times apart from the announced acceptance period.

Industry-academic collaborative research project statistics, 2014-2018

Item	2014	2015	2016	2017	2018
Number of projects	813	808	840	775	787
Funding (NT$1 m)	894	993	889	848	824
Participating enterprises	852	829	867	804	817
Corporate contributions (NT$1 m)	328	380	348	325	325
Manpower training (graduate students)	2,095	2,078	2,178	2,069	1,917
Patents received	216	155	146	95	50

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

The following was among the R&D results obtained in 2018:

An interdisciplinary, integrated project involving National Tsinghua University, National United University, Feng Chia University, and the Hiwin Mikrosystem Corp. developed a key element of smart machine tools—magnetic ruler encoders—which will enable Taiwan to produce machine tools with a high degree of precision. Apart from enhancing the overall performance and value of the machine tools made in Taiwan, the results of this project will also help cut costs. The magnetic ruler encoders developed in the project will enable Hiwin Technologies—a leading machine tool producer—to mass produce the first absolute magnetic rulers (resolution of 1 micron) to be sold commercially in the Chinese-speaking world.

These projects seek to couple the R&D capabilities of universities and industrial firms for the purpose of joint involvement in forward-looking, technology R&D activities, which will bring about the enhancement of Taiwan's industrial competitiveness and product added value.

II. University-Industry Collaboration Projects (Large Alliance)

In order to direct academic R&D capabilities and resources to the industrial sector, deepen Taiwan's industrial technology innovation capabilities, and gain an advantage in international markets, MOST and the Ministry of Economic Affairs joined forces in November 2012 to propose "University-Industry Collaboration Projects (Large Alliance)," which represent a novel interagency industry-academic collaboration model. MOST serves as a unified document acceptance and review window for proposals submitted by academic applicants.

This program channels academic R&D capabilities to industry by pairing Taiwan's finest scientists and researchers with its most internationally competitive companies, and results have included shrinking the gap between academia and industry, developing 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.

The four large alliance projects implemented in 2018 investigated topics in the fields of semiconductors, green chemical engineering technology, wireless/broadband network technology, and mobile communications technology. These projects attracted approximately NT$290 million in corporate R&D funding during the year; from the program's inception in 2013 until 2018, large alliance projects have attracted a cumulative total of NT$2.16 billion in investment and resulted in 515 patent applications. The following results were achieved in 2018:

An R&D project involving National Chiao Tung University, Quanta Computer, and MediaTek cooperatively developed the world's first M-CORD open source platform connected with the Internet; this platform relies on more flexible and efficient dynamic resource allocation to provide fast and effective Mobile Edge Services, and can effectively reduce mobile network investment and operating costs, while accelerating the online roll-out of new services.

In another project taking the Guangfu campus of National Chiao Tung University as an experimental site and seeking to create a "smart campus," researchers successfully developed the world's first LTE and WiGig dual network interface carried on an unmanned aerial vehicle (UAV), and achieved high-speed data offloading. This project also found that the use of WiGig to offload data can achieve speeds four times those of WiFi.

This program seeks to bring about a full-scale improvement in Taiwan's industrial competitiveness and product added value by

coupling Taiwan's academic and industrial R&D capabilities and inducing industry and academia to jointly pursue forward-looking and basic technology R&D activities.

III. Academia-Industrial Technology Development Alliance Projects

The plentiful research capabilities of Taiwan's academic research sector are not directed solely toward the publication of journal papers; apart from strengthening ties 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 position of SMEs in Taiwan's industries, and their urgent need for the R&D resources and capabilities of academia, MOST began funding "Academia-Industrial Technology Development Alliance Projects" ("Small Alliance projects") in 2012. These projects take technologies developed by the academic sector as their focal point, 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 corporations.

A total of 91 projects received funding during 2018. As of the end of 2018, 2,143 companies had participated in small alliance projects, and the program is continuing to team up with local governments and local industry groups and associations to promote the establishment of small alliances serving area industry, which will expand participation by industry and enhance benefit to industry.

IV. From IP to IPO

Taiwan's startup environment has gradually been becoming more active in recent years, which has been reflected in higher levels of innovation, policy adaptation, willingness to invest, teamwork, and social value. In order to maintain this positive trend, MOST has continued to implement various innovative startup support programs, including the "From IP to IPO" (FITI) program, which encourages academic research organizations to devote their attention to practical applications, and relies on the provision of accelerator training mechanisms and key resources to help Taiwan's S&T teams increase their startup success rate. This program chiefly seeks to accelerate and improve the transformation of academic R&D results into technological innovations that can be put on the market, sets multi-stage training goals, and attempts to let industry access the innovative capabilities of academic institutions. The program is constantly seeking out entrepreneurial ideas from professors, students, and full-time research personnel in such fields as information and communications, biology, medicine, physical science, and engineering. Two training sessions are held each year, and each session provides six months of professional business training and key resources needed for academic entrepreneurship, including angel startup funds, important connections, basic entrepreneurial skills, and practical learning opportunities.

In order to maintain the entrepreneurial trend at universities and promote the commercial of academic research results, MOST conducted two public requests for entrepreneurial ideas in 2018, and selected 80 promising teams to receive training. Core entrepreneurship classes and a consulting system with domestic and foreign mentors helped the teams hone their entrepreneurial skills and fine-tune their business proposals. The provision of resources and startup funding in multiple stages gave the teams' startups much-needed resources, and MOST's science parks in northern, central, and

southern Taiwan provided local assistance to the teams.

Apart from strengthening cooperation with private and interagency startup programs and accelerators, and maintaining continuous tracking of the teams' development, the program also assisted in the location of follow-up startup resources in accordance with the teams' needs and wishes. These resources have included, for instance, NARLabs/ITRI's prototype production and application verification capabilities, and the resources of "angel projects," the Taiwan Innovation and Entrepreneurship Center, DIT Startup, Emerging Industry Incubation-Accelerating Program, and the Taiwan Startup Stadium. The two training sessions each include 10 core classes, 4 in-depth training camps, 2 major angel matchmaking sessions (BIG Demo), and a selection process at each stage. Beginning from basic profitability models, the core classes progressively teach the teams patents, IPR portfolios, marketing, channels and pricing strategies, fund-raising management, and design of startup equity structure, and senior experts speak on entrepreneurship knowledge and conduct classroom exercises. Training camps seek to instill a basic consensus and culture in each startup team, such as through simulated business proposal scenarios, and the teams are urged to quickly establish a division of labor. The three-day, two-night core training camp encourages the teams to draft market testing milestones for their technologies. Held twice each year, the BIG Demo is a major event at which the teams are paired with venture investors and can announce their startup plans, and provide outstanding startup teams opportunities to display their results or product templates, and attract seed funds from venture investors or angels. Apart from the startup teams selected each year, MOST has continued to invite senior academic teams that have developed marketable projects or services to participate and add their innovative energies, which can help realize potential investment opportunities.

