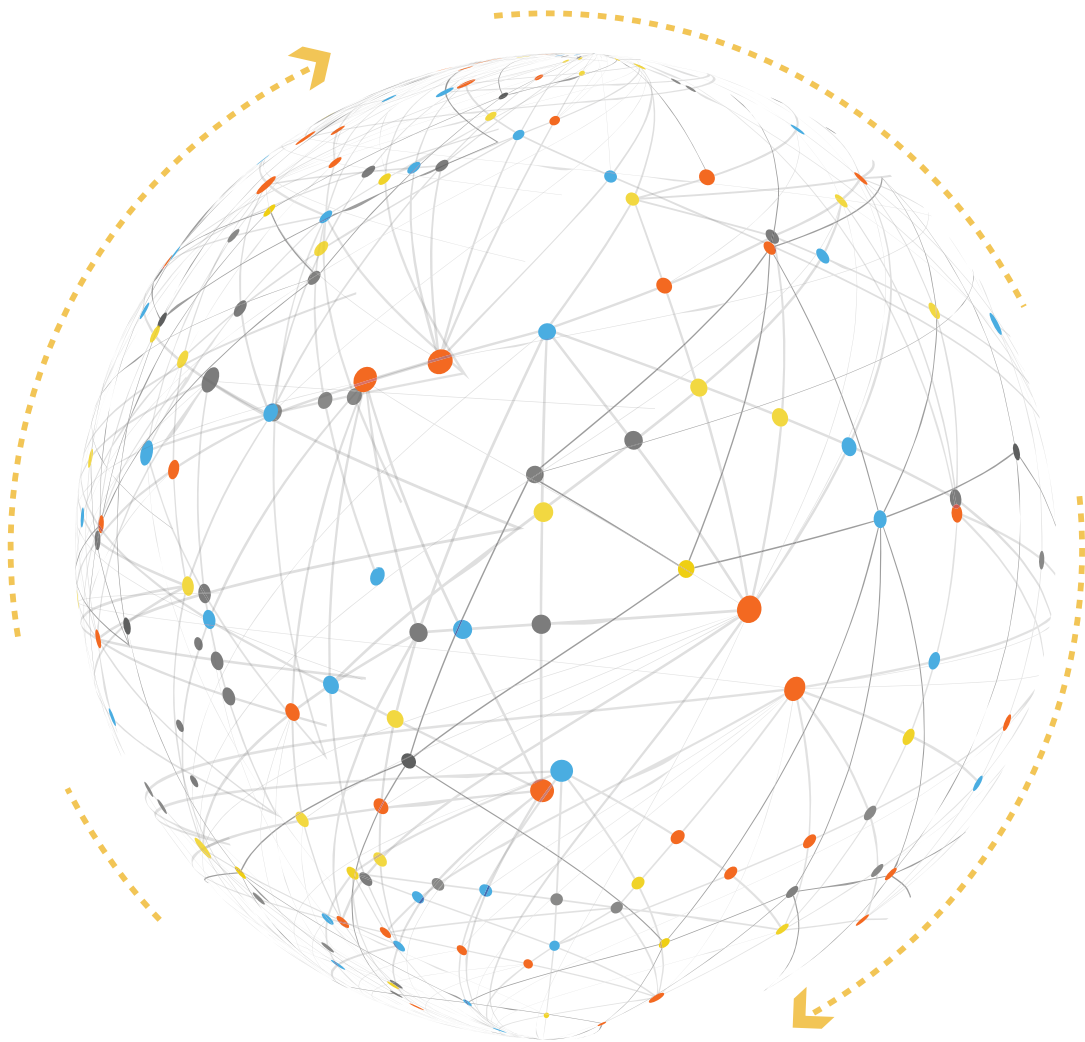


# 2017 ANNUAL REVIEW

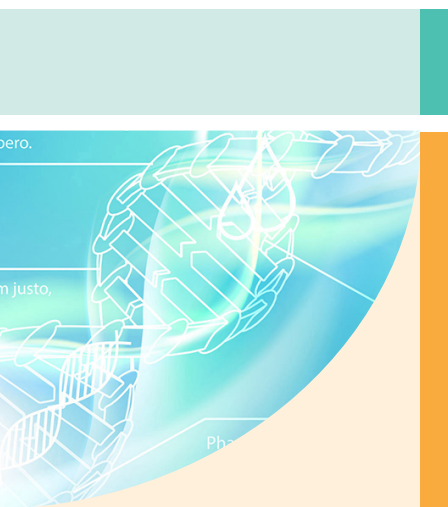


Innovation and Technology X Growth economy

# 2017 ANNUAL REVIEW



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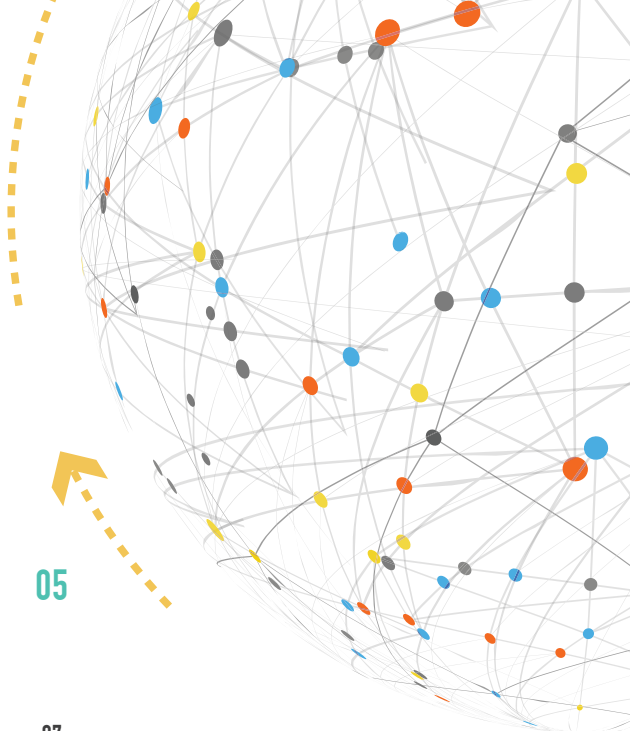
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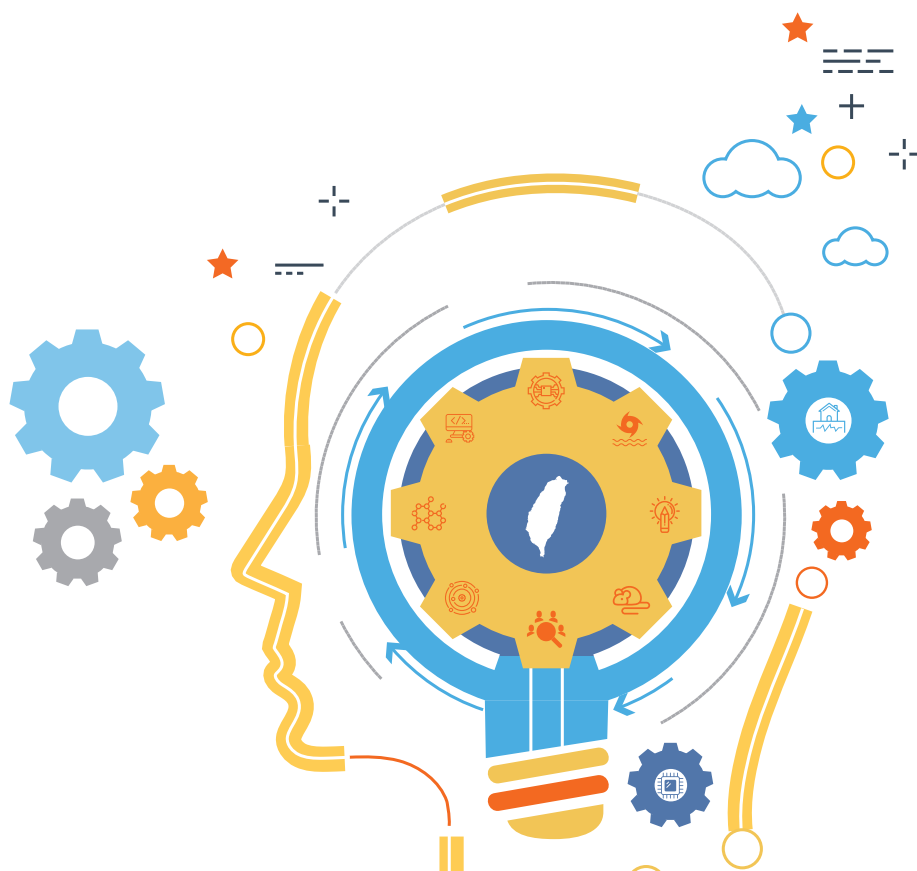


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## ACADEMIA | INDUSTRY SCIENCE | TECHNOLOGY



### Foreword



Science and technology are the cornerstone of national development, the driver of industrial innovation, and a key factor in the improvement of people's well-being and livelihoods. The Ministry of Science and Technology (MOST)—the government agency dedicated to the furtherance of science and technology in Taiwan—took "laying the groundwork for basic research, creating new scientific and technological value," "cultivating innovative entrepreneurship, fostering Moore's Law thinking," and "creating a foundation of scientific manpower, establishing ties to the world of the future" as its three guiding principles this year, and maintained an attitude of "proactive execution, boldly making changes" and "embracing the world, confidently experimenting" as it pursued various major policies.

Basic research is the foundation of S&T development. MOST is striving to achieve stable funding for scientific research, and seeks to provide long-term, stable funding support for basic research. This will be essential if Taiwan is to boost its scientific research capabilities, cultivate high-level research manpower, and build a superior R&D environment.

In order to foster an optimal scientific research environment, MOST has reformed many of its review mechanisms, such as by placing greater emphasis on highly original and goal-oriented research outputs and achievements, revising review committee member selection mechanisms, adding new emerging fields and disciplines, adjusting the content of the Outstanding Research Award, increasing payments for project PIs, and creating a research environment ensuring long-term support to young scholars. MOST will continue to enhance the effectiveness of reforms, select focal research directions, put its full weight behind the establishment of innovative research ecosystems, and ensuring that research personnel can engage in long-term, forward-looking research with full confidence.

With regard to linkage between industry, academia, and research organizations, MOST calls on university professors to organize TRUST-U project startup teams in conjunction with research organizations, and also established the Taiwan Startup Institute, which seeks to help project teams achieve the greatest possible commercial value. At the same time, in order to implement the 5+2 Industrial Innovation Plan's "Biomedical Industry Innovation Promotion Project," MOST has joined forces with agencies including the Ministry of Economic Affairs, Ministry of Health and Welfare, and National Development Council to create an effective ecosystem, cultivate innovation clusters, better access international markets, and promote distinctive industry niches; this effort is intended to make Taiwan a key global stronghold of the biotech pharmaceutical industry.

Human resources will ensure the core competitiveness of future development. Through the steady investment of resources, MOST is taking manpower as a bridge between Taiwan's hardware and software, and, keeping pace with Silicon Valley and the world's innovation trends, is creating a stage on which scientific research personnel can exercise and realize their skills. Apart from promoting the Learn-Explore-Aspire-Pioneer (LEAP Program) and relevant international manpower training programs, the Rebuild after Ph.D. Industrial Skill & Expertise Program steers postdoctoral manpower toward industry, where Ph.D.-holders can boost industry's R&D capabilities and international competitiveness. Furthermore, MOST is relying on the Young Scholar Formation Program and Mentor Program for Women in Science (WiSE) to replenish the country's research manpower at all levels, and thereby enhance the breadth and depth of scientific research.

Apart from continuing to intensify the revitalization of the academic research environment, MOST further seeks to build up the country's S&T development momentum, encourage the creation of cross-domain value in the knowledge economy age, foster the spirit of interdisciplinary cooperation, maintain a "Small Country, Smart Strategy" attitude, and strongly promote a "select and focus" approach to research. MOST hopes to focus heavily on making breakthroughs in selected areas, find appropriate partners around the world in order to achieve the benefits of teamwork, maintain close ties with the leaders of alliances, organize powerful teams, and ensure that Taiwan occupies a conspicuous position on the world's S&T stage.

Minister

陳良基

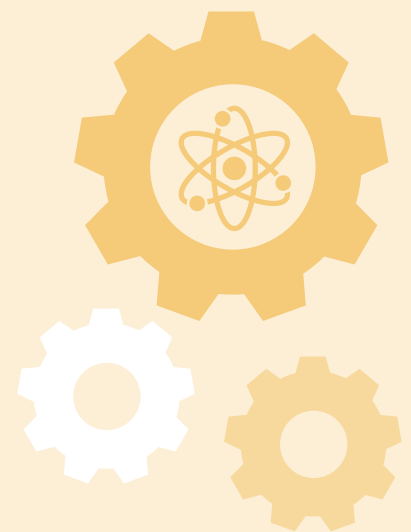
Liang-Gee Chen



# ACADEMIA | INDUSTRY SCIENCE | TECHNOLOGY

## Chapter 1 Overview

Science and Technology Development Policies  
Funding





## Chapter 1 / Overview

### I Science and Technology Development Policies

Scientific and technological progress is a process of continuous renewal. In view of its small area, dense population, and limited resources, Taiwan is compelled to adopt a "Small Country, Smart Strategy" way of thinking, and focus its efforts on areas where it possesses unique advantages and can assume a leading global position. The Ministry of Science and Technology (MOST) will therefore rely on the three major administrative directions of "laying the groundwork for basic research, creating scientific and technological value," "cultivating innovative entrepreneurship, fostering Moore's Law thinking," and "creating a foundation of scientific manpower, establishing ties to the world of the future" as it continues to support Taiwan's efforts to maintain its global competitiveness. According to the IMD's 2017 World Competitiveness Yearbook, Taiwan ranked 14th globally in terms of overall competitiveness, ranked 3rd in the Asia-Pacific region, behind only Hong Kong and Singapore, and was 10<sup>th</sup> and 15th in the S&T-related categories of "scientific infrastructure" and "technological infrastructure." Furthermore, according to the Global Competitiveness Report, 2017-2018 issued by the World Economic Forum (WEF), Taiwan ranked 15<sup>th</sup>, ahead of South Korea and China, and climbed 2 places since 2016, to reach 15th place globally in the category of "innovation and sophistication factors," which was Taiwan's best showing in this category during the past three years. However, despite Taiwan's steady progress in science and technology, in the face of a volatile global situation and the rapid development of many areas of science and technology, there are still many problems and challenges urgently waiting to be overcome.

#### A. Challenges Faced by S&T Development in Taiwan

##### 1. R&D and innovation

Innovation is the key element in maintaining national competitiveness. Responding to the challenges posed by emerging nations and the rapid development of artificial intelligence, Taiwan must keep up with global "innovation economy" development trends, and create an environment fostering all-round innovation through

macroscopic attention to the environment, laws and regulations, policies, funds, and manpower. Taking the strength of Taiwan's semiconductor industry as a foundation, the government must gather the resources and capabilities of industry, academia, and research organizations, promote artificial intelligence research strategies, and lead industry in renewing the country's innovative energies in conjunction with the Global Research & Industry Alliance.

##### 2. Manpower cultivation and recruiting

Human resources are the basis for all innovative economic activities. With the arrival of the digital, intelligent age, Taiwan's industries are in a time of upgrading and transformation, and urgently need greater linkage between manpower, industry, and international resources through the cultivation, retention, and recruiting of human resources. The government consequently hopes to create an innovative scientific research ecosystem with human resources as its core, promote the "Rebuild after Ph.D. Industrial Skill & Expertise" program and "Young Talent Cultivation Project," and actively recruit top-notch international manpower, while nurturing a work- and living-friendly environment.

##### 3. Industrial development and transformation

New S&T areas and breakthroughs are constantly appearing, and are often upending economic models and industry frameworks worldwide. Taiwan's industries must actively stay abreast of S&T trends, formulate brand-new development directions reflecting national and local long-term development outlooks, and join forces to realize their vision of the industry of the future. The government must focus on the development of key areas of science and technology, such as quantum computing, smart agriculture, and digital healthcare, while helping industry to establish irreplaceable competitive advantages. Demand-driven innovative R&D and government cooperation with industry, academia, and research organizations can achieve maximum benefit from research results and catalyze industrial upgrading and transformation.

##### 4. Living and the environment

An excellent quality of life and a safe environment comprise the foundation of the nation's development. However, medical and healthcare have become increasingly urgent in the face of Taiwan's aging population, declining birthrate, air pollution, and a spate of food safety

incidents. The government will forcefully use information and communications technology to promote precision medicine and effective food safety mechanisms, while building an all-round smart living environment. As for the national land environment, because the effects of global warming and climate change, plus the high frequency of natural disasters due to Taiwan's geographical location, the government will strive to reduce the impact of disasters through the advancement of disaster-mitigation science and technology, and create a livable, sustainable living environment for all citizens.

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

In accordance with the Fundamental Science and Technology Act, the government must hold a National Science and Technology Conference once every four years to discuss the country's future S&T development blueprint in light of national development directions, the needs of society, and a desire to maintain balanced regional development, and determine a National Science and Technology Development Plan, which serves as a basis for the drafting of S&T policies and the promotion of scientific and technological R&D. The National Science and Technology Development Plan (2017-2020) approved by the Executive Yuan on September 7, 2017 takes "intelligence, low carbon, health, and sustainability" as its keynote, and establishes a roadmap for Taiwan's S&T development during the

coming four years based on the current state of S&T in Taiwan, overall S&T development objectives, strategies, and resources, and the developmental goals of government agencies and in various S&T fields. This roadmap will serve as a basis for the promotion of S&T policies and R&D by all government agencies, and will seek to accelerate the development of cutting-edge science and technology, foster intelligent living, and successfully drive economic development on the foundation of an effective scientific research environment.

Building on the three major themes of "infrastructure environment, intelligent living, and economic development," the current National Science and Technology Development Plan contains the four major objectives of "reliance on innovation to regenerate economic momentum," "strengthening intelligent living S&T and industry," "cultivating and attracting talent and providing diverse channels for advancement," and "nurturing innovative scientific research ecosystems." The following is an overview of the four objectives and their visions:

innovative scientific research ecosystems" includes putting the legal environment and research infrastructure on a stronger footing, promoting diversified academic development, and channeling the innovative energies of industry, academia, and research organizations in order to foster self-reinforcing innovation ecosystems.

**OBJECTIVE  
1**

The vision of "reliance on innovation to regenerate economic momentum" includes seizing the opportunity to develop and apply artificial intelligence, developing innovative digital economy business models, relying on scientific research results to support for industrial innovation, developing diverse, boundary-crossing innovative applications, and promoting an innovation economy.

**OBJECTIVE  
2**

The vision of "strengthening intelligent living S&T and industry" includes use of innovative "smart" agricultural technology to boost agricultural competitiveness, use of digital technology to develop precision medicine and achieve better national health, development of intelligent disaster mitigation technologies to create a sustainable, safe, smart life circle, development of green energy technology and progress toward a green, non-nuclear homeland, rollout of an environmental quality sensing Internet of Things to effectively maintain environmental quality, and refinement of core information security technologies, which will boost international influence.

**OBJECTIVE  
3**

The vision of "cultivating and attracting talent and providing diverse channels for advancement" includes cultivation of interdisciplinary human resources with digital skills and professional expertise, training of doctoral-level manpower excelling at research and development work, and recruiting of top-notch international manpower in order to provide a basis for economic development and transformation through innovation.

**OBJECTIVE  
4**

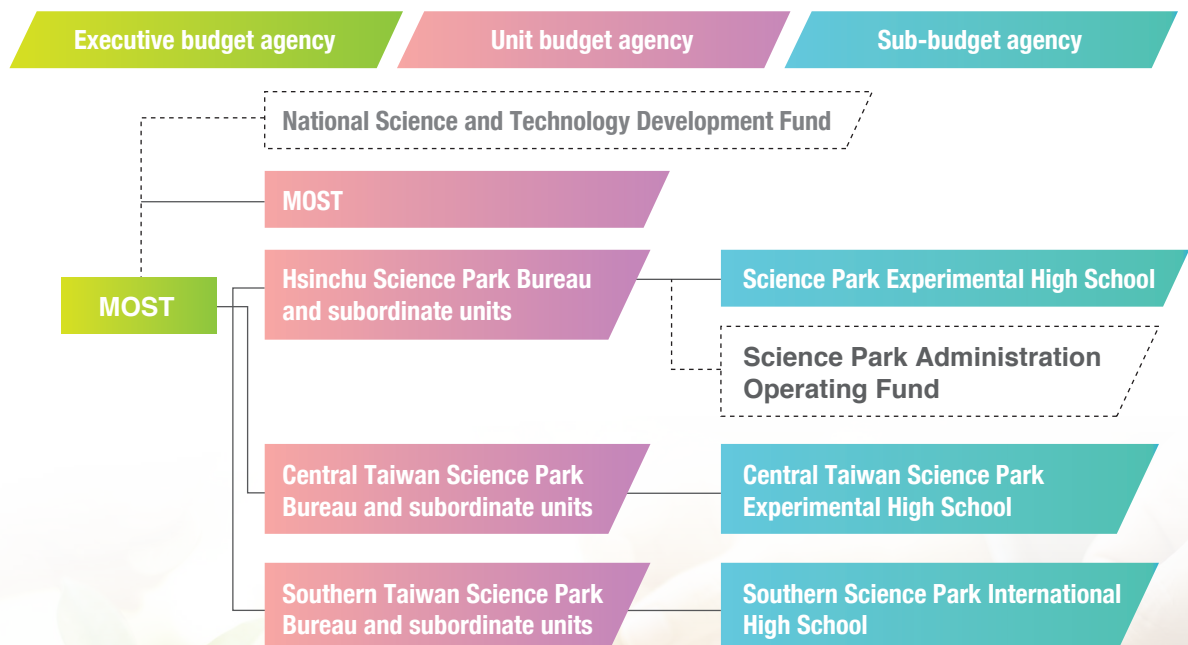
The vision of "nurturing innovative scientific research ecosystems" includes putting the legal environment and research infrastructure on a stronger footing, promoting diversified academic development, and channeling the innovative energies of industry, academia, and research organizations in order to foster self-reinforcing innovation ecosystems.



## II Expenditures

In 2017, MOST's executive budget consisted of four parts corresponding to MOST itself, the Hsinchu Science Park Bureau (HSPB) and subordinate units, the Central Taiwan Science Park Bureau (CTSPB) and subordinate units, and the Southern Taiwan Science Park Bureau (STSPB) and subordinate units. In addition, the budgets of the HSPB and its subordinate units, CTSPB and its subordinate units, and STSPB and its subordinate units also

included sub-budgets for the National Science Park Experimental High School, National Central Taiwan Science Park Experimental High School, and National Southern Taiwan Science Park International Experimental High School. Furthermore, MOST is also the management agency for the Executive Yuan National Science and Technology Development Fund, and the HSPB is the management agency for the Science Park Bureau Operating Fund.



\*Dotted lines indicate subordinate unit budgets





MOST's executive income budget for 2017 was NT\$126 million, which was a decrease of NT\$18 million (-12.5%) from the NT\$144 million income budget of the previous year. This income budget included fine and compensation income of NT\$27 million, which included compensation for late vendor deliveries; fee income of \$23 million, which included construction licenses and establishment and status change registration

fees paid by science park companies; property income of NT\$22 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\$54 million, which included tuition and fees at science park experimental high schools.

Annual MOST executive income budgets, 2013-2017

Units: NT\$100 m

Item	2013		2014		2015		2016		2017	
	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)
Fines and compensation	0.24	26.32	0.15	-37.50	0.20	33.33	0.29	45.00	0.27	-6.90
Fee income	0.42	-28.81	0.38	-9.52	0.28	-26.32	0.26	-7.14	0.23	-11.54
Property income	0.44	15.79	0.78	77.27	0.37	-52.56	0.42	13.51	0.22	-47.62
Other income	0.63	-5.97	0.47	-25.40	0.48	2.13	0.47	-2.08	0.54	14.89
<b>Total</b>	<b>1.73</b>	<b>-5.46</b>	<b>1.78</b>	<b>2.89</b>	<b>1.33</b>	<b>-25.28</b>	<b>1.44</b>	<b>8.27</b>	<b>1.26</b>	<b>-12.50</b>

MOST's executive expense budget for 2017 was NT\$50.2 billion, which was an increase of NT\$3.56 billion (7.63%) compared with the NT\$46.6 billion budget of the previous year. Of this budget, the MOST expense budget accounted for NT\$47.7 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 Executive Yuan National Science

and Technology Development Fund for S&T project funding. The HSPB and subordinate unit budget was NT\$1.07 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\$615 million, and was mainly used for park services. The STSPB and subordinate unit budget was NT\$781 million, and was mainly used for park services.

Annual MOST executive expenditure budgets, 2013-2017

Units: NT\$100 m

item	2013		2014		2015		2016		2017	
	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)
MOST	422.64	1.54	405.51	-4.05	456.05	12.46	436.10	-4.37	477.47	9.49
HSPB and subordinate units	17.75	16.62	11.81	-33.46	8.84	-25.15	9.22	4.30	10.67	15.73
CTSPB and subordinate units	11.57	-2.45	12.03	3.98	14.06	16.87	13.21	-6.05	6.15	-53.44
STSPB and subordinate units	9.24	-7.32	11.08	19.91	11.16	0.72	7.96	-28.67	7.81	-1.88
<b>Total</b>	<b>461.20</b>	<b>1.75</b>	<b>440.43</b>	<b>-4.50</b>	<b>490.11</b>	<b>11.28</b>	<b>466.49</b>	<b>-4.82</b>	<b>502.10</b>	<b>7.63</b>

MOST's predecessor, the National Science Council (NSC), established the Executive Yuan National Science and Technology Development Fund in order to promote the long-term development of science and technology. The

Fund's budget was included within the NSC's unit budget up to 1991, but was made a separate unit budget in 1992. In order to increase the flexibility and timeliness of fund implementation, the Fund's budget was changed to a subordinate

unit budget in 1998. Following the promulgation of the *Fundamental Science and Technology Act* in 1999, the Fund was taken from the NSC and put under the Executive Yuan's oversight, but NSC retained its status of fund management agency. The 2003 revision of the *Fundamental Science and Technology Act* specified that the Executive Yuan National Science and Technology Development Fund budget should be a subordinate unit budget.

The Executive Yuan National Science and Technology Development Fund received NT\$42.3 billion in 2017, which chiefly consisted of appropriations from the national treasury and R&D results income. The fund's disbursements of NT\$45.2 billion were chiefly used to fund various types of academic research, the replacement of marine research vessels I, II, and III, and innovative industry flagship programs.

Executive Yuan National Science and Technology Development Fund budget, 2013-2017

Units: NT\$100 m

item	2013 <sup>2</sup>		2014		2015		2016		2017	
	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)	Amount	Increase (%)
Source of funds	359.72	3.84	343.64	-4.47	390.82	13.73	372.23	-4.76	422.81	13.59
Government appropriations	341.60	3.46	327.46	-4.14	376.50	14.98	353.70	-6.06	406.01	14.79
Other <sup>1</sup>	18.12	11.58	16.18	-10.71	14.32	-11.50	18.53	29.40	16.80	-9.34
Fund uses	368.72	3.89	369.14	0.11	428.71	16.14	383.69	-10.50	451.76	17.74
Promotion of development	330.16	3.86	332.17	0.61	393.04	18.32	344.12	-12.45	408.14	18.60
Manpower training	23.91	6.69	22.34	-6.57	21.96	-1.70	22.34	1.73	30.40	36.08
Environment improvements	14.08	0.28	14.05	-0.21	13.18	-6.19	16.68	26.56	12.67	-24.04
Administration & management	0.57	0.00	0.58	1.75	0.53	-8.62	0.55	3.77	0.55	0.00
<b>Surplus/shortfall for period (-)</b>	<b>-9.00</b>		<b>-25.50</b>		<b>-37.89</b>		<b>-11.46</b>		<b>-28.95</b>	

<sup>1</sup> Includes royalty income, service income, miscellaneous income, and interest income, etc.

<sup>2</sup> The 2013 National Science and Technology Development Fund budget was not deliberated by the Legislative Yuan.

MOST's final executive income figure for 2017 was NT\$144 million, which represented an increase of NT\$18 million compared with the budget number. This increase was chiefly

attributable to larger-than-expected growth in late fine income returned by NARLabs for use in project funding.

Annual MOST final income figures, 2013-2017

Units: NT\$100 m

Item	2013		2014		2015		2016		2017	
	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	0.28	0.04	0.33	0.18	0.34	0.14	0.37	0.08	0.50	0.23
Fee income	0.19	-0.23	0.17	-0.21	0.20	-0.08	0.17	-0.09	0.19	-0.04
Property income	0.62	0.18	0.82	0.04	0.48	0.11	0.57	0.15	0.21	-0.01
Other income	0.53	-0.10	0.55	0.08	0.48	0.00	0.51	0.04	0.54	0.00
<b>Total</b>	<b>1.62</b>	<b>-0.11</b>	<b>1.87</b>	<b>0.09</b>	<b>1.50</b>	<b>0.17</b>	<b>1.62</b>	<b>0.18</b>	<b>1.44</b>	<b>0.18</b>



MOST's final executive expenditure figure for 2017 was NT\$50.0 billion, which represented a decrease of NT\$168 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, 2013-2017

Units: NT\$100 m

Item	2013		2014		2015		2016		2017	
	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	419.65	-2.99	402.86	-2.65	455.55	-0.50	435.19	-0.91	476.73	-0.74
HSPB and subordinate units	17.14	-0.61	11.19	-0.62	8.48	-0.36	8.80	-0.42	10.53	-0.14
CTSPB and subordinate units	10.94	-0.63	11.56	-0.47	13.89	-0.17	12.76	-0.45	5.60	-0.55
STSPB and subordinate units	8.80	-0.44	11.02	-0.06	11.11	-0.05	7.82	-0.14	7.56	-0.25
<b>Total</b>	<b>456.53</b>	<b>-4.67</b>	<b>436.63</b>	<b>-3.80</b>	<b>489.02</b>	<b>-1.09</b>	<b>464.57</b>	<b>-1.92</b>	<b>500.42</b>	<b>-1.68</b>

The Executive Yuan Science and Technology Development Fund had a final surplus of NT\$1.42 billion for 2017, which reversed the budget shortfall of NT\$2.89 billion. This difference was chiefly attributable to the fact that NT\$1.09 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 business 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, 2013-2017

Units: NT\$100 m

Item	2013		2014		2015		2016		2017	
	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	357.52	-2.20	346.36	2.72	392.04	1.22	371.01	-1.22	428.17	5.36
Government appropriations	341.60	0.00	327.46	0.00	376.50	0.00	353.70	0.00	408.86	2.85
Other <sup>1</sup>	15.92	-2.20	18.90	2.72	15.54	1.22	17.31	-1.22	19.31	2.51
Fund uses	330.59	-38.13	337.64	-31.50	391.37	-37.34	355.35	-28.34	413.98	-37.77
Promotion of development	297.02	-33.14	303.97	-28.20	355.53	-37.51	320.39	-23.73	373.69	-34.45
Manpower training	23.00	-0.91	21.87	-0.47	22.28	0.32	23.04	0.70	29.98	-0.42
Environment improvements	10.05	-4.03	11.23	-2.82	13.02	-0.16	11.42	-5.26	9.81	-2.86
Administration & management	0.52	-0.05	0.57	-0.01	0.54	0.01	0.50	-0.05	0.50	-0.04
<b>Surplus/shortfall for period (-)</b>	<b>26.93</b>	<b>35.93</b>	<b>8.72</b>	<b>34.22</b>	<b>0.67</b>	<b>38.56</b>	<b>15.66</b>	<b>27.12</b>	<b>14.19</b>	<b>43.13</b>

<sup>1</sup> Includes royalty income, service income, miscellaneous income, and interest income, etc



# ACADEMIA | INDUSTRY SCIENCE | TECHNOLOGY



## Chapter 2 Promoting National S&T Development

National R&D Trends

S&T Research Results

Integration of National Disaster Prevention Research

Increasing Citizens' S&T Literacy



## 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\$434 billion in 2012 to NT\$541 billion in 2016, which was equivalent to an annual growth rate of 6.1%. The private sector's R&D expenditures were NT\$426 billion, which represented growth of 5.7%. The government had R&D expenditures of NT\$115 billion, which represented an increase of 7.3% compared with 2015. Private sector R&D expenditures as a share of the nation's total R&D

expenditures decreased to 78.7% in 2016 from 78.9% in 2015.

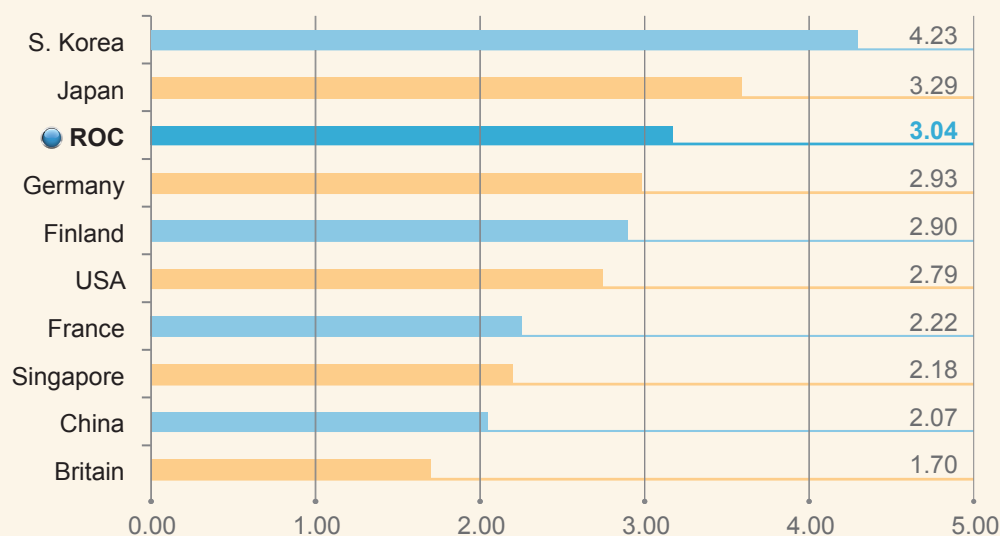
Taiwan's R&D expenditures as a share of GDP have increased steadily in recent years, and reached a historic high of 3.16% in 2016. Compared with other countries, in terms of R&D spending as a share of GDP, Taiwan lags behind South Korea, Japan, but is ahead of Germany, Finland, the US, France, Singapore, Mainland China, and Britain.

