



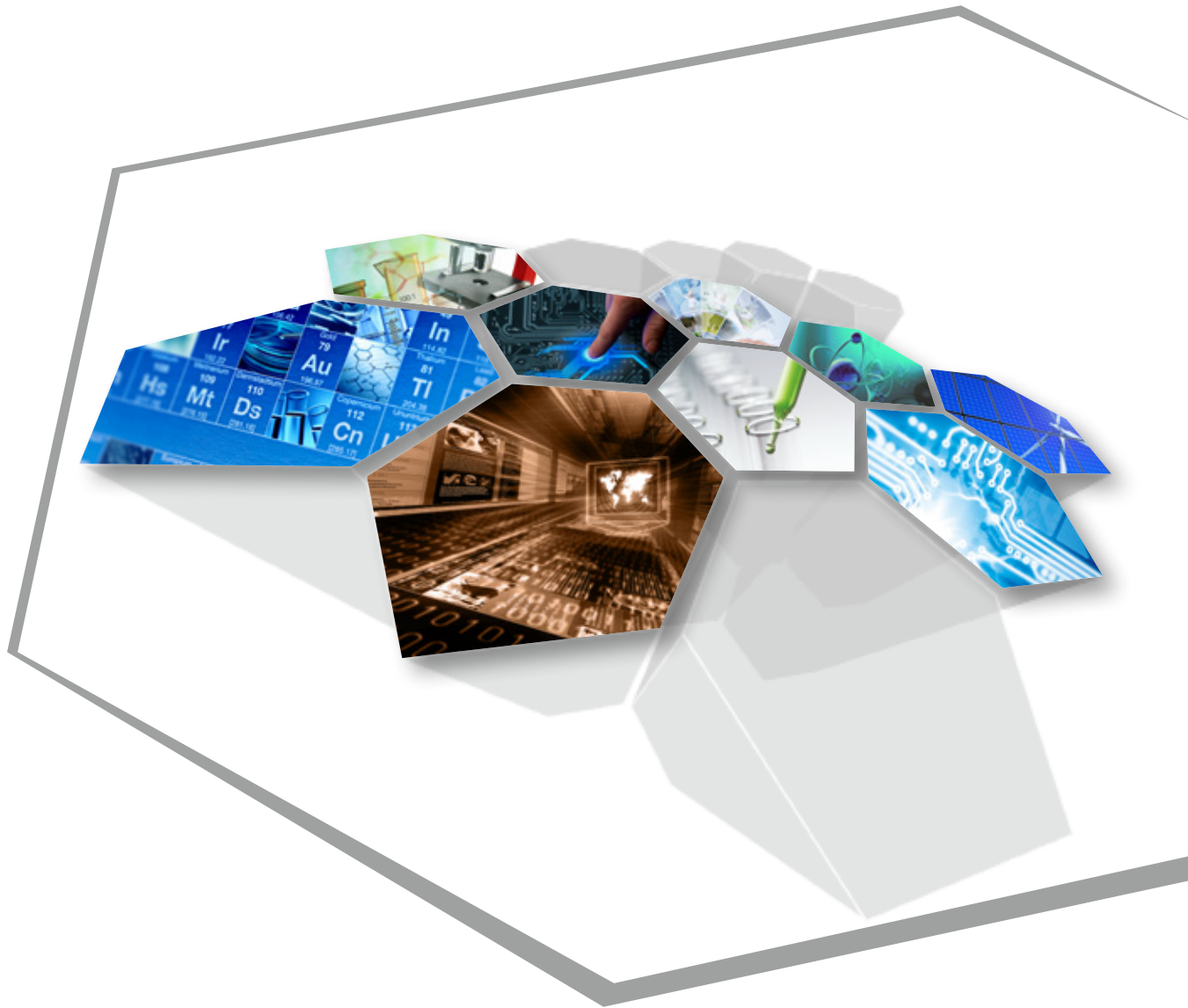
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# MOST 2014 Annual Report

Ministry of Science and Technology





**MOST 2014**  
Ministry of Science and Technology

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# Foreword

Since the National Science Council (NSC) was reorganized as the Ministry of Science and Technology (MOST) in March 2014, apart from continuing the NSC's mission of promoting basic research and emphasizing the value and application of academic research, MOST has overcome the restraints of outdated thinking, and obtained many innovative achievements in such areas as the cultivating of skilled research personnel, strengthened utilization of R&D results, and establishment of linkage between industry and academia.