With regard to community and inter-regional cooperation, MOST held the XFail 2018 Conference at Taipei's Syntrend Creative Park on April 7, 2018 in conjunction with Taipei City Government, Asia Silicon Valley Development Agency, Silicon Valley Entrepreneur Association of Taiwan, and the Taiwan

Held twice each year, the BIG Demo, provides outstanding startup teams with opportunities to increase their exposure, and attract seed funds from venture investors or "angels."

Innovation and Entrepreneurship Center. The speakers at this event including online trend observer Liu Wei Lin and Yun Feng Technology Deputy Executive General Manager Chao Keng-yuan, who shared their experience of failure, and encouraged the startup teams to maintain their entrepreneurial spirit and not fear failure. In addition, MOST and the Taidah Entreprenuership Center jointly held a Nobel scientist startup sharing conference on November 20. At this event, Dr. Dan Schechman—winner of the 2011 Nobel Prize in chemistry—shared his insights and experience concerning the training of entrepreneurial manpower. Since the From IP to IPO program was initiated in 2013, it has trained a total of 1,636 young entrepreneurs, collected over 2,000 ideas for startups, helped 480 teams establish 154 startups, and promoted the raising of NT$2.1 billion in startup funds, with a team fund-raising success rate of 32.7%. Looking ahead to the future, the program will continue to promote and strengthen Taiwan's startup community, and stimulate the development of innovative technological applications. The program hopes to foster the innovative and entrepreneurial spirit among Taiwan's youth, strengthen the performance of the public, companies, and investors, achieve greater value, and jointly create an even more entrepreneur-friendly innovative startup ecosystem.

V. Applied Research Incubation Projects

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

Although Taiwan's academic institutions and research units have accumulated considerable potential and actual achievements in the areas of biotech pharmaceuticals and medical equipment, most academic research results still remain at the front end of industry value chains, and have made insufficient progress toward commercialization. These projects are initially promoting early R&D in the fields of pharmaceuticals and medical devices. As of the end of 2018, more than 290 proposals had passed the initial screening process, 91 of these had been subjected to in-depth assessment, and funding had been provided to over 30 teams. The teams receiving assistance seek to commercialize their research results in such areas as, for instance, smart medical device manufacturing systems, leukocyte reduction filtration technology, and in vitro cancer diagnostic reagents, and have established 18 registered startup companies thus far. The cumulative paid-in capital of these startups has exceeded NT$989 million, and 6 startups have been induced to enter science parks, where they are participating in the development of a biomedical R&D cluster ecosystem. These results indicate that this program has successfully facilitated the transformation of R&D results into marketable applications, and enabled citizens to enjoy the fruits of the commercialization of domestic biotech R&D.

VI. 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 research results possessing industrial value via appropriate promotional mechanisms. Following collection of assessment recommendations during the first stage, which lasted from 2007 to 2010, the Germination Program got underway in 2011, and has sought to systematically promote the commercialization of promising scientific discoveries. Germination projects are geared

to assisting the industrialization of the results of MOST's general research projects, and provide resources and promotional mechanisms for the commercialization of early R&D results. This program has helped to successfully promote many promising R&D results to the product development and commercialization stages at the back end of product value chains, where they can serve as the starting points of applications projects.

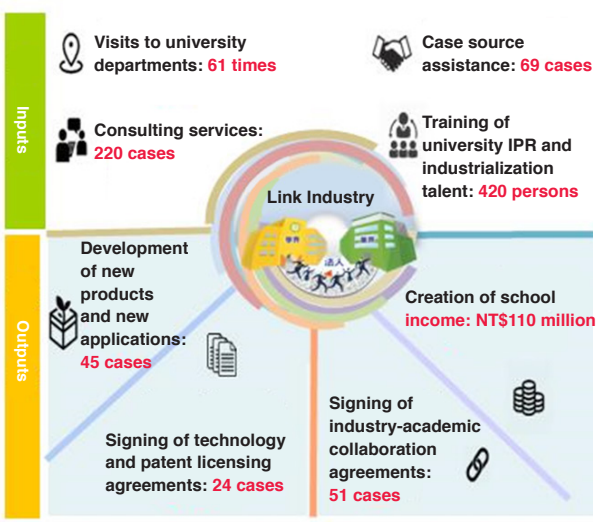
The chief mission of this program is to "uncover potentially commercializable R&D results," and it seeks to ferret out R&D findings with commercial potential at universities and research institutions. The program conducts a Germination project selection process, seeks to add individuals with business knowledge to project teams, holds inter-university business manpower matchmaking and training activities, and performs matchmaking between project teams and business manpower. The program's second key aspect is the "acquisition of the assistance capabilities of industry experts to reinforce team formation." As of the end of 2018, the program had uncovered a cumulative total of over 1,600 promising proposals, and incubated 58 startups, which had raised total funds in excess of NT$1.07 billion.

VII. Using Research Institutions to Link Industry-Academia Collaboration Projects

In order to reinforce the linkage between academia, industry, and society, MOST is actively promoting "Using Research Institutions to Link Industry-Academia Collaboration Projects," 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 strengthening industry-academic linkage, accelerating the establishment of an innovation ecosystem characterized by "Discovery, Development, Delivery, and Commercialization" ("3D1C"), inducing industry to make effective use of academic research capabilities, and thereby maximizing the social and economic value of R&D results.