National R&D expenditures, 2012-2016

Item	2012	2013	2014	2015	2016
<b>National R&amp;D expenditures (NT\$100 m)</b>	<b>4,335</b>	<b>4,576</b>	<b>4,835</b>	<b>5,104</b>	<b>5,414</b>
As share of GDP (%)	2.95	3.00	3.00	3.04	3.16
By funding source (%)					
Government	24.6	23.3	21.7	21.1	21.3
Private sector	75.4	76.7	78.3	78.9	78.7

Source: Indicators of Science and Technology, ROC, 2017, MOST

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



Note : Apart from 2014 data for Singapore, the remaining data is for 2015.

Source : 1. Various countries: *Main Science and Technology Indicators, 2017/1*, OECD

2. Taiwan: Indicators of Science and Technology, ROC, 2017, 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%-61.1% of R&D personnel during the most recent five years. The number of researchers grew over the most recent five years from 140,102 FTE (full-time equivalent) person-years in 2012 to 147,710 FTE person-

years in 2016; the number of technicians grew from 77,500 FTE person-years in 2012 to 90,143 person-years in 2016; and the number of supporting staff grew from 11,565 FTE person-years in 2012 to 13,189 person-years in 2016.

The number of female researchers rose from 29,003 FTE person-years in 2012 to 31,639 FTE in 2016. The number of female researchers as a share of all researchers likewise rose from 20.7% in 2012 to 21.4% in 2016.

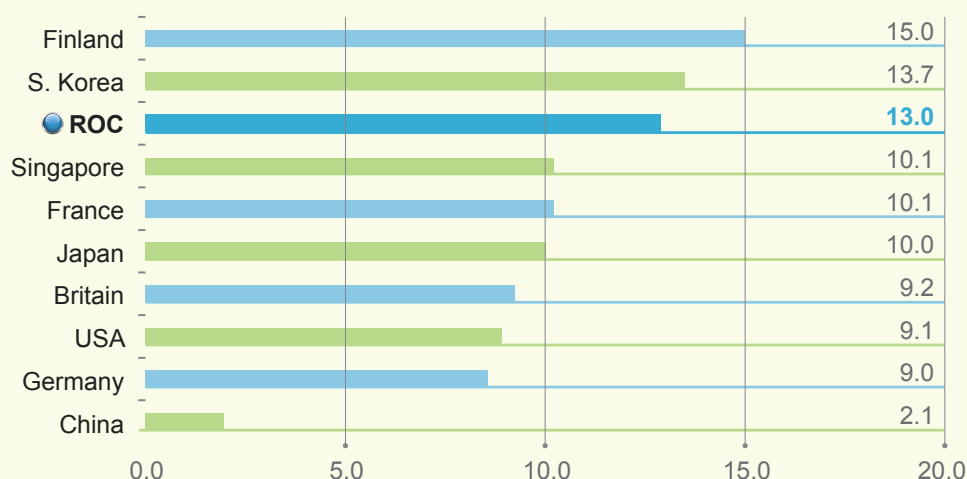
R&D personnel in Taiwan, 2013-2017

Item	2012	2013	2014	2015	2016
<b>FTE R&amp;D manpower (person-years)</b>	<b>229,167</b>	<b>234,248</b>	<b>240,528</b>	<b>245,941</b>	<b>251,042</b>
Researchers	140,102	141,159	142,983	145,381	147,710
Technicians	77,500	80,909	84,874	87,311	90,143
Supporting staff	11,565	12,180	12,671	13,249	13,189
<b>FTE female research personnel (person-years)</b>	<b>29,003</b>	<b>29,423</b>	<b>30,187</b>	<b>30,951</b>	<b>31,639</b>
Female research personnel as a share of all research personnel (%)	20.7	20.8	21.1	21.3	21.4
<b>Number of researchers per 1,000 employment (person-years)</b>	<b>12.9</b>	<b>12.9</b>	<b>12.9</b>	<b>13.0</b>	<b>13.1</b>

Source: Indicators of Science and Technology, ROC, 2017, 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 2015.

Source: Main Science and Technology Indicators, 2017/1, OECD

Compared with other countries, the number of FTE R&D personnel per 1,000 employed population in Taiwan was 13.1 person-years in 2016, 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 2014-2015 period.



## II S&T Research Results

A total of 26,589 research papers by authors from Taiwan were contained in *Science Citation Index (SCI)* in 2016, giving Taiwan a global rank of 21<sup>st</sup>. A total of 19,531 research papers from Taiwan were cited in *Engineering Index (EI)* in 2014, giving Taiwan a world rank of 16<sup>th</sup>. To assess the quantity and quality of Taiwan's research output, the following is a comparison of Taiwan with eight major industrialized countries and the leading Asian countries in terms of the three indicators of number of *SCI*-cited papers per million people, impact factor of *SCI*-cited papers, and number of *EI* papers per million people.

### 1. Number of *SCI*-cited papers per million people

This indicator is calculated by dividing the average number of papers cited in *SCI* during the most recent five years by the average population during the same period. Taiwan's 1,129 *SCI*-cited papers per million people in 2016 put Taiwan behind Finland, Singapore, Britain, Germany, the USA, South Korea, and France, but ahead of Japan and Mainland China. The best performer in this category, Finland, increased its output from 2,210 cited papers in 2012 to 2,549 in 2016. Although China's output still remains far behind most of the other countries, its number of cited papers grew at the fastest average rate between 2012 and 2016 (14.1%).

Number of *SCI*-cited papers per million people and five-year average growth rate in various countries, 2012-2016

Units: papers

Country	2012	2013	2014	2015	2016	Average growth rate, 2012-2016
Finland	2,210	2,331	2,512	2,530	2,549	3.44%
Singapore	2,158	2,325	2,406	2,518	2,539	4.35%
Britain	1,853	1,952	1,924	1,979	1,984	1.80%
Germany	1,302	1,344	1,365	1,377	1,388	2.15%
USA	1,300	1,329	1,350	1,337	1,327	0.57%
S. Korea	1,003	1,047	1,097	1,146	1,164	4.64%
France	1,108	1,142	1,144	1,162	1,177	1.66%
<b>ROC</b>	<b>1,204</b>	<b>1,225</b>	<b>1,198</b>	<b>1,144</b>	<b>1,129</b>	<b>-1.08%</b>
Japan	627	642	634	623	638	0.35%
China	141	165	190	211	230	12.61%

Source: 1. *SCI*-cited papers: *InCites*<sup>TM</sup>, Clarivate Analytics /date updated: 10/2017

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>

### 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, the European and North American countries generally have high impact factors, and Singapore, Britain, the US, Germany, Finland, France, and Japan all had impact factors higher

than 6 in 2016. Taiwan's impact factor rose from 4.46 in 2012 to 5.57 in 2016, which shows that although the quality of Taiwan's academic papers has improved, it still lags behind the leading European and North American countries and Japan. In comparison with Singapore, the quality of Taiwan's academic papers has been improving at a slower rate; the impact factor of Mainland China's *SCI*-cited papers rose from 4.39 in 2012 to 5.64 in 2016, putting ahead Taiwan.

### SCI impact factors of various countries, 2012-2016

Country	2012	2013	2014	2015	2016
Singapore	6.92	7.62	8.44	9.07	9.83
Finland	7.30	7.45	7.77	7.79	8.12
Germany	7.33	7.49	7.73	7.89	8.08
Britain	7.26	7.34	7.49	7.56	7.80
USA	7.44	7.51	7.59	7.66	7.78
France	6.88	7.12	7.38	7.55	7.75
Japan	5.50	5.60	5.76	5.90	5.98
China	4.39	4.64	4.94	5.27	5.64
S. Korea	4.44	4.72	5.04	5.30	5.59
<b>ROC</b>	<b>4.46</b>	<b>4.74</b>	<b>5.03</b>	<b>5.35</b>	<b>5.57</b>

Source: Web of Science, arranged by Science & Technology Policy Research and Information Center, NARLabs/date updated: 10/17/2017

### 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 787 papers

per million people in 2016, and its *EI* citations per million persons has been in the range of 787-1,045 during the most recent five years. Although Taiwan was behind only Singapore, Finland, and Britain in this category, the average growth rate of Taiwan's *EI* citations per million persons during this five-year period was the lowest of any of the countries compared.

Number of EI citations per million people and five-year average growth rate in various countries, 2012-2016

Units: papers

Country	2012	2013	2014	2015	2016	Av. growth rate 2012-2016
Singapore	1243	1922	1961	1974	1967	10.46
Finland	791	1323	1374	1405	1352	11.71
Britain	458	750	782	785	793	12.15
<b>ROC</b>	<b>889</b>	<b>1045</b>	<b>969</b>	<b>844</b>	<b>787</b>	<b>-4.35</b>
Germany	471	725	763	749	743	10.95
S. Korea	578	733	756	757	707	5.34
France	414	697	692	685	650	9.92
USA	419	600	584	579	560	6.33
Japan	357	462	439	422	395	1.93
China	189	206	222	196	230	4.23

Source: 1. *EI*-cited papers: Web of Science, arranged by Science & Technology Policy Research and Information Center, NARLabs/date updated: 10/2017

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 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



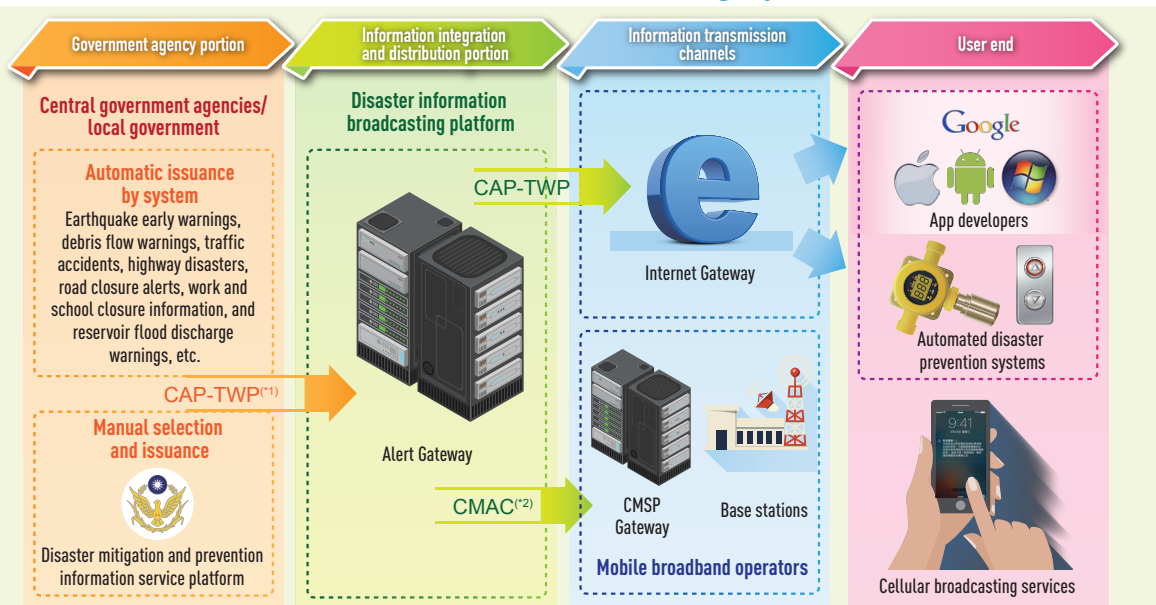
research organizations to participate in disaster prevention R&D and applications, and other services connected with disaster prevention technology. Apart from routinely planning disaster prevention and disaster mitigation technology R&D and applying R&D results, NCDR further serves as a disaster response operation support coordinator during the disaster response period. 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 the survey and assessment team's investigation of the disaster. In 2017, NCDR supported various response tasks at CDEOC seven times; participation in these tasks involved over 313 persons-hours and 460 persons. NCDR further assisted the CDEOC in holding 40 survey and assessment conferences and 31 working meetings, as well as 26 additional explanatory meetings for journalists, which strengthened

communication and the transmission of information concerning disaster situations.

In addition, in order to support the government's disaster prevention and relief work, NCDR completed the Public Warning System, which is a cell phone push service, in cooperation with central government agencies involved in disaster prevention, the National Communications Commission, and various mobile broadband operators. This system encourages mobile broadband operators to fulfill their public duty of providing immediate notification of disasters, links disaster prevention platform systems, and establishes a partnership with the private sector, and further strengthens Taiwan's disaster prevention and mitigation capabilities.

Taiwan's Public Warning System consists of four portions, namely a government agency portion, information integration and distribution portion, information transmission channel portion, and applications portion.

### Framework of the Public Warning System



(1) CAP-TWP: Common Alerting Protocol-Taiwan Profile

(2) CMAC: Commercial Mobile Alert for Communications Interface; alert gateway to mobile broadband system gateway interface protocol

NCDR plays the role of a "disaster information broadcasting platform" in this service, and is situated between disaster prevention and relief agencies and mobile telecoms' cell broadcast centers. The intent of the Public Warning System as a whole is to establish rapid warning information processing and transmission capabilities while maintaining a high level of availability. As a consequence, to ensure the timeliness and dependability of early warnings, the

design of the system ensures that the platform's information processing time will not exceed 3 seconds, dual-site service redundancy is provided, alerts are sent to government agencies, and switching between the two sites can be performed in less than 1 second. In addition, with regard to information security requirements, point-to-point physical dedicated lines connect the cell broadcast centers of five mobile broadband operators, which ensures a system availability of over 99%.

As for actual operation, if the platform design consisted of an active-standby (A-S) framework involving sites A and B, with a global server load-balancer to perform switching between equipment at the two sites, the platform would be limited to domain system operation, and it would be difficult to meet the 1-second switching requirement. The platform framework therefore employs an active-active (A-A) service design, and the design of the system interface standards requires the agency-end portion to regularly, actively test the availability of platform sites A and B. In addition, the system autonomously switches the default transmission channel on the basis of the availability and quality of the link between the agency-end and platform network. Furthermore, the mobile broadband operator end also relies on regular, active checking to ensure autonomous switching when abnormalities occur, and will notify the system management in real-time.

As of the end of 2017, the Public Warning System was able to transmit messages to a wide range of members of the public within several seconds, and was supported and used by the central government competent authority in charge of disaster mitigation and relief. During 2017, the system had helped the Central Weather Bureau, Ministry of Transportation and Communications to issue four earthquake early warning messages, 20 earthquake reports, and 14 real-time messages concerning severe thunderstorms; helped the National Police Administration issue 14 messages concerning the Wanan Exercises; helped the Soil and Water Conservation Bureau to issue 13,661 debris flow alerts; helped the Directorate General of Highways issue five warnings of road closures; helped the Centers for Disease Control and Prevention to issue one message concerning a disease outbreak; and helped the National Fire Agency to issue one emergency support message. NCDR will continue to strengthen the effectiveness and control of this disaster information broadcasting platform, and in conjunction with exercises involving the central government competent authority in charge of disaster prevention and relief, National Communications Commission, and mobile broadband operators, NCDR will continue to perfect the system and ensure its ability to transmit messages in real-time.

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 2017:

#### A. Popular science activities

MOST has used 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 2,490 popular science activities were held throughout 2017, and attracted over 1.1 million participants; the 67 websites established in conjunction with these activities provided free browsing and shared science resources with the public, and received more than 2.44 million visitors.

The "Sci-Tech Vista" website is an online sharing service providing popular science resources. This website has had an average of more than one million visits monthly since it was launched in September 2014. Apart from setting up a Facebook fans page and a Google+ page, the website has its own YouTube channel, and has uploaded several hundred short popular science videos provided by or licensed from academic workers and multimedia companies. As of the end of 2017, Sci-Tech Vista's Facebook fans page had received over 38,000 "likes," its Facebook page had received over 3.9 million posts, and its YouTube channel had been viewed a total of more than 7 million times.

In order to enhance the online dissemination of S&T news, MOST has continued to implement "Projects for News Media for Popular Science," which encourage interdisciplinary academic cooperation, introduce new S&T knowledge via special reports, and provide full-scale, in-depth reports on major news events and facts. The public can view reports and quickly obtain information



using computers or mobile devices, and the projects promote public understanding of science and enhance citizens' scientific literacy. The writing teams for these projects had completed more than 1,300 popular science articles as of the end of 2017, and 323 new articles were published during the year. Funding was provided to seven writing teams in 2017, and the topics reported on chiefly consisted of healthcare, food nutrition and safety, life science, space science and technology, energy development, environmental protection, sustainability, and environmental education, finance, and climate change. The projects' writing teams will produce at least 288 popular science articles within a year's time, and will rely on the *Sci-Tech Vista* website and Facebook posts to help the public to conveniently obtain new S&T knowledge.

MOST held over 167 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. More than 25,000 students and members of the public took part in these events, which received media coverage more than 200 times. 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, enabling 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 diffusion of popular science content. In 2017, funding was provided for the production of 50 popular science video programs in 8 series (1,640 minutes), 7 online reports on popular science topics, and 50 animated short video episodes totaling 150 minutes. Funding was provided to 8 projects (including one extension project), in which the Academia Sinica, five public universities, including National Tsinghua

University, and two private schools, including Chinese Culture University, cooperated with 8 enterprises, including Sanlih TV and Formosa Television Culture. These collaborative efforts are expected to result in the production of 6 popular science films (including 3 3D animated films) and one live program; 3 of the films will concern innovative industrial S&T, and one will introduce the countries of Southeast Asia to Taiwan's agricultural S&T in conjunction with the New Southward Policy.

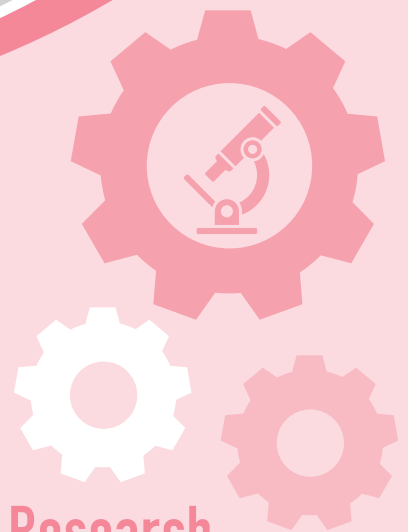
In the area of extension, in order to get the public in the habit of viewing, the "Science Discovery" popular science show continued to be broadcast every Saturday morning on FTV News, and 51 hours of programming (including a New Year's holiday special) was broadcast over the course of 2017. The program's highest viewing rate reached 0.43% (average: 0.21%). 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 by 16 special reports in the media, 51 question and answer games with prizes for correct answers, one televised panel discussion, a Facebook community, and media exchanges. "Science Discovery" will continue to be broadcast in 2018.

With regard to output quality, popular science programs produced with funding from MOST have earned a very favorable reception for many years, have been finalists in the Golden Bell Awards for 10 consecutive years, and have won this honor for seven consecutive years. Two popular science programs were finalists in the Golden Bell Awards during 2017; of these, "Never Compromise," which records the enterprising spirit of scientific research in a laboratory, was the winner in the natural science documentary category at the 52<sup>nd</sup> Golden Bell Awards. Over the years, popular science content produced with funding from MOST has accumulated a total of 16 Golden Bell Awards, which indicates the high level of quality of these shows.

Starting in 2018, popular science programs will be produced in conjunction with superior popular science production enterprises; these programs will introduce the world to Taiwan's S&T highlights and progress, while striving to instill scientific and technological literacy and perspectives among the people of Taiwan.



# ACADEMIA | INDUSTRY SCIENCE | TECHNOLOGY



## Chapter 3 Support for Academic Research

- Support for Specific-Topic Research Projects
- Research and Development Performance
- Human Resources Recruiting and Training
- Research Awards
- International Cooperation in Science and Technology
- S&T Interchange with China
- Improving the Research and Development Environment
- Management and Extension of R&D Results
- Publications



## 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 instructors and research personnel who meet MOST's specific-topic research project funding application requirements may, within a specified period of time, apply to MOST for research operation funding, equipment funding, or foreign travel funding based on the real needs of their research. Furthermore, to encourage long-term, in-depth research, MOST also promotes multi-year projects.

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

#### B. Project types

Specific-topic research projects are classified as either individual or integrated projects. Individual projects focus on research in the applicant's area of specialization or on

a topic proposed in MOST's discipline plan. Integrated projects include main projects and subprojects; the principal investigator of a main project generally organizes a research team to address one of the mission-oriented focal research topics laid out by MOST, and proposes an interdisciplinary or inter-university project, or organizes a team research project on some specific topic.

#### C. Overview of Funding

A total of 18,534 specific-topic research projects were implemented during 2017 (including 13,407 newly-approved 2017 projects, 3,343 second-year projects of multi-year projects approved in 2016, 1,753 third-year projects of multi-year projects approved in 2015, 24 fourth-year project of multi-year projects approved in 2014, and 7 fifth-year projects of multi-year projects approved in 2013). Total implemented funding was NT\$22.40 billion, of which 65.24% went for research at public universities, 20.29% went for research at private universities, and 14.47% went for research at government research organizations and other units. Basic research projects accounted for 50.52% of the total, applied research projects accounted for 37.51%, and technology development projects accounted for 11.97%. By research field, natural science projects accounted for 19.67% of the total, engineering and applied science projects accounted for 30.81%, life science/medicine/agriculture research projects accounted for 26.26%, humanities and social science projects accounted for 13.25%, science education projects accounted for 4.13%, and other projects accounted for 5.88%. By length of research period, one-year projects accounted for 34.78% of the total, and multi-year projects accounted for 65.22%.

Numbers of specific-topic research projects and approval rate, 2013-2017

Item	2013	2014	2015	2016	2017
Applications	29,484	28,870	28,542	28,136	28,258
Approved	14,265	13,890	13,913	13,179	13,407
<b>Approval rate</b>	<b>48.38%</b>	<b>48.11%</b>	<b>48.75%</b>	<b>48.76%</b>	<b>47.44%</b>
Implemented projects	19,603	19,460	19,318	18,865	18,534 <sup>1</sup>

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

<sup>1</sup> Projects implemented in 2017 included projects approved in 2017, second-year projects of multi-year projects approved in 2016, third-year projects of multi-year projects approved in 2015, fourth-year projects of multi-year projects approved in 2014, and fifth-year projects of multi-year projects approved in 2013.

Numbers of specific-topic research projects at different types of organizations and funding, 2013-2017

Units: NT\$1 m

Item	2013		2014		2015		2016		2017	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
Public universities	12,023	13,986.18	12,008	14,552.39	11,904	14,357.43	11,720	14,426.03	11,569	14,616.15
Private universities	5,514	4,446.46	5,334	4,560.65	5,238	4,516.38	4,947	4,384.55	4,798	4,547.88
Military/police schools	228	204.24	229	203.34	239	241.83	240	235.53	227	227.16
Government research organizations	914	1,549.90	907	1,532.61	924	1,483.5	926	1,449.93	918	1,530.79
Academic research organizations	282	618.96	325	822.11	334	770.74	360	696.79	325	642.45
Teaching hospitals	638	710.02	655	743.59	677	722.56	672	741.04	697	839.00
Other	4	57.75	2	3.19	2	47.39	0	0	0	0
<b>Total</b>	<b>19,603</b>	<b>21,573.51</b>	<b>19,460</b>	<b>22,417.91</b>	<b>19,318</b>	<b>22,139.83</b>	<b>18,865</b>	<b>21,933.87</b>	<b>18,534</b>	<b>22,403.43</b>

Numbers of funded basic research, applied research, and technology development projects and funding, 2013-2017

Units: NT\$1 m

Item	2013			2014			2015			2016			2017		
	Projects	Funding	Funding (%)	Projects	Funding	Funding (%)	Projects	Funding	Funding (%)	Projects	Funding	Funding (%)	Projects	Funding	Funding (%)
Basic research	10,418	11,399.41	52.84%	10,379	11,737.81	52.35%	10,534	11,794.94	53.27%	10,114	11,428.96	52.11%	10,003	11,319.03	50.52%
Applied research	8,051	8,363.62	38.77%	7,892	8,592.26	38.32%	7,610	8,203.49	37.05%	7,485	8,126.51	37.05%	7,287	8,404.10	37.51%
Technology development	1,134	1,810.48	8.39%	1,189	2,087.83	9.33%	1,174	2,141.39	9.68%	1,266	2,378.39	10.84%	1,244	2,680.30	11.97%
<b>Total</b>	<b>19,603</b>	<b>21,573.51</b>	<b>100%</b>	<b>19,460</b>	<b>22,417.91</b>	<b>100%</b>	<b>19,318</b>	<b>22,139.83</b>	<b>100%</b>	<b>18,865</b>	<b>21,933.87</b>	<b>100%</b>	<b>18,534</b>	<b>22,403.43</b>	<b>100%</b>

Numbers of male and female principal investigators of specific-topic projects, 2013-2017

Item	2013		2014		2015		2016		2017	
	Person times	Percentage	Person times	Percentage	Person times	Percentage	Person times	Percentage	Person times	Percentage
Female	4,429	22.59%	4,488	23.06%	4,485	23.22%	4,473	23.71%	4,433	23.92%
Male	15,174	77.41%	14,972	76.94%	14,833	76.78%	14,392	76.29%	14,101	76.08%
<b>Total</b>	<b>19,603</b>	<b>100%</b>	<b>19,460</b>	<b>100%</b>	<b>19,318</b>	<b>100%</b>	<b>18,865</b>	<b>100%</b>	<b>18,534</b>	<b>100%</b>



Numbers of funded specific-topic research projects in each research area and funding, 2013-2017

Units: NT\$1 m

Item	2013		2014		2015		2016		2017	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
Natural science	2,356	3,950.25	2,444	4,440.59	2,584	4,526.42	2,721	4,638.89	2,639	4,408.28
Engineering	6,886	6,513.72	6,740	7,343.21	6,390	6,898.6	6,231	6,999.39	5,963	6,901.74
Life science, medicine, and agriculture	4,274	5,939.49	4,398	6,212.24	4,341	5,885.34	4,247	5,685.07	4,224	5,883.47
Humanities and social sciences	5,120	3,001.91	4,948	2,963.12	4,851	2,951.32	4,658	2,952.60	4,650	2,968.46
Science education	850	815.10	905	1,122.22	969	1,058.54	827	907.08	864	925.95
Other	117	1,353.05	25	336.51	183	819.61	181	750.83	194	1,315.53
<b>Total</b>	<b>19,603</b>	<b>21,573.51</b>	<b>19,460</b>	<b>22,417.89</b>	<b>19,318</b>	<b>22,139.83</b>	<b>18,865</b>	<b>21,933.87</b>	<b>18,534</b>	<b>22,403.43</b>

Numbers of one-year and multi-year specific-topic research projects and funding, 2013-2017

Units: NT\$1 m

Item	2013		2014		2015		2016		2017	
	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding	Projects	Funding
<b>One-year projects</b>										
Natural science	1,058	1,137.35	1,122	1,432.14	1,229	1,314.17	1,318	1,416.91	1,324	1,432.14
Engineering	3,753	2,693.54	3,673	2,946.22	3,418	2,581.66	3,393	2,751.80	3,107	2,377.92
Life science, medicine, and agriculture	1,289	1,263.81	1,217	1,293.44	1,343	1,279.79	1,365	1,388.67	1,342	1,534.03
Humanities and social sciences	2,778	1,353.22	2,655	1,308.25	2,627	1,337.43	2,535	1,337.51	2,473	1,328.20
Science education	378	277.73	379	248.93	419	305.57	276	167.51	317	275.78
Other	65	587.94	21	260.72	67	368.43	83	364.90	70	843.17
Subtotal	9,321	7,313.59	9,065	7,489.72	9,103	7,187.05	8,970	7,427.31	8,633	7,791.24
<b>Multi-year projects</b>										
Natural science	1,298	2,812.90	1,322	3,008.45	1,355	3,212.25	1,403	3,221.98	1,315	2,976.14
Engineering	3,133	3,820.17	3,067	4,396.98	2,972	4,316.94	2,838	4,247.59	2,856	4,523.82
Life science, medicine, and agriculture	2,985	4,675.67	3,181	4,918.80	2,998	4,605.55	2,882	4,296.40	2,882	4,349.43
Humanities and social sciences	2,342	1,648.69	2,293	1,654.87	2,224	1,613.89	2,123	1,615.09	2,177	1,640.27
Science education	472	537.37	528	873.29	550	752.97	551	739.57	547	650.17
Other	52	765.11	4	75.79	116	451.18	98	385.93	124	472.36
Subtotal	10,282	14,259.92	10,395	14,928.19	10,215	14,952.78	9,895	14,506.56	9,901	14,612.19
<b>Total</b>	<b>19,603</b>	<b>21,573.51</b>	<b>19,460</b>	<b>22,417.91</b>	<b>19,318</b>	<b>22,139.83</b>	<b>18,865</b>	<b>21,933.87</b>	<b>18,534</b>	<b>22,403.43</b>

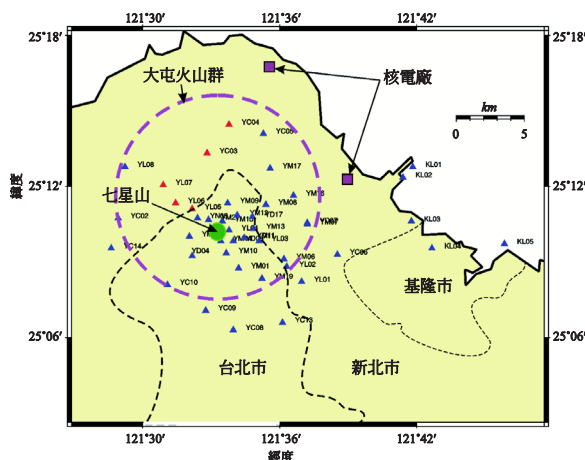
## A. General Specific-topic Research Projects

### 1. Natural Science

Natural science research chiefly takes the form of basic scientific research, and encompasses the areas of mathematics, statistics, physics, chemistry, and earth science, etc. Natural science research also includes interdisciplinary research in statistics, physics, chemistry, earth science, atmospheric science, ocean science, sustainability research, disaster mitigation technology, and spatial information technology. 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 research results, solve scientific problems and problems concerning human survival, train research manpower in the natural sciences and mathematical/statistical science, realize MOST's mission of "providing the groundwork for excellent basic research, realizing diverse academic value, and training scientific research manpower," and achieve the goal of creating new value for Taiwan through scientific research. The following were among some of the most significant research results of the year:

#### (1) Evidence for a magma reservoir beneath the metropolitan Taipei area

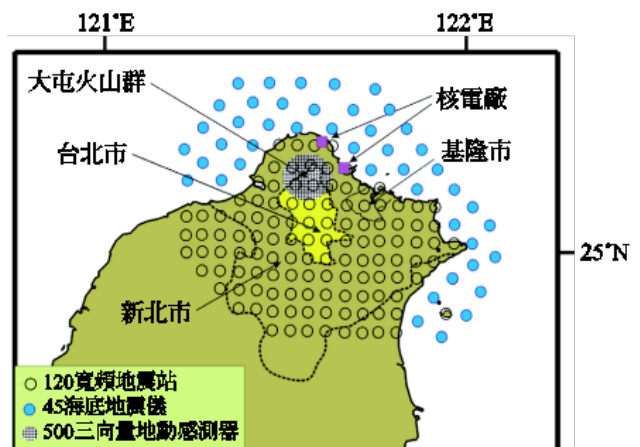
Yangmingshan National Park, which is adjacent to the metropolitan Taipei area, is the site of significant surface geothermal activity. This activity includes the numerous fumaroles,



Distribution of earthquake monitoring stations on the Datun Volcano Group (triangles) and locations of chief cities in northern Taiwan (Source: Researcher Lin Cheng-hung, Institute of Earth Sciences, Academia Sinica)

hot springs, and other geothermal phenomena of the Xiaoyoukeng, Liuhuang Gu ("Sulfur Valley"), Gengziping, Qigu, and Bayan areas, and these phenomena are due to the volcanic activity of the Datun Volcano Group. The Datun Volcano Group consists of over 20 distinct volcanoes, including Mt. Datun, Mt. Qixing, Mt. Shamao, Mt. Huangzui, Mt. Xiaoguanyin, and Mt. Dahoujian, etc. Due to their proximity to the city, the possibility that the volcanoes in the Datun Volcano Group may experience renewed activity is an issue that may affect the safety of Taipei and the surrounding area. Rock dating results indicate that the Datun Volcano Group last erupted roughly 100,000-200,000 years ago, which led most people to once believe that these volcanoes would not resume activity. However, research involving geochemistry, seismic activity, crustal deformation, and dating of volcanic ash over the course of the past one or two decades has suggested that the Datun Volcano Group may still be active. But although observation results strongly suggest that the volcanoes in the Datun Volcano Group are active, there has been no direct evidence for the presence of a magma reservoir beneath the Datun Volcano Group.

Thanks to the dedicated efforts of a research team consisting of personnel from the Institute of Earth Sciences, Academia Sinica, Department of Geology at National Taiwan University, and the Taiwan Volcano Observatory – Tatun, evidence of a magma reservoir has finally been discovered. Since a magma reservoir is mostly liquid, S-waves (transverse or



Schematic diagram of magma reservoir and array of high-resolution earthquake monitoring stations in the vicinity of the metropolitan Taipei area. (Source: Researcher Lin Cheng-hung, Institute of Earth Sciences, Academia Sinica)



shear waves) cannot pass through the reservoir, and a liquid magma reservoir is also able to cause a significant delay in the transmission of P-waves (longitudinal or compression waves). Detailed analysis of data from the dense network of earthquake monitoring stations on the Datun volcanoes has indeed revealed a shadow in S-waves and the delay of P-waves. These two important results have fully verified that a magma reservoir exists in northern Taiwan.

Scientists believe that this is the first time that a shadow in S-waves and the delay of P-waves have been used simultaneously anywhere in the world to verify the existence of a magma reservoir. In order to gain a detailed understanding of how the magma reservoir formed and its geometry, MOST is providing funding to the project "Metropolitan Taipei Disaster Mitigation Mission: Confirming the Location and Morphology of the Magma Reservoir being the Datun Volcanoes" (2017-2020), which plans to establish an intensive earthquake monitoring station array in northern Taiwan. The full-scale installation of monitoring stations, which will form a chessboard-pattern broadband seismic monitoring network with nodes approximately 5 km from each other, will expand the scope of this research and enhance ability to monitor undersea volcanoes in northern Taiwan. The project will also establish undersea seismometers in coastal areas around northern Taiwan, which will enhance the scope and resolution of scientists' view of underground structures, and deploy an ultra-high resolution earth movement sensing array with measurement points spaced several dozen meters from each other in key research areas, such as volcanic vents, rupture zones, and active fault zones. This sensing array will allow scientists to determine the magma reservoir's detailed structural characteristics, including its geometric form, which will provide an important reference for disaster mitigation efforts and allow the assessment of the chance of future natural disasters.

This major research result was published in *Scientific Reports* in 2016, and also published in the international journals *Geophysical Journal International*, *Asian Earth Sciences*, and *Journal Volcanology Geothermal Research* in 2017.