The impact of academic research should not stop with the publication of papers, but should yield scientific, technological, economic, industrial, and social benefits. In order to ensure the all-round assessment of research results, MOST has continued to perform rolling reviews of funding and research review mechanisms, and expects to perform adjustments to procedures from the time of project funding application to review. Regardless of whether research is intended to explore the unknown or solve problems, MOST encourages scientists to spend time thinking about their importance of their research, abandon the fixation on quantity for its own sake, and strive to enhance the quality and influence of their research results.

In order to cultivate future research manpower, MOST has drafted many funding measures intended to provide opportunities to young research personnel. Apart from channeling funds from industry to academic research, and training the innovative R&D manpower needed by industry, MOST also seeks to enable post-doctoral researchers to pursue their own lines of research, encourage the selection of high-value research topics, promote promising young post-docs, and provide them with the stable research funding they need to plan their research careers.



With regard to boosting the practical value of R&D results, MOST's "Trial Program to Rely on Research Institutes to Promote Industry-Academic Collaboration" will rely on research institution's experience in adding value to research results and channeling research findings to applications, and plans to focus on electronics, information, and communications during 2015. This program will seek to perform a full-scale inventory of academic R&D results, find results that have industrialization potential, and promote industry-academic collaborative commercialization projects that will serve to further strengthen industry-academic linkage.

For many years, the science parks under MOST have fostered growing high-tech industry clusters. In 2014, the three main science parks set new revenue and export records, with total revenue of NT\$2.32 trillion, which was up by 6.28% compared with 2013, and exports of NT\$1.37 trillion, which was up by 2.04%. The science parks are striving to promote the establishment of value-added innovation startups within their existing industry clusters, and also seek to create a superior operating environment. After receiving the diamond ecological community Green Building Mark in 2013, the Southern Taiwan Science Park was awarded the Ministry of Culture's 4<sup>th</sup> Public Art Excellence Award in 2014.

The development of science and technology is a driver of national progress. In the years to come, MOST will continue to support excellence in academic research, promote ties between academic research and industrial development, and encourage interdisciplinary integration for problem-solving applications and strengthening the social impact of scientific research.

*Shyu Jyuo-min*  
Minister of Science and Technology



# Chapter 1 Overview

- **Science and Technology Development Policies**
- **Funding**



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## I Science and Technology Development Policies

Throughout recent years, Taiwan has achieved superb scientific and technological performance in terms of both international competitiveness and academic research outputs. According to the IMD's *2014 World Competitiveness Yearbook*, Taiwan ranked 13<sup>th</sup> in terms of overall competitiveness, and rose from 5<sup>th</sup> and 13<sup>th</sup> to 4<sup>th</sup> and 9<sup>th</sup> in the S&T-related items of "technological infrastructure" and "scientific infrastructure" in 2014. Nevertheless, in spite of Taiwan's S&T progress and excellent achievements, in the face of a volatile world situation and S&T development trends, Taiwan still faces numerous problems and challenges.

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

#### 1. Scientific research

The government has devoted consistent efforts to funding scientific and technological R&D, and seeks to channel the results of basic research to industry. However, the rapid development of industrial technologies, and the gap between talent supply and demand, have slowed the rate at which research findings can be industrialized. As a consequence, key challenges for Taiwan include how academic research organizations can meet industry's key technology development needs, how the research capabilities of academic research organizations can be strengthened, and how such organizations can increase their market-oriented innovative research.