This program was initiated on a trial basis focusing on the field of information and communications during 2015. In 2018, in conjunction with the Executive Yuan's "Ten Major Innovative Industries," the program also began promoting smart machinery, biotech pharmaceuticals, biotech medical devices, green energy technology, business management, and digital finance, and implementation was expanded to the Industrial Technology Research Institute, NARLabs, National Health Research Institutes, Commerce Development Research Institute, Institute for Information Industry, Metals Industry Development Center, Plastics Industry Development Center, Automotive Research & Testing Center, Precision Machinery Research & Development Center, China Productivity Center, and Taiwan Textile Research Institute. At the same time, the program has harnessed the capabilities of industry associations, linked companies, and jointly promoted the industrialization of university R&D results.

Some of the results of project implementation in 2018 are shown in the figure below.



Results of Using Research Institutions to Link Industry-Academia Collaboration Projects in 2018

VIII. Taiwan Innovation and Entrepreneurship Center

Established in California's Silicon Valley on June 19, 2015, the Taiwan Innovation and Entrepreneurship Center (TIEC) has been assigned the mission of linking startup teams in Taiwan with Silicon Valley's entrepreneurial resources. To date, 99 startup teams have been sent to continue their development in Silicon Valley; these teams have received a cumulative total of more than US$89 million in funds raised internationally. One team's startup has currently achieved an estimated valuation in excess of US$100 million, and 10 teams have reached valuations of more than US$10 million.

In order to help Taiwanese startups to raise investment funds internationally, MOST cooperated with InnoVEX and Meet Taipei in holding two international investment matchmaking meetings during 2018. These events attracted more than 135 domestic and foreign startups and 49 prominent international venture investors and corporate representatives. MOST also conducted a total of 211 matchmaking activities.

An international investment matchmaking activity held jointly by MOST and InnoVEX in 2018

IX. Global Research & Industry Alliance

The Global Research & Industry Alliance (GloRIA) program primarily seeks to establish and strengthen interactive linkage between global corporations and the commercializable research results generated by domestic universities/

Program Results

GLoRIA program results

research organization, provide industry forward-looking technologies able to meet the market's needs, train manpower needed by domestic industry, and ensure that Taiwan's scientific research is in keeping with the needs of international industry.

Based on universities, GloRIA projects focus on artificial intelligence, semiconductors, green energy, Industry 4.0, biotech medicine, financial technology, smart agriculture, and aquaculture/tropical fish. As of the end of 2018, the program had established 18 academic-industry alliances, which had attracted 290 domestic and foreign corporations as members; membership fee income was close to NT$100 million, 36 startups had been established, and the program had provided industry-ready training to 2,552 persons.

The following are some of the results that have been achieved by this program:

The program has promoted various models of cooperation between schools and companies; for instance, the GloRIA teams at National Yang Ming University and National Chengchi University organized a healthcare alliance that has been cooperatively developing applications based on elderly long-term care health data. The Laurel Group is cooperating with university partners under this alliance, and has achieved NT$20 million in collaborative industry-academic benefits with National Yang Ming University over the course of 5 years. A GloRIA project at National Tsinghua University has facilitated the development of practical applications of chemical technology by professors, while helping corporate partners to save NT$30 million in waste oil processing expenses. This project currently has 7 corporate partners, and has achieved NT$35 million in collaborative industry-academic benefits. A GloRIA project at National Chengchi University has teamed up with the Taiwan Financial Services Roundtable to uncover potential customers, establish an "innovation hub" establish six major leading laboratories in conjunction with IBM, Refiniti, Microsoft, and the Industrial Technology Research Institute, and assist with the commercialization of innovative digital finance.

X. New Industry-University Cooperative Research Linking Program

This program seeks to accelerate the commercialization of scientific research results and realize new technologies in the form of socially-beneficial applications. This program encourages universities to recruit industrial manpower for joint value-creating project teams, with the expectation that the teams will enhance the potential commercial value of research results after receiving government funding, and ultimately establish a spin-off or be acquired by a manufacturer. MOST provided funding to 34 selected startup teams in 2018, and full-time investment managers at the Taiwan Startup Institute assisted the teams to establish feasible business models and connected them with potential investors.

At a MOST press conference on December 4, 2018, Science and Technology Minister Chen Liang-gee (4th from left) announces that the team led by Jui Hsiang-peng of National Taipei University of Technology received NT$120 million in investment from Mechema Chemicals, T&T Industries Corp., and National Taipei University of Technology's LEAP center.

As of the end of 2018, six teams—a team led by Prof. Yang Chiu-chung of National Chung Hsing University, a team led by Prof. Chen Cheng-hsiung of National Chung Hsing University, a team led by Prof. Jui Hsiang-peng of National Taipei University of Technology, a team led by Prof. Chang Yi of National Chiao Tung University, a team led by Prof. Su Yi-jen of Southern Taiwan University of Science and Technology, and a team led by Prof. Wen Chih-hung of Sun Yat-Sen University—established spin-offs and completed a first round of fund-raising, receiving a total of NT$771 million in investment from domestic and foreign investors, and the spin-off companies have an estimated value of NT$1.38 billion.

Chapter 5
Developing Taiwan's Science Parks

Chapter 5 / Developing Taiwan's Science Parks

I. Hsinchu Science Park

A. Relying on Software to Support Hardware: Updating the Hsinchu Science Park

The Hsinchu Science Park (HSP) has developed an all-inclusive integrated circuit industry cluster, and the highly efficient vertical integration of its industry chains has long been an international benchmark and the driver of the science park's overall revenue growth. In addition, HSP's other industries, including information and communications, biotechnology, and precision machinery have also grown in pace with the IC industry's technological development. To meet the rising need for chips used in "AIoT" (Artificial Intelligence of Things) computing devices, and maintain their global leadership, HSP's firms are integrating their hardware and software advantages. The Hsinchu Science Park Bureau (HSPB) has six sites under its jurisdiction: The HSP's main site in Hsinchu (653 ha developed), Zhunan Site (123 ha), Hsinchu Biomedical Science Park (38 ha), Yilan site (71 ha), Tongluo site (308 ha already developed, 42 ha still under development), and Longtan site (76.2 ha already developed, 30.8 ha still being developed). As of the end of 2018, a total of 148,928 persons were employed at the park (excluding persons working in industrial and commercial services), and there were 512 registered tenant firms. Tenant firms had total operating revenue of NT$1,075.5 billion in 2018, 44 companies made new investments totaling NT$13.1 billion, and training was provided 8,895 person-times.