(2) A weak light optical driven organic imaging element: All-new display/detection applications involving the transformation of extremely weak light into electricity

A series of new organic optoelectronics technologies have been introduced in recent years, and a wide range of organic optoelectronics process technologies have been successfully employed in the components of wearable electronics products, such as the organic LEDs used in smartphone panels (electroluminescence technology) and photovoltaic charging modules that can use either indoor or outdoor light (photovoltaic technology). These two types of element technology involve the independent application of LEDs' electricity-to-light and photovoltaic batteries' light-to-electricity operating models. The interdisciplinary research team in the MOST-supported "New-generation Optical Driven Battery Technology Project" has developed a new-generation weak light optical driven organic imaging element, where the element structure combines the independent functions of LEDs and photovoltaic batteries in the same electronic element for the first time. This element employs an organic light-absorbed layer nearly 10 nm in thickness to convert weak light collected from the environment into a tiny electric current; when a forward bias is applied to the element, it will cause a light-emitting unit in the rear to produce a visible light real-time image, which provides an imaging mechanism driven by a weak light signal. It's worth noting that this element is currently highly sensitive to weak light in the near infrared waveband; as long as the ambient illumination at night is at least 0.05 mW/cm<sup>2</sup> (roughly one-fifth of the illumination from an ordinary indoor fluorescent light), the element can easily display night-vision images of things that cannot ordinarily



A weak light optical driven organic imaging element: Simultaneously employs the characteristics of a photovoltaic battery and LED (Source: Prof. Liu Shun-wei, Mingchi University of Technology)

be seen by the human eye. In addition, the element's total volume is only one-fourth that of a conventional photomultiplier tube module. In the future, this technology can be used in vehicles and high-end night-vision optical sighting systems, and it is expected that it will be used by domestic OLED panel manufacturers in the development of new types of high unit price thin night-vision imaging elements and products. This research result was published in the international academic journal *Science Reports and Organic Electronics*; a patent portfolio has already been established and the technology has been licensed to companies. Relevant practical R&D results will be used by a domestic OLED manufacturer on an experimental production line in order to perform preliminary testing of element characteristics.

### (3) Bacteria-mediated hypoxia-specific delivery of nanoparticles for tumor imaging and therapy

Cancer is currently one of the leading causes of death, and many kinds of cancer-fighting strategies have been developed to combat this disease. Recently-developed alternative strategies have included specific targeted therapy, inhibition of angiogenesis, and attacking cancer growing in a hypoxic micro-environment. However, because cancer is caused by complex cellular structures, when most cancer cells have been killed, there will still be a small number of cancer cells that are not drug-sensitive; and because of the stimulus of hypoxia and acidity in their micro-environment, these remaining cells may express a different metabolic form, which will lead to drug resistance and risk of recurrence. Because solid tumors grow quickly, and because of the abnormal distribution of capillaries in the spherical cancerous tissue, the oxygen content of tumor tissue will be less than in the surrounding normal tissue. This phenomenon causes anti-cancer drugs transmitted by blood vessels to be less effective, and drug activity will be lower in the central tissue of the tumor due to hypoxia, which has the effect of increasing the difficulty of conventional drug therapy, and the hypoxic environment fosters the growth of anaerobic bacteria. In 1995, scientists discovered that while spores of tetanus bacteria will kill mice with tumors, they will have no effect on healthy mice. Subsequently, scientists used genetic engineering involving the non-pathogenic *C. difficile* bacteria to transform a precursor (CB 1954, 5-aziridino-2,4-dinitrobenzamide) into a chemotherapy drug attacking DNA. In other research, scientists developed a drug conversion strategy involving the use of genetically engineered

*Bifidobacterium* probiotic bacteria to produce enzymes converting a precursor (5-fluorocytosine) into the toxic (5-fluorouracil).

In order to reduce the complexity of this therapeutic method, a research team at National Cheng Kung University research team used near infrared in conjunction with light-sensing nanomaterials to diagnose and treat tumors, and employed probiotic bacteria and *C. difficile* to transmit materials to hypoxic areas via two different approaches. The materials are then converted in order to image and diagnose the tumor area, and nanometer gold rods can be used to perform photothermal therapy of the tumor. This approach can also be used to carry large molecular drugs or organic materials or drugs.

This research result represents the first use of a modular concept in this application, and takes advantage of bacteria's growth habit to make the bacteria a "robot" for transporting materials to the hypoxic location of a tumor with great specificity. Although past research has suggested that tumor tissue has greater permeability to and retention of nanomaterials and large molecules, the use of bacteria to guide or carry nanoparticles can increase the specificity of their transport. The significance of this strategy includes: (1) Even if tumor biomarkers change, as long as the hypoxic environment does not change, the method can target a tumor with great specificity. (2) As soon as a tumor's hypoxic environment disappears (at the completion of treatment), the bacteria's growth environment will also disappear, and there is no need to worry that the bacteria will continue to grow in a patient's body. (3) The combination of bacteria and materials science can achieve quick and convenient tumor diagnosis and treatment.

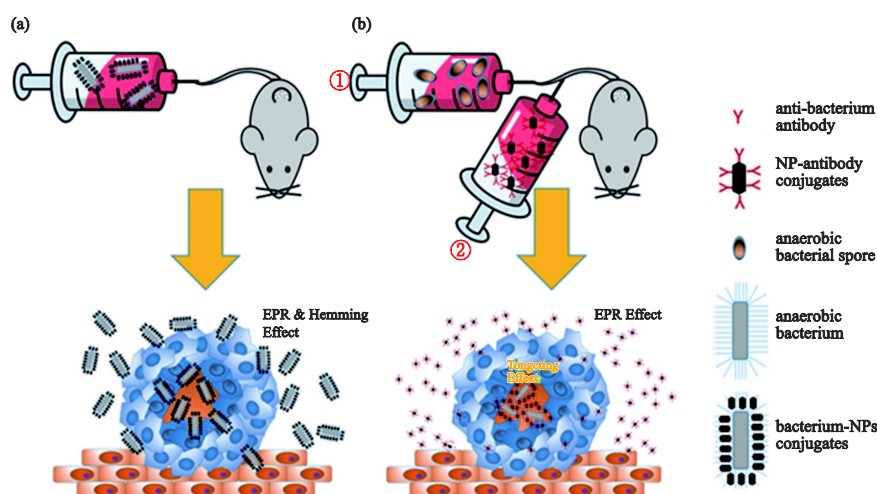
One method using this research approach is to adsorb materials on *Bifidobacterium*, and take advantage of the fact that *Bifidobacterium* will only remain and grow in hypoxic areas to transmit nanoparticles. In a second method, after introduction of the spores of *C. difficile*, the circulatory system will carry the spores to the hypoxic area where the tumor is located, where they will be activated and grow. At that time, antibodies able to recognize active bacteria grafted onto materials are used to transmit functional nanoparticles to the hypoxic tumor area by taking advantage of the antibodies' specific attack on the bacteria.

A research team from the Department of Chemistry at National Cheng Kung University used experiments to verify these methods. In a



tumor imaging and diagnosis experiment, the use of bacteria to carry contrast agents had a better imaging effect than the pure contrast agents. The strategy of using antibodies carrying materials to recognize bacteria yielded the best results in an imaging experiment. In a treatment experiment, in an experimental group receiving antibodies carrying gold rods used to mark

bacteria obtained significant therapeutic benefits. This modularized approach is an improvement on conventional complex therapeutic designs, and can expand the scope of applications to the treatment of all tumors in hypoxic areas. The results of this study were published in *Nano Letters* in 2016.



Schematic diagram of research strategy: (a) After materials adsorbed on bacteria are introduced into mice via systemic injection, scientists observe whether the materials are carried by the bacteria to the tumor. (b) Bacterial spores are introduced via systemic injection; when the spores reach the hypoxic area of the tumor and begin to grow, materials grafted to antibodies are introduced via systemic injection, and the antibodies carry the materials to the bacteria (in the hypoxic area where the tumor is located). (Source: Prof. Yeh Chen-sheng, Department of Chemistry, National Cheng Kung University)

Research manpower in natural science specific-topic research projects, 2013-2017

Item		2013	2014	2015	2016	2017
Research personnel	Professors	1,302	1,433	1,533	1,634	1,590
	Associate professors	693	763	835	884	875
	Assistant professors	680	689	710	756	695
	Lecturers	6			7	4
	Other	664	701	791	915	889
Subtotal		3,345	3,586	3,869	4,196	4,053
Research assistants	Full-time assistants	803	892	947	1,035	1,016
	Part-time assistants	39	30	45	62	45
	Graduate students	8,561	9,086	9,688	9,710	8,881
Subtotal		9,403	10,008	10,680	10,807	9,942
<b>Total</b>		<b>12,748</b>	<b>13,594</b>	<b>14,549</b>	<b>15,003</b>	<b>13,995</b>

Numbers and of one-percentage and multi-year specific-topic research projects in natural science, 2013-2017

Year	All projects	One-year projects (%)	Multi-year Projects (%)
2013	2,356	1,058 ( 44.91 )	1,298 ( 55.09 )
2014	2,444	1,122 ( 45.91 )	1,322 ( 54.09 )
2015	2,584	1,229 ( 47.56 )	1,355 ( 52.44 )
2016	2,721	1,318 ( 48.44 )	1,403 ( 51.56 )
<b>2017</b>	<b>2,639</b>	<b>1,324 ( 50.17 )</b>	<b>1,315 ( 49.83 )</b>

Numbers of natural science and mathematics specific-topic research projects and funding, 2017

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 <sup>1</sup>	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
<b>Total</b>	<b>3,580</b>	<b>16,188.09</b>	<b>2,005</b>	<b>3,352.43</b>	<b>2,639</b>	<b>4,408.28</b>

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



## 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 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) Development of transparent soft mica electronics

With technological progress, a steadily stream of new applications of materials science have been emerging. Taking ceramic materials as an example, people began making ceramics approximately during the 7<sup>th</sup> century BC. From that time on, ceramics have been inseparable from human civilization. With the relatively recent invention of ceramic silicon semiconductor elements, ceramics have had an even greater impact on human science and technology. While conventional ceramic materials are characterized by high mechanical strength (hardness) and resistance to high temperatures, acids, and alkalis, they are brittle and easily fractured. A research team from National Chiao Tung University has recently developed an all-new transparent soft mica substrate. This team has taken advantage of mica's laminar structure to shave off layers less than 100 microns in thickness; thanks to their superb flexibility and high transparency, these layers can be used to create highly promising transparent, flexible substrates, which can allow ceramics to bend, while offering the advantages of thermal and environmental stability. The project team first deposited a film of multifunctional material on a mica substrate with the properties of transparency and flexibility. The epitactic technology used to perform this deposition is an area in which Taiwan is a world leader, and the project's results represent a new feat in the field of mica electronics. Many scientists worldwide are watching this research work with great interest, and it is the most important recent breakthrough in soft electronics. With the arrival of the Internet of Things, the public is demanding

more and more from electronic products, such as compact size, convenience, multiple devices in one unit, novelty and appeal, and environmentally-friendliness, etc. The realization of electronic elements on soft substrates is gradually becoming an important trend, but since most soft substrates currently consist of organic polymers, they have the major weakness of lack of resistance to heat, acids, and alkalis. As a consequence, the performance of the electronic elements made on them cannot meet the highest standards. The research team in this project plans to develop new types of soft in organic functional materials and elements able to overturn existing soft electronics technology and promoting the development of a soft electronics industry in Taiwan.



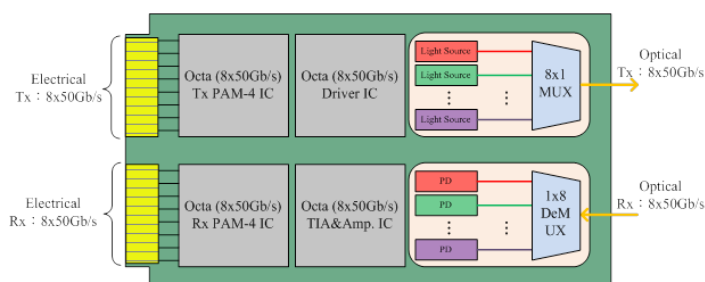
Brand-new soft mica electronics products will employ transparent soft mica wafers as a substrate (upper image), also involve advanced semiconductor processes (lower left), and adopt a fashionable wearable device concept (lower right). (Source: Associate Prof. Chu Ying-hao, Department of Materials Science and Engineering, National Chiao Tung University)

### (2) A multimode optical transmission module with the world's highest transmission rate

With the rise of mobile communications and big data, cloud data using smartphones and tablets as terminals has become a part of people's lifestyles, and the behind-the-scenes cloud data centers processing and sharing this data have become key information infrastructure. To keep pace with up with this trend, MOST has promoted the "High-speed Cloud Optical Data Communications Key Network Module Technology" project, and is funding the project research team's efforts to develop an optical transmission module with a data transmission

rate reaching 400 Gb/s. This research team, which includes professors from National Taiwan University of Science and Technology, National Taiwan University, and National Chiao Tung University, is taking advantage of corporate resources and manpower to cooperatively develop an illumination source with a single-channel transmission speed of up to 56 Gb/s, and accompanying transmission and reception circuits and high-speed connectors; it is expected that this system will be able to achieve a transmission and reception rate of 400 Gb/s with eight channels, which will realize 400 Gb/s data center links in the near future, while also bringing Taiwan closer to achieving the goal of 100% domestically-produced key elements and components.

Within this project, the laboratory headed by Prof. Chen Chih-hung of the Department of Photonics, National Chiao Tung University has developed two types of signal processing technology: One type consists of a Volterra balancer with nonlinear compensation, and the other consists of a balancer based on a deep convolution neural network. These two types of balancers can be used in conjunction with rules to control complexity to compensate for loss of signal fidelity due to insufficient channels or electrical conversion bandwidth, and can remove noise, perform signal recovery, and meet signal quality requirements during high-speed transmission, while also effectively reducing system complexity. As a consequence, the project team holds world's current record for highest transmission speed. The team has achieved a world-record transmission rate of 64Gbps in a 4km VCSEL multimode fiber cable demonstration system, and presented its results at the 2017 Optical Fiber Communication Conference and Exhibition (OFC 2017)—one of the world's leading optical communications conferences.



Block diagram of a single-mode multi-wavelength 400Gb/s optical transmission and reception module system  
(Source: Team of Prof. Li San-liang, Department of Electronic Engineering, National Taiwan University of Science and Technology)

### (3) A new method of treating seizures involving electronic medicine

A neurology research team from the Department of Electronic Engineering, National Chiao Tung University and Chung Shan Medical University has developed a new type of closed loop electro-stimulation treatment method for epileptic seizures, and a report on this project was chosen by the leading international conference Symposia on VLSI as a highlight paper. This project has also made important findings using this method in animal experiments.

Epileptic seizures are a commonly-seen neurological disorder. Although seizures are still typically controlled using medication, nearly one-third of all seizure patients either cannot effectively control their seizures even when taking two or more types of seizure drugs, or experience difficult-to-tolerate side effects to the drugs. This situation is known as drug-resistant epilepsy, and patients of this type may require the surgical removal of the area of the cerebral cortex containing the focus of the seizures. However, the surgical removal of brain tissue may also entail various lingering effects, such as memory loss or organ dysfunction. One of the newest treatment method is known as closed loop electro-stimulation; in this method, a seizure control system implanted in patients' brains, can immediately apply electro-stimulation in order to inhibit incipient seizures that have not yet affected the whole body.

The effectiveness of the device developed by the research team in this project has already been verified in animal experiments involving pigs. It can be seen from the diagram below that as soon as the brain waves indicating a seizure have been detected, the device will immediately initiate electro-stimulation to inhibit the seizure, and the seizure brain waves will return to normal after receiving electro-stimulation.

### (4) A miniature electronic nose system for breath disease detection applications

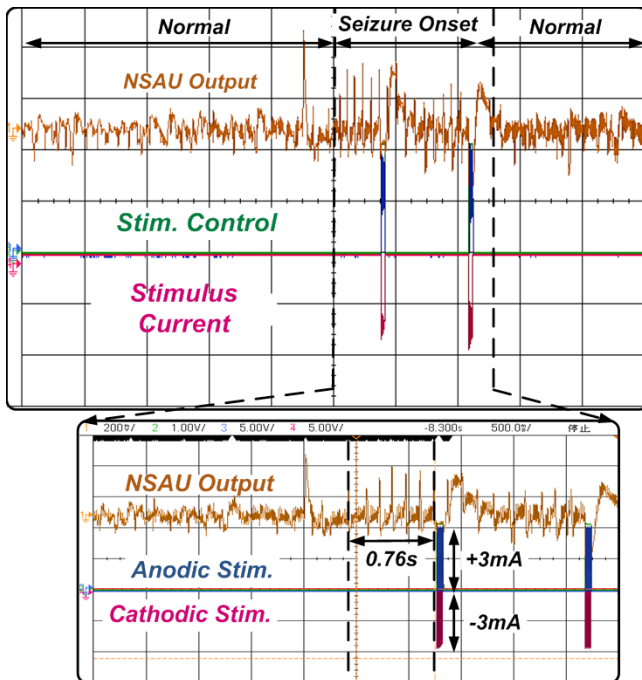
In age-old traditional Chinese medicine, the four major diagnostic methods are looking, listening/smelling, questioning, and palpation. Of these, smelling is considered a particularly important basis for the diagnosis of diseases. In interdisciplinary team of individuals from National Tsinghua University, Taipei Medical University, and National Chung Shan Institute of Science



and Technology has proposed an artificial smelling concept involving a so-called "electronic nose." An electronic nose is a device capable of repeatedly "smelling" diseases, and consists of multiple sensors arranged in an array. This highly-sensitive electronic nose system takes the form of light compact system chip, and is capable of sensing various gases and comparing their composition with the database in order to facilitate disease identification and testing.

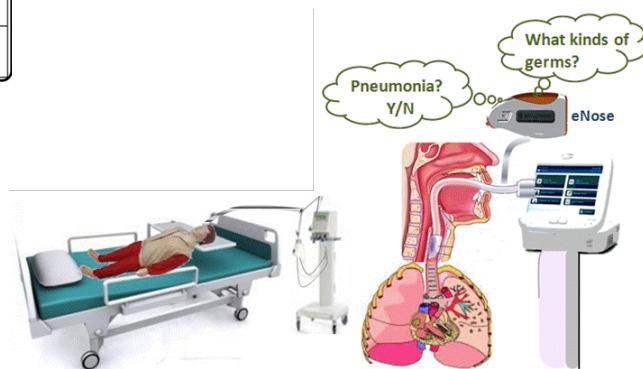
particularly ventilator associated pneumonia and chronic obstructive pulmonary diseases, and it has achieved a 90% identification rate when used in over 100 clinical cases.

Because the "breath testing instrument" developed in this project can perform noninvasive testing of breath gases and provide reliable and accurate results, apart from serving as an important means of detecting drugs, asthma, tuberculosis, and other diseases, he can also meet many of the vast testing needs of developing countries. It can also be widely applied in such areas of biomedicine as the detection of respiratory infections, lung cancer, urinary tract infections, kidney cancer, and liver cancer. To put the huge potential of this device in context, according to a research report issued by Grand View Research, the breath testing market will experience explosive growth in the future, and reach US\$11.3 billion by 2024.



Successful control of seizure brain waves in a pig experiment (Source: Biomedical Electronics Translation Center, National Chiao Tung University)

The electronic nose system chip technology developed by this research team is currently the most advanced in the world. The compact electronic nose system incorporates several gas sensors and a back-end processing circuit on a single, small chip, and represents a breakthrough from the conventional approach to using individual sensors to detect specific individual gases. The key technologies developed in this project include (1) CMOS integrated gas sensors, (2) a robust clustering algorithm, (3) a sensor array calibration algorithm, (4) system chip integration, and (5) use of a high-sensitivity porous carbon sensing material. With regard to clinical applications, the system can be used to test for respiratory diseases,



Application of a miniature electronic nose system to testing for ventilator-associated pneumonia (Source: Team of Prof. Cheng Kui-chung, Department of Electrical Engineering, National Tsinghua University)

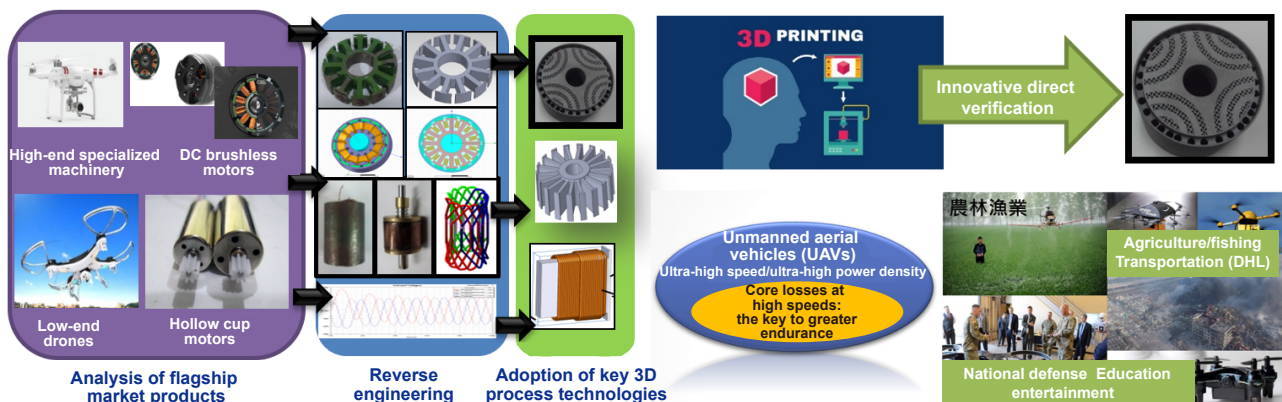
### (5) Application of fiber laser additive manufacturing system to motor design

In this project, the innovative use of metal additive manufacturing (3D printing) technology has allowed researchers to overcome the restrictions that mechanical bearings conventionally impose on motor structure, and quickly use additive manufacturing to produce motors with ultrahigh rotation speed, ultrahigh power density, low cost, small volume, and power saving efficiency. Since existing laser additive manufacturing equipment cannot produce functional magnetic materials, the members of this project used additive manufacturing (3D printing) in a creative manner to overcome restrictions on conventional processing methods

and magnetic materials. The project's novel achievements include the development of innovative stator and rotor structures with three-dimensional magnetic circuits, and the built-in end winding, a biomimetic reticular structure, and a complex cavity muffler have special geometric designs. This motor design will enable the development of innovative high-power applications and self-starting synchronous reluctance motors, which will greatly facilitate the future development of unmanned aerial vehicles, vehicle starting motors, power-assisted robotic suits, and green energy power applications.

The research team has also developed an innovative fiber laser additive manufacturing system able to control the structural characteristics of materials. The high-

performance motor design and additive manufacturing technology developed in this project includes magnetic powder, an all-fiber laser source, laser beam shaping, and a magnetic transmission element. Compared with the technology supplied by EOS, a leading international laser additive manufacturing equipment manufacturer, notable technological features of this research campaign include special oxidation methods and use of laser additive manufacturing to perform direct coding with SMC materials, which can reduce high-frequency eddy current losses. In addition, the design of the compound laser beam shaping module can reduce surface roughness to  $Ra=4.0 \mu m$ , which is an order of magnitude lower than that achieved by leading international manufacturers and approaches the world record.



Use of additive manufacturing technology in motor design and applications  
(Source: Team of Prof. Tsai Ming-chi, Department of Mechanical Engineering, National Cheng Kung University)

Research manpower in engineering specific-topic research projects, 2013-2017

Item		2013	2014	2015	2016	2017
Research personnel	Professors	4,568	4,883	4,796	4,845	4,894
	Associate professors	2,587	2,595	2,508	2,353	2,178
	Assistant professors	2,268	2,047	1,805	1,690	1,467
	Lecturers	30	25	28	18	17
	Other	653	760	775	849	849
Subtotal		10,106	10,310	9,912	9,755	9,405
Research assistants	Full-time assistants	423	708	661	708	772
	Part-time assistants	68	52	37	67	67
	Graduate students	22,733	23,179	22,103	21,688	20,605
Subtotal		23,224	23,939	22,801	22,463	21,444
<b>Total</b>		<b>33,330</b>	<b>34,249</b>	<b>32,713</b>	<b>32,218</b>	<b>30,849</b>



Numbers and percentage of one-and multi-year specific-topic research projects in engineering, 2013-2017

Year	All projects	One-year projects (%)	Multi-year Projects (%)
2013	6,886	3,753 (54.50)	3,133 (45.50)
2014	6,740	3,673 (54.50)	3,067 (45.50)
2015	6,390	3,418 (53.49)	2,972 (46.51)
2016	6,231	3,393 (54.45)	2,838 (45.55)
<b>2017</b>	<b>5,963</b>	<b>3,107 (52.10)</b>	<b>2,856 (47.90)</b>

Numbers of engineering specific-topic research projects and funding, 2017

Units: NT\$1 m

Item	Applications		Approved		projects	
	Projects	Funding	Projects	Funding	Projects	Funding
Electrical/mechanical/group <sup>1</sup>	2,904	4,479.07	1,447	1,161.29	1,848	1,552.06
Chemical/materials/consumer applications group <sup>2</sup>	2,678	5,604.98	1,248	1,194.80	1,772	1,794.82
Electronics/information/communications group <sup>3</sup>	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
<b>Total</b>	<b>9,360</b>	<b>25,229.74</b>	<b>4,500</b>	<b>5,334.88</b>	<b>5,963</b>	<b>6,901.74</b>

<sup>1</sup>Includes aviation technology, remote sensing, mechanical statics, fabrication and stress, shipbuilding engineering, electrical engineering, industrial engineering, automation technology, control engineering, space technology, heat transmission and fluid dynamics, and marine engineering.

<sup>2</sup>Includes materials and applied chemistry, chemical engineering, materials engineering, food engineering, civil and hydraulic engineering, environmental engineering, medical engineering, and polymers and fibers.

<sup>3</sup>Includes electronic and information systems, telecommunications engineering, microelectronic engineering, optoelectronic engineering, and information system/intelligent computing.

### 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 promotion 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 providing effective

research funding, pursuing academic excellence, fostering S&T interchange and collaboration, and achieving the development of life science. The following major results were obtained during 2017:

#### (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 2017 included the following:

Due to oxidation in rhizosphere soil, the

sulfides generated by the reducing environment of paddy fields tend to form dissolved sulfates, which causes the ability of the roots of paddy rice to absorb cadmium to increase. The sandy beach at Dongqing on the island of Lanyu has shrunk due to human factors, and is no longer suitable for the laying of eggs by the green sea turtle (*Chelonia mydas*), which has caused the Formosa kukri snake (*Oligodon formosanus*) to shift to eating the eggs of the longtail Mabuya (*Mabuya longicaudata*, a species of skink). However, the fact that the longtail Mabuya of Lanyu provide parental care, attack snakes to protect their eggs, and practice filial cannibalism has altered the population dynamics of the snake and lizard. Researchers incorporated chip-type copper composite electrodes in a disposable capillary electrophoresis chip, which can be used for the rapid, convenient detection of meat product species and freshness, will facilitate monitoring of imported and exported fish, and will lessen the risk of food poisoning. Natural seeding by Formosan Hinoki cypress (*Chamaecyparis obtusa* var. *formosana*) was found to renew the soil in forest sample areas, and was not a source of methane (a greenhouse gas) emissions, as had been expected, but instead absorbed methane. Like most wetlands, the marsh at Yuanyang Lake emits large amounts of methane.

In research unraveling the physiological function of genes in the OsGA2ox gene family, which regulate gibberellin (GA) metabolism in rice, it was found that mutations cause the poor expression of these genes, which in turn causes reduced semi-dwarfing and increased lodging in rice plants, while enhancing ability to withstand adverse conditions and boosting yield; this research represents a significant breakthrough and will make an important contribution to the breeding of new rice varieties. A research project discovered that three MYB transcription factors in orchids participate in enriching orchid pigment patterns, and also found that bHLH transcription factors and WD proteins interacting with MYB transcription factors have a mutually regulating effect with floral pigment control factors. In research on the telomere dysfunction caused by the reprogramming of cloned animals, it was experimentally verified that only one or two rounds of reprogramming can effectively extend the telomere length of totipotent stem cells (*Terc*<sup>+/-</sup> ntESC) with haploid dysfunction to nearly the length found in normal cells, and this effect is due to reprogramming factors within oocytes.

The problem of premature ovarian failure not only causes infertility in women, but also affects the reproductive ability of livestock in Taiwan's hot, damp climate. Researchers found that the transplant of amniotic fluid stem cells to the ovaries of mice that had undergone chemotherapy can effectively prevent atretic follicles in the ovaries and maintain the viability of follicles, restoring the reproductive ability of the mice. A study discovered that natural substances from marine organisms and derivative marine matter contains active substances with the ability to combat such skin diseases as atopic eczema and psoriasis, and can also promote the healing of wounds. Research seeking to determine why commercial *Antrodia camphorata* fungus fruiting bodies induce pathologies with a vacuolated appearance in the cells of the adrenal glands and ovaries analyzed the mechanisms of vascular relaxation and genetic toxicity in an animal model, and found that ergocalciferols in the fruiting bodies of *Antrodia camphorata* have unstable structures, are readily digested by gastric fluid, and may reduce vascular relaxation; this work will greatly facilitate efforts to maintain the safety of *Antrodia camphorata*.

Researchers have discovered over 40 superior breeder shrimp marker molecules from a shrimp molecular database, including potential key molecules in involved reproduction and infection by shrimp white spot disease; this project has helped develop molecular breeding technology for Taiwan's shrimp farming industry, and the research team is cooperating with the major domestic shrimp-raising enterprises Uni-President and Great Wall Enterprise in promoting this technology in international shrimp farming market in Southeast Asia. The deconstruction of the protein reaction network of RNA polymerase III in yeast has provided a better understanding of the transcription initiation complex formation mechanism, and this work has had a major impact on molecular mechanism research in such other fields of biomedicine as gene control and expression, cellular growth, and disease.

## (2) Basic medicine

The field of basic medicine includes morphological and physiological medicine, biochemistry and pharmacology, microbiology, immunity, and testing, pharmacy science, and traditional Chinese pharmacology. The following research results were obtained in 2017:

Researchers using an animal model discovered changes in production of leptins



pregnancy due to the mother's obesity can influence the mother's behavioral development. A project discovered the mechanism of drug resistance in the bacteria *Klebsiella pneumoniae*. Researchers discovered that the pain induced by peripheral neural pathologies caused by diabetes is attributable to the disruption of ATP metabolism in small-diameter neurons. Primary culture astrocytes were used to establish an in vitro model of neuroinflammation, which can be used to screen for anti-neuroinflammation drugs that can be used in the treatment of degenerative diseases of the central nervous system. It was found that anti-interferon-gamma monoclonal autoantibodies are connected with diseases caused by mycobacteria; this discovery will have great value to the diagnosis and treatment of disease, and has been acclaimed a major breakthrough in the field. Although specific intestinal imbalances and specific changes in bacteria caused by antibiotic treatment can increase risk of lung infections, researchers discovered that immunity-promoting commensal bacteria may be able to improve intestinal imbalances and poor immunity in patients with infectious diseases.

Enterovirus 71 and adenovirus are highly infectious in children, and may cause severe illness in infected children. Researchers uncovered promising plant extracts by screening over 100 species of plants, and successfully developed an antiviral drug mixture (EPA-W+SMf-2-E) with great potential; this mixture has recently been sent to the United States for preliminary patent application, and licensing negotiations with a domestic company are currently underway. Nanometer targeted drug therapy has an extremely wide range of applications, and can be used to enhance treatment efficiency while reducing side effects. A recently-developed dual-target inhibitor for histone deacetylase and topoisomerase can be used as a new type of anti-cancer drug. Furthermore, recently-developed bacteria attacking nanometer targets will be useful in treating infections by drug-resistant bacteria.

The plant Japanese amelopsis (*Ampelopsis japonica*) has traditionally been used as a skin whitening agent in Chinese medicine. However, the components of amelopsis that inhibit the activation of melanin and the mechanism of related medicinal effects have not been clearly elucidated. A systematic research project on amelopsis has clarified and verified the substances in amelopsis

that have a whitening effect, and determined their pharmacological mechanism; this work will increase the pharmacological value of amelopsis and assist in the development of new whitening agents.

It is known that an alcohol extract of red quinoa, which contains betanin, rutin, kaempferol, and their glycosides, can decrease the number of differentiated adipocytes and their triglyceride content, indicating that this extract can effectively inhibit fat formation by adipocytes. The advantages of media milling including no wastewater production, small water production, and little environmental pollution; this method can be used to prepare chitin films with germicidal properties that can be used as a food packaging material.

### (3) Clinical medicine

The field of clinical medicine includes social medicine, engineering medicine, digestive medicine, cardiac medicine, thoracic medicine, neurology, women's and children's medicine, hematology and immune medicine, nephrology/urology/ endocrinology, and sensory system medicine. The following research results were obtained in 2017:

Researchers working in the area of environmental toxicology compiled and investigated epidemiological research in Asia based on information from the Birth Cohort Consortium of Asia (BiCCA); this research campaign focused on such endocrine disruptors as perfluorocarbons (PFAS) and phthalate plasticizers, and examined such topics as health problems occurring during pregnancy and child growth, neural and behavioral problems, allergenicity and the immune system, the endocrine system, and adolescence. Researchers used single-node transcranial random noise electro-stimulation (tRNS) in normal individuals, and developed an assessment tool to determine the effectiveness and side effects of this technique. The project's assessment results can be used to determine whether tRNS causes various types of variability in cerebral function in normal individuals, namely variability in the distribution of energy in brainwave bands, variability in the functional network linkage of different brain areas, or variability in cortical excitability.

Research on the effect of a high-fat diet and duodenal-jejunal bypass surgery on the intestinal tract barrier sought to determine the

permeability of the intestinal tract and changes in the intestinal tract barrier in rats receiving Roux-en-Y duodenal-jejunal bypass (DJB) surgery or sham surgery. Bypass surgery was found to cause strengthening of the intestinal barrier function, which may provide an explanation for why the risk of general endotoxemia decreases after patients receive this surgery. The use of an innovative signal similarity algorithm to position a rotor atrial fibrillation positioning module offers real-time image processing, high precision, and rapid computing advantages; in conjunction with existing 3D mapping systems, analysis of complex intracardiac electrophysiological signals from atrial fibrillation can rapidly confirm cauterization sites, and overcome the existing problem of poorly positioned site. Clinical experiments have shown that this approach can greatly increase the success rate of electrocauterization.