#### 2. Industry

In the face of intensely competitive international markets and rapidly advancing information and communications technology, industrial innovation, transformation, and increased addition of value are necessary methods of staying ahead in this age of thin profit margins. As a result, encouraging best use of intellectual property, promoting "intelligent" industries, and putting the innovation investment environment on a sound footing will be the government's foremost tasks as it strives to enhance industrial upgrading and innovation.

#### 3. Economic Growth and the Environment

Taiwan is located in a region plagued by frequent

typhoons and earthquakes, and global warming and climate change threaten to intensify the impact of natural disasters. The demand for land and resources caused by industrial and economic development also imposes a heavy burden on the earth. How to create a low-carbon, intelligent society, and institute sustainable development mechanisms balancing the needs of the environment against those of economic development, is another important challenge currently faced by Taiwan.

#### 4. Society

While citizens' health and safety is the basis for national competitiveness, food safety problems caused by unscrupulous merchants and various emerging infectious diseases have reduced people's margin of safety. In addition, differences in resources and socioeconomic conditions have led to a gap between urban and rural areas, and an aging population and falling birth rate are causing imbalances in the demographic structure. These are also challenges that the government must actively address.

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

In accordance with the *Fundamental Science and Technology Act*, the government must give an account of the country's S&T development vision, strategies, and current situation every two years. Accordingly, the Ministry of Science and Technology (MOST) called together related agencies to jointly draft the *ROC White Paper on Science and Technology (2015-2018)*, which explains Taiwan's current S&T policies, and maps out Taiwan's S&T development vision and strategies from 2016 to 2018 as an administrative reference for various agencies with S&T missions. The content of the *White Paper* will also serve to guide the planning of topics for the 2016 10<sup>th</sup> National Science and Technology Conference.

The *White Paper* takes the "use of intelligent science and technology to build a sustainable and prosperous society" as its S&T development vision, sets forth the four objectives of "transforming innovation from scientific research," "building a sustainable green energy environment," "adding value

to industrial S&T," and "creating a prosperous, diverse society," and proposes eight strategies and relevant implementation measures:

**Strategy 1** Focusing on S&T strengths, creating high research value: This includes the establishment of reasonable budget allocation mechanisms, and focused promotion of areas of strength; strengthening of basic research in order to uncover emerging future S&T issues; enhancement of education and research addressing emerging diseases, environmental restoration, and disaster prevention and relief, and reliance on academic excellence to drive industry; and establishment of market-oriented R&D strategies and models of cooperation among industry, academia, and research organizations that reflect the domestic industrial structure.

**Strategy 2** Balancing academic/industrial manpower supply and demand, putting the scientific startup environment on a solid footing: This strategy focuses on improving mechanisms promoting the flow of manpower between academia and industry; promoting the transmission of commercialization knowledge and skills training, and balancing academic/industrial manpower supply and demand; making Taiwan a hub of creativity, innovation, and entrepreneurship; and promoting S&T entrepreneurship and providing multiple fund-raising channels in order to establish early investment mechanisms and disperse investment risk.

**Strategy 3** Rebuilding the country on a basis of green energy technology, creating a low-carbon, intelligent society: This strategy includes enhancing Taiwan's overall international competitiveness in the area of green energy S&T; creation of an intelligent safety and disaster prevention network able to protect citizens' lives and safety; establishment of a safe, intelligent environment, linkage of green energy supply chains and service chains; and promotion of a low-carbon urban aesthetic, breathing new life into urban and rural landscapes.

**Strategy 4** Implementing sustainable development mechanisms, striking a balance between economic development and the environment: This

strategy contains four major directions: Accelerating the establishment of sustainable development decision-making mechanisms, creation of a legal system and market environment favorable to the development of the green energy industry, integration of green energy technologies and consumer industries, and placing balanced emphasis on environmental protection and economic development.