Taking advantage of its current strength in hardware, HSP is promoting the integration of hardware and software by the members of its high-tech industry clusters. This will stimulate HSP's upgrading, and is an important

Overview of Hsinchu Science Park Industries, 2018

Item	Companies[1]	Number of employees[2]	Revenue (NT$100 m)	Number of investing companies[3]	Amount of investment (NT$100 m)[4]
Integrated circuits	182	92,127	7,911.87	3	32.83
Computers and peripherals	53	8,561	438.69	3	0.34
Optoelectronics	48	7,162	1,343.89	9	45.48
Communications	90	30,437	403.94	0	0
Precision machinery	48	4,617	469.01	7	5.17
Biotechnology	86	5,724	117.40	22	47.54
Total	507	148,628	10,684.80	44	131.36
Other[5]	5	300	70.34	0	0
Total	**512**	**148,928**	**10,755.14**	**44**	**131.36**

[1]Number of approved companies
[2]Employment figures do not include persons working in industrial and commercial services
[3]Companies approved during the year to make investments in the park
[4]Amount of investment in the park approved during the year
[5]Includes "other science industries"

future policy direction for HSPB. In order to meet the operating needs of its tenant firms, HSP is introducing a new series of standard plant buildings, which possesses intelligent management and service facilities, while also gradually upgrading its older standards plant buildings. In addition, HSP is jointly planning the "HSP X software campus" in conjunction with Hsinchu Municipal Government, and is constructing an investment environment that is in keeping with industry trends.

In order to monitor global industry trends, better understand the state of science park development on a global basis, and help companies expand their overseas markets, the HSPB has continued to maintain close ties with relevant international industrial organizations, actively participate in international activities, maintain international norms, and strive to enhance the international competitiveness of its tenant firms. In October 2018, Director-general Wang Yung-chuang assumed the chair of ASPA (Asian Science Park Association) on behalf of HSP, and there will be more opportunities in the future to strengthen cooperation between HSP and other Asian countries, which will increase the opportunities for HSP's tenant firms to expand their international business.

B. Building a Nest to Attract a Phoenix: Injecting New Energy in HSP

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 companies, HSPB has actively promoted youth entrepreneurship opportunities in conjunction with MOST's "From IP to IPO" program, and provides innovative startup teams with an outstanding working environment. As of the end of 2018, a total of 317 entrepreneurial teams had set up operations in the park or received HSP assistance, and 152 teams had established companies, of which 125 companies are still operating. HSPB hopes that startups of this type can grow quickly, which will spur a renewed surge in entrepreneurial activity and help drive the innovative transformation of Taiwan's industries. Apart from establishment of the "Bamboo Dragonfly" (Young Entrepreneur's Studio, YES) on the Hsinchu campus, HSPB also seeks to increase entrepreneurial activity at the Yilan campus. After studying the environment at other domestic and foreign youth entrepreneurship sites, HSPB put great effort into the development of the "Bamboo Dragonfly" studios, which consist

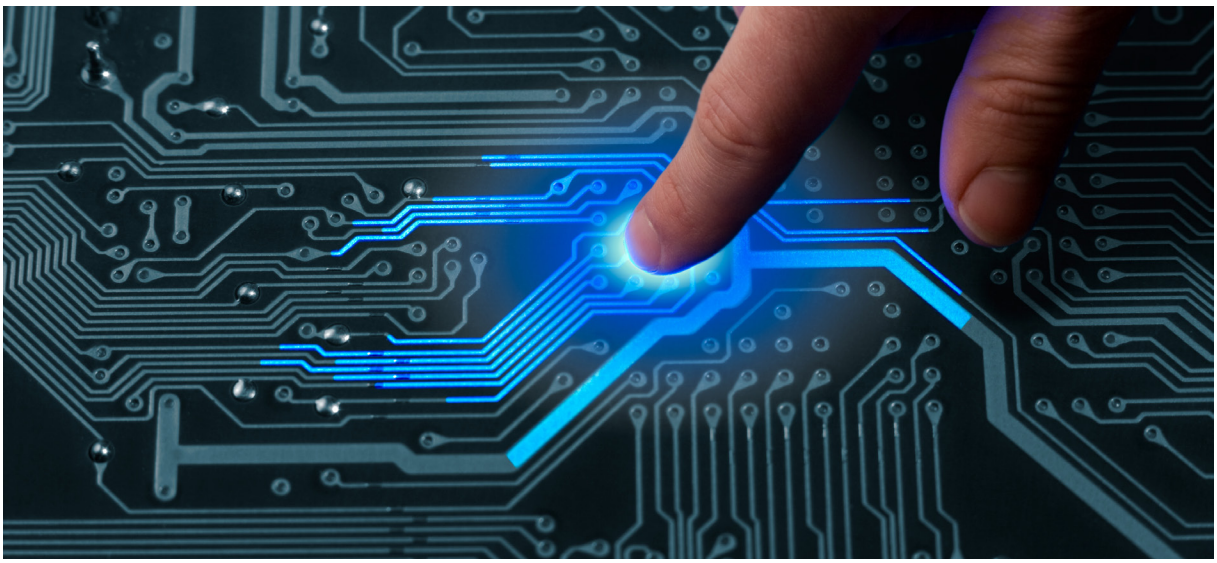
Hsinchu Science Park growth, 2014-2018

Item	2014	2015	2016	2017	2018
Number of companies[1]	489	478	487	492	512
Increase / decrease (%)	-1	-2	1	1	0.04
Number of employees[2]	149,116	149,100	147,624	147,862	148,928
Increase / decrease (%)	1	0	-1	0.2	0.01
Revenue (NT$100 m)	11,633	11,012	10,394	10,189	10,755
Increase / decrease (%)	4.57	-5.34	-5.94	-1.98	5.56
Manpower training[3] (person times)	9,321	9,285	8,446	8,398	8,895

[1]Number of approved companies

[2]Employment figures do not include persons working in industrial and commercial services

[3]Manpower training completion person-times figures include participation in talks on advanced technology and benchmark corporate leader talks.



of eight independent offices and 20 common working areas, and the teams occupying the independent offices can perform company registration at the site. HSPB expects that the Bamboo Dragonfly program will achieve a consensus among industry, government, academia, and the research community, and will encourage other innovative entrepreneurial teams to jointly participate in the development of technological industry, which will establish a high-tech industry ecosystem at the Yilan campus.