Research on lung cancer continued to investigate the biological characteristics of lung tumors, new mechanisms of drug resistance, and their influence on clinical prognosis in lung tumor cases. Numerous genes and cellular signal transmission pathways have been shown to be connected with the epithelial-mesenchymal transition of lung cancer cells, cancer cell metastasis, and cancer stem cell drug resistance, and may provide new therapeutic targets. Researchers showed that a synthetic lethal screen employing the EGFR signal transmission pathway can select microRNA (miRNA) conferring resistance to targeted drugs, which will provide information on novel genes and signal transmission pathways in tumors arising from

genetic mutations. These results can facilitate the development of lung cancer treatment strategies.

Research on the early clinical changes caused by functional and structural linkage in the brain in Alzheimer's disease investigated the pathological mechanism by which amyloid induces the production of Tau protein. Comparative analysis of structural magnetic resonance images of patients with self-reported cognitive decline and individuals in a normal control group revealed that the patients with self-reported cognitive decline had significantly thinner cortex in the parahippocampus, perirhinal cortex, and entorhinal cortex areas than the normal individuals.

Gouty arthritis is a commonly seen form of inflammatory arthritis. Cellular autophagy involves the use of autophagosomes to transport intracellular matter to lysosomes, where it is degraded, and thereby maintains cellular homeostasis. Research on the role of autophagy in the pathogenic mechanism of gouty arthritis proposed the possible use of autophagy in interventional therapy. Research on mRNA expression changes during acute kidney damage investigated direct and indirect linkage with hepcidin expression and physiological function. Researchers verified that mRNA influence iron balance via control of the JV-BMP-hepcidin pathway in cases of acute kidney damage, which provides a new target for possible treatments. 3D computer assisted orthognathic surgery can aid surgical planning, reduce operating difficulty, and facilitate positioning and fixation of the complex mandible by the surgeon during an operation.

Research manpower in life science specific-topic research projects, 2013-2017

Item		2013	2014	2015	2016	2017
Research personnel	Professors	2,824	2,965	3,003	2,906	14,677
	Associate professors	1,630	1,635	1,519	1,497	7,799
	Assistant professors	1,386	1,439	1,382	1,348	6,923
	Lecturers	55	62	48	39	242
	Other	2,923	3,088	3,224	3,274	15,915
Subtotal		8,818	9,189	9,176	9,064	45,556
Research assistants	Full-time assistants	2,687	2,937	2,790	2,831	14,298
	Part-time assistants	25	23	16	14	87
	Graduate students	5,321	5,393	4,956	4,568	24,611
Subtotal		8,033	8,353	7,762	7,413	38,996
<b>Total</b>		<b>16,851</b>	<b>17,542</b>	<b>16,938</b>	<b>16,477</b>	<b>84,552</b>



Numbers and percentages of one-and multi-year specific-topic research projects in life science, 2013-2017

Year	All projects	One-year projects (%)	Multi-year Projects (%)
2013	4,274	1,289 ( 30.16 )	2,985 ( 69.84 )
2014	4,398	1,217 ( 27.67 )	3,181 ( 72.33 )
2015	4,341	1,343 ( 30.94 )	2,998 ( 69.06 )
2016	4,247	1,365 ( 32.14 )	2,882 ( 67.86 )
<b>2017</b>	<b>4,224</b>	<b>1,342 ( 31.77 )</b>	<b>2,882 ( 68.23 )</b>

Numbers of life science specific-topic research projects and funding, 2017

Units: NT\$1 m

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
<b>Total</b>	<b>5,926</b>	<b>29,909.51</b>	<b>2,647</b>	<b>3,897.58</b>	<b>4,224</b>	<b>5,883.47</b>

#### 4. Humanities and Social Sciences

The humanities and social sciences comprise 17 disciplines in the three major areas of the humanities (literature, history, philosophy, and art), the social sciences (law, political science, sociology, education, and psychology), and management (administration, finance and accounting, regional studies, and geography). The following is an overview of the results of projects during 2017:

##### (1) Establishment of a Taiwan Empirical Database

Taiwan's developmental experience, which encompasses the aspects of politics, economics, society, and education, must be systematically compiled and preserved as a resource for scholars in relevant fields. In recent years, MOST has established the Taiwan Social Change Survey Database, Election and Democracy Survey Database, Database for Empirical Legal Studies, Taiwan Education Panel Survey Database, Communications Survey Database, National Longitudinal Study of Child Development & Care, and Survey Research Data Archive, etc., which provide researchers multifaceted long-term tracking data, help pass on experience, and have become 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 and boost academic standards in relevant domestic fields, MOST has been supporting the acquisition and installation of functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG) equipment. During 2017, fMRI units had an average use rate of 87%, while the MEG use rate was approximately 32%. To help researchers use these instruments, the instrument service centers plan to give talks at universities to promote the use of MEG, establish a data analysis service team, offer MEG classes, and provide relevant consulting services.

##### (3) High school classic reading camp program

The participants in this camp consisted 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 relied 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 of students' summer vacation. Professional lecturers in various academic fields were hired to teach the basic ideas and concepts of various subjects, and the classes also included field trips and presentation of group results. 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

The 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 2017 to engage in academic interchange activities.

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

These projects are intended to enhance the quality of scholarly books in the humanities and social sciences, ensure that academic books more comprehensively present scholars' research results and perspectives, have greater academic depth and breath, contain both local and international outlooks, and are highly influential in their fields. MOST makes an open call for proposals each year, and provides funding for a maximum of 6 projects. A total of 16 projects received funding from 2013 to 2017. Among the books that have been reviewed and published was *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.

#### (6) ASEAN and Southern Asian Humanities and Social Sciences Research Projects (New Southbound Program)

In conjunction with the government's New Southbound Policy, MOST encourages scholars to engage in academic research with policy implications and establish "human-centered, two-way, diversified" models, which can be used as a reference by government in planning of the New Southbound Policy. A total of 298 funding applications were received after a call for proposals was made in 2017, and funding was approved for 46 projects, which consisted of 34 individual and 4 integrated projects

#### (7) Innovative Emerging Technology Operating Model Program (Flagship Program)

The goal of this plan is to establish cross-system bridges between the humanities and technology and increase the value of technology to the humanities and social sciences. In conjunction with the "Ten Major Innovative Industries Program," local links, and the New Southbound Policy, MOST is providing funding for the establishment of from four to six innovation operation research centers. Funding was provided to 8 projects during 2017, and the following results were achieved:

- 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 have individually organized inter-organizational/departmental cooperative teams to propose new industrial innovation operating models for 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 in the case of the establishment of the "Taiwan Intelligent Manufacturing Innovation Consortium," and establish platforms to bring together potential partners to exploit cross-domain business opportunities.
- c. MOST held various relevant conferences and workshops for industry, academia, and research organizations, including the "Financial Technology and Oversight Sandbox," "Transforming Innovative Communications Networks into Digital Government Solutions," and the "2017 Dechnology Forum."



### (8) Humane Innovation and Social Practice

This program is currently in its second stage (2016-2019), and is being conducted at four schools: Taipei Medical University, National Chi-Nan University, National Cheng Kung University, and National Dong Hua 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 has promoted community-based mixed-age education letting seniors introduce the community to kids at the Taipei Da-an Active Aging Center. The community work crew creating barrier-free spaces at the New Taipei Nuannuan Community gained a clearer understanding of seniors and life situations, which initiated new social relationships and helped realize a sustainable social care system, enabling seniors to lead vigorous lives amidst active social relationships.
- b. National Chi-Nan University conducted in-school food and agriculture education, new rural economics, and concern for ecological conservation in Lancheng Community, Puli, Nantou County. The university also installed PM2.5 particulate sensors developed at the school at over 200 monitoring points throughout Taiwan, and created a monitoring website and smartphone app in order to provide the public real-time knowledge of air quality around their homes. This initiative also encouraged students at National Chi Nan University to think about local issues and how they can do their part to resolve the problem of air pollution.
- c. National Cheng Kung University performed an assessment of "senior-friendly spaces" in Tainan's Yintong Community, and attempted to construct mechanisms needed for continuous care in a different context than the "long-term care 2.0" policy. In Tainan's Dongyuan Community, the university employed a CoLab:D community workshop as a platform allowing university students to participate and practice, and join with local youths in thinking about local development possibilities involving community enterprises.
- d. National Dong Hua University conducted a weaving workshop at Ciyakang Village, Hualien County, and established a platform

for participating youths. This activity brought young people together for the purpose of learning weaving, let young people work in the village, and inspired participants to plan weaving-related publications that could serve as teaching materials in tribal education. The university further helped the "Tastubuqu tu maduq i malas-Bunun tu papatasanan" independent publishing workshop to publish its sixth book: *Becoming Bunun: Childhood and Child-raising among the Bunun*.

### (9) Cooperation between Universities and Local Governments in Promoting Local Cultural Development and Interregional Governance Plans:

This project encourages universities to cooperate with local governments in addressing the cultural development and cross-domain governance problems faced by isolated communities throughout Taiwan from the perspective of humane concern and value innovation. The project had achieved the following preliminary results as of the end of 2017:

- a. A team from National Tsinghua University relied on data collected in the field to understand existing problems affecting Hsinchu's Dongmen Market, integrated the needs of market stall-keepers and local youths, established physical work locations, and held market revitalization activities. The team additionally signed a formal cooperation agreement with Hsinchu city government calling for the team to help Dongmen Market become an innovative entrepreneurship site.
- b. A team from Shih Chien University helped publicize the "Nation Champion" wax apples grown in Jiadong, Pingtung County, and designed a Jiadong corporate identification system giving Jiadong's produce a new symbol and new value.
- c. A team from National United University conducting a landscape narrative survey of Miaoli County negotiated with the county government the preservation of an Agriculture and Food Agency granary that had previously been the subject of a dispute concerning whether it was indeed a historic building; apart from preserving this historic structure, the National United University team also proposed to repurpose the space as a youth entrepreneurship site encouraging young people to start businesses and revitalize Miaoli.

## (10) Cultural Salons

In order to publicize the practical applications of humanities and social science research, and thereby generate greater benefit for society, MOST has held "Cultural Salon" talks in northern, central, southern, and eastern

Taiwan since May 2017. MOST hopes that these crowd-pleasing talks will make known the universal value of research on culture, the arts, and the social sciences. Seven talks have been held to date, attracting a total of over 600 participants.

Research manpower in humanities and social science specific-topic research projects, 2013-2017

Item		2013	2014	2015	2016	2017
Research personnel	Professors	2,025	2,080	2,056	2,051	10,327
	Associate professors	1,915	1,888	1,930	1,801	9,323
	Assistant professors	1,928	1,727	1,584	1,483	8,125
	Lecturers	34	22	16	12	96
	Other	445	433	457	483	2,339
Subtotal		6,347	6,150	6,043	5,830	30,210
Research assistants	Full-time assistants	625	648	648	634	3,158
	Part-time assistants	136	108	113	65	484
	Graduate students	10,381	9,915	9,970	9,237	48,565
Subtotal		11,142	10,671	10,731	9,936	52,207
<b>Total</b>		<b>17,489</b>	<b>16,821</b>	<b>16,774</b>	<b>15,766</b>	<b>82,417</b>

Numbers and percentage of one-and multi-year specific-topic research projects in humanities and social science, 2013-2017

Year	Total projects	One-year projects (%)	Multi-year projects (%)
2013	5,120	2,778 (54.26)	2,342 (45.74)
2014	4,948	2,655 (53.66)	2,293 (46.34)
2015	4,851	2,627 (54.15)	2,224 (45.85)
2016	4,658	2,535 (54.42)	2,123 (45.58)
<b>2017</b>	<b>4,650</b>	<b>2,473 (53.18)</b>	<b>2,177 (46.82)</b>



Numbers of humanities and social science specific-topic research projects and funding, 2017

Units: NT\$1m

Item	Applications		Approved		Implemented	
	Projects	Funding	Projects	Funding	Projects	Funding
Literature/history/philosophy <sup>1</sup>	1,424	1,077.83	737	368.18	970	516.27
Law/political science/sociology/education/psychology <sup>2</sup>	1,669	2,271.11	762	505.31	1,107	766.41
Economics/management research: including economics, management, finance, and accounting <sup>3</sup>	2,064	1,820.86	1,001	613.39	1,250	816.01
Mass communication, regional studies & geography, gender studies, and religion	729	690.62	304	172.30	385	234.00
Digital humanities	158	342.09	39	21.02	87	61.64
Taiwan's development within a global framework	121	246.27	25	13.76	78	45.95
Information and innovation management	371	360.98	156	94.76	223	146.32
Research on indigenous peoples' development	117	215.43	71	41.57	83	49.68
ASEAN and South Asia humanities and social sciences research	298	594.89	46	23.70	46	23.70
Art, physical education, library science	717	778.61	319	191.61	381	238.21
Other <sup>4</sup>	80	590.02	30	56.38	40	70.27
<b>Total</b>	<b>7,748</b>	<b>8,988.71</b>	<b>3,490</b>	<b>2,101.98</b>	<b>4,650</b>	<b>2,968.46</b>

<sup>1</sup>Includes literature of China and Taiwan, Hakka literature, indigenous literature, foreign literature, philosophy, linguistics, history, anthropology, and ethnic studies.

<sup>2</sup>Includes education, psychology, law, political science, sociology, and cognitive science & brain imaging research.

<sup>3</sup>Includes economics, management, finance, and accounting.

<sup>4</sup>Includes cultural research, flagship projects in the humanities and social sciences, Projects for Books Writing in the Field of Humanities and Social Sciences, and emerging technology operating model projects.

## 5. Science Education

Science education research includes the fields of mathematics education, science education (including multiethnic science education); information education; applied science education; medical education; technology, society & mass communications; and science education practice, and MOST also plans goal-oriented projects in key areas. Research in this field seeks to achieve the goals of enhancing the academic standards of science education, boosting the effectiveness of science education instruction and learning, realizing research-based science education practice, and training future scientific and technical manpower. The following were among some of the most significant research results of 2017:

### (1) "Online assessment of collaborative problem solving: Use of AutoTutor and ECD"

This research project developed an online collaborative problem-solving assessment system in accordance with the 2015 Programme for International Student Assessment's (PISA) collaborative problem solving assessment framework. In this system, students collaboratively perform problem-solving activities involving different topics or types of role playing with one or more computer agents, employing summary (employed by PISA 2015) and open (students input dialogue) human-machine dialogue methods. Natural language processing and artificial intelligence technology allow automatic analysis and dialogue, and enable better assessment of complex skills and aptitudes than traditional pen and paper or computer examinations. The system's different assessment units reveal students' collaboration

and problem-solving abilities through the use of computer partners with different attitudes (such as highly and poorly cooperative attitudes) or by letting students play different roles. The assessment units for mathematics, science, reading, and life skills developed in this project are suitable for upper-grade elementary school, junior high school, and high school students. The system developed in this project will be employed in conjunction with a large Ministry of Education extension project, and will be used by over 100,000 students at more than 400 schools. The system will be combined with the Ministry of Education's personalized teaching qualifications and assistance platform (adaptive learning website), and the fact that it involves the use MOST's R&D results in Ministry of Education extension project makes it a good example of interagency cooperation. The project's results have received international attention, and the project team was invited to jointly present a paper with PISA 2015 collaborative problem-solving assessment chairperson Dr. Arthur Graesser. The team was further invited to give talks in China, Hong Kong, Malaysia, and Indonesia about their collaborative problem-solving assessment results.

(2) Integrated project: "Use of a real-time scaffolding-based e-learning platform to help university students learn important learning strategies in complex problem situations: Learning strategies and cognitive load, development of assessment tools, and learning environment development and assessment"

This e-learning platform trains learners apply a wide range of learning strategies when solving complex problems. But although this is a key lifelong learning skill in the digital age, little international research had systematically explored this topic. This three-year integrated project (which includes four subprojects) has taken the social science issue of nuclear energy as a learning topic, and has developed e-learning platforms for investigation of this issue. Important results obtained by the project include: (1) the successful development of four learning platforms (including a computer-aided virtual learning, online information exploration learning, cooperative, argumentation-based learning, and learning through games) and e-learning content; (2) discovery and verification of learners' learning strategies on the various platforms, and development of relevant theory; (3) development of teaching strategies and verification of their effectiveness; (4) development of several assessment tools with good reliability and validity; and (5) development of a scaffolding-

assisted learning environment based on eye tracking technology, learning process analysis tools, and a theoretical framework. The results of this integrated project can effectively help learners to develop various learning strategies through practice and eye-tracking scaffolding, while giving them an understanding of nuclear energy concepts and operating situations, and encouraging them to ponder the impact of nuclear energy on society, the economy, and ecology.

(3) "Exploring a Mechanism of Web-Based Scientific Explanation Evaluation and Self-Regulated Learning Using Eye Tracking Techniques"

This project investigated effective scaffolding design principles as part of the development of a scientific explanation assessment scaffold. This can help citizens evaluate scientific evidence and correctly judge the quality of commonly-seen arguments. The project also examined the possible applications of eye tracking technology in the study of self-regulated learning, and looked into its limitations.

This project, which includes four subprojects, has yielded the following chief findings: (1) A comparison of self-reported thinking aloud and the self-reported results of eye tracking prompts found that eye-tracking technology can be applied to science education research situations, and can provide extensive cognitive and meta-cognitive data on learning strategies. (2) Learners' high and low levels of preconceptions will not only affect the allocation of interaction during the assessment process, but are also associated with differences in eye movement behavior and cognitive or meta-cognitive frequency linkage models, which can reflect the dynamics and complex details of the self-regulated learning process; (3) Use of the general principles contained within scientific explanations as assessment standards cannot effectively change learners' allocation of attention, and therefore fails to improve assessment performance. The evidence indicates that, apart from the additional inclusion of topic differentiating prompts, effective assessment standards must also be accompanied by explanation in the form of comprehensive narrative examples if they are to help learners understand the main content of assessment standards, which can effectively reduce assessment bias and enhance assessment performance. Beyond locating the difficulties encountered by learners



when attempting to understand and use assessment scaffolds, this project also proposed scaffold design principles that can improve the effectiveness of existing scaffolds, and provided recommendations concerning the teaching of assessment and the design of standards.

(4) "Developing an Affective Feedback-Centered E-Book Environment for Achieving a Creative Classroom in Vocational Practical Courses"

In the face of international competition in this age of globalization, industry has found that the creation and use of a distinctive brand to add value to products is a prime means of survival. The world's best-known brands, including Google, Apple, Microsoft, HTC, and Samsung, all have their own brand features and distinctive product design concepts. This suggests that apart from imparting professional knowledge and skills, vocational practical courses at universities and colleges must also incorporate training in innovation and creative thinking. This project seeks to use affective elements in educational applications for vocational practical courses, and has been developing in-class assistive interfaces and affection identification mechanisms for an affective feedback-centered e-book system. This work has included the collection of data concerning learners' learning processes and affective process when using the e-book system, and the project has used affective feedback in a practical course to help learners to acquire practical and design concepts through the three aspects of cognition, feelings, and skills. The project has further attempted to use affective techniques to put learners into an active, positive state as a means of enhancing their learning. This project's multinational research team includes members affiliated with National Cheng Kung University, University of North Texas, and East China Normal University; the project is using electroencephalography and virtual reality product creativity systems and performing experiments to understand the interactions between creative behavior, learners' brain wave status, and creativity. The goal of the project as a whole is to use affective aspects to realize the "creative classroom" concept in vocational practical courses, and use the information gained in this way to guide the design of future courses emphasizing creative thinking.

(5) "New Immigrant Schoolchildren's Domain-specific and Domain Generality Creative Performance and its Psychological Mechanisms: Use of Racial Growth Belief, Cultural Distance, and Multicultural Creative Instruction as Moderating and Mediating Variables"

Past research has shown many times that new immigrant children face academic performance and school adaptation difficulties. However, the researchers in this project recently discovered that new immigrant children also demonstrate excellent creative performance, which is attributable to the "Medici effect" that occurs when different cultures intersect. The psychological mechanisms that underlie this phenomenon still require investigation, however. This project created a Chinese version "racial essentialism/growth belief scale" that possesses excellent reliability and validity and is suitable for use with adolescents in Taiwan, and discovered that new immigrants have relatively high levels of belief in racial growth. The project also found that when controlling for background variables, new immigrant children's racial growth belief and originality scores were higher than those of other students, and further discovered that new immigrant children's advantage in originality is mediated by racial growth belief, extroversion, and cognitive closure. The study performed intervention with a six-week class that incorporated multicultural instruction, and discovered that the class could not only help the students to cultivate more open racial beliefs and information processing models, but also effectively fostered better creative performance and achieved better mathematics results. This project was the first study in Taiwan to discover the superior creative performance of new immigrant students, and also the first systematic investigation of related mechanisms and teaching aptitude strategies. When put into practice, the results of this project can make an important contribution to dispelling the stereotyped impression people have of new immigrants and encourage the development of teaching strategies and learning environments that will benefit new immigrants. Academically, this study was the first worldwide to verify the linkage between multicultural identity and creativity, and the principal investigator has already published the study's results in at least 7 papers listed in SSCI (*Social Science Citation Index*). In addition, the project's findings have attracted favorable international attention, and are the sole research results from Chinese scholars to be included in the 2017 *Cambridge Handbook of Creativity and Personality Research*.

(6) "Integration of the Medical Care and Social Systems to Establish a More Effective Teaching and Assessment Methods for a Community Living End-of-Life Care Model"

In recent years, numerous reports have remarked on the growing community end-of-life care trend, and promotion of this trend is currently an important task for the medical system. This project used an e-learning platform in conjunction with auxiliary teaching materials and TC-OSCE (Team-based Compassion OSCE) teaching strategies and assessment approaches to train clinical interns, resident physicians, and community primary-level physician in community life end-of-life care skills, so that they can provide patients in the community with convenient, humane residential end-of-life care. This project has achieved the following objectives over a three-year period: (1) The project team has developed teaching materials and diversified teaching strategies suitable for communities and addressing the six major issues in community end-of-life care in an effort to boost the core end-of-life care skills of medical school students and medical personnel. (2) The TC-OSCE-based teaching strategies developed by the research team have also been converted into an assessment tool suitable for community learning. (3) In order to boost the practical care and teaching abilities of community teams, the project conducted a survey of the continuing education needs of community medical personnel, and will use the resulting information to design classes. (4) The research team is providing a teaching plan for the "community living end-of-life care model" developed in the project to educational and practical units for their reference, and it is also serving as a reference for the government's promotion of an "aging in place, end of life at home" policy.

(7) "Climate Change Adaptation Risk Communication: From Communication Education and Life Practice to Social Innovation Future Communication Workers' Awareness of Climate Change Adaptation, Practice, and Risk Communication Effectiveness"

This project addressed empowerment of future communications workers, who will play an important mediating role between experts and ordinary citizens, from the perspective of communications professional education, and examined the feasibility of improving communications workers' ability to present issues

connected with climate change adaptation. The first part of this project conducted an online questionnaire survey of master's students at 20 graduate schools at 21 universities and higher-year-level undergraduate students at 26 universities (obtaining 875 valid questionnaires) to assess the students' awareness of, attitude toward, practice, and assessment of current media methods of representing climate change-related issues. The second part of the project designed and compared university and graduate school-level environmental communication course teaching content and activities on the basis of the results of the online survey, and compiled principles for the representative of information concerning topics connected with climate change adaptation. This study selected the undergraduate course "Environmental changes and mass communications" (a newly-offered course) and the graduate-level course "Communication of environmental and health hazards" to test the teaching design and intervention methods developed in the project. Assessment employing a qualitative pretest/posttest revealed: (1) The undergraduate course had a more evident intervention effect than the graduate course, and the fact that the course fully addressed environmental and climate change issues allowed the design of diverse activities. (2) While the graduate students originally had a greater awareness and knowledge of relevant issues than the undergraduate students, because they had reached the saturation point, the posttest did not reveal any statistically significant change, and the effectiveness of the intervention was limited. The project also provided reference recommendations concerning relevant future research and practical intervention.

(8) "Development of an Integrated e-Learning Diagnostic Assessment and Feedback App System"

Although e-learning has developed quickly, there has been insufficient work on educational apps focusing on the diagnostic assessment of learning. In order to ensure that e-learning and assessment are more personalized, and promote optimal learning effectiveness, this project developed a learning diagnosis app (Kezhidou app) that can be used on various types of device and perform real-time feedback, and an integrated competitive assessment app (Dou Runway App). These apps' assessment feedback functions can be used in conjunction with the interactive e-book e-learning media



developed in this project to help users learn scientific concepts and thinking skills, and achieve learning through assessment and precision assistance.

Trial use revealed that the error record and error feedback functions of the system developed in this project (Kezhidou app and Dou Runway app) can help students effectively learn correct concepts and improve their thinking skills. After large-scale extension, the system has received excellent feedback from users.

The major results of this project have included: (1) The project established a feedback examination question database with learning content and learning performance assessment dimensions consistent with those of the 12-year national education system. The project also completed seven fourth grade units, nine fifth grade units, and four sixth grade units that are consistent with the those grades' curriculum outlines, as well as approximately

1,500 examination questions with assessment feedback. (2) The research team completed 16 topical units (78 e-books) of interactive e-book e-learning media, which can be combined with a learning diagnosis app providing real-time feedback to create an integrated learning and diagnostic assessment framework. This integrated app system and learning framework combining diagnosis, assessment, feedback, and learning functions can provide flexible, personalized instructional methods enabling learners to understand their study status and promoting more effective learning.

### B. National Science and Technology Program-Energy

The second stage of the National Science and Technology Program-Energy is being jointly implemented by the Ministry of Economic Affairs, MOST, Ministry of Transportation and Communications, and Atomic Energy Council. Implementation began in 2014; the goals of this stage include:

Research manpower in science education specific-topic research projects, 2013-2017

Item		2013	2014	2015	2016	2017
Research personnel	Professors	773	788	844	807	3,955
	Associate professors	570	589	611	616	2,952
	Assistant professors	448	467	498	458	2,239
	Lecturers	–	21	39	39	128
	Other	149	174	236	270	1,089
Subtotal		1,940	2,039	2,228	2,190	10,363
Research assistants	Full-time assistants	378	414	385	384	1,903
	Part-time assistants	236	312	315	297	1,332
	Graduate students	2,211	2,278	2,233	2,066	10,549
Subtotal		2,825	3,004	2,933	2,747	13,784
<b>Total</b>		<b>4,765</b>	<b>5,043</b>	<b>5,161</b>	<b>4,937</b>	<b>24,147</b>

Numbers and percentage of one- and multi-year specific-topic research projects in science education, 2013-2017

Year	Total projects	One-year projects (%)	Multi-year projects (%)
2013	850	378 (44.47)	472 (55.53)
2014	905	377 (41.66)	528 (58.34)
2015	969	419 (43.24)	550 (56.76)
2016	827	276 (33.37)	551 (66.63)
<b>2017</b>	<b>864</b>	<b>317 (36.69)</b>	<b>547 (63.31)</b>

Numbers of science education specific-topic research projects and funding, 2017

Units: NT\$1 m

Item	Applications		Approved		Implemented	
	Projects	Funding	Projects	Funding	Projects	Funding
Science education	91	380.87	38	29.98	71	68.28
Mathematics education	79	137.67	44	32.13	72	60.83
Information education	185	407.16	90	65.56	160	146.91
Applied science education	186	292.85	86	61.38	138	111.51
Medical education	163	379.52	79	55.42	112	87.22
Indigenous projects	43	159.59	21	17.36	21	17.36
Diversity science education	27	56.34	14	9.94	21	17.65
Gender and science research	57	65.94	10	7.90	11	8.62
Science education practice, technology, society & communications	128	223.23	66	48.64	104	84.63
Popular science activities, popular science communications, industry-academic projects, and public science education	279	792.53	111	207.87	139	244.02
Mission-oriented projects, cutting-edge international research centers	29	319.91	10	66.82	10	66.81
	6	65.08	2	2.53	5	12.11
<b>Other<sup>1</sup></b>	<b>1,273</b>	<b>3,280.69</b>	<b>571</b>	<b>605.53</b>	<b>864</b>	<b>925.95</b>

<sup>1</sup>Includes practical research projects, cutting-edge technology workshops, Taiwan e-Learning and Digital Archives Program, and journal planning

- (1) enhancement of energy efficiency and reduction in dependence on imported energy sources.
- (2) increased international competitiveness of alternative energy industries.
- (3) development of a smart grid technology industry and assisting with the establishment of smart grid systems in Taiwan.
- (4) development of an offshore wind power and marine energy industry and strengthening of offshore wind power development.
- (5) development of clean geothermal energy.
- (6) exploration of gas hydrates.
- (7) establishment of a carbon dioxide capture, storage, and utilization (CCSU) and new combustion system industry.

Apart from basic research on energy, this stage of the program also emphasizes the energy industry's development, such as via the verification of the possibility 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\$1.86 billion, and the licensed technologies were derived from such projects as "Offshore Wind Turbine Stability Risk Assessment Procedures and Quantitative Analysis Technology," "Development of an Integrated Energy Management Interface System for Drying Processes," "Metal Supported Solid Oxide Fuel Cell Production Technology," and "Micro-Grid Power Control Technology: Three-Phase Power Converter Control Design." Furthermore, the program induced companies to invest more than NT\$3.2 billion in relevant energy technology R&D and more than NT\$4.1 billion in production, which has facilitated the upgrading and transformation of the domestic energy industry. The following results were achieved in 2017:



## 1. Energy creation

- (1) Solar energy: Establishment of perovskite mass production materials processes; first ever use of hot casting in an atmospheric environment to produce calcium/titanium solar cells with 16.4% efficiency on a mass production scale via a Cs(FAMA)Pb(I1-xBrx)3 process.
- (2) Biomass energy: Development of poly lactic acid biomass technology, and planning of a fiber poly lactic acid plant next to a plywood plant in Malaysia in conjunction with the New Southbound Policy; this plant will use excess wood chips from the plywood plant as raw materials, and the poly lactic acid plant will serve as an overseas demonstration site for biomass refining technology that can be used in Taiwan.
- (3) Offshore wind energy: MOST helped Swancor Ind. Co., Ltd. complete two 4MW demonstration wind turbines and begin commercial operation. On average, the wind turbines can supply enough power to meet the everyday needs of 8,000 small households, which can reduce CO<sub>2</sub> emissions by the equivalent of 40 times the CO<sub>2</sub> absorbed by Taipei's Da-an Forest Park each year.
- (4) Marine energy: Development of key technology for a floating generating unit in the Kuroshio current; this unit can capture the current's kinetic energy in a deep-water open ocean environment. A 1/25 scale FKT model tank experiment has been completed, an industrial/academic collaborative project established with the CSBC Corp., and NT\$3 million in investment obtained.
- (5) Geothermal energy: Geothermal energy potential testing was performed at Sikuangziping, Jinshan, where the No. 1 well reached a depth of 1,304 meters and found a maximum temperature of 134°C. An acid corrosion-resistant alloy cladding technology was developed to prevent corrosion from hot acidic liquid with a pH of 2.5-2.9.

## 2. Energy conservation

- (1) Energy conservation by Science Park firms: 1,000 variable-frequency DC ceiling and roof fans were mass produced using a newly-developed DC variable-speed fan design, and the cooperating firm provided investment of NT\$100 million. If these

fans are used ubiquitously, they can save approximately 60MWh, equivalent to NT\$202 million, annually.

- (2) Industrial energy conservation: Development of low-temperature thermal energy turbine ORC power generation technology, establishment of a 125kW turbine ORC generating system at the Cheng Loong Company, and establishment of a 200kW screw-type ORC exhaust heat recovery system at the China Steel Company; the two generating systems have a combined capacity of 2,140MW, and can reduce CO<sub>2</sub> emissions by approximately 1,133 tons annually.
- (3) Transportation energy conservation: Development of key modules for energy-conserving electric vehicles, and shipment of commercial electric vehicles by the end of 2017; MOST promotion of the establishment of the eTreeto Company.

## 3. Energy storage

Development of STOBA safe material technology and assistance to Amita Technologies in adapting its lithium battery, which has been certified and adopted by China Motor for use in electric motorcycles. A 10Ah high-safety STOBA-encased battery is being used in China Motor's EM series of electric motorcycles, and over 10,000 batteries have been shipped to date.

## 4. Systems integration

- (1) Smart grid: Taiwan's first renewable energy micro-grid system was established on Dongji island and successfully began commercial operation. As of the end of November 2017, the system had generated 65,668kWh for the grid using its solar energy and energy storage systems, and is estimated to have saved NT\$1.3 million in diesel generating costs. It is projected that the system can save 330,000 liters of fuel oil and reduce CO<sub>2</sub> emissions by roughly 58 tons each year.
- (2) Low carbon system: Researchers developed a "Tubular Membrane Gas/Gel Modification Technology for Carbon Oxide Capture," and the patent for this technology won a gold medal at the 2017 Pittsburgh INPEX. The project team also licensed its "Functional Tubular Inorganic Membrane Technology" to the startup ExtreMem Ind. Co., which will use it for waste gas treatment, carbon capture, and carbon conversion.

## Major achievements of the National Science and Technology Program-Energy, 2017

Category	Item	Total
Academic papers	Conference papers	868
	Journal papers	446
Manpower training	Ph.D. students	194
	M.S. students	748
Patents	Received	308
	Pending	319
Technology licensing	Cases	269
	Licensing fees (NT\$1,000)	212,901
	Royalties (NT\$1,000)	26,321
	Signing fees (NT\$1,000)	305,104
Promotion of corporate investment	Cases	245
	R&D (NT\$1,000)	3,374,327
	Production (NT\$1,000)	12,561,094
Startups	Companies	3
Employment	Persons	798

### 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 experimental facilities, and also completed construction of the 3.0 GeV Taiwan Photon Source (TPS) synchrotron accelerator, which is now in stable operation. NSRRC is currently involved in beamline experimental facility development and operation work, and looks forward to providing users nationwide powerful new research tools supporting advanced scientific and applications research. NSRRC is also continuing to promote research on forward-looking topics in the fields of biomedicine, nanotechnology, and green energy, train scientific and technological talent, encourage international cooperation, and strengthen industry's R&D capabilities. In addition, NSRRC has taken on operating and maintain 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 facility

The TLS and TPS accelerator light sources have continued to operate stably 24 hours a day. The accelerators had had operating times of 6,351 hours (TLS) and 6,193 hours (TPS) during 2017, and had an electron beam stability index ( $\Delta I_0/I_0$ , beam strength fluctuation ratio) of less than 0.2% for 99.8% (TLS) and 99.4% (TPS) of times when in use by users. Throughout the year, NSRRC continued to perform maintenance of the accelerators' power supply, beam power, high-frequency, instrumental control, magnet, vacuum, and precision mechanical subsystems and light source-related facilities, optimize the integration of subsystems, and provide domestic and foreign light source users with continuous, long-term, high-quality synchrotron radiation.