**Strategy 5** Establishment of S&T intellectual property portfolios, strengthening the basis for industrial innovation: Relevant efforts will include putting the venture investment environment on a solid footing, energizing the use of intellectual property by the academic sector, emphasizing the protection and development of early technology IP in order to promote the accumulation a global IP portfolio, and fostering a highly-profitable industrial innovation environment.

**Strategy 6** Accelerating intelligent industrial upgrading, developing key emerging industries: The government's role will include encouragement of the establishment of forward-looking IP portfolios in key industries, promotion of intelligent technologies in industry, uncovering and developing key industrial technologies, and creation of an intelligent industry operating environment.

**Strategy 7** Building a safe and prosperous environment, promoting smart, healthy living: This strategy includes meeting society's varied safety needs, realizing the value of public safety technology R&D results in consumer applications, using ICT to strengthen the healthcare system, and developing effective disease outbreak prevention strategies and technologies.

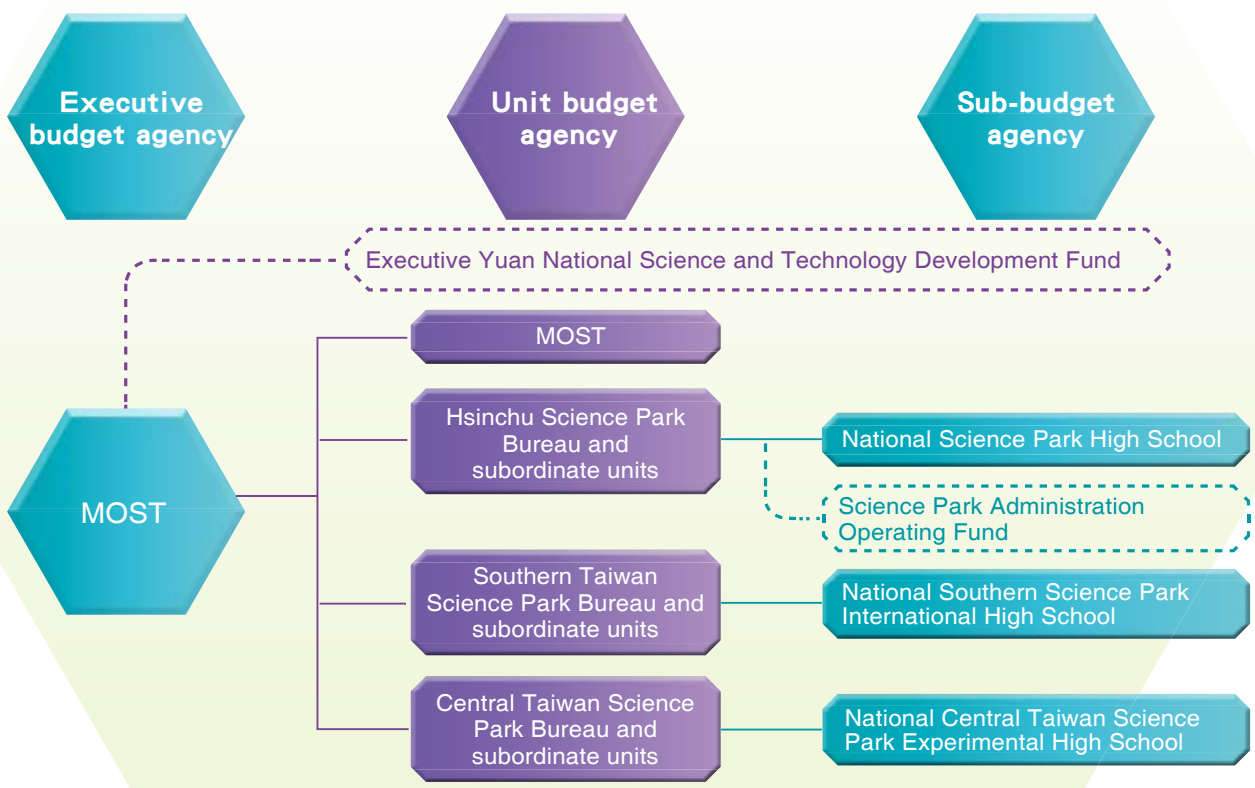
**Strategy 8** Establishment of a tolerant, diverse society, realizing balanced rural-urban development: The government's four major areas of effort will include provision of fair e-learning opportunities in order to enhance citizens' information qualifications, promotion of the development of senior-friendly cities, placing balanced emphasis on the environment and digital qualifications, developing effective urban and rural functions, and strengthening urban and rural interaction while using S&T innovation to drive the diversified, coordinated development of urban and rural areas.