C. Planning HSP's Role in Biomedicine

HSPB is vigorously promoting the development of the Hsinchu Biomedical Science Park, which provides a complete ecosystem spanning industry, government, academia, research institutions, and hospitals, and the Biomedical Park is making good use of the strengths of HSP's information and communications industry to create new business opportunities in the field of biomedical. As of the end of 2018, the Biomedical Science Park had approved a total of 55 tenant firms, which had cumulatively invested a total of NT$24.6 billion. As a whole, HSP's biotech industry cluster consists of 111 companies, which had total revenue of NT$11.7 billion during 2018, which set a new high and represented growth of 16.3% compared with 2017. In the wake of the semiconductor industry, HSP has become the home to Taiwan's most significant biotech industry cluster. As more firms complete plant construction, and with the expected completion of National Taiwan University Hospital's Hsinchu Biomedical Park branch in January 2020 and a second biotech building in March 2020, the biomedical industry cluster will gradually consolidate, and is likely to become the biggest driving force in Taiwan's biotech industry.

II. 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-two more firms (including 4 startups) were approved to occupy park sites in 2018, and the park now has a cumulative total of 230 tenant companies, of which 194 have already occupied sites and begun operations. As of the end of 2018, 679.1 hectares of land in the park had been leased out, and the leasing rate had reached 95.6%. The following is an overview of industrial development in 2018:

A. Strengthening Innovative Entrepreneurship Service Platforms

STSP is relying on startup workshops and incubation spaces, in conjunction with the resources of industry, government, academia, and the research community, to provide prototyping, small batch production, fund-raising assistance, and mentorship services to promising entrepreneurs.

A total of 134 entrepreneurial teams had moved into STSP's startup workshops by the end of 2018; 24 of these teams had each obtained NT$2 million in seed funds from MOST's "From IP to IPO" program, 71 had established companies (with total capital of more than NT$1.4 billion), and 12 had become science enterprise teams.

STSP's mentoring office, which has obtained the services of 9 mentors from leading companies, has provided mentoring to 20 startup teams, helped 9 startup teams to create prototypes, and assisted two startups to raise NT$99 million in investment.

B. Establishment of the STSP AI_ROBOT Robotics Maker Factory

Starting in December 2017, STSP has offered southern Taiwan's first national-level smart robotics open innovation maker platform, and it has also relied on international interchange, team interaction, classes, and competitions to train personnel in interdisciplinary innovation. STSP provides these assistance services through Taiwan's first ISO-certified robotics maker factory, which has developed its own smart robotics patented technology online assessment system to provide dedicated service to members, and hopes to let makers realize their dreams.

As of the end of 2018, STSP's robotics initiative had undergone significant broadening and deepening, including the holding of the First Robot Competition (FRC) Seed Team and Teacher Training Camp, which attracted teams from high schools throughout Taiwan; at the FRC playoffs held August 25-26, 2018, teams from STSP's National Nanke International Experimental High School and Junior High School teams received the Winner Award, and STSP helped the teams find corporate sponsors willing to contribute over NT$1 million to enable them to participate in the regional competition. STSP also held the first-ever Taiwan AI x Robotics Accelerator (TAIRA), which selected 10 outstanding domestic and foreign teams to occupy spaces in the Robotics Maker Factory (the two foreign teams were from Canada and Japan). Fourteen major companies, including the United Microelectronics Corp. (UMC), King's Town Bank, and E-Da Hospital, conducted a technology value-adding co-creation application project for robotics makers, and the project obtained approximately NT$52.9 million in resources from international corporate sponsors including Google, Amazon, and IBM. STSP has further established maker group alliances in the six areas of intelligent manufacturing/robotics, unmanned vehicle, smart agriculture, smart medicine, IoT/AR/VR, and intelligent algorithms/Fintech, which are linked with roughly 6,500 persons in maker groups throughout Taiwan. STSP cooperated with Taiwan AI Labs, NARLabs National Center for High-Performance Computing, and Tainan City Government to produce panoramic 360-degree high-resolution videos of Tainan's sightseeing spots, establish an AI data platform, use an artificial intelligence algorithm to perform value-added image processing, and develop automatic aesthetic filming and AI automated annotation tools and AI image resolution enhancement technology, which can apply Tainan's scenic spots in the future development of an intelligent urban infrastructure.

C. Semiconductor Industry Investment in Advanced Processes at STSP

After investing NT$550 billion in the construction of a 5nm process 12" foundry in 2017, TSMC announced that it would also build a 3nm process foundry at STSP, and the chips produced at this facility will be used in mobile devices, high-performance computing applications, automotive electronics, and IoT devices. This

investment will sustain the growth momentum of the semiconductor industry, and is expected to employ 5,000 persons. Winbond broke ground for a Kaohsiung plant in October 2018; this plant is expected to be completed in 2020 and begin production in 2021. Looking ahead to the future, Winbond plans to adopt 25nm process technology at this plant, which will meet the needs of IoT, smart systems, and industrial automation.

D. Continued Improvement of STSP's Smart Manufacturing Capabilities

Beginning in 2017, the four-year STSP Smart Manufacturing Industry Cluster Development Program has brought about the establishment of an STSP smart manufacturing alliance and promoted the growth of a 3D printing industry cluster. As of the end of 2018, this program has induced 5 firms to occupy sites in STSP and make investments totaling NT$503 million, assisted 5 tenant firms to improve their automated processes, and held the "Semiconductor Technology and Manpower Matchmaking Conference" and "AI Tool Matchmaking Conference," which helped 11 tenant firms, 17 supply chain firms, and 18 professors to perform technology and manpower matchmaking. In order to promote the development of a 3D printing industry cluster, STSP has established a first-of-its-kind 3D printing medical device manufacturing site at the Kaohsiung park; this facility helps domestic medical device manufacturers to integrate their production processes, including design, trial production, and commercial contract manufacturing, and has enabled tenant firms to develop 3D-printed metal medical devices meeting international certification requirements and enter the international 3D-printed medical device market.