#### 2. Beamline experimental facilities

Beamlines made available by NSRRC include the infrared, UV, soft X-ray, and hard X-ray spectral ranges. 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, to make full use of the newly-completed (September 2016) TPS's outstanding performance, NSRRC



began opening the first phase of experimental facilities to users by the end of 2017; these have included protein crystallography (TPS 05A), temporally coherent X-ray spectroscopy (TPS 09A), X-ray nanometer diffraction (TPS 21A), X-ray nanoprobe experiments (TPS 23A), and coherent X-ray scattering (TPS 25A) experimental facilities, and are being used in advanced scientific research in such fields as natural science, biomedicine, and nanotechnology. Plans call for TPS to have 25 beamline experimental facilities, which will be constructed in three phases. The 7 phase-one facilities were completed in 2017, and construction of the 9 phase-two beamline facilities is currently getting underway.

### 3. User extension and scientific research

A total of 1,845 research projects (12,124 person-times) used NSRRC's light sources for cutting-edge experiments during 2017, and these projects involved a cumulative total of 54 domestic and 95 foreign organizations. The scope of these projects encompassed atomic and molecular science, condensed state physics, materials science, soft materials, biological structures, nanometer fabrication, and industrial applications. As of the end of the year, users had published a total of 333 SCI-cited papers in prominent international scientific journals, including 142 papers published in prestigious journals with impact factors in the top 10%, and 103 papers published in journals with impact factors in the top 5%. Notable papers included "Light of Taiwan: The World's Most Advanced Near Infrared Light-emitting Materials and Elements," which used TLS' small-angle X-ray scattering experiment station (experiment stations 23A1) and was published in *Nature Photonics*; "A High-efficiency Electrochemical Hydrogen Evolution Catalyst—Composition and Structure of P-doped Mo<sub>2</sub>C in Carbon Nanowires and Electron Regulation," which used an X-ray absorption spectrum experiment station, soft X-ray absorption experiment station, and soft X-ray absorption spectrum experiment station (experiment stations 01C1, 20A1, and 16A1) and was published in *Energy & Environmental Science*; "Use of Chromomycin and Nickel Metal Dimer to Diagnose Fragile X Syndrome Via an Induced-fit Model," which used protein crystallography experiment and biomedical protein crystallography experiment stations (experiment stations 13B1, 13C1, and 15A1) and was published in *Angewandte Chemie International Edition*; "Silicon Microwire Arrays Modified with Amorphous Heterometal-doped

Molybdenum Sulfide for Water Photoelectrolysis and Hydrogen Production," which used an X-ray absorption spectrum experiment station and X-ray absorption spectrum experiment station (experiment stations 01C1 and 17C1) and was published in *Nano Energy*; and "A Natural Preservative Preserving Dinosaur Collagen for 195 Million Years," which used an infrared microspectroscopy experiment station (experiment station 14A1) 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 2017 user conference featured National Chiao Tung University's President Chang Mao-chung as keynote speaker, and featured the four seminars Synchrotron Applications for Industries, High Flux Small-Angle X-ray Scattering on Biological Complex Structures, High Resolution X-ray Spectroscopy of Quantum Materials, and TPS & Complementary Methods for Emerging Materials, which gave the participants opportunities for sharing the most recent research progress in relevant fields. Furthermore, NSRRC also held several synchrotron light source conferences and activities, including the RadSynch17 international conference, Taiwan-Japan medical imaging conference, high-resolution soft X-ray detector conference, scientific consulting committee conference, 35<sup>th</sup> Conference on Spectroscopy and Surface Science, Conference on Establishment of Structural Biology Network in Asia and Oceania, Workshop on Data Collection and Analysis of X-ray Nanodiffraction, a conference on the spectroscopy of energy materials. NSRRC further held popular science activities such as the "Tour of the Universe" and "Culture, Art, and Paleontology," as well as open houses, in conjunction with MOST's Future Tech activity.

### 4. Collaboration with industry

Apart from providing scientific research service, NSRRC also strives to promote the industrial applications of synchrotron radiation and help industry resolve problems. In 2017, in addition to successfully continuing to deepen ties with key semiconductor industries, NSRRC laid plans to meet industry's needs by increasing the time beamlines available for industrial applications can be used for industry research. This year, NSRRC was quite

successful at promoting use of beamlines by the plastics industry; apart from signing a five-year cooperative project contract concerning the R&D of high-value ultra-high strength fibers with a company in Taiwan, NSRRC also performed commissioned research helping companies develop 3C applications for graphitized plastic projects. During the year, NSRRC extended a microspectrometer startup project involving synchrotron radiation to a 4<sup>th</sup> year, and completed pre-commercialization display of functions; NSRRC licensed technology to the startup at the end of 2017, which plans to begin commercial production within two years. In addition, NSRRC also vigorously promoted its technical services among the domestic and foreign biopharmaceutical industries, and successfully induced a Japanese pharmaceutical company and Taiwanese new drug company to use a beamline at TPS for structural analysis of large molecular drugs.

#### **5. Manpower training**

Apart from helping train synchrotron radiation talent by teaming up 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 also occasionally held training classes on light source technology and applications. NSRRC hopes that the integration and practice of light source knowledge and experimental technology will create even more talented synchrotron radiation researchers. Beyond this, NSRRC held several synchrotron light source-related classes in 2017, including advanced light source summer science internships, an 8<sup>th</sup> X-ray science summer school, a winter class on free electron lasers, a protein crystallography training class, an X-ray absorption spectra data analysis workshop, a high-resolution powder diffraction structural calculation training class, and synchrotron accelerator application and practice summer classes.

#### **6. New light source facilities and prospects**

With regard to the first phase of TPS experimental facilities, the X-ray nanoprobe (TPS 23A) has already passed on-site safety interlocking system testing and trial operation, and has successfully sent radiation to an experiment station, which has acquired Cu K-edge absorption spectra under the X-ray Absorption Near Edge Spectra (XANES) project;

the X-ray nanoprobe beamline was opened to users at the end of 2017. The resonant soft X-ray scattering (TPS 41A) and submicron soft X-ray spectrum (TPS 45A) beamlines completed grating spectroscopy installation and trial operation, and are currently undergoing experiment station optical element adjustment, parameter optimization, and spectrum measurement. As a consequence, the first phase of experimental facility construction at TPS has been fully completed, and trial operation is now underway. As for the second phase of experimental facilities at TPS, the soft X-ray tomography beamline (TPS 24A) has begun trial operation after passing on-site safety interlocking system testing and completing core optical mirror surface measurement and mechanism installation. This will be the first operating beamline in the second phase of experimental facilities at TPS, and the construction of other experimental facilities is gotten underway.

Responding to the government's green energy policy, NSRRC has implemented a rooftop solar power generating project, and installed solar panels on the roofs of buildings, which has also beautified the roofs and saved air conditioning costs by blocking sunlight. The first and second stages of installation work had been completed by December 2017, and power output has reached as high as 1.1 MW. The system can produce 1.15 million kWh annually, which is approximately one-fifth of the city of Hsinchu's total solar power output, and is enough to meet the power needs of over 300 households. The system is also Hsinchu's largest solar generating facility. NSRRC is not only Taiwan's largest interdisciplinary common research platform, but also has the largest solar generating system of any synchrotron light source in the world. At a time when the Ministry of Economic Affairs is promoting the "Million Rooftop PVs Program," we hope that NSRRC's example can induce other units to install green energy facilities.

#### **D. Research Results of the National Applied Research Laboratories**

Since it was established in 2003, the National Applied Research Laboratories (NARLabs) has relied on the development of R&D platforms to support academic research, promote forward-looking technologies, and train scientific and technological manpower. Because 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 undertake



on its own, NARLabs is better able to provide academic researchers needed S&T research services, and enable research personnel at universities and research organizations to use the superior, high-accuracy, high-efficiency instruments, facilities, and software modeling and analytical systems needed to develop forward-looking applied technologies.

Furthermore, in order to enhance the effectiveness and industrialization value of S&T innovations, NARLabs has been actively promoting the application of R&D results. This takes the form of uncovering potential industry needs, and connecting industry with academic

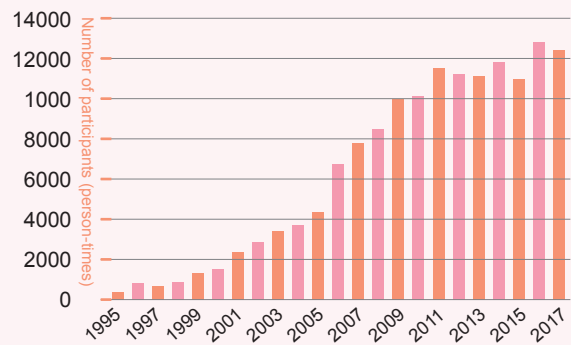
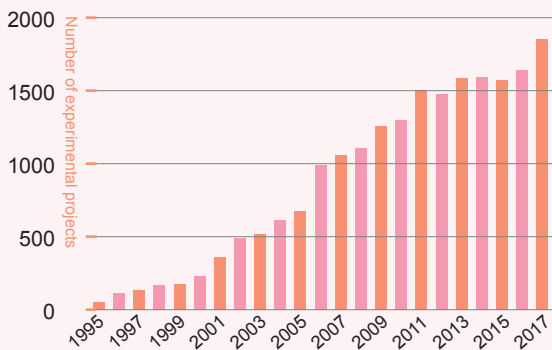


The Synchrotron Radiation Research Center has installed solar panels on the roofs of its buildings; in addition to generating power, this has also beautified the roofs and saved air conditioning costs by blocking sunlight.

research units, which serves to boost industrial competitiveness. NARLabs also employs market analysis to harness the R&D capabilities of industry, academia, and research organizations in order to create key intellectual property portfolios and translate forward-looking R&D results into innovative industrial applications. NARLabs' 2017 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) The Formosat-5 satellite was launched successfully on August 25, 2017. After completing orbital testing and verification, the satellite succeeded in acquiring images from space and scientific data, and it will formally begin operation keeping an eye on Taiwan and the world during 2018. The launch date of the Formosat-7 satellite is scheduled for 2018; after this satellite has been deployed, it will be able to provide weather observation data for the broad band between 50° north and south latitude. This satellite will transmit 3-4 times the data of the Formosat-5 satellite, sharply increase the amount of weather data for low latitude areas, including Taiwan, and will improve weather forecasting accuracy and typhoon tracking and rainfall prediction.



Beamline experiments and user person-times statistics, 1995-2017

(2) The National Center for Research on Earthquake Engineering's southern Taiwan experimental facility was inaugurated on August 9, 2017. This facility is simulating and analyzing near-fault earthquakes, which will speed up the development of

earthquake-resistance assessment and reinforcing techniques for medium-height and high-rise buildings, and help to improve the earthquake resistance of older buildings, which will usher Taiwan into a new era of earthquake damage-mitigation technology.

- (3) The new 2,629-ton research vessel "Legend" was completed on December 31, 2017; plans call for it to be formally inaugurated in May 2018 and begin formal operation in September, after a maiden scientific voyage. In the future, the vessel will bear responsibility for major far-seas exploratory research missions lasting long periods of time. The Taiwan Ocean Radar Observing System (TOROS) established a monitoring station at Fangliao, which filled a blind spot in maritime observation coverage to the southwest of Taiwan. The TOROS system is demonstrating the practical value of technology to marine search & rescue.
- (4) An unmanned aerosonde successfully performed observation within the storm circle of Typhoon Hato, and collected data on the typhoon's air pressure, temperature, humidity, wind direction, wind speed, and sea temperature, which enabled the Central Weather Bureau, MOTC to better judge the strength and magnitude of the typhoon. A radar data assimilation and shallow landslide modeling project developed localized look-ahead real-time landslide early warning technology, which can enhance ability to assess whether heavy rainfall will induce a landslide or mudslide.

## **2. Information and communications technology**

- (1) Taiwan's first petascale high-performance computer will serve as a basis for big data and artificial intelligence research, and will accelerate the development of value by industry. An interagency project developed a virtual/physical humanities technology platform, created Taiwan's first integrated virtual/physical industrial technology testing platform and completed system testing, and cultivated the talent with "T-shaped skills" able to support the creation of value.
- (2) A project completed development of asthma testing, daily muscles movement, and indoor air quality sensor elements, and conducted the vertical integration of self-developed Internet of Things industry chain sensors; plans call for the future mass production of relevant sensor elements and modules, which will enable sensor module technology to take root and thrive in Taiwan.
- (3) A recently-developed compact "multiple gas sensing system" allows users to obtain air

quality information in real-time using their smartphones, and can ensure safety by enabling the detection of abnormalities in the environment at any time or place. With its array of highly portable mobile sensors, the new-generation "MorSensor Lite" puts the goal of "smart living" within reach.

- (4) A three-axis acceleration sensing system chip can be used in the development of wearable, Internet of Things, and smart machinery applications. Newly-developed key technology for high-power semiconductor chips will help industry, academia, and research organizations to develop high-power elements and verify the quality of epitaxial wafers.

## **3. Biomedical technology platforms**

- (1) The Biomedical Industry Innovation Promotion Project Implementation Center established by NARLabs in the Hsinchu Biomedical Science Park chiefly serves as a means of linking the resources and capabilities of industry, universities, medical institutions, and research organizations for the purpose of increasing employment, cultivating flagship companies, and boosting innovation in Taiwan's biomedical industry.
- (2) The "Tumor Animal Model and Drug Testing Platform" enables the use of humanized mice immunity models to create cancer research platforms, and offers transplantation of tumors originally taken from cancer patients, which will support the development of precision medicine in Taiwan.
- (3) Newly-developed "all-gene modification technology" uses complete gene promoters to perform genetic modification and produce GM mice with the cells in various types of tissues expressing fluorescent proteins. This technique results in brighter fluorescence and a wider range of tissues expressing the protein. Relevant technologies can help industry, academia, and research organizations develop more advanced animal models.

## **4. S&T policy**

- (1) NARLabs helped MOST to draft the "National AI Research Strategy" and "Artificial Intelligence Promotion Strategy," which seek to create AI innovation ecosystems based on human resources, technology, locales, and the industry's



structure, transform Taiwan into an AI development stronghold, and encourage the development of emerging industrial applications of AI.

- (2) In conjunction with government policy, NARLabs has been supporting MOST's efforts to promote and implement international scientific research cooperation under the New Southbound Policy, has drafted an integrated promotional strategy, and helped to establish six overseas science and technology innovation centers tasked with broadening cooperative scientific research and promoting technological talent recruiting and interchange.
- (3) NARLabs has helped with the implementation of numerous key policy programs, including the "From IP to IPO" (FITI) program, "STB Medical Device Product Design Specialist Training," "SPARK Taiwan: Biomedical Translation Value-added Manpower Training," "Learn-Explore-Aspire- Pioneer (LEAP Program)," "Leaders in Future Trend (LIFT)," "X Venture Project," "BioMed Talent Training Program," and "Formosa Speech Grand Challenge," which have reinforced the training and recruiting of innovative manpower and laid foundations for the development of emerging industries.
- (4) NARLabs helped the Board of Science & Technology, Executive Yuan to establish the "S&T Project Appraisal Experts' Room," which has significantly strengthened the initial selection, mid-course management, and post-completion assessment of S&T projects, and enhanced the S&T budget's value to industry and society via an institutional approach.

The following is an overview of major R&D results at each center in 2017:

### 1. Chip Implementation Center

#### (1) Encryption process application and use service

The Chip Implementation Center (CIC) has provided encryption process application and use service since January 2017, and currently provides 90nm CMOS, 0.18 CMOS, 0.18

SiGe, and 0.35 CMOS encryption process design environments. CIC uses electronic design automation (EDA) software to obtain highly-confidential encryption process data ensuring that users can perform circuit design, simulation, and testing in a highly-secure

computing environment, and can use special and self-developed design processes and tools with greater peace of mind. This service will dramatically increase users' design efficiency and convenience.

#### (2) Multiple gas sensing system

Responding to the In light of the growing public attention to the health hazards of air pollution, CIC has used the "MorSensor" wireless sensing building blocks hardware and software to develop a compact "multiple gas sensing system," which includes built-in carbon monoxide, carbon dioxide, formaldehyde, and particulate matter sensing systems. Thanks to this system's WiFi communications capability and cloud service functions, users can use a smartphone app to obtain air quality information in real-time, browse historical data, detect abnormalities at any time or place, and protect their lives and safety.

#### Multiple gas sensor system and mobile phone app screen



#### (3) MorSensor Lite

In order to provide users a more convenient and compact sensing system develop platform, CIC has created the new-generation "MorSensor Lite" on the basis of its MorSensor wireless sensing building block hardware and software. The MorSensor Lite system offers the advantages of small size, low power consumption, and low-cost; it includes temperature & humidity, UV radiation, and absolute orientation sensors, and has both Bluetooth and Wi-Fi wireless communications interfaces. Apart from using the sensors to perform basic environmental monitoring, users can also use multiple sets of MorSensor Lite building blocks to develop absolute orientation sensing applications; in conjunction with wearable equipment, this system will put the goal of "smart living" through ubiquitous mobile sensing within reach.

(4) Three-axis acceleration sensing system chip

CIC has completed simulation and verification of CMOS MEMS sensing element and digital circuit integrated design methods. The project has successfully integrated a three-axis accelerometer, analog reading circuit, analog/digital conversion circuit, memory, and an ARM Cortex-M0 microprocessor within a single chip. This design is currently the world's most fully integrated sensing system chip, and can be applied in the development of wearable devices, Internet of Things applications, and smart machinery, etc.

(5) Internet of Things system chip design platform

CIC's Internet of Things (IoT) system chip design platform enables the integration of a common bus and analog sensing circuits or digital algorithm accelerator circuits in smart sensing chips, which can be used in IoT, biomedical, industrial control, vehicular electronics, and smart city applications. This platform includes an ARM Cortex-M0 processor core and CMSDK platform silicon IP; the processor core consists of a 32-bit microprocessor (MCU) offering the advantages of small circuit size, low power consumption, simplicity, and ease of use. The platform's silicon IP consists of a SoC (system on chip) design solution with a processor core, and includes an AMBA bus element, memory controller, GPIO/UART peripheral circuits, and embedded software. This work can accelerate the development of a domestic IoT industry.

(6) Light sensing and high-voltage resistant integrated chip

Small devices like voltage converters and large equipment such as air conditioners, industrial equipment, and photovoltaic systems all need highly-isolated voltage and low-power signal transmission. To achieve low cost, compact size, and light weight, this project found that integration of a light detector with a CMOS integrated circuit able to withstand high voltages is one of the best solutions. CIC has completed light detector and integrated circuit chip design and testing, and performed red, blue, green, and far infrared characteristic testing. Overall signal transmission speed is at least twice that of comparable products currently on the market, and the system is expected to resolve the industry's design challenges.

(7) On-chip millimeter wave antenna S parameter measurement service

Growing demand for 5G and AI applications has prompted domestic researchers to engage in high-speed, high-bandwidth system (such as 802.11ad systems, 5G mobile communications systems, and smart vehicular radar, etc.) research and development, which is what motivated this millimeter wave antenna design project. CIC used a measurement mechanism and tool developed in-house, along with an existing probe, to develop on-chip millimeter wave antenna S parameter measurement technology, and has also established a stable millimeter wave antenna voltage standing wave ratio measurement environment that it has made available to academic users. This work can help boost domestic wireless communications R&D capabilities and further stimulate the development of relevant industries.

(8) CMOS image sensor for a sub-meter remote sensing satellite

CIC has been working with the National Space Organization in the development of strategies for a remote sensing satellite, and has performed the design and development of a CMOS image sensor for a sub-meter remote sensing satellite. This sensor will help the Formosat-5 satellite meet its ground imaging resolution requirements, and will improve resolution from 2m to less than 1m. In this project, CIC used TSMC's back-side illumination (BSI) CIS 0.11  $\mu\text{m}$  process to develop a 7.5  $\mu\text{m}$  4T high sensitivity pixels, and also designed a low-noise reading circuit and high-resolution analog/digital converter. CMOS time delay integration technology and mask stitching technology developed in cooperation with TSMC was used to create the space-grade CMOS image sensor, which is 12cm in size. This technology can be extended to the mobile device and self-driving car markets in the future.

(9) AI system chip design platform

To support academic artificial intelligence hardware and software R&D, CIC has established an artificial intelligence system chip design platform with a Synopsys ARC HS3x processor as its core. The platform's important silicon IP includes the built-in Synopsys ARC HS3x processor, DDR3 memory controller, locked loop circuit, and AMBA bus circuit. Users only need to use the AMBA bus as the input/output interface for an AI hardware accelerator circuit in order to integrate the platform into an AI SoC. Apart from sharply reducing the threshold for academic AI R&D, this R&D campaign also cultivated human resources with AI hardware and software design capabilities.



## 2. Instrument Technology Research Center

- (1) Establishment of the "Biomedical Industry Innovation Promotion Project Implementation Center"

The Biomedical Industry Innovation Promotion Project, which seeks to realize the three principles of "innovation, employment, and distribution" in the government's industrial administration blueprint, has established the Biomedical Industry Innovation Promotion Project Implementation Center in the Hsinchu Biomedical Science Park. In the future, this center will seek to link the resources and capabilities of industry, academia, medicine, and research organizations, promote the biomedical industry in line with government policy, help create well-paying jobs, cultivate flagship companies, and foster innovation in the biomedical industry.



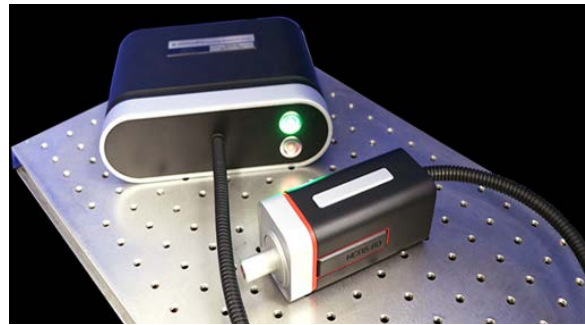
Opening ceremony for the Biomedical Industry Innovation Promotion Project Implementation Center on January 25, 2017

- (2) Gate valve testing system wins the 13<sup>th</sup> Metrology Innovation Award

Responding to the need for equipment vendors to perform particulate pollution assessment when supplying components and products to the semiconductor industry, the Instrument Technology Research Center (ITRC) joined forces with King Lai Hygienic Materials, National Formosa University, and National Central University in the development of a "high-cleanliness vacuum gate valve component particulate testing system." This system allows particulate matter and other pollutants produced by gate valves to be tested in real-time, and provides collected data to the product design end, where it helps vendors improve their products. The system was awarded the "13th Metrology Innovation Award."

- (3) Development of a non-contact displacement testing system

The non-contact displacement testing system developed at ITRC uses a visible light laser to measure the displacement of optical elements, and can be easily aligned with the elements to be measured, which reduces the risk of scratching. All conducting, non-conducting, and transparent elements can be measured. The system has a broad range of potential applications, and the working distance, measurement range, and resolution can be adjusted to meet users' needs; customized development modules are currently being developed.



Non-contact displacement testing system

- (4) Use of a 193nm anti-reflection coating to increase stepper illumination energy

The steppers used in the chip production process rely on a certain type of illumination to make circuit patterns to appear on the surface of wafers. During exposure, however, the surface of a silicon wafer or metal layer will reflect the incoming light, which will cause areas where exposure is not wanted to be exposed, and also causing poor pattern replication. Addressing these problems, ITRC has successfully developed an anti-reflection coating for the ArF deep UV (193nm wavelength) illumination most often used by steppers. This double-sided coating can increase the light penetration of a silicon substrate from 88% to 94.5%, which will increase steppers' illumination energy and reduce the effects of reflection.

- (5) Participation in NARLabs' annual results exhibition

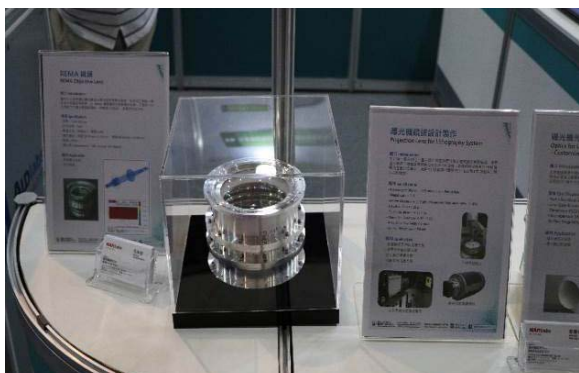
ITRC displayed the results of its smart factory R&D campaign at NARLabs' annual results exhibition. The smart factory concept involves real-time monitoring of operating procedures, and will boost factory performance, reduce resource consumption, and exert a positive socioeconomic effect.

#### (6) Initiating a new age in IoT sensing

Domestic IoT technology tends to emphasize the network level and applications level, and seldom focuses on the sensing level, which is an obstacle to full integration. Addressing this situation, ITRC began the IoT Sensing Service Platform Project in 2015 in order to bring about the vertical integration of self-developed sensor technology and applications in the IoT industry chain. The 2017 project demonstrated sensor elements capable of testing whether asthma attacks may occur, whether daily muscular activity is sufficient, and whether indoor air quality is adequate. Future work will include the mass production of sensor elements and modules, and integration with domestic commercial IoT applications platforms, which will deepen the localization of sensor module technology in Taiwan.

#### (7) Participation in the SEMICON Taiwan international semiconductor trade show

The steppers used for lithography at domestic semiconductor plants chiefly come from large instrument manufacturers in the Netherlands and Japan, maintenance service depends completely on the original manufacturers, and prices are very high. ITRC is using its advanced opto-electromechanical expertise to develop key stepper parts and components, and provide stepper maintenance services to semiconductor plants. This work will not only boost technological standards at domestic equipment manufacturers and create employment opportunities, but also help domestic semiconductor plants to cut costs.



Domestically-developed stepper lens assembly displayed at the SEMICON Taiwan international semiconductor trade show, which was held September 13-15, 2017

#### (8) First-time participation in the AVS International Symposium conference & exhibition

The American Vacuum Society (AVS) is an international group organized by scientists, engineers, and instruments manufacturers, and has the goal of promoting research and the sharing of knowledge in the fields of surface, interface, vacuum, and film science and technology. The AVS is the world's leading organization focusing on vacuum science and technology. During 2017, ITRC participated in the AVS International Symposium for the first time, and took this opportunity to display many years' of R&D in the areas of film technology, optical lens polishing, vacuum parts and components, and self-developed systems, etc. ITRC hopes that its participation in this international interchange opportunity will help it find collaborative international projects.

### 3. National Center for High-Performance Computing

#### (1) With the completion of a new-generation petascale high-performance computer, Taiwan's high performance computers return to the top 100

To ease the shortage of high-performance computing resources in Taiwan, and continue to provide large-scale common-use computing platforms, the National Center for High-Performance Computing (NCHC) has established a new generation of high-performance computers. These computers are composed 630 pure CPU computing nodes and 64 CPU plus GPU accelerator nodes; the CPUs can achieve a maximum computing speed of 1.325 PFLOPS, which is approximately 7.5 times the speed of NCHC's existing Advanced Large-scale Parallel Supercluster (ALPS) computer, and the GPUs have a speed exceeding 1.7 PFLOPS. The computers' computing capacity is sufficient to give them a rank of 95<sup>th</sup> worldwide in the November 2017 TOP500 ranking of the world's 500 fastest computers. This new supercomputer will be the new workhorse of research and development in Taiwan, and will promote Taiwan's overall industrial and economic development. Apart from supporting domestic large-scale computing applications in key fields, the supercomputer will provide an important research tool in new areas of big data and AI, facilitate major technological breakthroughs, and ensure that domestic scientific and industrial research capabilities continue to grow.



- (2) New-generation TWAREN 10G optical channel service provides secure network transmission

NCHC is using the most advanced optics and optical channel control technology to enable TaiWan Advanced Research and Education Network (TWAREN) users to establish virtual private networks meeting their specific needs, including highly flexible optical networks. Accompanying the upgrading of TWAREN's backbone bandwidth to 100G, NCHC formally began providing 10G point-to-point optical channel dedicated bandwidth service in 2017. The dedicated 10G bandwidth provided by the new-generation TWAREN optical channel service can be used to dramatically increase users' data transmission rate and security, protect online applications research data and results, assist in education and research conducted by domestic companies, universities, and research organizations, and promote the development of advanced technology and applications, including in such areas as high-energy physics, astronomy, and telemedicine. Secure high-speed data transmission will catalyze the accelerated development of new applications technologies, and boost Taiwan's research competitiveness.

- (3) Big data text mining technology: A fast and versatile text mining service on the cloud

In the wake of the rapid development of artificial intelligence, NCHC has been taking advantage of its existing high-performance computing, storage, and network architecture capabilities to develop AI applications services, which include text mining technology. The text mining processing framework developed by NCHC can quickly extract textual correlation data, can use its highly expandable index storage framework to perform subsequent analysis in value-added applications, and can facilitate convenient acquisition and use services via the cloud. NCHC's text analysis applications service chiefly rely on specialized textual knowledge acquired from various applications and a vocabulary knowledge model developed through training to immediately structure textual materials. This service can help domestic companies, universities, and research organizations to analyze and use large bodies of text via value-adding applications such as textual structural analysis, document classification, automatic document summarization, mood analysis, topic and incident detection, equipment record review and analysis.

- (4) Use of artificial intelligence to diagnose the health of machinery

As deep learning and machine learning applications become increasingly mature, NCHC will extend artificial intelligence applications to such fields as smart machinery, integrate the front-end sensing and AI analysis technologies needed in machinery networks, and develop a real-time monitoring system that can be used to diagnose equipment. After vibration sensing devices collect the vibration response of equipment under different normal and abnormal operating conditions, this data will be paired with diagnostic models based on engineers' experience. When the system senses that machinery about to function abnormally, it can stop for maintenance or replenishment of consumable materials or spares, reducing the delayed shipment losses and work safety hazard caused by abnormal operation. This project has established a basis for the development of advanced smart manufacturing in Taiwan.

- (5) Launch of a cloud information security attack & defense platform

At a time when information security is equated with national security, how to respond to looming information security threats has become a crucial issue for government agencies, academic and research organizations, and companies. Since conventional information security manpower training lacks suitable settings and technology verification platforms, NCHC has developed Cyber Defense Exercise (CDX) cloud information security attack and defense platform, which seeks to provide information security personnel with a comprehensive training environment. CDX allows users to study more than a dozen information security technologies, and over 150 system or applications software vulnerabilities, while serving as an information security technology learning testing environment. The platform has teaching and information security competition applications as its chief lines of development, and is enhancing the effectiveness of practical exercises to ensure that users can apply what they learn. Sixty departments at 50 universities and colleges nationwide are currently using the platform in the teaching of information security classes, and the platform has been used to teach information security skills to over 1,000 students.



NCHC holds a cybersecurity competition in June 2017 using the Cyber Defense Exercise cloud information security platform

#### (6) Using artificial intelligence to monitor flooding

NCHC's nationwide monitoring of water levels can display 1,250 images at one time, and previously used image technology to analyze water height and spread; on-duty personnel were notified when the results exceeded threshold values. However, because image analysis was limited to detection of water height and spread, human identification of the images' background environment and actual weather was needed in order to correctly judge the location and whether flooding had occurred. As a consequence, NCHC has used machine learning to train a special-purpose network model able to automatically identify the weather in images without human intervention. This system can be used to automatically identify flooding, and determine the location of flooding; current accuracy is at least 90%.

#### (7) A virtual/physical humanities technology platform

Since it launched Taiwan's first cloud rendering farm in November 2011, NCHC has striven to promote the application of high-performance computing in video special effects and 3D animation, etc. To date, the rendering farm's services have been used in over 100 films and TV shows, including six movies with a total box office take of close to NT\$1.0 billion. Nevertheless, due to international trend toward the automation of video technology development, virtual/physical applications including the real-time computing of special effects, virtual reality (VR), and augmented reality (AR) have become another mainstream area of the market. Using virtualization as a basis, NCHC has therefore integrated GPU computing and a high-throughput storage system to develop Taiwan's first integrated virtual/physical industrial technology testing platform, and has completed

system testing. NCHC also provides leading virtual/physical applications spanning such fields as technological art, virtual clothing try-on, motion sensing entertainment, anime/film/TV, and museums. NCHC has further established a cultural data access and cloud virtual classroom platform service supporting the cultivation of talent with "T-shaped skills."



Use of NCHC's virtual/physical humanities technology platform to verify a real-time interactive performance.

### 4. National Center for Research on Earthquake Engineering

#### (1) Opening of NCREE's Tainan laboratory

In order to ease the threat of near-fault earthquakes and speed the development of appropriate earthquake-resistance technologies, MOST, the National Development Council, NARLabs, and National Cheng Kung University have jointly constructed the NCREE Tainan Laboratory over the course of three years, and an opening ceremony for this new facility was held on August 9, 2017. This laboratory's "long stroke, high-velocity vibration system" has the world's best performance in its class, and can simulate the characteristic high-velocity pulses and large displacement of near-fault earthquakes. Looking ahead to the future, the Tainan laboratory will work together with the functionally-complementary Taipei laboratory to develop cutting-edge earthquake-resistance technology in keeping with Taiwan's environment, and thereby ensure that Taiwan becomes an international seismic engineering research stronghold.

#### (2) Soil liquefaction

In the wake of the February 6, 2016 Meinong earthquake, the issue of soil liquefaction has become a matter of great concern for all citizens, and the National Construction & Planning Administration, Ministry of the Interior has embarked on the "Safe Homeland Program." As part of this program, NCREE has



The Tainan laboratory's long stroke, high-velocity vibration system can help develop technologies to resist shaking from near-fault earthquakes.

developed a rigorously-tested computer program for assessment of soil liquefaction potential; this program is provided free to all users who complete download applications, and the National Construction & Planning Administration has designated it a standard analysis program. The cities and counties currently implementing the "Safe Homeland Program" all use this as their standard program for assessment of liquefaction potential. In addition, NCREE is also serving as general consultant for Taipei and New Taipei in charge of compiling soil liquefaction potential data and maps under the Safe Homeland Program, and is promoting R&D of applications allowing new technologies to benefit society.

### (3) Breaking with traditional biomimetic pre-cast bridge piers

In order to reduce the impact of bridge construction on the environment, NCREE has developed a "New Biomimetic Building Block Pre-cast Bridge Pier System" by combining "spinal column" and "building block" concepts. This system, which mimics the structure of the human spine, retrofits steel shear keys from top down on pre-cast segments, and uses prestressed steel tendons to pull on the various segments, which ensures increased earthquake resistance. This project has also applied a building block concept allowing engineers to stack small segments to achieve a large cross-sectional area in accordance with design needs. When this approach is used, pre-cast plants will not need to consider different bridge pier shapes or sizes, but only have to produce segments with uniform specifications, boosting segment production efficiency and reducing steel mold production costs. Furthermore, due to the relatively small design blocks, they are convenient to transport, and will reduce environmental impact. When natural disasters occur, the blocks can be used to build temporary

emergency bridges in mountainous areas, speeding up the disaster relief process.