## II Funding

In 2014, MOST's executive budget consisted of four parts corresponding to MOST itself, the Hsinchu Science Park Bureau (HSPB) and subordinate organizations, the Southern Taiwan Science Park Bureau (STSPB) and subordinate organizations, and the Central Taiwan Science Park Bureau (CTSPB) and subordinate organizations. In addition, the budgets of the HSPB and subordinate organizations, STSPB and subordinate organizations, and CTSPB and subordinate organizations also include sub-budgets for the National Science Park Experimental High School, National Southern Taiwan Science Park International High School, and National Central Taiwan Science Park 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.

MOST's executive income budget for 2014 was NT\$178.5 million, which was an increase of NT\$5.96 million (3.45%) over the NT\$172.5 million income budget of the previous year. This income budget included fine and compensation income consisting of NT\$14.86 million compensation for late vendor deliveries; NT\$37.74 million in fee income, which included establishment and status change registration fees from science park companies and construction licenses; NT\$78.39 million in property income, which



Note: Dotted lines indicate subordinate unit budgets.

included income from leasing of Hsinchu Biomedical Park land and plants, and rental of technology building office space; and NT\$47.48 million in other income, which included tuition and miscellaneous fees at the Science Park experimental high schools.

MOST's expense budget for 2014 was NT\$44.04 billion, which was a decrease of NT\$2.077 billion (-4.5%) compared with the NT\$46.12 billion budget of the previous year. Of this budget, the MOST expense budget accounted for NT\$40.55 billion, and was mainly used to fund the National Synchrotron Radiation Research Center (NSRRC) and National Applied Research Laboratories (NARLabs), and increase national treasury support for S&T project

funding from the National Science and Technology Development Fund. The HSPB and subordinate unit budget was NT\$1.181 billion, which was mainly used for various park services and development of the Hsinchu Biomedical Park. The STSPB and subordinate unit budget was NT\$1.108 billion, and was mainly used for park services and increased national treasury support for an HSR vibration reduction project funded through the Science Park Bureau Operating Fund. The CTSPB budget was NT\$1.203 billion, and was mainly used for park services and for increasing national treasury support for advanced park development project funding from the Science Park Administration Operating Fund.

#### Annual MOST executive income budgets, 2010-2014

Units: NT\$1 m

| Item                                    | 2010   |           | 2011     |           | 2012   |           | 2013   |           | 2014   |           |
|---|--------|-----------|----------|-----------|--------|-----------|--------|-----------|--------|-----------|
|   | Amount | Increase% | Amount   | Increase% | Amount | Increase% | Amount | Increase% | Amount | Increase% |
| Fines and compensation                  | 11.38  | -1.56     | 12.57    | 10.46     | 19.10  | 51.95     | 24.00  | 25.65     | 14.86  | -38.08    |
| Fee income                              | 61.28  | -1.78     | 60.38    | -1.47     | 58.51  | -3.10     | 41.92  | -28.35    | 37.74  | -9.97     |
| Property income                         | 32.15  | -47.10    | 34.05    | 5.91      | 37.87  | 11.22     | 44.06  | 16.35     | 78.39  | 77.92     |
| Operating revenue and enterprise income |        |           | 5,000.00 | 100.00    |        | -100.00   |        |           |        |           |
| Other income                            | 50.77  | 2.59      | 50.48    | -0.57     | 67.42  | 33.56     | 62.53  | -7.25     | 47.48  | -24.07    |
| Total                                   | 155.58 | -15.55    | 5,157.48 | 3,215.00  | 182.90 | -96.45    | 172.51 | -5.68     | 178.47 | 3.45      |