E. Promoting the International Linkage of the Biotech Medical Device Industry Cluster

The 2017-2020 STSP Smart Biomedical Industry Cluster Development Program is boosting the added value of medical devices through the application of information and communications technology to the fields of minimally invasive surgery, precision medicine, and customized medicine, and STSP is also relying on clinical research and market expansion programs to help manufacturers increase the value of their products.

As of the end of 2018, the 78 companies in STSP's biomedical industry had made total investment of NT$26.9 billion, and the park's biomedical cluster was growing steadily. At that time, four STSP firms had passed the Ministry of Health and Welfare's artificial tooth root inspection registration, 37 firms had passed GMP (Good Manufacturing Practice) certification, 14 firms had passed qualifications review under the *Biotech and New Pharmaceutical Development Statute*, 38 firms had received sales permits from the Taiwan Food and Drug Administration, 16 firms had received sales permits from the US Food and Drug Administration, and 24 firms had received European Union certification. In 2018, STSP approved a reconstructive surgery experience diagnosis line at Kaohsiung Hospital and the establishment of an orthopedics teaching center at Kaohsiung Medical University. There are now 9 experience diagnosis lines in Taiwan, which will ensure that even more products made at STSP will enter hospital purchasing systems, and increase the sales of tenant firms.

In 2018, STSP provided funding to five clinical research projects, and encouraged medical organizations to work with tenant firms to enhance clinical trust in their products. In addition, in order to provide a marketing platform promoting the biomedical industry cluster's image, STSP relied on the national image pavilion at medical trade shows, overseas technology interchange and matchmaking conferences, and overseas sales promotion campaigns geared to enhancing the visibility of Taiwan's medical device products. STSP participated in five foreign trade shows in 2018, namely the Guangzhou Dental South China Expo, Shanghai International Medical Devices Exhibition, Exhibition of Britain's International

Association for Dental Research (IADR), Vietnam International Dental Exhibition & Congress, and Shanghai International Dental Equipment Expo. STSP also encouraged the companies MEM Dental Technology, General Biologicals, Advanced Biomedical Technology, Powerway, and EPED to sign collaboration MOUs with foreign firms, and participated in Taiwan's Exhibition For Dental Sciences and Taiwan Healthcare Expo, where STSP displayed the fine products of its medical device industry cluster.

Overview of industries in the Southern Taiwan Science Park, 2018

Item	Number of companies[1]	Number of employees[2]	Revenue (NT$100 m)	Number of investing companies[3]	Amount of investment (NT$100 m)[4]
Integrated circuits	21	22,028	4,859.75	1	1.57
Optoelectronics	52	37,133	18.61	2	2.11
Computers and peripherals	6	305	54.42	2	7.2
Telecommunications	11	1,346	2,446.96	1	15
Precision machinery	58	8,219	460.03	9	18.82
Biotechnology	74	2,889	91.52	7	3.4
Subtotal	222	71,920	7,931.29	22	48.10
Other[5]	8	2,431	25.14	0	0
Total	**230**	**74,351**	**7,956.42**	**22**	**48.10**

[1]Number of approved companies
[2]Employment figures do not include persons working in industrial and commercial services
[3]Companies approved during the year to make investments in the park
[4]Amount of investment in the park approved during the year (final approved amount)
[5]includes "other science enterprises" and "other park enterprises"

Southern Taiwan Science Park growth, 2014-2018

Item	2014	2015	2016	2017	2018
Number of companies[1]	196	204	210	222	230
Increase / decrease (%)	6%	4%	3%	5.70%	3.60%
Number of employees[2]	78,992	79,877	78,432	76,293	74,351
Increase / decrease (%)	10%	1%	-2%	-2.70%	-2.55%
Revenue (NT$100 m)	6,394.38	7,151.37	8,295.63	8,787.59	7,956.42
Increase / decrease (%)	3.95%	11.84%	16%	5.93%	-9.5
Manpower training[3] (person times)	1,315	1,318	1,361	1,124	1,024
Increase / decrease (%)	-4%	0.20%	0.70%	-17.40%	-8.90%

[1]Number of approved companies
[2]Employment figures do not include persons working in industrial and commercial services
[3]Manpower training completion person-times figures do not include participation in advanced technology talks and benchmark corporate leader talks.

F. Establishing an Aerospace Industry Cluster

In order to assist aerospace companies in boosting their level of technology and obtaining aerospace certification, while promoting the establishment of an aerospace industry cluster in southern Taiwan, STSP has been implementing the "Technology Upgrade Promotion Program for Aerospace Critical Systems" since 2017. Under this program, STSP provided funding in the amount of NT$39.4 million to 16 companies in 2017, and funding of NT$37.9 million to 12 companies in 2018.

As of the end of 2018, four aerospace companies (Drewloong, JSPCO, Chaheng, Pyras) had reached supply chain status, and two companies (JSPCO, Nakawo) had occupied plant sites at STSP; furthermore, aerospace companies had made investments totaling NT$1.51 billion, increased their output value by NT$1.05 billion, added 518 employees, and obtained 30 certifications. Within the industry, four international collaborative projects (Magnate and Safran, Chaheng and GE, Drewloong and Safran, and AvioCast and Sumitomo) and four industrial/academic collaborative projects (Gongin and National Yunlin University of Science and Technology, Gongin and National Taipei University of Technology, Magnate and National Cheng Kung University, and Drewloong and National Kaohsiung University of Science and Technology) were initiated, 15 persons were given internships, 242 persons received education, and 369 persons received training. STSP's aerospace promotion program thus effectively enhanced the competitiveness of aerospace firms, helped firms to establish links with major international aerospace corporations and acquire the newest technology, and had a very constructive effect on STSP's aerospace industry cluster.

III. 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.

In 2018, 20 more companies received approval to occupy sites and/or increase their investment in the park, giving it a cumulative total of 196 firms, of which 143 had already occupied registered sites in the park. Tenant firms had revenue of NT$725 billion in 2018, which represented growth of 28.6% compared with 2017.