Assembly of pre-cast bridge piers using new biomimetic building blocks

## 5. National Nano Device Laboratories

### (1) Low energy consumption next-generation transistor technology

The National Nano Device Laboratories (NDL) has produced germanium nanowire transistors using a ferroelectric gate dielectric film developed in-house. The transistors' characteristics include (1) a low-temperature process ( $<450^{\circ}\text{C}$ ) and a subthreshold swing of less than  $60\text{mV/dec}$ ; and (2) use of a single annealing process to complete source/drain activation and ferroelectric film crystal phase conversion, which will greatly reduce process steps and heating budget. This project constituted the first time that stress reliability analysis was performed for ferroelectric germanium elements. The results of the project will facilitate the development of low-power consumption portable electronic product and IoT applications, and provide new opportunities for development of a next-generation non-silicon nanometer element industry.

- (2) Use of broadband oscillations to induce magneto-electric induction no-cantilever structures

Smart factories currently have no self-testing early malfunction warning systems. Abnormalities during high automated production have such possible causes as abnormal machine vibration, overheating, and abnormal operating noise. NDL has now developed an environmental vibration sensor that can function without need for external bias, and this sensor can overcome conventional sensors' inability to detect broadband vibrations. Furthermore, a newly-designed no cantilever structure in which broadband magneto-electric oscillations induce magneto-electric induction (three-dimensional stacked coils) can improve sensor detection ability within a fixed area.

- (3) Development of key technologies for high-power semiconductor chips

NDL has successfully established a 6"/8" GaN energy-conserving power element service platform, and completed the development of always open/always closed GaN elements on a silicon substrate. This work can help industry, academia, and research organizations to develop high-power elements and verify epitaxial wafer quality. Future plans call for the provision of a high-power circuit process platform that will assist the development of circuits needed in green energy technologies (such as green energy vehicle charging stations, transformers, and industrial motor controllers, etc.).

- (4) More than Moore: transcending the limits of process technology

NDL's development of heterogeneous wafer packaging and integration technology has facilitated the establishment of a 2.5D / 3D-TSV service platform, which provides services needed by research teams working in areas relating to 2.5D / 3D packaging and silicon via technology. This platform can also promote IoT-heterogeneous element integrated packaging technology platforms, such as silicon via (TSV), Cu seed layer, through silicon via electroplated copper, Sn/Ag solder balls, CMP, and wafer to wafer bonding. In response to the current "More than Moore" concept and need for IoT sensing elements, NDL is working to promote the development of miniaturized, low-energy consumption elements.

- (5) Development of a high-efficiency cancer testing chip

The high-performance cancer testing chip technology developed by NDL uses an external electric field to alter the orientation the proteins (such as antibiotics) adhering to the chip surface. When the electric field has an optimal rotational angle, antibody and antigen reactions will be maximized, which will increase the testing chip's performance. Commercial testing has verified that when CEA antibodies, which are colon cancer tumor marker antigens, adhere to the chip, as long as 30% antibodies are used, reaction with the antigen will achieve results equaling or improving on those attained in the past. If broadly applied to the use of antibiotics to test for cancer antigens, this technology can save several billion US dollars in antibody costs worldwide.

## 6. National Laboratory Animal Center

- (1) Development of next-generation genetic-modification technology: Development of reporter mice with whole-body fluorescence

In stem cell and regenerative medicine applications research, it is often necessary to use cells containing reporter genes able to express fluorescent proteins to track cell movement and development after the cells have been transplanted into animals. The National Laboratory Animal Center (NLAC) has used bacterial artificial chromosomes to develop all-gene modification technology, which overcomes the problem of insufficient gene expression, and has used this technology to produce transgenic mice that can express fluorescent proteins in all types of tissues throughout their bodies. Compared with the fluorescent mice cited the most times in recent research papers, these fluorescent reporter mice offer greater brightness and broader distribution of expression in tissues; the mice can therefore replace products currently on the market. Related technologies can help domestic companies and universities to develop even more advanced animal models.

- (2) Development of a germfree and known bacterial flora rodent platform: An important tool for study of intestinal tract flora

The effect of the microbial flora of the human gut on health has attracted growing attention in recent years, and the causative mechanism and treatment of metabolic disorders, mental illness, and cancer may be affected by microbes in the intestinal tract. NLAC used hypercholesterolemia ApoE gene knockout rats to investigate the relationship between the intestinal flora and initiation of arteriosclerosis.



Experimental results revealed that ApoE gene knockout rats did not experience significant arteriosclerosis when their intestinal flora was normal. However, after the intestinal tracts of ApoE knockout rats have been sterilized, the formation of arteriosclerotic plaques can be observed. The fact that this phenomenon can be inhibited by specific antibiotics indicates that specific intestinal microbes in their metabolic products may be promoting the formation of the plaques. This research verified that germfree mice can serve as an important platform for research on the intestinal flora, and can support domestic R&D in relevant fields.

- (3) Establishment of an animal model for precision medicine: Development and verification of immune humanized mice

"Precision medicine" has been a major area of medical development in recent years, and precision medicine research is heavily dependent on experimental rodents bearing human immune cells: "immune humanized mice." NLAC used introduced human blood cells into highly immunodeficient mice, and successfully developed immune humanized mice with human blood stem cells or peripheral blood cells. These mice can be used in conjunction with patients' blood cells to investigate pathogenic mechanisms and seek out treatment methods. At the same time, NLAC also used these immune humanized mice to establish cancer research and drug testing platforms that are expected to provide academic research units and biotech companies effective new tools for drug development.

### 7. National Space Organization

- (1) Successful launch of the Formosat-5 satellite

Under the watchful gaze of citizens and the world, the Formosat-5 satellite was launched on a SpaceX Falcon-9 rocket from Vandenberg Air Force Base in California on August 25, 2017, and successfully entered its mission orbit with an altitude of 720 km. After nearly half a year of element adjustment and calibration, orbital maneuvers, and image processing, the satellite has embarked on its mission of global ionospheric observations and remote sensing imaging, and its remote-sensing image quality meets preset requirements.



Formosat-5 satellite was launched on a SpaceX Falcon-9 rocket from Vandenberg Air Force Base in California on August 25, 2017

- (2) The Formosat-7 satellite enters the manufacturing and testing stage

The Formosat-7 domestically-developed satellite is a 300kg grade satellite, and will carry an advanced global navigation satellite system-reflectometry (GNSS-R) system developed by a domestic team. The satellite's measurements of sea level data will facilitate the understanding of typhoon structure, and it will also provide important information for research on sea-air interactions. The design, production, and testing of most self-developed satellite elements was completed during 2017, including such key elements as the satellite bus, computer, power control element, GPS navigation receiver, fiber-optic gyroscope, and hydrogen peroxide propulsion module. The GNSS-R system has completed two airborne flight tests, data postprocessing, and engineering body production and testing, and the engineering verification body will soon begin environmental testing. After the final testing review conference at the end of 2017, the satellite flight vehicle assembly and testing stage formally began.



The Formosat-7 domestically-developed satellite

(3) Successful flight testing of the global navigation satellite system-reflectometry system receiver

The development of the global navigation satellite system-reflectometry (GNSS-R) system used on the Formosat-7 satellite draws on the technical capabilities established by the National Space Organization (NSO) in developing a space-grade GPS receiver. The GNSS-R system completed two flight tests on aircraft over the Taiwan Strait in 2017, and the flight body is currently being produced. During flight testing, payload function and operating status was normal, and signal acquisition, tracking, and generation of scientific data all met expectations. Preliminary scientific data verification results indicate that the system can achieve meaningful observation results. The technologies mastered by NSO in this process can be used in a wide range of future applications.

(4) Successful flight testing of an airborne hyperspectral imager

The airborne hyperspectral imager (encompasses the two wavebands of visible light (380nm-780nm) and shortwave infrared (900nm~1700nm)) jointly developed by NSO and National Taiwan University of Science and Technology successfully completed a first imaging flight test mission on August 25, 2017. During this flight, the imager achieved a ground resolution of approximately 70cm, with a swath of approximately 0.5km, from an altitude of 1-2.3km. Imaging locations included the area between Tianwei and Xizhou in Changhua and the Taibao area of Chiayi. The imager acquired images continuously along the flight path, and subjected the hyperspectral imaging data obtained from the resulting image to spectral analysis guiding algorithm development. This R&D project has successfully established a new milestone in hyperspectral image data processing and analysis.

## 8. Science & Technology Policy Research and Information Center

(1) Artificial intelligence: Small Country, Smart Strategy

Based on Taiwan's "Small Country, Smart Strategy" thinking, the Science & Technology Policy Research and Information Center (STPI) seeks to draw on Taiwan's advantages and

seize the opportunity for developing artificial intelligence. STPI helped draft the "National AI Research Strategy" and "Artificial Intelligence Promotion Strategy," which were formally implemented in September 2017. To collect views concerning AI from industry, government, and academia, and ensure that AI research strategies are formulated as thoroughly as possible, during the planning period, STPI helped conduct artificial intelligence promoting strategy discussions in northern, central, southern, and eastern Taiwan; these events received an enthusiastic response, and STPI used the resulting recommendations to ensure sound promotional strategies.

(2) Promoting a new model of scientific research development

Time is the most important factor in the global race to capture the huge economic benefits promised by AI technology. To accelerate the development of this technology, STPI has recommended that MOST rely on competitions to stimulate technological innovation and uncover AI talent and skills, while also helping domestic companies to develop relevant applications. This was how the idea for the "Formosa Speech Grand Challenge" was born. This event consists of warm-up and final competitions; the former is restricted to high school, junior college, and university students, provides relevant training, and seeks to increase students' interest in AI. The final competition is open to all, and seeks to resolve the problem of AI Chinese speech recognition and syntactic analysis in a complex environment.



On December 22, 2017, this photo of Science and Technology Minister Liang-Gee Chen (4th from left in front row), Vice Minister Hsu You-chin (4th from right in front row), and participants was taken following the warm-up competition of the Formosa Speech Grand Challenge.

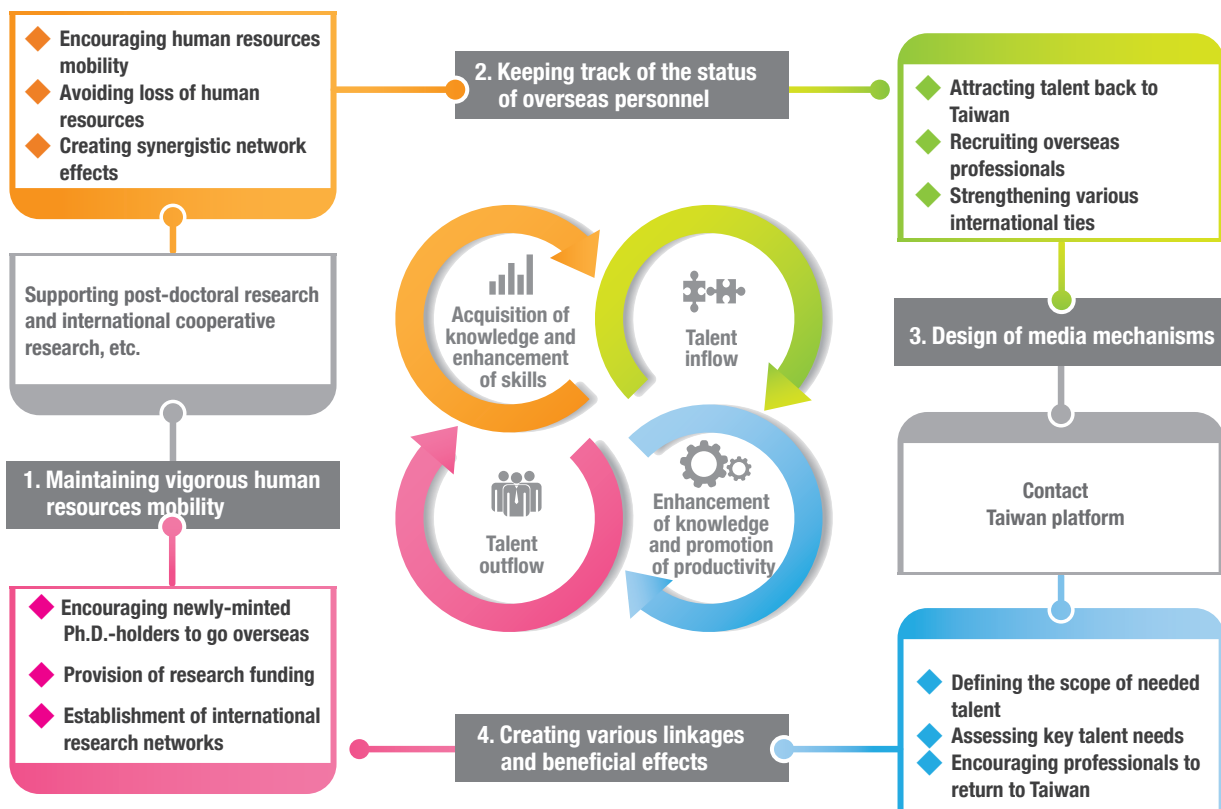


(3) Building technological bridges with the New Southbound Policy

STPI has lent its full support to MOST's planning and promotion of scientific research cooperation in conjunction with the government's New Southbound Policy. This work includes research concerning New Southbound Policy countries' S&T policies and international cooperation, provision of strategic recommendations, production of briefings and memoranda for external parties (including the Executive Yuan), holding of discussions involving the Science and Technology Minister and Taiwanese firms with operations abroad, solicitation, review, and finalization of documents concerning the establishment of overseas scientific research centers, holding of the Yushan Forum, holding of MOST New Southbound Policy working conferences, and website creation. In addition, apart from inviting Vietnamese and Thai officials and scholars in Taiwan to discussion meetings to explore possible bilateral scientific research cooperation, STPI further consulted with important think tanks and relevant government agencies in both countries in order to map out future bilateral cooperation strategies.

(4) Providing policy recommendations, encouraging the return of talent to Taiwan

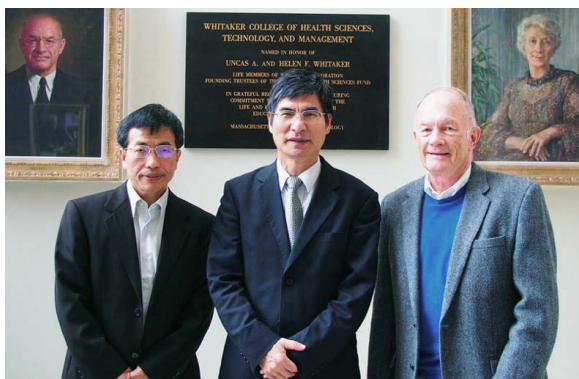
With the spread of globalization, the international movement of talent has become routine. In order to gain an understanding of the current situation of talent in Taiwan, STPI conducted a survey of domestic Ph.D.-holders, and use the resulting information to design policy incentives and rewards geared to enhancing Taiwan's innovation capabilities. The results of this survey indicated that domestic Ph.D.-holders have a positive view of international interchange, and will be very willing to return to Taiwan in the future. STPI consequently recommends that the government support younger Ph.D.-holders who wish to develop their careers overseas, rely on joint research to maintain international networks, and promote the return of knowledge and technology from overseas. After accepting STPI's recommendations concerning the selection, training, and return of individuals studying and working overseas, MOST formulated a series of policy plans in the areas of "forward-looking infrastructure" and "industrial innovation" in hope of establishing a foundation for the country's future development.



STPI's recommendations concerning the human resources mobility cycle

(5) Planning and implementation of the Learn-Explore-Aspire-Pioneer (LEAP) Program

To encourage Taiwan's elite talent to keep up with global S&T development trends, Science and Technology Minister Liang-Gee Chen and STPI Director Chuang Yu-tze visited the United States during April, where they first signed cooperative human resources training programs with Stanford University and the University of California at Berkeley, then reached a consensus concerning a bilateral post-doctoral personnel interchange program with MIT's Institute for Medical Engineering and Science (IMES), and formally introduced the "Learn-Explore-Aspire-Pioneer" (LEAP) Program. Under the LEAP Program, Ph.D.-level manpower will be sent to the well-known high-tech clusters in Silicon Valley and Boston, where they will be trained as entrepreneurship seed personnel with international outlooks and strategic thinking via joint research and internships. After they return to Taiwan, they can pursue technological innovation and entrepreneurship, or help existing companies upgrade themselves.



Science and Technology Minister Liang-Gee Chen (center) and STPI Director Chuang Yu-tze (left) are shown here with Prof. Roger Mark of MIT's Institute for Medical Engineering and Science in Boston on April 7, 2017

(6) Planning and implementation of the Vision Program

To quickly realize the innovation ideas that are constantly being generated by industry, academia, and the research community, boost the international perspectives and venture investment networks of Taiwan's startup teams, and sustain the wave of innovative startups in Taiwan, STPI planned and implemented the Vision Program in 2017. Under the Vision Program, 18 of the 41 startup teams that signed up for the activity were chosen to receive

three-week, three-stage marketing and fund-raising briefings, equity negotiations, value-adding business consulting, and connection with international markets. In the end, 10 teams were chosen to spend one month at Silicon Valley's well-known Plug and Play accelerator. Thanks to Silicon Valley's entrepreneurial mindset and international interchange, the trainees gained an understanding of overseas investment networks, acquired a grasp of international startup market trends, absorbed international fund-raising experience, and obtained the wherewithal to realize their ideas



At the "Plug and Play Taiwan Demo Day" and matchmaking event held in Silicon Valley on September 22, 2017, startup teams from Taiwan demonstrated their creative results in front of representatives of international venture investors.

and establish international startups.

(7) Planning and implementation of the Boston-Taiwan HealthTech Program

Because the Boston-Taiwan HealthTech Program (BTH Program) is a link in the LEAP Program, STPI bore responsibility for planning and implementation of a smart medical seed talent training program. STPI's duties include selecting domestic personnel with medical information background or smart medicine knowledge or experience to go to Mass General Hospital in Massachusetts to receive one year of practical training in the area of smart medicine and commercialization. Since the Greater Boston area possesses extensive high-tech and medical research capabilities, and has a distinctively entrepreneurial environment, it is comparable with the West Coast's Silicon Valley. After an intensely competitive selection process, two trainees were chosen in 2017 to participate in local accelerator and entrepreneurship activities at Mass General, where they gained the skills needed to develop smart innovative medical technologies and seek out startup opportunities.



(8) Planning and implementation of the X Venture Project

STPI selected business management personnel from the fields of technology/media/telecommunications (TNT), engineering, and biomedicine to attend a one-year course offered by the TWSV Tech Fund 's American venture investment partners. This course covers the newest domestic and foreign venture investment trends, instills necessary skills in entrepreneurs committed to making startup investments, trains startup investment manpower, and helps domestic startup teams to navigate the initial stage of startup development. Two selection sessions were held in 2017, and two trainees were sent to the US to receive training. This program takes advantage of Silicon Valley's entrepreneurial atmosphere, venture investment experience, and business networks to transmit investment and management experience, and enhance the energies needed for industrial transformation in Taiwan.

(9) FITI Program stirs up an academic innovation whirlwind

Starting in 2013, STPI has implemented "From IP to IPO" (FITI) program, which encourages domestic academic research organizations to launch startup based on innovative technologies, and thereby diffuse their R&D results. Since the program was first implemented, it has received 1,622 startup ideas, helped establish 127 startup companies, which were funded with approximately NT\$1.3 billion in disclosed paid-in capital, and employ a total of more than 500 persons. The program not only provides links to the startup resources of the organizations under MOST, but has also fostered a new wave of innovative entrepreneurship and given Taiwan's economic development a shot in the arm. The program was listed class A in the 2016 Executive Yuan-Controlled Project Assessment."

(10) Enhancing the effectiveness of government S&T project implementation

The overriding theme of the government's pursuit of S&T development has been to achieve the greatest possible socioeconomic benefits through the use of limited budget resources, and S&T projects are the government's most important means of promoting S&T development. In 2017, apart from continuing to support the government's review of S&T projects, STPI has also helped the Board of Science & Technology, Executive

Yuan to establish the "S&T Project Appraisal Experts' Room" in order to enhance project management and implementation effectiveness. The Project Appraisal Experts' Room relies on the broad perspective of interdisciplinary experts to strengthen the initial selection, mid-course management, and post-completion assessment of S&T projects, and enhance the S&T budget's value to industry and society.

(11) Monitoring Taiwan's research innovation capacity

On July 25, 2017, STPI held the "Analysis of Taiwan's Competitiveness: Looking at the Endurance of Taiwan's S&T Innovation Activities from the Perspective of Patent Maintenance" press conference, at which it described the results of research on maintenance of US patents by Taiwan's academic research organizations and corporations. STPI's analysis of maintenance of US patents by patent-holders in Taiwan can help industry, government, academia, and the research community to more precisely monitor S&T areas in which Taiwan has an advantages, and implement the effective and precise management of resources. This is just one of the ways that STPI's research is making an important contribution.

(12) Supporting MOST's efforts to strengthen Taiwan's academic research capabilities

STPI supports MOST's various departments by providing academic capability analysis data and analysis of the results of specific projects. The several dozen types of statistical information used in these services include "Analysis of Taiwan's Performance in Top-notch Journals such as Nature and Science," "Analysis of Taiwan's Academic Capabilities in the Life Sciences," and "Performance of Taiwan's International Collaboration Papers." STPI reported on the international competitiveness of Taiwan's academic research at the "Forward-looking Report" conference convened by MOST, and discussed the academic discipline systems of countries including Taiwan, Switzerland, the Netherlands, Australia, and the United States. After summarizing the views of discipline conveners, STPI comparing the advantages and disadvantages of Taiwan's academic discipline system, and proposed recommendations for future modifications

(13) Face-to-face meetings giving policy a human touch

To ensure that policy planning and

implementation better meets actual needs, STPI helped MOST to hold six discussion sessions under the heading of "MOST's Appointment with Young Scholars," "Appointment with the Winners of the Ta-You Wu Memorial Award, " and "MOST Young Scholar Cultivation Program." The topics of these meetings included how government can help young researchers to realize their ideals, and how to ensure that Taiwan's scientific research environment has greater international competitiveness. Approximately 400 elite young scholars interested in academic research attended these events, and the many views they provided at the meetings have been incorporated within MOST's Young Scholar Cultivation Program as a reference for future policy planning and implementation.

### 9. Taiwan Ocean Research Institute

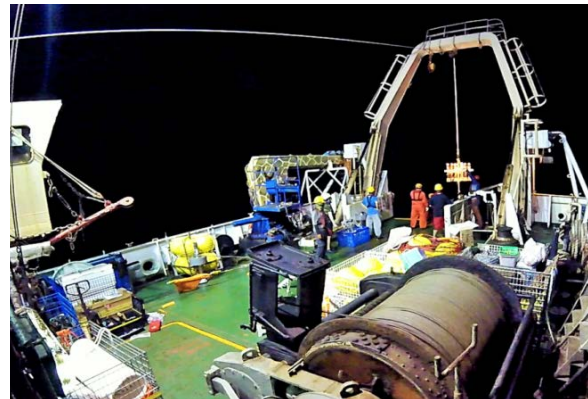
- (1) The Fangliao marine radar station stands guard over Taiwan's southwest corner

In order to increase the availability of the Taiwan Ocean Radar Observing System's (TOROS) real-time, long-term ocean current monitoring service, and particularly in order to provide coverage of the blind spot in inshore waters off Pingtung, after determining the real needs of academic researchers and the Coast Guard Administration, the " Taiwan Ocean Research Institute (TORI) established a new radar monitoring station at Fangliao. This station will provide tremendous assistance to the study of physical phenomena, including the invasion of waters to the southwest of Taiwan by a branch of the Kuroshio Current, internal tides, turbulent mixing, the dispersal of pollution, and concentration of methane ices, and also support navigation safety, environmental protection, new energy development, and marine search & rescue. It's worth noting that current information provided by the station not long after it was established helped rescuers to successfully determine the direction in which crew members were floating following the sinking of a fishing boat from Donggang, which showed the practical importance of this maritime technology to search & rescue operations.

- (2) South China Sea biological/geological/chemical time series observations

To strengthen monitoring of the environment and resources in the South China Sea to the south of Taiwan, since 2013 the " Taiwan Ocean Research Institute (TORI) has been operating the " South East Asia Time-Series Station

(SEATS), which is an international research station located at 18° N, 116° E. TORI makes regular visits to the station in summer and winter to collect basic hydrological, chemical, ecological information, and has deployed an anchored deep sea time series sinking particle collector. During the most recent four years, the sinking particle collector has provided much valuable hydrological observation data, and has assisted with sample collection (water samples, particles, and plankton, etc.). A time series of deep sea sinking particles facilitates academic researchers' investigation of marine carbon flux, climate change, trace metals' biological/geological/chemical cycles, marine pollution, and reconstruction of the ancient sea and climate environment.



TORI personnel working at sea at night to recover a sinking particle collector

- (3) A mobile castle on the sea: the research vessel Legend

With a gross tonnage of 2,629 tons, the research vessel "Legend" boasts a double-walled hull built to high specifications and great attention to safe operation. The Legend's chief missions will include deep sea exploration using a remote control unmanned underwater vehicle, sampling of undersea sediments and collection of ultra-large long rock cores, high-accuracy mapping of the undersea topography at all depths, and collection of seabed bottom material data. Like the Space Shuttle, this research vessel will provide ocean researchers various major scientific instruments and operating carriers, and can undertake long research voyages to distant waters. The availability of this vessel will strengthen Taiwan's ocean science research and ocean exploration capabilities, and will provide an able platform for ocean R&D work.



The research vessel Legend during sea testing

- (4) Use of a lidar wind profiler to perform typhoon observations

TORI used a Doppler lidar wind profiler to perform typhoon wind field observations at Xingda Harbor. The goal of this research was to gain a better understanding of the vertical distribution of wind speed in a typhoon wind field, verify theoretical models, and apply the resulting information to the assessment of the wind power load behavior of wind turbines' support structures in typhoons. This research project chiefly measured the wind speed profile of Typhoon Matmo between the altitudes of 48m and 268m. Under conditions of atmospheric neutral stability, four types of wind speed profile were observed: (1) a wind speed profile with a fully logarithmic form in the wind speed boundary layer of the measurement height zone; (2) a wind speed profile with wind speeds deviating from a logarithmic form at a height greater than the surface layer and the Coriolis force exerting a significant effect; (3) a shallow boundary layer with a gradient height; and (4) a profile similar to a low-level jet in areas where rainfall is occurring. If an exponential form is used to perform curve fitting, upper and lower layers with independent exponent signs can describe changes in the vertical of average wind speed.

- (5) Warming and accelerating acidification of deep-sea water

As the atmosphere receives more and more carbon dioxide generated from human activities, the world's seas are acidifying. As a rule, the acidification rate drops as gaps increases. But under the influence of global warming, the major oceans' warm salty currents may tend to slow. As soon as deep-water residence time increases, the water will accumulate even more carbon dioxide released from decomposing organic matter, and its pH will drop. TORI

has discovered that the vertical exchange of seawater in the Sea of Japan has indeed slowed during the past several decades, and has also found that the acidification rate of bottom water in the Sea of Japan is 27% faster than in the case of surface water. The Sea of Japan can be considered a miniature ocean, and like a large ocean, has surface water and bottom water. As a consequence, the changes seen in the Sea of Japan may foretell the accelerating acidification of deep water in the world's oceans with increased warming.

### 10. Taiwan Typhoon and Flood Research Institute

- (1) Development and use of an aerosonde unmanned aerial vehicle

The aerosonde unmanned aerial vehicle developed by the Taiwan Typhoon and Flood Research Institute (TTFRI) in 2016 has now successfully flown into the storm circle of the 2016 Typhoon Nepartak and the 2017 Typhoon Hato, where it collected data on the typhoons' air pressure, temperature, humidity, wind direction, wind speed, and sea temperature. This data enabled the Central Weather Bureau, MOTC to better judge the strength and magnitude of the typhoons. Automated night landing training was successfully completed at Hengchun Airport this year. The aerosonde will be used to perform challenging flights completely around a typhoon and through a typhoon's center in 2018. TTFRI is also currently making arrangements with the Yilan County government and National Ilan University to jointly establish a runway, which will be used in the future as a base for observations of typhoons making landfall in northern Taiwan



TTFRI's unmanned aerosonde aerial vehicle on its catapult in August 2017, while preparing for take-off on a mission during the approach of Typhoon Hato

- (2) Application of wind profiler radar

TTFRI's mobile wind profiler radar is part of a mobile wind observation experiment radar deployment project; the L-band radar has a chief function of measuring the vertical profile

of the atmosphere's three-dimensional wind field. Because a wind profiler radar with this wave band is relatively sensitive to precipitation particles, TTFRI uses this wind profiler radar to measure the average horizontal speed and vertical drop speed of precipitation particles through continuous observations of rainfall events. Apart from facilitating the estimation of horizontal wind speeds, the instrument can also be used in rainfall research. The high-resolution atmospheric and rainfall data obtained in this way can serve as an important basis for comparisons with the results of other observation methods

### (3) R&D of ensemble rainfall big data analysis technology

Since 2010, with support from the National Center for High-Performance Computing, TTFRI has been jointly conducting an ensemble forecasting experiment together with academic units (National Taiwan University, National Central University, National Taiwan Normal University, Chinese Culture University), the Central Weather Bureau, and National Science and Technology Center for Disaster Reduction. In addition, addressing the random development of strong frontal convection systems during the late spring "Plum Rains" season, and the fact that it is more difficult to predict rainfall during this time than during typhoons, TTFRI joined forces with the Central Weather Bureau starting in 2016 for the purpose of developing ensemble rainfall big data analysis technology involving machine learning. This technology has achieved more optimal rainfall forecasting results, and has enhanced the accuracy of rainfall forecasts during the Plum Rains period.

### (4) R&D of forward-looking LETKF radar data assimilation technology

TTFRI has developed local ensemble transform Kalman filter (LETKF) radar data assimilation technology, and used it to assess extreme short-term quantitative precipitation forecasts during several torrential rain events. These events included Typhoon Megi (2010), Typhoon Nanmadol (2011), Typhoon Nalgae (2011), Typhoon Saola (2012), Typhoon Soulik (2013), Typhoon Kong-rey (2013), and the 2012 Plum Rains front. All of these events caused the closure of the Suao-Hualien Highway along Taiwan's east coast. A comparison of the root-mean-square error of sub-3-hour quantitative precipitation forecasts with and without data assimilation revealed that the forecasts with

radar data assimilation were largely better than forecasts without data assimilation.

### (5) Combined radar data assimilation technology and shallow landslide model R&D and applications

By using radar data assimilation technology to develop extremely short-term rainfall forecasts, TTFRI has been able to provide even more accurate 6-hour hourly rainfall forecasts. TTFRI has also integrated extremely short-term rainfall forecasts with a shallow landslide model, and used average safety factor (FS) variation curves to assess the stability of sideslope watershed areas above kilometer mark 115.9K along the Suao-Hualien Highway during the period of Typhoon Saola. This study found that the time of landslide occurrence coincided with the time forecast by the model, and the prediction score was a high 0.88. This indicated that integrated atmospheric and hydrological models in the form of radar data assimilation technology and a shallow landslide model can be used to develop localized forward-looking landslide real-time early warning technology, boosting the ability to assess risk that heavy rainfall will initiate landslides.

### (6) The Dayu Smart Water System

The Dayu Smart Water System developed by TTFRI takes a cyber-physical system (CPS) and a water monitoring Internet of Things concept as its basis, and can provide real-time service during routine times and before, during, and after a flooding event. The system is composed of four levels, where the first level consists of on-site real-time water level monitoring Internet of Things sensors, which can provide single-point monitoring information, including water level, rainfall, and real-time images; the second-level CPS performs value-added real-time monitoring, and provides single-point water level forecasts for the next hour; the third-level CPS provides water level forecasts for the next 6 hours; and the fourth-level CPS provides regional water level forecasts for the next 72 hours.

## 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 personnel. 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 2017:

### 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 2017, a total of 2,367 visiting personnel and post-doctoral researchers were recruited to participate in S&T research projects, and 104 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 by outstanding young post-doctoral researchers.
- (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. Promotion of measures for the recruiting of special outstanding manpower and the granting of academic work awards to post-doctoral researchers

- (1) The *Subsidy Measures for the Recruiting of Special Outstanding Manpower by Universities* provide funding support for the competitive recruiting of foreign elite S&T manpower by universities, and allow universities to put S&T personnel on their regular payrolls as full-time teaching and research personnel with monthly salaries. This encourages elite international S&T personnel to accept employment in Taiwan, and will induce such persons to pursue long-term S&T research in Taiwan. A total of 38 applicant organizations obtained subsidies for this purpose in 2017.
- (2) MOST provides the Post-doctoral Researcher Academic Work Award in order to encourage post-doctoral researchers to publish superior, innovative, and important academic works, and provide incentives for the country's future academic elite to engage in long-term, in-depth S&T research. A total of 40 post-doctoral research personnel received this award in 2016, and 2017 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, 2013-2017

Units: person-times

Item	2013	2014	2015	2016	2017
Visiting personnel	133	136	118	115	82
Post-doctoral research	2,201	2,223	2,261	2,405	2,285
Research scholars	59	76	109	140	104
<b>Total</b>	<b>2,393</b>	<b>2,435</b>	<b>2,488</b>	<b>2,660</b>	<b>2,471</b>

## B. Training of S&T Personnel

In order to broaden the qualifications and international perspectives of domestic teaching and research personnel, and acquire the newest S&T knowledge from the world's leading nations, since 1960 the National Science Council—MOST's predecessor— has provided subsidies to S&T personnel wishing to study at foreign universities or perform research at foreign research organizations. Furthermore, based on the country's long-term S&T development manpower training policies, in order to absorb international R&D experience and boost Taiwan's R&D capabilities, and in response to a drop in university students studying abroad, MOST has instituted the "Graduate Student Study Abroad Program" to provide funding for participation in 7-12 month short-term research and study programs at prominent foreign universities and research organizations in the case of in-school Ph.D. students, and participate in up to 24 months of postdoctoral research in the case of Ph.D.-holders.

In order to send selected outstanding domestic teams to world-class R&D organizations overseas, where they can study areas of science and technology urgently needed in Taiwan in 1-2 year joint research projects and receive training to become the human resources needed for Taiwan's future development, MOST provided subsidies on a

trial basis starting in 2009, and implemented the "New Partnership Program for Connection to the Top Labs in the World" in 2012. These subsidies have been issued to a cumulative total of over 90 research teams performing forward-looking research at organizations in 9 countries since the program was initiated, providing training to over 200 young research personnel, and subsidies were provided to 11 teams (including 14 individuals) in 2017.

In addition, to encourage young persons of Taiwanese descent overseas to visit Taiwan and learn about the country's development, MOST and the Ministry of Foreign Affairs; Overseas Compatriot Affairs Commission; Ministry of Health and Welfare; Environmental Protection Administration; Council of Agriculture; National Youth Commission, Ministry of Education; Academia Sinica; NARLabs; and the Taiwan Foundation for Democracy have jointly implemented the "Taiwan Tech Trek" program. This program sponsors summer trips to Taiwan by youths of Taiwanese descent living abroad for the purpose of participating in internships at public and private organizations and enterprises. Thirteen sessions of the Taiwan Tech Trek have been implemented from 2005 to 2017, and a total of over 3,200 trainees have participated.

Manpower training statistics, 2013-2017

Units: person times

Item	S&T personnel engaging in short-term research overseas	Graduate Student Study Abroad Program		Taiwan Tech Trek
		Ph.D. students	Post-doctoral researchers	
2013	257	160	65	289
2014	228	147	77	276
2015	236	143	95	282
2016	235	102	101	246
<b>2017</b>	<b>222</b>	<b>120</b>	<b>95</b>	<b>228</b>

## 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 standards and international academic status. Apart from receiving a certificate from MOST, recipients receive an award of NT\$900,000. A total of 73 persons received this award in 2016, and the 2015 academic research awards ceremony was held on June 26, 2017, 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 diverse 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 toward society, the economy, people's livelihoods, the environment, and industry. Applications for the 2017 award are currently in the midst of review, and it is expected that the list of award-winners will be announced at the end of March 2018.

## 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 40 persons received this award in 2016. Recipients receive a medal and NT\$200,000 from MOST. The 2016 winners received the award from the minister of science and technology at an academic research awards ceremony held on June 26, 2017.

To encourage more young scholars, the number of recipients has been increased by five persons (to a total of 45 persons) starting in 2017, and the amount of prize money has been increased to NT\$300,000. A total of 44 persons were granted the award in 2017, and will receive the award at a ceremony for multiple awards to be held in June 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 will establish a "Presidential Science Prize Committee" consisting of 15 experts and scholars. This committee will select individuals 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 through basic academic research.

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. Thirteen applications were received in 2017, of which three persons were chosen to receive the award. These consisted of Academician Wang Hui-chun in the Life Science section, Deputy General Manager Hsu Chen-hua in the Applied Science section, and Academician Chen Chien-teh in the Physical Science section. The president personally conferred the awards at an awards ceremony held in the Office of the President on November 21, 2017.

### 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 encourage technological R&D and recognize the country's outstanding S&T personnel. The award was renamed the "Executive Yuan Award for Outstanding Science and Technology Contribution" in 2006, at which time the relevant regulations were revised as the *Executive Yuan Award for Outstanding Science and Technology Contribution Implementation Regulations*, *Executive Yuan Award for Outstanding Science and Technology Contribution Review Committee Establishment Regulations*, and *National Science Council, Executive Yuan Selection Operating Guidelines for the Executive Yuan Award for Outstanding Science and Technology Contribution*, and the amount of the award was increased from the original NT\$600,000 to NT\$1 million. All citizens engaged in science and technology in the natural sciences, engineering, life science/medicine/agriculture, or the humanities and social sciences whose R&D results lead to outstanding inventions or innovations, and thereby make significant, groundbreaking, and original contributions to 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 units, performs a review, the results are sent to the Executive Yuan for approval and conferral of awards.

In 2017, 42 nominations for the award were received, and the award was granted to five persons in two cases following the selection process. The winners were Mr. Tsai Ko-chuan and three others in the natural science and engineering category and

Mr. Hsieh Ching-chun in the humanities and social sciences category. The Executive Yuan held the awards ceremony on December 27, 2017, and the awards were bestowed by Executive Yuan Premier Lai Ching-teh.

Research awards, 2013-2017

Item	2013	2014	2015	2016	2017
Outstanding Research Award (persons)	72	72	74	73	78
Ta-You Wu Memorial Award (persons)	40	40	40	40	44
Presidential Science Prize (persons)	3	-	3	-	3
Executive Yuan Outstanding Contribution in Science and Technology Award (cases)	4	2	4	3	2

### C. Technology transfer incentives

In order recognize research personnel and research teams that have made significant contributions to the transfer of R&D results and have demonstrated excellent performance, project-implementing organizations may apply to MOST for the Outstanding Technology Transfer Contribution Award when 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. Nineteen persons in 12 cases received this award in 2016, and applications for 2017 are currently being reviewed.

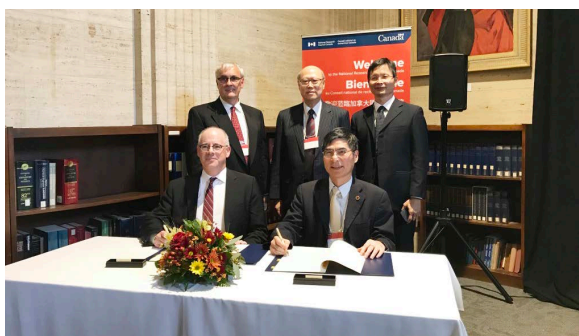
also strives to encourage emerging areas of technological R&D in line with the development of key industries, and thereby promote the goals of innovation and entrepreneurship. Beyond deepening S&T cooperation with the leading countries, MOST is also developing bilateral and multilateral S&T cooperation platforms in conjunction with the government's expansion of its New Southbound Policy and cooperation with key countries in Southeast Asia, and is jointly discussing mutually-beneficial multinational cooperation with these countries.

MOST has signed 119 cooperation agreements, MOUs, and other cooperation documents with 43 countries and 3 international organizations. New developments during 2017 include signing of an S&T cooperation MOU with Canada's National Research Council (NRC), the signing of the research project cooperation letter of intent with Japan's National Institute of Advanced Industrial Science and Technology (AIST), the signing of a cooperation MOU with France's National Cancer Institute (INCa), and a 5th implementation agreement under the development, launch, and operating technology cooperation agreement concerning the United States' Constellation Observing System for Meteorology, Ionosphere and Climate. MOST also continued to implement the "Taiwan-Indonesia S&T Innovation Accelerator MOU" signed with Indonesia's Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi – BPPT) and negotiated a new cooperation framework with the British Academy.

## V International Cooperation in Science Technology

### A. Establishment of international cooperation networks

MOST and foreign funding agencies are relying on agreements and MOU to establish bilateral cooperation frameworks, within which both parties will provide funding for calls for bilateral projects on priority areas, two-way visits of research personnel, and joint 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



On October 16, 2017, Science and Technology Minister Liang-Gee Chen (right, front row) signed a Taiwan-Canada S&T cooperation MOU with Iain Stewart (left, front row), president of the Canadian National Research Council.



Science and Technology Minister Liang-Gee Chen (5<sup>th</sup> from left, front row) and NRC President Iain Stewart (5<sup>th</sup> from right, front row) were among those in attendance at the "Taiwan-Canada Science and Technology Cooperation 20th Anniversary Celebration" held in Canada on October 16, 2017.

## B. State of international cooperation and interchange

### 1. North America

In an effort to expand Taiwan-US S&T interchange, MOST and the US National Science Foundation (NSF) jointly approved the following two international cooperative projects in 2017: "Partnerships for International Research and Education" (PIRE) and "Feedbacks Among Climate, Erosion and Tectonics" (FACET), and MOST and the NSF also jointly held the "2017 Taiwan-US Earth Science Bilateral Cooperation Symposium," which promoted interchange and cooperation between the two countries' scientists. Furthermore, MOST continued to deepen bilateral interchange and cooperation with partner units, including the US National Academy of Sciences (NAS), US National Institutes of Health (NIH), and National Cancer Institute (NCI), and actively participated in the "National Cancer Moonshot" international cooperative project.

To commemorate the 20<sup>th</sup> year of bilateral cooperation between MOST and Canada's NRC, a "Taiwan-Canada Science and Technology Cooperation 20<sup>th</sup> Anniversary Celebration" was held in Ottawa, Canada on October 16, 2017, along with the "Medical Devices enabled by Internet of Things" Symposium, and many representatives of the two countries' industry, government, academia, and research communities participated.

### 2. Europe and the EU

The EU's 8<sup>th</sup> Framework Program—entitled "Horizon 2020"—will extend from 2014 to 2020. Responding to the Horizon 2020

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



Participants at the "Taiwan-Europe H2020 Researchers Night" held on March 16, 2017 In 2017, in order to strengthen

In order to strengthen international linkage in forward-looking research projects on green energy technology, MOST jointly issued a call for Taiwan-German battery research projects with the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung –BMBF), and approved three projects relating to energy storage. As for bilateral international cooperation with European countries, in order to expand and deepen bilateral cooperation, MOST signed the a bilateral co-funding R&D project agreement with the Technology Agency of the Czech Republic, and the two parties jointly held the 5<sup>th</sup> Taiwan-Czech Science and Technology Day Activity in Taipei. MOST also jointly held the 6<sup>th</sup> Taiwan-Poland Bilateral Symposium: Artificial Intelligence with Poland, and the 16<sup>th</sup> Annual Taiwan-Latvia Science and Technology Cooperation Conference in Vilnius with Lithuania. MOST further renewed a two-year cooperation agreement involving research projects and conferences with the National Research Council of Italy (CNR), restarted a joint research project program with the British Academy, and jointly held the 19<sup>th</sup> "Taiwan-France Science and Technology Awards Ceremony" in France on November 22, 2017.

### 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 helps hold joint bilateral S&T conferences with these countries to discuss cooperative projects of joint interest. The 5th Taiwan-Philippines Ministerial Conference on

Science and Technology held by MOST in Taipei on December 9, 2016 approved three multi-year Taiwan-Philippines research projects concerning volcanoes, the sea, typhoons, and earthquakes in order to promote regional cooperation between Taiwan and the Philippines. MOST has continued to promote bilateral cooperation between Taiwan and the Philippines in science and technology based on the consensus reached at this conference, and the Taiwan-Philippines Vice Ministerial Conference on Science and Technology held on September 28, 2017 approved five Taiwan-Philippines bilateral projects and provided funding to nine persons to participate in a Taiwan-Philippines Sandwich Program (under which students from the Philippines study and perform research in Taiwan). Apart from this, in line with the government's New Southbound Policy, MOST also proposed Taiwan-Philippines cooperation in the areas of medicine, agriculture, and manpower training, and two Taiwan-Philippines medical projects and two agricultural projects were drafted following bilateral discussion.

In conjunction with the government's New Southbound Policy, MOST staffed a Taiwan science park exhibition area introducing Taiwan's science parks, high-tech industry, and future goals at the Taiwan Expo held in Manila from September 29 to October 1 by government agencies and city and county governments under the Executive Yuan's coordination.

MOST held the 9<sup>th</sup> Taiwan-Indonesia Joint Conference on Science and Technology in Taipei on June 15, 2017, and the two countries used



this opportunity to approve seven multi-year bilateral research projects and plan two new Taiwan-Indonesia bilateral conferences, which will be on the topics of artificial intelligence and smart cities.

MOST seeks to joint promote innovative entrepreneurship and industry-academic collaboration projects with India, and has already planned a call for proposals for joint Taiwan-India projects during 2018. Emphasis is being placed on obtaining project proposals with a technology readiness level greater than 4, and MOST has reached a consensus with its Indian counterparts to encourage companies in Taiwan and India to jointly participate in Taiwan-India bilateral research projects.

In order to promote regional scientific research cooperation, while taking Taiwan's S&T strengths and bilateral common interests as the subjects of cooperation, MOST provided funding to academic research organizations in Taiwan for 124 research projects connected with New Southbound Policy countries in 2017. MOST is also relying on the "Overseas Science and Technology Innovation Center Program" to support the establishment of focal research centers in New Southbound Policy countries by academic research organizations in Taiwan; these research centers will enable research personnel to exert Taiwan's S&T influence during long overseas stays, while establishing connections with local manpower and innovations. The establishment of six three-year overseas scientific research centers was approved during 2017; these centers will be located in Vietnam, the Philippines, Thailand, Indonesia, Laos, and Malaysia, and will focus on topics in the humanities, medicine, natural science, agriculture, and engineering.

In order to promote interchange with highly-skilled personnel in the Southeast Asian countries, MOST is targeting government officials and S&T personnel 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 14 S&T workshops held under the program in 2017 trained

over 200 S&T personnel and established regional cooperation networks. For example, 35 trainees participated in the October 11 Yushan Forum: Asian Dialogue for Innovation and Progress, which gave them a first-hand understanding of the content of Taiwan's New Southbound Policy. Furthermore, in order to strengthen bilateral S&T cooperation in the New Southbound Policy region and establish an S&T cooperation bridge between Taiwan and Indonesia, MOST continued to implement the "Taiwan-Indonesia S&T Innovation Accelerator MOU" signed with Indonesia's Agency for the Assessment and Application of Technology (BPPT).

With regard to Northeast Asia, MOST held a joint research project results presentation meeting on the topic of information security in Tokyo with the Japan Science and Technology Agency (JST) in April, and held a joint conference on the topic of quantum materials at Japan's Tsukuba University with the Japanese National Institute for Material Sciences (NIMS). As for Western Asia, MOST held the 6<sup>th</sup> S&T Joint Committee meeting and 4<sup>th</sup> research project results presentation meeting with Israel's Ministry of Science and Technology in Jerusalem on November 12; MOST plans to take artificial intelligence and advanced materials as the topics of cooperation with Israel during the coming two years.

### C. Participation in major international S&T organizations

#### 1. Asia Pacific Economic Cooperation (APEC)

MOST participates in APEC's annual senior officials' meetings and chief science advisor meetings, as well as APEC's working groups. Via APEC's Policy Partnership on Science, Technology and Innovation (PPSTI), MOST has funded the establishment of the Research APEC Center for Advanced Biohydrogen Technology and APEC Research Center for Typhoon & Society. These centers' operations include promotion of multinational cooperative research, conferences, professional training, and establishment of registration S&T platforms, and they serve to build on Taiwan's S&T soft power. The 9<sup>th</sup> and 10<sup>th</sup> APEC Policy Partnership on Science, Technology and Innovation (PPSTI) conferences were held in Vietnam; the 2017 APEC Typhoon Symposium and Smart Power Management for Self-Sustained Green Community in the APEC Region were approved at these conferences, and the latter obtained funding from the APEC energy efficiency subfund.

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

In coordination with the Academia Sinica, MOST has continued to promote two-way cooperation and interchange with the European Molecular Biology Conference/European Molecular Biology Organization (EMBC/EMBO). On November 20, 2017, Dr. Luis Valente, the new head of EMBO's International Cooperation Department, visited Taiwan at the head of a delegation, and promoted mutual understanding and deeper ties while at a discussion meeting with partners held at the Academia Sinica.

### D Funding international academic interchange activities

In order to expand the scope of international S&T cooperation and enhance Taiwan's visibility in the international academic world, MOST has striven to promote participation of domestic teams in the activities of international scientific and technological organizations and international academic organizations, and continues to provide support for the promotion of S&T research cooperation via attendance at international academic conferences, the holding of international academic conferences, and the invitation of foreign

figures to Taiwan. This work is strengthening Taiwan's international cooperation human resources and putting the internationalization environment on a stronger footing.

To help young scholars broaden their international perspectives and gain international experience, MOST provides funding to domestic graduate students for participation at international conferences allowing them to present their research results. This participation also expands graduate students' international outlooks, sharpens their research skills, and fosters collaborative international 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 encourage and support 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.

Funding for international academic interchange activities, 2013-2017

Year	Joint international research projects	Invited visits by foreign S&T personnel (person-times)	Attendance at international academic conferences (Dept. of International Cooperation & Science Education projects/ specific-topic research projects)(person-times)	Graduate student attendance at international conferences (person-times)	International conferences held in Taiwan	Participation by teams in international academic organization conferences (teams/ person times)	Enhancing the international influence of domestic scientists (cases)
2013	138	856	982 / 12,290	3,314	345	42 / 223	29
2014	114	839	953 / 12,607	3,300	345	49 / 313	34
2015	250	758	934 / 12,774	3,375	327	42 / 224	27
2016	282	730	1,009 / 12,288	3,545	315	42 / 243	25
<b>2017</b>	<b>216</b>	<b>800</b>	<b>1,110 / 12,504</b>	<b>2805</b>	<b>285</b>	<b>37 / 227</b>	<b>25</b>

### E. Overseas Science Divisions

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 and serve overseas Chinese S&T personnel and academic 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 14 overseas conferences held in 2017 discussed topics including translational cancer biology, biomedical engineering, reliance on innovation and education to realize sustainability, big data technology development and applications, nature disaster prevention engineering, biotech medicine, circular economy, innovative biotechnology, and future medicine, etc.



## 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, 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 2017:

1. Based on the *Regulations Governing the Recruitment of Visiting Science and Technology Personnel with Subsidies from the Ministry of Science and Technology*, MOST provided subsidies to research organizations for the recruiting of S&T personnel from China for participation in scientific research in Taiwan; such subsidies were provided 79 person-times in 2017.
2. Based on the *Operating Guidelines for Subsidies for the Holding of Cross-straits Academic and Sci-tech Conferences*, MOST encouraged and supported the holding of cross-strait S&T and academic conferences

by academic or S&T organizations and universities. Support was provided for 55 conferences in 2017.

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 77 such visits in 2017, which were chiefly for the purpose of public lectures and participation in discussions.
4. In 2017, 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 395 such applications.
5. In order to promote positive cross-strait academic interchange, MOST continued to fund its share of bilaterally-funded joint research projects with China on specific issues concerning public welfare. The topics of this year's joint investigation encompassed "From Near-Earth Objects to Galactic Evolution" and "Applications of Disaster Prevention Science and Technology."

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

S&T interchange with China and permit review statistics, 2013-2017

Item	2014	2015	2016	2017
Recruited S&T personnel from China (person-times)	121	108	85	<b>79</b>
Cross-strait academic conferences	64	73	47	<b>55</b>
S&T personnel from the Mainland China Area, Hong Kong, and Macao invited to Taiwan (person-times)	89	67	83	<b>77</b>
Professional S&T activity permits reviewed (person-times)	464	433	547	<b>395</b>

## VII Improving the Research and Development Environment

### A. Online services

An all-new version of MOST's international website went online in September 2017. This website features a starry sky as its design theme, and an extra-large banner is used on the front page provides information concerning MOST's important activities, including projects and online videos, in slideshow format. MOST also uses social media to spread information, and has added Facebook fans page information and links to YouTube channels. Apart from revamping its website, to ensure that users can read website information in convenience and safety, MOST has made sure that its website meets information security testing standards.

With regard to online information service improvements, MOST revised 20 online application systems during 2017, including "Subsidies for domestic graduate students to attend international academic conferences," "Specific-topic research project online application procedures," and "University and college student research projects"; apart from providing online application, final report, report submission, and

agency compilation and online review functions, these webpages now offer greater compatibility with major browser versions.

With regard to paperless online application for academic research grants and funding, after many years of paperless online submission for review, the system has effectively reduced paper and postage costs, shortened processing time, and boosted administrative efficiency. Taking conservation of paper through paperless application for academic research funding as an example, compared with the original on-paper procedures, throughout the process from initial application to final review and approval, application cases in 2017 conserved close to 40 million sheets of paper, which is equivalent to saving 4,788 trees and demonstrates significant energy conservation and reduction in carbon emissions.

In order to seek further improvement, MOST began use of paperless academic review fee receipts on a trial basis in 2013. Paperless receipts were used to request funding reimbursements approximately 123,752 person-times during 2017; apart from boosting administrative efficiency, this also achieved energy conservation and carbon emissions reduction goals.

Paperless online application statistics, 2015- 2017

Item	2015		2016		2017	
	Cases	Person- times	Cases	Person- times	Cases	Person- times
Project funding	28,443	88,049	28,233	87,205	27,983	87,524
International cooperation	8,123	11,034	8,516	10,900	9,000	12,222
Manpower recruiting	1,609	2,804	1,692	3,087	1,608	3,042
Industrial/ academic collaboration	1,680	5,638	1,638	6,208	1,363	4,620
<b>Total</b>	<b>39,855</b>	<b>107,525</b>	<b>40,079</b>	<b>107,400</b>	<b>39,954</b>	<b>107,408</b>

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

### B. Major Instrument Common Use Service

MOST's major instrument common use service program provides needed equipment to researchers in academia and industry. During 2017, 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 Taiwan University of Science and Technology, National Dong Hua University, Taipei Medical University, National Taiwan Ocean University, Chung Yuan Christian University, Feng Chia University, Kaohsiung Medical University, National Pingtung University of Science and Technology, National Taipei



Institute of Technology, Tunghai University, Yuan Ze University, National Chin-Yi University of Technology, National Changhua University of Education, and National Chi Nan University. Facilities at these universities housed 206 in-

service instruments during the year. These major instrument centers provided services 422,080 times in 2017, and service time totaled 392,613 hours. The aggregate value of instrument services amounted to over NT\$558.3 million.

Paperless online review cases and person-times, 2015-2017

Item	2015	2016	2017
Project funding	103,592	102,576	101,136
International cooperation	18,663	18,757	22,092
Manpower recruiting	15,842	15,893	15,716
Industry-academic collaboration	5,885	5,940	5,692
<b>Total</b>	<b>143,982</b>	<b>143,166</b>	<b>144,636</b>

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

Major instrument use center service statistics, 2017

School name	Number of instruments	Cases	Service hours
National Taiwan University	24	64,005	63,613
National Taiwan Normal University	6	10,782	16,974
National Central University	13	25,524	22,840
National Tsinghua University	29	77,905	58,481
National Chiao Tung University	27	51,334	58,787
National Chungshing University	20	46,913	36,245
National Chung Cheng University	12	16,843	20,168
National Cheng Kung University	24	58,557	48,796
National Sun Yat-sen University	18	26,545	32,893
Non-major instrument centers (14 schools)	33	43,672	33,817
<b>Total</b>	<b>206</b>	<b>422,080</b>	<b>392,613</b>

Source: Major information management system

## VIII Management and Extension of R&D Results

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

as a rule, been granted to the implementing organization.

In view of the important role played by academic research organizations in the development and application of knowledge, MOST drafted the *Guidelines for the Funding of the Management and Extension of Academic Research and Development Results* in order to help implementing organizations boost the effectiveness of R&D results management and

extension, and has adopted many performance-oriented funding and award measures since 2003. In the case of R&D results resulting from MOST-funded projects, when the implementing organization applies for an invention patent, subsidies during the application stage will cover 40% of expenses, and subsidies covering additional 40% of application expenses and 80% of maintenance expenses during the first 3 years can be obtained after the patent has been received.

In order to further boost the industrial application of academic research organizations' invention patents, the Guidelines were revised on June 5, 2015 in order to adjust funding ratios. Funding is now provided for 60% of patent application expenses, and for 50% of patent certificate acquisition and maintenance expenses during the first three years. All academic research organizations that have instituted sound management mechanisms are now eligible to initiate invention patent application, maintenance, and extension cases, which will induce research organizations to strengthen their internal management mechanisms and make their performance management more rigorous. Subsidies covering invention patent expenses were provided in 4,779 cases involving the results of funded projects during 2017.

Furthermore, to encourage technological diffusion, project-implementing organizations need pay only a certain percentage of income from R&D results to the funding agency (these payments are included in the Science and Technology Development Fund in accordance with budget procedures); this percentage is 20% in the case of schools and government research organizations, and 40% in the case of companies and other research organizations. MOST's royalty income from R&D results was approximately NT\$60 million in 2017.

## 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 striven 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 understanding of science. This magazine won the Executive Yuan's Outstanding Government Publication Award from 2002 to 2007, and also won the 2<sup>nd</sup> and 3<sup>rd</sup> 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 input and output indicators of Taiwan and other major nations during the most recent five years; apart from explanatory text, charts and graphs help readers to clearly understand the significance of major indicators and the current state of R&D in Taiwan and other countries. The second section, "International Comparison of S&T Activity," contained relevant data concerning major S&T indicators in various countries. The third section, "S&T Activity in Taiwan," included a breakdown of R&D funding and R&D manpower across the business enterprise, government, higher education, and private nonprofit sectors, the government's S&T budget and R&D budget, S&T results, and science park R&D data. The fourth section consisted of appendices explaining the survey, defining terms, and providing the survey questionnaire and comparisons of OECD and Taiwan industry classifications. The entire volume can be viewed on the MOST website (<http://www.most.gov.tw/>).

### Journal of Biomedical Science

This international academic periodical is edited by domestic scientists, and the editorial committee consists of domestic and foreign experts and scholars. There is a strict review system, and the journal is published in English by a prominent international publishing company.



First published in 1994, the *Journal of Biomedical Science* was originally a quarterly, but was changed to a bimonthly in 1996. In order to disseminate academic research results faster and more widely, this journal was changed to open access in 2009; any user can use papers free of charge via the Internet, and research personnel can freely share resources from the journal, promoting academic development. The Journal had an *SCI* impact factor of 2.799 according to the 2016 *Journal Citation Reports (JCR)*, and is one of the most representative biomedical journals in Asia.

#### ***International Journal of Science and Mathematics Education***

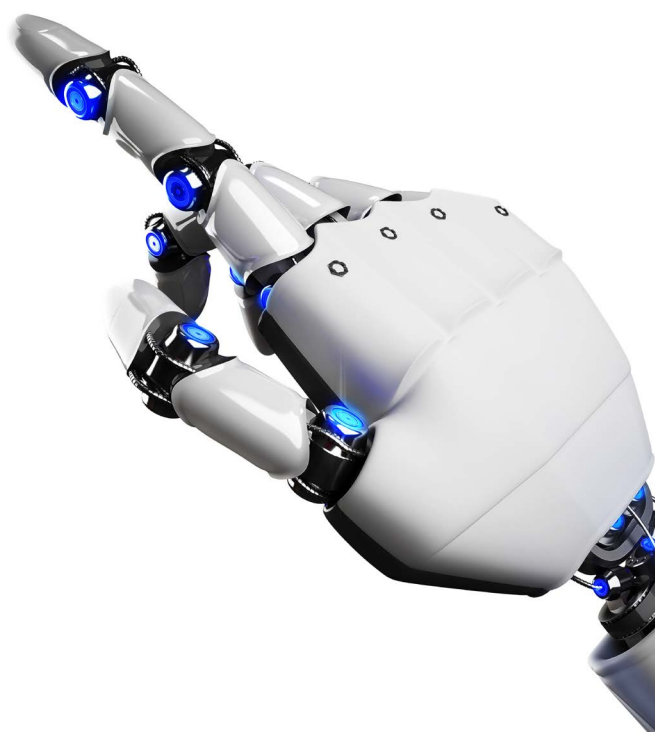
First published in 2003, this quarterly international academic periodical was changed to a bimonthly in 2009. It is edited by domestic scholars with the help of an editorial committee consisting of prominent domestic and foreign experts in relevant areas, and is published by a well-known international publishing company. The journal employs a strict double-blind peer review system. Manuscripts are received from many countries worldwide, and roughly 73% of manuscripts are from non-English-speaking countries, which makes 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 1.474.

#### ***East Asian Science, Technology and Society : an International Journal***

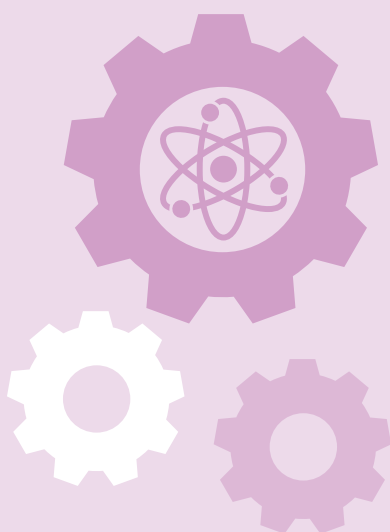
First issued in 2007, this quarterly is published in cooperation with a prominent international publishing company, and contains articles, book reviews, and short communications concerning science, technology and society (STS). MOST hopes that the studies of East Asia experiences and phenomena and comparative research in this journal will enable the emergence of STS perspectives differing from those in the West, which will highlight Taiwan's contribution to the international STS academic community. Apart from a domestic chief editor, the journal has invited experts and scholars from Taiwan, Japan, Korea, Britain, the US, and Australia to form the editorial committee. The journal relies on its rigorous review system to continuously improve the quality of articles.

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





# ACADEMIA | INDUSTRY SCIENCE | TECHNOLOGY



## Chapter 4 / Strengthening Industry-Academic Linkage and Innovation

Industry-academic Collaborative Research Projects

University-Industry Collaboration Projects (Large Alliance)

Academia-Industrial Technology Development Alliance Projects

From IP to IPO

Additive Manufacturing (Digital Manufacturing) Industrial Application Research Projects

New Industry-university Cooperative Research Linking Program

Applied Research Program for Startups

Germination Program

Using Research Institutions to Link Industry-Academia Collaboration Projects

Taiwan Innovation and Entrepreneurship Center (TIEC)

Learn-Explore-Aspire-Pioneer Program (LEAP Program)



## 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 corporations to participate actively in academic applied 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. 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 projects requiring long-term R&D. Developmental projects focus on innovative technologies for core applications assisting industrial development, and include industry-academic collaborative projects in which the cooperating corporation 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 1,239 project applications were accepted in 2017, of which 775 were approved to receive funding, and the total funding amount was NT\$848.4 million. The projects provided training to 2,069 graduate students, attracted NT\$325.5 million in corporate R&D funding, and participating corporations numbered 804. 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, 2013-2017

Item	2013	2014	2015	2016	2017
Number of projects	842	813	808	840	775
Funding (NT\$1 m)	816	894	993	889	848
Participating companies	829	852	829	867	804
Corporate contribution (NT\$1 m)	306	328	380	348	325
Manpower training (graduate students)	2,081	2,095	2,078	2,178	2,069
Patents received	150	216	155	146	56 <sup>1</sup>

<sup>1</sup>2017 data is still being compiled

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

### II University-Industry Collaboration Projects (Large Alliance)

In order to direct academic R&D capabilities and resources to the industrial sector, strengthen Taiwan's industrial technology innovation ability, and gain an advantage in international markets, MOST and 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 window for these projects, and the academic participants submit proposals for review.

This program channels academic R&D capabilities to industry by pairing Taiwan's finest scientists and researchers with internationally

competitive companies. The beneficial results of this approach include shrinking the gap between academia and industry, fostering the development of cutting-edge industrial technologies, strengthening the key technological capabilities and patent portfolios of Taiwan's high-tech firms, and training scientific and technological manpower of the highest caliber.

A total of 6 large alliance projects were implemented in 2017, and the participating companies consisted of 16 well-known domestic firms, including companies in the fields of semiconductors, green chemical engineering technology, wireless/broadband network technology, and mobile communications technology. The projects have attracted a cumulative total of approximately NT\$1.9 billion in R&D funding, and have resulted in more than 444 patent applications. This year's results have included nano-precipitation technology, which has enabled China Steel to become the world's second steel-maker (behind only Japan's JFE Steel) able to produce 980 grade hot-rolled high-strength steel; this steel will help domestic auto parts manufacturers to enter the international high-strength steel supply chain. 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 abundant research capabilities of Taiwan's academic research sector are not directed solely to the publication of papers in journals; 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 role played by SMEs in Taiwan's industries, and their urgent need for the R&D resources and capabilities of academia, MOST began funding "academia-industry technology 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 companies.

Implementation of the first batch of small alliance projects got underway in February 2013; 75 projects received funding during the first year, 92 projects received funding in 2014, 106 projects received funding during 2015, 91 projects received funding in 2016, and 91 projects again received funding in 2017. Project implementing organizations have included 37 public and private universities and research organizations. As of the end of December 2017, 1,339 companies had participated in small alliance projects, and this program has achieved its preliminary goal of establishing a platform for industry-academic collaboration. Alliances are currently being encouraged to expand their membership and thereby further increase the diffusion of academic technologies to industry.

### IV From IP to IPO

While Taiwan's scientific and technological R&D results have been impressive, there was long little effort to develop the training mechanisms and resources needed to encourage academic research teams to perform market testing of their R&D results. Hoping to overcome this state of affairs, MOST began implementation of the "From IP to IPO" (FITI) program in March 2013 with the goal of helping entrepreneurially-minded youths to successfully establish startups. The program seeks to encourage students, professors, and research personnel with innovative technologies, outstanding research project results, or patents, or who have won innovative design awards or invention awards to form teams and jointly realize their entrepreneurial dreams.

Those persons and teams who wish to transform their academic research into innovation-based startups often face many obstacles, which require thoroughgoing training and assistance mechanisms to be overcome. Investigation has found that domestic research-based startup teams almost always lack practical entrepreneurial skills, including market knowledge, team formation and cooperation, operational planning, and resource- and relationship linking abilities. These teams must



therefore systematically accumulate and cultivate key knowledge and resources, and must assess their results on the basis of experience garnered in the real world. As a consequence, this program designed training mechanisms modeled on international accelerators, including accelerated team formation training, and promotion of startup establishment based on creative ideas and innovations. The program focuses on S&T topics, and seeks to link academic research with industrial technology R&D capabilities in order to forge new economic momentum.

This program's selection mechanism is different from ordinary innovative startup idea competitions, and its industry-oriented focus will gradually shift from competition to "competition/cooperation." The program re-emphasizes the essence of innovative entrepreneurship—cooperative and creation—and de-emphasizes ranking and comparisons. The program provides starter funds to startups, and encourages team entrepreneurship by focusing on assistance to teams, and not specific individuals. FITI helps teams perform market surveys, prototype production, marketing exposure, and financial planning in conjunction with practical operations during the training period. There are two training sessions each year, and the calls for participants is open to entrepreneurs in the fields of biotechnology medicine, innovative technologies, design and information applications, and services. During the 4-6 months training period for each session, guru recruiting from Silicon Valley and in Taiwan provide assistance via two in-depth training camps, five core classes are held to reinforce the teams' startup knowledge, and MOST's B.I.G. Demo events provide opportunities to find venture investors and initiate public fund-raising. Teams are provided with key startups resources throughout the training period, along with accelerated matchmaking with sales channels, funding, and contacts. As a result, the FITI program can usually help resolve startups teams' specific problems within a short period of time, and the presentation of open business fund-raising briefings ensure that teams can quickly transform their entrepreneurial ideas into mature business plans. At the same time, the program uses social networking websites and workshops or professional classes to bring together teams, and provide teams with opportunities to receive comprehensive entrepreneurship skills training and professional consulting. The trainees can study and develop their abilities together with

like-minded companions, form teams, obtain industry contacts, and complete business models or confirm target markets, etc.