A. AI Robotics Maker Spaces

With the development of artificial intelligence (AI), the transformation of industry has become even faster. Responding to possible future AI manpower shortages, the Central Taiwan Science Park Administration has established the "AI Robotics Hub at CTSP" (http://ctsphub.tw) with special budget funding. The goal of the Robotics Hub is to provide spaces bringing together international makers and maker groups, promote small-scale prototype production, assist in the incubation of innovations, and provide patent/IPR and financial management, technological R&D services, and unmanned vehicle big data collection and analysis, while training personnel with maker and problem-solving skills.

(1) Laying a foundation for intelligent robot development

The AI Robotics Hub provides basic and advanced AI robotics facilities; the first floor contains a robotics software/hardware integration and operation experience exhibition area, which includes a multifunctional exhibition area, robotic arm experience area, 3D printing area, finished

product assembly area, and briefing area; the B1 floor contains a common experimental facility, which includes an assembly area, laser cutting area, carpentry area, metalworking area, CNC processing area, and circuit production room; the second floor consists of an innovative team area, and contains a conference room, team offices, and a lounge and snack bar.

(2) Training manpower through experiential learning

Linking industry, academic, research, and training organizations in central Taiwan, CTSP relies on a series of experiential learning classes to provide manpower training, including basic NVIDIA classes, open source software, image processing, and advanced maker training, DGX application training, FRC assembly training, FIRA competitions, Pickathon competitions, and AI robotics forums. These classes and activities have attracted over 20,000 participants to date. CTSP has further promoted First Robotics Competition (FRC) activities since 2017, and the "FRC Playoffs" held at CTSP in 2018 attracted very favorable attention. As a result, the number of teams participating in FRC regional competitions increased from three to 20, and the competitions have successfully stimulated interest in robotics study and practice.

(3) Funding satellite site development

In conjunction with 33 satellite site projects, CTSP is jointly involved in professional human resources training and intelligent technology development, including multi-axis smart mechanical arms, grinding and polishing robots, underwater AI 3D topographical exploration robots, intelligent medical glasses linked with surgical robots, and other special and special-purpose intelligent robots. In addition, apart from broad-scale application of AI robotics in various types of machine vision and tactile sensing modules, and reliance on maker spaces and satellite sites to achieve the full-scale development of intelligent robotics capabilities, the development of practical AI technologies will help industries to upgrade their technology and expand on the benefits of implementation.

(4) Establishment of a sustainable innovation ecosystem

CTSP has established an ecosystem for the development of intelligent machinery, automation, and AI in central Taiwan, and is relying on its maker spaces and smart robotics industry alliance to uncover problems that industry can resolve. Looking forward, CTSP's chief goal is to employ accelerator functions to achieve autonomous maker space operation by 2021, while continuing to help startup teams to establish a sustainable innovation ecosystem.

B. Seizing Opportunities to Expand International Interchange

CTSP has been relying on cooperation MOUs with other global science parks and scientific research organizations to establish platforms for technological interchange and cooperation, create international linkage for tenant firms, help firms to expand their overseas marketing opportunities, and induce even more foreign-owned corporations to establish plants in the science park. In early July 2018, the Central Taiwan Science Park Administration signed a four-way Taiwan-German MOU with the Fraunhofer Institute for Integrated Circuits, University of Erlangen Nuremberg, and Feng Chia University; this MOU calls for linkage between the two countries' high-tech industries and innovation ecosystems, and seeks to lay a foundation on which German and Taiwanese companies and research organizations can develop in each other's markets. During the middle of the same month, CTSP also signed a three-way MOU with India's Karnataka Innovation and Technology Society and the Hsinchu Science Park Administration in Bangalore; the MOU calls for cooperation in the areas of innovative startups and emerging technologies, and will expand the partnerships between Taiwan's Science Parks and New Southbound Policy countries.

C. Science Park Revenue Reaches Another New High

CTSP's tenant firms had total revenue of NT$725 billion in 2018, which set a new record, this figure represented an increase of 28.6% compared with the NT$564 billion figure for 2017. This growth was driven by major semiconductor manufacturers' successful mass production using high-level processes, and also benefited from the rise of artificial intelligence, high-performance computing, Internet of Things, automotive electronics, mobile devices, and the insatiable demand for memory from the world's growing number of servers, which has stimulated sales throughout the foundry, memory, and packaging supply chains. In addition, the rising demand for process and automation equipment from the semiconductor, flat panel display, and aerospace industries has increased sales of machine tools and automation devices, which has also contributed to tenant firms' growing revenue.

During 2018, the integrated circuit industry had the largest revenue—NT$515 billion—which accounted for 71.0% of all CTSP revenue, and was followed by the optoelectronics industry, with NT$171 billion in revenue (23.6%), and the precision machinery industry, with NT$29.2 billion in revenue (4.03%); the remaining industries had combined revenue of approximately NT$9.94 billion.

D. Qixing and Erlin Sites Pass Stage 2 Environmental Assessment

The Executive Yuan approved the establishment plan for CTSP's Qixing site, which has an area of 111.6 hectares, on January 3, 2006. After passing two rounds of stage-one environmental impact assessment, the site passed a stage 2 EIA at the 332nd EIA review committee conference on June 13, 2018. The second stage of the EIA process took over four years to complete, and scoping and review meetings gave local residents and environmental protection groups ample opportunities to express their views, while also enlisting public support for the project. Acting in accordance with the recommendations of EIA committee members, experts, scholars, and local residents, CTSP has also implemented an environmental survey and environmentally-friendly protective measures based on review opinions. In addition, CTSP has also implemented the terms of the settlement reached with the plaintiffs in a 2014 administrative suit. After 12 years of disputes, passing EIA review essentially marks the successful conclusion of the EIA process for CTSP's third stage of expansion. CTSP hopes that the development of the Qixing site will proceed harmoniously and bring shared prosperity, and looks forward to everyone cooperating with the site's development and helping make it an environmentally-friendly, economically-beneficial model science park.