As for economic effectiveness, from the time it was initiated in 2013 until December 31, 2017, the program has provided training to 400 teams (consisting of 2,184 entrepreneurially-minded young people) and helped establish 136 startups, which have total paid-in capital of NT\$1.4 billion, leveraged private investment of roughly NT\$1.2 billion, and created 553 jobs. In addition, with regard to inducement of private participation, the program has obtained support from 14 leading corporations, namely Hiwin Technologies, Chunghwa Telecom, O-Bank, Delta Electronic, TSMC, Ernst & Young, Kinpo Group, Acer Foundation, Lee and Li Attorneys-at-Law, Fubon Financial Holdings, Far Eastern Group, Ruentex Group, MediaTek, and Liton Group, which have provided NT\$67.5 million in sponsorship funds to outstanding FITI teams. This program has encouraged numerous research teams in Taiwan to boldly pursue their dreams, overcome obstacles, and realize the market value of their innovations.

#### V

#### Additive Manufacturing (Digital Manufacturing) Industrial Application Research Projects

Smart additive manufacturing technology (3D printing) involves the use of additive processing methods in conjunction with existing subtractive manufacturing methods, and can fully realize the ideal of digital manufacturing; it can handle the manufacture of items that are impossible or extremely difficult to produce using conventional methods, inspire new thinking in manufacturing, and has become one of the world's most attention-getting advanced manufacturing techniques.

MOST-promoted "Additive Manufacturing (Digital Manufacturing) Industrial Application Research Projects" have induced domestic universities to focus their energies on the field of smart additive manufacturing technology R&D and train elite manpower. The goals of this program are to boost the realizability and marketability of forward-looking basic technologies, establish mechanisms for cooperation between industry and universities, promote cooperative alliances among industry, academia, and research organizations, encourage joint R&D of new applications, new

equipment, new materials, new software, and key parts and components, foster the joint development of technological applications and services, develop metal manufacturing industries (including the machine tool, mold, and auto industries), innovative biotech medical industries (including the precision medical equipment and biomedical printing industries), and plastics industries (including the shoemaking industry), and ensure that smart additive manufacturing resources are used as effectively as possible.

Current applications research projects have resulted in the establishment of 13 3D printing teams and dedicated additive manufacturing laboratories. Academic participants include National Taiwan University, National Tsinghua University, National Chiao Tung University, National Cheng Kung University, National Central University, National Chung Cheng University, National Chungshing University, National Sun Yat-sen University, National Yang Ming University, Kaohsiung university, National Taiwan University of Science and Technology, National Taipei Institute of Technology, Huwei technology university, National Pingtung University of Science and Technology, Asia University, China Medical University, National Defense Medical Center, and Kaohsiung Medical University, and 375 additive manufacturing specialists and interdisciplinary personnel took part. The projects have obtained 17 domestic and foreign patents, and have yielded extensive innovation capabilities in connection with the development of additive manufacturing technology (3D printing), including materials, software, key components, and systems integration.

The participants in this program have also engaged in technological cooperation with 10 research organizations, including the Industrial Technology Research Institute, Metals Industry Development Center, NARLabs Instrument Technology Research Center, Tri Service General Hospital, Taipei Veterans General Hospital, China Medical University Hospital, Show Chwan Memorial Hospital, An-Nan Hospital, and Kaohsiung Medical University Hospital. Furthermore, 32 leading domestic corporations, including Tongtai Machine, Delta Electronics, Himag Magnetic, Super Electronics, Taiwan Tungsten Steel, Gang Chuan Ultra-Hard Alloy, Cheng Chang Carbide, United Orthopedic, ShineIN Biotech, Triad Orthopedic, Ling Hsien Masterbatch, Digital-Can, OtO Photonics, General Integration Technology, Taiwan ONP's prosthetic-orthotic center, Vincent Vacuum

Tech, Taiwan Additive Manufacturing, Taiwan Hsin Hsiu, Moldex3D, Sinodynamics, Nan Pao Resins, How-Mau, View Grand, Samwell, Advanced Ion Beam, Shui-Mu, Enlighten Materials, Biotron, Deh Lab, Ting Hsin Precision, and Cold Spring Biotech, cooperated in the projects and provided materials production, extension, sales, and technology transfer and licensing services. By developing key additive manufacturing technologies, materials, product structural design, and increasing smart additive manufacturing speed, these projects are boosting the global status and competitiveness of industry in Taiwan.

## VI Applied Research Program for Startups

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

Although Taiwan's academic institutions and research units have accumulated considerable potential and good results in the areas of biotech pharmaceuticals and medical equipment, most relevant academic research results still remain at the front end of industry value chains, and have made insufficient progress toward commercialization. These projects are consequently intended to promote early R&D in the fields of pharmaceuticals and medical equipment. As of the end of 2017, more than 260 promising proposals in the fields of pharmaceuticals and medical equipment had passed the initial screening process, and 75 of these had been subjected to in-depth assessment. After rigorous review and selection by an advisory team consisting of domestic and foreign experts, 30 projects were approved to receive MOST funding and full-scale incubation assistance. The program has assisted the establishment of 16 new startups, and has helped research results in the medical equipment-related areas of neural conduits, new drug release systems, bone screw positioning,



leukocyte reduction filtration technology, in vitro endometriosis diagnostic reagents, and smart dialysis blood leakage detection devices to advance to commercialization. The cumulative paid-in capital of these startups has exceeded NT\$670 million, which indicates 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.

## VII Germination Program

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

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

In 2017, this program provided funding for nine germination centers, which are located at National Taiwan University, National Yang Ming University, National Tsinghua University, National Cheng Kung University, National Chung Hsing University, National Sun Yat-sen University, National Central University, Chung Yuan Christian University, and Taipei Medical University. Targeting original technologies developed at universities and research organizations, these germination centers seek to uncover the commercial applications of these technologies at a stage when their potential is still unclear, and assist teams with innovative, technical, and early ideas to establish startups.

As of the end of 2017, this program had brought about the establishment of nine germination centers and 42 startups, with the latter having paid-in capital of NT\$425 million and total raised funds of NT\$886 million.

## VIII Using Research Institutions to Link Industry-Academia Collaboration Projects

In order to strengthen linkage between academia, industry, and society, MOST has actively promoted "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, creating a self-reinforcing ecosystem involving university R&D results and industrial application, shrinking the gap between universities and industry, ensuring that industry makes effective use of academic research capabilities, and thereby giving a significant boost to Taiwan's industrial competitiveness and capacity for S&T innovation.

This program was initiated on a trial basis during 2015, and its applicable industrial areas were expanded to include electronics/information/communications, biotech medicine, machinery materials, and sustainable energy in 2016. At the same time, the program has also integrated the capabilities of the Industrial Technology Research Institute, Institute for Information Industry, Metals Industry Development Center, Biotechnology Research Center, and Taiwan Textile Research Institute, organized an industry-academic matchmaking service team, and actively visited universities nationwide in order to uncover academic R&D results with industrialization potential. In 2017, in conjunction with the Executive Yuan's promotion of the "5+2" areas of industrial innovation—biotech medicine, green energy technology, smart machinery, Asian Silicon Valley, defense & aerospace, new agriculture, and circular economy, the program has been expanded to include the NARLabs Science & Technology Policy Research and Information Center, Automotive Research & Testing Center, and Plastics Industry Development Center, and it has continued to promote the industrialization of R&D results in conjunction with industry associations and corporations.

The program achieved the following results in 2017:

1. Accelerated promotion of the industrialization of industry-academic R&D results: The program completed identification of 1,012 R&D results, and uncovered academic results with industrialization potential. With the value-adding input of research organizations' capabilities and experience, the program helped initiate 37 industrial-academic collaborative projects.
2. Boosting the industrial value of universities' R&D results: Promotion of the industrialization of R&D results and patents increased universities' income by NT\$64 million.
3. Enhancement of universities' intellectual property management capabilities: The program provided training to practical university intellectual property professionals 186 person-times and one-on-one assistance to 25 teams, which helped universities establish intellectual property and market assessment capabilities.
4. An inventory of key biomedical technology R&D results enabled the drafting of four reports concerning the establishment of R&D clusters with linkage with academia and research organizations; these reports are serving as the preliminary plans for establishment of regional "biomedical technology R&D results value creation industrialization centers" in northern, central, and southern Taiwan and promotion of "innovative medical clusters."
5. Linking corporations and universities: The program relied on the capabilities of research organizations to link corporations and universities, and completed 178 consulting service cases, including over 70 industry-university matchmaking service cases, which guided and assisted universities to engage in product R&D meeting industry's needs.
6. Enhancing the positive effect of academic R&D results on the innovative capabilities of Taiwan's industry: Reliance on research organizations to foster industrial-academic collaboration resulted in 37 commercialization cases and two startups, which boosted the value of academic R&D results to industry.

IX

## Taiwan Innovation and Entrepreneurship Center (TIEC)

On June 19, 2015, the Taiwan Innovation and Entrepreneurship Center was established in the United States Silicon Valley, and assigned the mission of linking startup teams in Taiwan with Silicon Valley's entrepreneurial resources. To date, 76 startup teams have been selected to continue their development in Silicon Valley; these teams have received a cumulative total of more than US\$69 million in funds raised internationally. In addition, 23 other teams have entered Silicon Valley's most prominent accelerators. One team's startup has currently achieved a 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, WCIT, and Meet Taipei in holding three international investment matchmaking meetings during 2017. These events attracted more than 200 domestic and foreign startup teams and 50 prominent international venture investors and corporate representatives. MOST also conducted a total of 218 matchmaking activities.



MOST's Vice Minister Tsou Yu-Han and other VIPs at the Meet Taipei startup matchmaking event on November 16, 2017.

X

## Learn-Explore-Aspire-Pioneer Program (LEAP Program)

With a goal of training high-level technologically-innovative startup manpower for Taiwan, the Learn-Explore-Aspire-Pioneer



Program (LEAP Program) selects doctoral-level personnel who seek to establish innovative startups and non-Ph.D.-holding individuals who have backgrounds aligned with the country's



S&T development directions and possess notable achievements to engage in cooperative projects lasting 6-12 months at corporations, startups, and well-known academic research organizations in the US, France, and Israel. The program seeks to boost Taiwan's international competitiveness by fostering the innovative transformation and upgrading of high-tech industry in Taiwan. A total of 35 trainees were selected in 2017, and studied advanced technologies at companies such as IBM and Nvidia and universities including MIT and Stanford.

Science and Technology Minister Liang-Gee Chen (3<sup>rd</sup> from right) is shown with other distinguished guests at the LEAP Camp conducted November 9-11, 2017.

## XI New Industry-university Cooperative Research Linking Program

With the goal of deepening linkage between industry, academia, and research organizations, and creating a new model of innovation-based entrepreneurship, this program has coupled the capabilities of universities and research organizations throughout the formation of value-adding project startup teams. Under the program, research organization and university participants jointly perform the commercialization of disruptive innovation R&D results and establish spin-offs, while transforming R&D results into tangible industrial benefits. MOST expects that the input of government funding will enable value-adding project teams to increase

the value of their R&D results, and ultimately establish derivative spin-offs or be acquired by other corporations. MOST provided funding to 35 selected startup teams in 2017, and also established the Taiwan Startup Institute, which recruits investment managers with international experience to help startup teams to achieve the greatest commercial value.

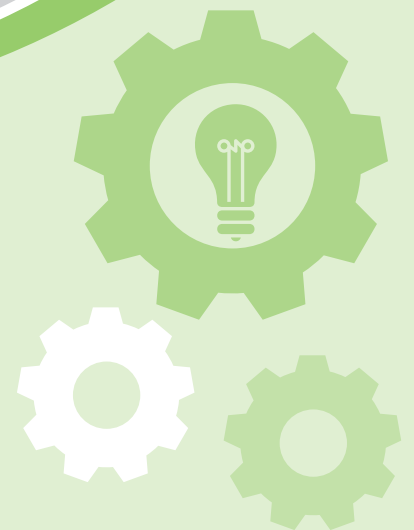
The "Value-adding Project Pledge Assembly" held by MOST on October 25, 2017 was attended by the vice president, representatives of the Dutch, Israeli, and French representative offices in Taiwan, and domestic and foreign angel investors and venture capital firms, who jointly pledged to promote the establishment of innovative startups based on promising academic R&D results.



Photo of Vice President Chen Chien-Jen (5<sup>th</sup> from left, front row), Science and Technology Minister Liang-Gee Chen (5<sup>th</sup> from right, front row), and participants at the October 25, 2017 "Value-adding Project Pledge Assembly."



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## Chapter 5 Developing Taiwan's Science Parks

Hsinchu Science Park  
Southern Taiwan Science Park  
Central Taiwan Science Park



## Chapter 5 / Developing Taiwan's Science Parks

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

### I Hsinchu Science Park

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

The Hsinchu Science Park comprises six sites, which include the fully-developed 653-hectare Hsinchu site, 123-hectare Zhunan site, the 38-hectare Hsinchu Biomedical Science Park, the 71-hectare Yilan site, the Tongluo site (308 ha already developed, 42 ha still being developed) and the Longtan site (76.2 ha already developed, 30.8 ha still being developed). As of the end of 2017, a total of 147,862 persons were employed at the park (excluding persons working in industrial and commercial services), and the 492 registered tenant firms had had total operating revenue of NT\$1.02 trillion. In 2017, 32 companies made new investments totaling NT\$11.5 billion, and training was provided 8,398 person-times.

The Hsinchu Science Park Bureau (HSPB) has a vision of "creating an innovative, entrepreneurial, pioneering science park," and strives to promote innovation and upgrading of industry. Apart from steadily acquiring flagship, innovative domestic and foreign innovative companies, HSPB established the "Bamboo Dragonfly" (Young Entrepreneur's Studio, YES) in conjunction with MOST's "From IP to IPO" program to provide innovative startup teams with an attractive, considerate working environment. As of the end of 2017, a total of 266 entrepreneurial teams had set up operations in the park or received HSP assistance, and 131 teams had established companies, of which 111 companies are still operating. MOST 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.

During 2017, the Hsinchu Biomedical Science Park accepted six biotech firms, which made total investment of NT\$2.35 billion. As of the end of 2017, the Biomedical Science Park had approved a total of 41 tenant firms (including firms still not operating in the park), and another six HSP firms had been approved to expand in the Biomedical Park. As a result, a total of 47 science-oriented companies had been approved to operate in the park and make investments totaling NT\$17.9 billion. Another surge in investment is expected to occur when a second biotech building is completed at the end of 2020, and the campus' future should be bright. In accordance with the "Biomedical Industry Innovation Promotion Project" approved by the Executive Yuan April 17, 2017, the Ministry of Health and Welfare and the Hsinchu Science Park Bureau will jointly promote "Special Medical Enterprises at the Hsinchu Biomedical Science Park," and 2.48 ha in the park's 2<sup>nd</sup> area has been set aside as a "dedicated special medical enterprise area." This area is intended to be the nucleus of a world-class special medicine cluster incorporating domestic medical strengths and an all-round service model. The cluster will be close to National Taiwan University's biomedical campus; five special medical enterprises have been approved to occupy sites thus far.

## Overview of Hsinchu Science Park Industries, 2017

Item	Companies <sup>1</sup>	Number of employees <sup>2</sup>	Revenue (NT\$100 m)	Number of investing companies <sup>3</sup>	Amount of investment (NT\$100 m) <sup>4</sup>
Integrated circuits	182	91,382	7,402	6	32
Optoelectronics	51	7,654	1,418	4	12.2
Computers and peripherals	47	6,697	393	2	0.37
Telecommunications	85	33,304	368	3	31.6
Precision machinery	43	4,117	440	6	6.99
Biotechnology	79	4,409	101	10	31.12
Subtotal	487	147,563	10,122	31	114.28
Other <sup>5</sup>	5	299	67	1	0.5
<b>Total</b>	<b>492</b>	<b>147,862</b>	<b>10,189</b>	<b>32</b>	<b>114.78</b>

<sup>1</sup>Number of approved companies

<sup>2</sup>Employment figures do not include persons working in industrial and commercial services

<sup>3</sup>Companies approved during the year to make investments in the park

<sup>4</sup>Amount of investment in the park approved during the year

<sup>5</sup>Includes "other science enterprises" and "other park enterprises"

## Hsinchu Science Park growth, 2013-2017

Item	2013	2014	2015	2016	2017
Number of companies <sup>1</sup>	481	489	478	487	492
Increase/decrease (%)	2	-1	-2	1	1
Number of employees <sup>2</sup>	148,608	149,116	149,100	147,624	147,862
Increase/decrease (%)	1	1	0	-1	0.2
Revenue (NT\$100 m)	11,125	11,633	11,012	10,394	10,189
Increase/decrease (%)	5	4.57	-5.34	-5.94	-1.98
Manpower training <sup>1</sup> (person-times)	8907	9321	9285	8446	8398

<sup>1</sup>Number of approved companies

<sup>2</sup>Employment figures do not include persons working in industrial and commercial services

<sup>3</sup>Manpower training completion person-times figures include participation in advanced technology talks and benchmark corporate leader talks.



Hsinchu Biomedical Science Park from the air



## 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 more firms (including six startups) were approved to occupy park sites in 2017, and the park now has a cumulative total of 222 tenant companies, of which 196 have already occupied sites and begun operations. The revenue earned by park companies during the year totaled NT\$878.8 billion, which represented growth of 5.93% compared with 2016. As of the end of 2017, 634.61 hectares of land in the park had been leased out, and the leasing rate had reached 90.66%. The following is an overview of industrial development in 2017:

#### A. Gradual transformation into an innovation-based startup park

In conjunction with MOST's "From IP to IPO" (FITI), STSP has established linkage with the entrepreneurial resources of government agencies and local governments, the equipment of R&D organizations, and the resources of tenant firms in order to provide prototyping and small-scale pilot production service, funds infusions, and assistance from gurus via the "Southern Taiwan Innovative Startup Service Platform." From 2013 to the end of 2017, STSP has helped 112 teams to occupy startup spaces in the park, of which 41 teams have been promoted to the top-10 best startups among their cohorts in the FITI program, 21 teams obtained NT\$2 million in startup funds, and 57 teams completed company registration (with total capital of NT\$1.17 billion); 9 startups have become tenant firms, and 8 startups have occupied spaces in the park's incubation center.

#### B. Flagship semiconductor makers step up investment in STSP

In 2017, the Taiwan Semiconductor Manufacturing Co. (TSMC) invested NT\$550 billion in the construction of a 12" foundry employing a 5nm process. It is expected that this foundry will provide 4,000 employment opportunities during the next five years, and propel the industry into the advanced process development stage. TSMC also announced that its planned future 3nm process and smaller foundries will be located in STSP. Winbond plans to invest NT\$335 billion in STSP, and expects to hire 900 more employees during

the coming five years. The fact that major semiconductor manufacturers are continuing to invest in STSP has attracted the leading international equipment supplier Tokyo Electron and materials vendor Taiwan Tohcello Functional Sheet, both of which are Japanese firms, to invest in STSP. As of the end of 2017, STSP's semiconductor industry cluster was continuing to grow, and contained 20 members.

#### C. STSP continues to increase smart manufacturing capabilities

The Southern Taiwan Science Park Bureau has initiated the four-year (2017-2020) "STSP Smart Manufacturing Industry Cluster Development Program," which relies on the establishment of assistance platforms, grants, and incentives to encourage industry, academia, research organizations, and medical institutions to cooperatively develop innovative technologies and boost the science park's smart manufacturing capabilities. In 2017, this program provided funding to 13 projects, of which a facilities project helped the Industrial Technology Research Institute to establish the STSP Kaohsiung park's first 3D printing facility for medical devices; this facility will help domestic medical device companies to develop internationally-certified metal 3D printed medical devices, including the design, trial production, commercialization, and contract manufacturing stages, and capture their share of the international medical device market.

#### D. The biotech/medical device industry cluster goes international

The 2017-2020 "STSP Smart Biomedical Industry Cluster Development Program" implemented by the Southern Taiwan Science Park Bureau will boost medical device value through the application of information and communications technology, encourage the minimally invasive surgery, precision medicine, and customized medicine development trends, and rely on clinical research and market expansion programs to stimulate increased output value.

As of the end of 2017, a total of 73 companies in the biomedical industry had joined this program, making a total investment of NT\$26.2 billion, and the park's biomedical cluster was growing steadily. Four STSP firms have passed the Ministry of Health and Welfare's artificial tooth root inspection registration, 34 firms have passed GMP (Good Manufacturing Practice) certification, 14 firms have passed qualifications review under

the *Biotech and New Pharmaceutical Development Statute*, 37 firms have received sales permits from the Taiwan Food and Drug Administration (TFDA), 13 firms have received sales permits from the US Food and Drug Administration, and 23 firms have received European Union certification. In 2017, the Science Park Bureau provided funding for Tri Service General Hospital, National Cheng Kung University (2 cases), Kaohsiung Medical University, and Shuang Ho Hospital to establish five clinical diagnosis lines, and even more park products are expected to enter hospital purchasing systems, which will increase tenant firms' sales.

In 2017, the Science Park Bureau sponsored three clinical research projects, including projects on dental lasers, all-ceramic crowns, and rapid urinalysis. In addition, the Science Park Bureau has conducted marketing via a STSP pavilion at trade shows, and took 10 tenant firms to the Dental South China International Exposition in March 2017 and nine firms to Medical Fair Thailand in September. The Science Park Bureau established the "STSP Medical Device Overseas Research and Commercialization Center" at Vietnam's Ho Chi Minh Medical University in November; it placed the medical device products from 13 biomedical firms in

#### Overview of industries in the Southern Taiwan Science Park, 2017

Item	Number of companies <sup>1</sup>	Number of employees <sup>2</sup>	Revenue (NT\$100 m)	Number of investing companies <sup>3</sup>	Amount of investment (NT\$100 m) <sup>4</sup>
Integrated circuits	20	22,235	5,372.39	3	3,357.57
Optoelectronics	53	39,721	2,815.57	3	4.71
Computers and peripherals	4	295	19.87	2	1.41
Telecommunications	11	1,328	51.5	0	0
Precision machinery	53	7,579	406.34	2	1.23
Biotechnology	71	2,808	95.69	7	3.55
Other <sup>5</sup>	10	2,327	26.23	3	0.52
<b>Total</b>	<b>222</b>	<b>76,293</b>	<b>8,787.59</b>	<b>20</b>	<b>3,368.99</b>

<sup>1</sup>Number of approved companies

<sup>2</sup>Employment figures do not include persons working in industrial and commercial services

<sup>3</sup>Companies approved during the year to make investments in the park

<sup>4</sup>Amount of investment in the park approved during the year (final approved amount)

<sup>5</sup>Includes "other science enterprises" and "other park enterprises"

#### Southern Taiwan Science Park growth, 2013-2017

Item	2013	2014	2015	2016	2017
Number of companies <sup>1</sup>	185	196	204	210	222
Increase/decrease (%)	-0.50%	6%	4%	3%	5.70%
Number of employees <sup>2</sup>	70,896	78,992	79,877	78,432	76,293
Increase/decrease (%)	8%	10%	1%	-2%	-2.70%
Revenue (NT\$100 m)	6,151.21	6,394.38	7,151.37	8,295.63	8,787.59
Increase/decrease (%)	-1.10%	3.95%	11.84%	16%	5.93%
Manpower training <sup>3</sup> (person-times)	1,369	1,315	1,318	1,361	1,124

<sup>1</sup>Number of approved companies

<sup>2</sup>Employment figures do not include persons working in industrial and commercial services

<sup>3</sup>Manpower training completion person-times figures do not include participation in advanced technology talks and benchmark corporate leader talks.



STSP at this center, which will provide training classes and cooperate with local hospitals in the development of medical device products suitable for location conditions. All of these developments show that the biomedical industry cluster is poised for success.

### 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.

Fifteen more companies received approval to occupy sites and/or increase their investment in the park during 2017, giving it a cumulative total of 186 firms, of which 144 have already registered to occupy sites in park. Tenant firms had revenue of NT\$564 billion in 2017, which represented growth of 11.13% compared with 2016.

#### A. Establishment of the "Science Park Smart Robotics Innovative Maker Site"

In the wave of industrial innovation and market changes coming in the wake of the artificial intelligence (AI) age, MOST will serve as Taiwan's technological explorer; apart from guiding industrial transformation, MOST is also building a technological foundation, training manpower in relevant fields, and filling human resource gaps. With funding from a special budget, MOST has established a "Science Park Smart Robotics Innovative Maker Site," which is using various methods to cultivate interdisciplinary maker manpower able to meet the needs of tenant firms undergoing innovative transformations.

Establishment of a maker and cyber-physical-system (CPS) smart robot environment: As part of a joint effort to establish a national-level innovative maker site, MOST has established an AI and robotic environment, a maker facility, and an advanced training and pilot production environment, and established linkage with the capabilities of the National Center for High-Performance Computing and relevant tenant firms.

Use of experiential learning in manpower training: MOST has organized a maker alliance linked with industry-academic training resources in central Taiwan, and is relying on grants and funding resources to jointly conduct a series of experiential learning activities (the FIRST Robotics Competition was held in 2017), including high school robotics camps and results competitions, junior high school and elementary school robotics camps and related classes, and university drone competitions and talks on AI- and robotics-related topics; these activities attracted over 850 persons in 2017, and are cultivating the hardware and software specialists needed for the development of smart robotics.

Establishment of a sustainable innovation ecosystem: MOST has established a smart machinery automation ecosystem in central Taiwan, and is relying on the CTSP maker site and smart robotics industry alliance to uncover problems that industry hopes to resolve, and pursue sustainability. MOST is also taking steps to promote R&D on key technologies needed by the smart robotics industry and establish an innovation-based startup platform, while simultaneously encourage industry-academic collaboration and training of R&D manpower.

#### B. Expanding international interchange

Apart from supporting the government's New Southbound Policy, CTSP also sought out cooperation opportunities with science parks and industry/academic/research units in New Southbound Policy countries during 2017. In February, CTSP established a sister park relationship with Japan's Kyoto Research Park, which will promote joint innovation incubation and cooperation between the two countries' tech industries. In April, CTSP, the Indian Institute of Technology, National Yunlin University of Science and Technology, and the Hsinchu Science Park Bureau jointly signed a four-party MOU, which calls for the establishment of a cooperation platform promoting Taiwan-India S&T academic interchange and manpower training. In July, CTSP signed a three-part MOU with Thailand's Chiang Mai University (representing the Northern Thailand Science Park) and Feng Chia University, which will link the capabilities of industry, academia, and research organizations in both countries, and promote greater tech R&D innovation.

The Asian Science Park Association (ASPA) holds its annual ASPA Awards to recognize those science park SMEs that have demonstrated

outstanding management and technological innovation, and provide the award-winning firms multinational commercial matchmaking opportunities. During 2017, CTSP recommended the Zhongxing New Village campus firm CH Biotech to participate in this competition, and brought a company representative to Vietnam's Ho Chi Minh City take part in the selection process; the company's innovation technology and R&D capabilities won the judges' affirmation, and it ultimately received the Grand Prize in the 2017 ASPA Awards.

### C. Park revenue hits a new high

CTSP's tenant firms had total revenue of NT\$563.8 billion in 2017, and this figure was up by 11.13% compared with the NT\$507.4 billion figure in 2016, setting a new high. This growth was largely fueled by rising demand for smart handheld mobile devices, servers, and better-performing auto electronics, as well as demand for memory, which caused revenue to increase throughout the semiconductor industry supply chain, including the foundry, memory, and packaging and testing segments. In addition, demand attributable to capacity expansion by semiconductor and panel producers, and the steadily brightening prospects of the auto and aerospace industries, has stimulated demand for machine tools and automation systems, which is also boosting the sales of tenant firms.

As for the performance of CTSP industries in 2017, the integrated circuits industry had the largest revenue—NT\$349.5 billion—which accounted for 61.98% of all CTSP revenue, and was followed by the optoelectronics industry, with NT\$178.1 billion in revenue (31.58%), and the precision machinery industry, with NT\$27.65 billion in revenue (4.90%); the remaining industries had combined revenue of approximately NT\$8.652 billion.

As of the end of 2017, a total of 186 companies had been approved to occupy sites in CTSP, which contained 15 research organizations and incubation centers; the total amount of investment in the park was NT\$2.478 trillion, and recruiting results had been excellent.

### D. Future outlook

Looking ahead to 2018, CTSP will continue to take "laying the groundwork for basic research, and creating new value from technology," "cultivating innovative startups, fostering Moore's Law thinking," and "creating a foundation of scientific manpower, establishing ties to the world of the future" as its three main strategic directions, and seeks to realize the ideals of being a "smart, innovation-driven low-carbon park sharing prosperity with the local region." CTSP hopes that its smart science park initiative will enhance the strengths and specialties of existing industries (in such areas as advanced semiconductor processes and technologies, optoelectronics and optical industry, and precision machinery, etc.). CTSP is also promoting the integrated use of new technologies (such as AI, big data, Internet of Things, and software services), and has adopted the expression "AI x" to signify the multiplicative synergy derived from the fusion of hardware and software. By combining the specialized expertise of domestic industry with information and communications technology, CTSP hopes to encourage firms to incorporate AI in many types of applications service systems, and attract the smart robotics, smart machinery, medical equipment, and green energy industries to the science park. This will encourage hardware-software synergy, position CTSP as a demonstration site and low-carbon green energy park, and help tenant firms to achieve new successes.



## Overview of Central Taiwan Science Park industries, 2017

Item	Companies <sup>1</sup>	Employment	Revenue (NT\$100 m)	Investing firms <sup>2</sup>	Amount of investment (NT\$100 m) <sup>3</sup>
Integrated circuits	8	15,837	3,494.47	3	1,081.74
Optoelectronics	36	17,461	1,780.81	1	19.25
Computers and peripherals	15	1,296	29.91	0	0
Telecommunications	1	108	0.76	0	0
Precision machinery	67	6,085	276.45	6	17.8
Biotechnology	40	2,030	39.48	2	5.8
Subtotal		42,817	5,621.88	12	8.6
Other <sup>4</sup>	19	713	16.38	3	1.16
<b>Total</b>	<b>186</b>	<b>43,530</b>	<b>5,638.26</b>	<b>15</b>	<b>9.76</b>

<sup>1</sup>Number of approved companies.

<sup>3</sup>Amount of investment in the park approved during the year.

<sup>2</sup> Companies approved during the year to make investments in the park.

<sup>4</sup>Includes "other science enterprises" and "other park enterprises."

## Central Taiwan Science Park growth, 2013-2017

Item	2013	2014	2015	2016	2017
Number of companies <sup>1</sup>	158	174	180	189	186
Increase/decrease (%)	13	10	3.45	5	-1.6
Employment <sup>2</sup>	31,242	32,260	33,018	39,956	43,530
Increase/decrease (%)	8.66	3.26	2.35	21.01	8.94
Revenue (NT\$100 m)	4599.08	5,220.70	4,921.17	5,073.67	5,638.26
Increase/decrease (%)	42.24	13.52	-5.74	3.10	11.13
Manpower training <sup>3</sup> (person-times)	645	635	631	706	709
Increase/decrease (%)	-22.94	-1.57	-0.63	11.89	0.4

<sup>1</sup>Number of approved companies

<sup>2</sup>Employment figures do not include persons working in industrial and commercial services.

<sup>3</sup>Manpower training completion person-times figures do not include participation in advanced technology talks and benchmark corporate leader talks.



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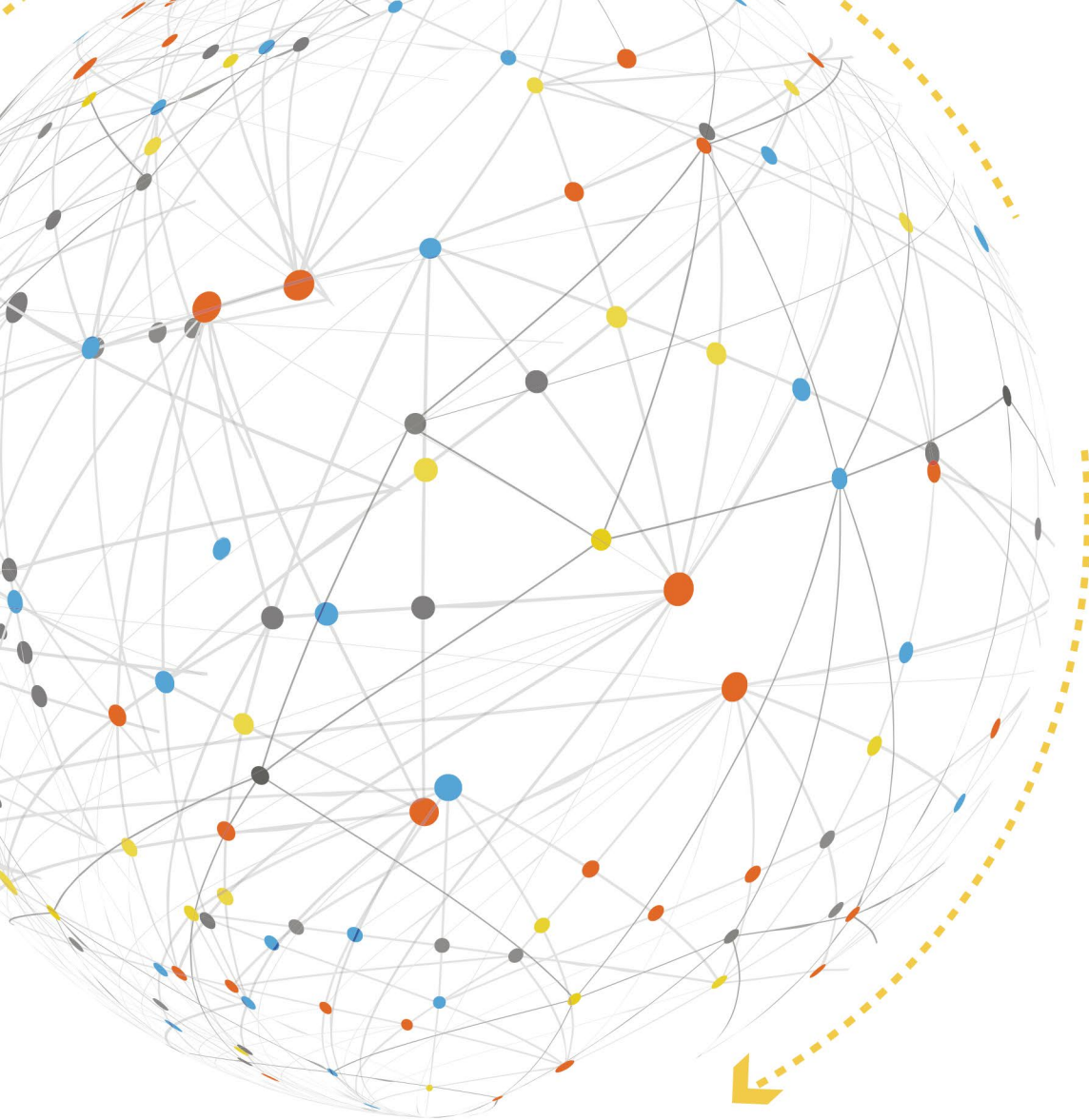
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