After the environmental impact statement for the 631-hectare Erlin site—the fourth phase of CTSP expansion—passed review by the EPA on October 30, 2009, ground was broken for the project on December 26, 2009. Subsequently, due to an administrative suit against the project's EIA process initiated by an environmental protection group, and the resolution made by the 262nd meeting of the EPA's EIA review committee on June 11, 2014 that the project should undergo a second stage of EIA procedures, in order to respond to the court's decision and EPA resolution, the Central Taiwan Science Park Administration immediately embarked on a second stage of EIA review, and also switched the site's chief focal industry from TFT-LCD panel manufacturing to precision machinery, which better meets the requirement for "low water consumption, low energy consumption" industry. The second-stage EIA review period included three scoping meetings, one public hearing, and two case task force review conferences, and the project passed review at the 331st conference of the EPA's EIA review committee on May 23, 2018. In the wake of passing the second stage of the EIA process, apart from meeting the expectation of

local residents that the project will increase local employment opportunities, site will also stimulate full-scale industrial upgrading and transformation, while satisfying domestic firms' demand for land. In the future, the Erlin site will strive for harmony with the local community, and seek to become a model science park promoting both economic progress and environmental protection.

E. Future Outlook

CTSP's tenant firm revenue, employment figure, and number of tenant firms all hit new highs in 2018. Looking ahead to 2019, CTSP plans to maintain its momentum, work hard to achieve its four major goals, and embark on a fresh new stage.

(1) Establishing an innovative startup ecosystem: Taking advantage of central Taiwan's strength in precision machinery, CTSP will attract AI and robotics technologies, make good use of its maker spaces and facilities, promote cooperation between industry, academia, and research organizations, and acquire and cultivate startup teams, while establishing an industrial innovation system in central Taiwan.

(2) Transformation into an NT$1 trillion high-tech industry hub: By creating a superior investment environment, accelerating development of the Erlin site, and vigorously recruiting tenant firms, CTSP hopes to enhance its industry clustering effect, achieve greater economies of scale, and drive and sustain current revenue growth.

(3) Creating new opportunities through expansion of international ties: In conjunction with the country's dual language policy, CTSP's experimental high school has established a dual-language section, forged ties with sister science parks, established multinational cooperation mechanisms, helped domestic firms to expand into overseas markets, and recruited new-technology industry from overseas, which has boosted CTSP's international visibility.

Overview of Central Taiwan Science Park industries, 2018

Item	Companies[1]	Employment	Revenue (NT$100 m)	Investing firms[2]	Amount of investment (NT$100 m)[3]
Integrated circuits	9	17,174	5,147.38	1	1.95
Optoelectronics	36	19,371	1,709.86	3	22.1
Computer and peripheral	15	1,303	33.19	1	1
Telecommunications	1	120	0.82	0	0
Precision machinery	77	6,781	292.17	11	43.85
Biotechnology	40	2,309	46.58	4	8
Subtotal	178	47,058	7,230.00	20	76.9
Other[4]	18	849	18.82	0	0
Total	**196**	**47,907**	**7,248.82**	**20**	**76.9**

[1]Number of approved companies.
[2]Companies approved during the year to make investments in the park.
[3]Amount of investment in the park approved during the year.
[4]Includes "other science enterprises" and "other park enterprises."

(4) Becoming a global model of a green science park: CTSP is creating a sustainable environmentally-friendly green park, and providing a superior living environment and comprehensive living amenities, which has enabled it to attract more companies and personnel.

As of the end of 2018, 196 enterprises had been approved to take up occupancy, there were 15 research organizations and incubation centers, the cumulative amount of investment made in the science park totaled NT$2.84 trillion, and tenant firm recruiting efforts were yielding outstanding results.

Central Taiwan Science Park growth, 2014-2018

Item	2014	2015	2016	2017	2018
Number of companies[1]	174	180	189	186	196
Increase / decrease (%)	10	3.45	5	-1.6	5.4
Employment[2]	32,260	33,018	39,956	43,530	47,907
Increase / decrease (%)	3.26	2.35	21.01	8.94	10.06
Revenue (NT$100 m)	5,220.70	4,921.17	5,073.67	5,638.26	7,248.82
Increase / decrease (%)	13.52	-5.74	3.10	11.13	28.56
Manpower training[3] (person times)	635	631	706	709	439
Increase / decrease (%)	-1.57	-0.63	11.89	0.4	-38.08

[1]Number of approved companies
[2]Employment figures do not include persons working in industrial and commercial services
[3]Manpower training person-time figures do not include participation in advanced technology talks and benchmark corporate leader talks.

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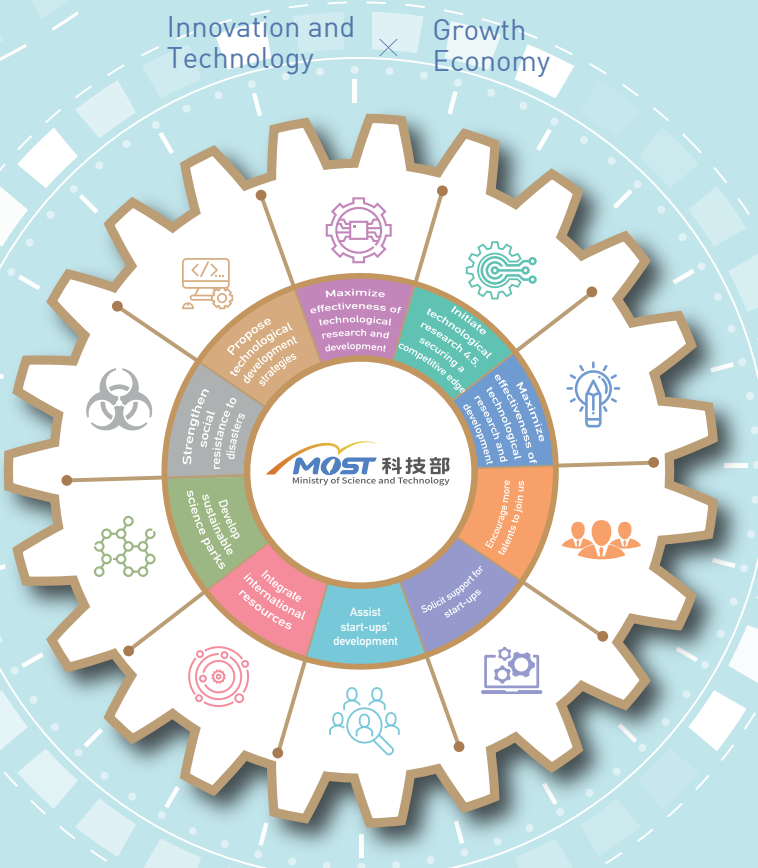

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