#### Annual MOST executive expenditure budgets, 2010-2014

Units: NT\$100 m

| Item                        | 2010   |           | 2011   |           | 2012   |           | 2013   |           | 2014   |           |
|-----------------------------|--------|-----------|--------|-----------|--------|-----------|--------|-----------|--------|-----------|
|                             | Amount | Increase% | Amount | Increase% | Amount | Increase% | Amount | Increase% | Amount | Increase% |
| MOST                        | 371.37 | 3.46      | 389.99 | 5.01      | 416.21 | 6.72      | 422.64 | 1.54      | 405.51 | -4.05     |
| HSPB and subordinate units  | 15.22  | -37.90    | 12.61  | -17.15    | 15.22  | 20.70     | 17.75  | 16.62     | 11.81  | -33.46    |
| STSPB and subordinate units | 13.62  | -57.26    | 13.31  | -2.28     | 9.97   | -25.09    | 9.24   | -7.32     | 11.08  | 19.91     |
| CTSPB and subordinate units | 17.12  | 94.10     | 12.69  | -25.88    | 11.86  | -6.54     | 11.57  | -2.45     | 12.03  | 3.98      |
| Total                       | 417.33 | -1.61     | 428.60 | 2.70      | 453.26 | 5.75      | 461.20 | 1.75      | 440.43 | -4.50     |

MOST originally established the 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 MOST's unit budget up to 1991, but was made a unit budget item 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 MOST and put under the Executive Yuan's oversight, but MOST retained its status as the fund management agency. The 2003 revision of the *Fundamental Science and Technology Act*

specifies that the National Science and Technology Development Fund budget should be a subordinate unit budget.

The National Science and Technology Development Fund received NT\$34.36 billion in 2014, which chiefly consisted of appropriations from the national treasury and R&D results income. The fund's disbursements of NT\$36.91 billion were chiefly used to fund various types of academic research.

MOST's final executive income figure for 2014 was NT\$187.5 million, which represented an increase of NT\$9.01 million compared with the budget number. This increase was mainly attributable to an

#### National Science and Technology Development Fund budget, 2010-2014

Units: NT\$100 m

| Item                              | 2010   |           | 2011   |           | 2012   |           | 2013 <sup>2</sup> |           | 2014   |           |
|-----------------------------------|--------|-----------|--------|-----------|--------|-----------|-------------------|-----------|--------|-----------|
|                                   | Amount | Increase% | Amount | Increase% | Amount | Increase% | Amount            | Increase% | Amount | Increase% |
| Source of funds                   | 312.31 | 5.33      | 318.00 | 1.82      | 346.41 | 8.93      | 359.72            | 3.84      | 343.64 | -4.47     |
| Government appropriations         | 298.00 | 5.11      | 304.02 | 2.02      | 330.17 | 8.60      | 341.60            | 3.46      | 327.46 | -4.14     |
| Other <sup>1</sup>                | 14.31  | 10.08     | 13.98  | -2.31     | 16.24  | 16.17     | 18.12             | 11.58     | 16.18  | -10.71    |
| Fund uses                         | 329.55 | 4.87      | 385.02 | 16.83     | 354.91 | -7.82     | 368.72            | 3.89      | 369.14 | 0.11      |
| Promotion of development          | 298.99 | 7.31      | 304.51 | 1.85      | 317.89 | 4.39      | 330.16            | 3.86      | 332.17 | 0.61      |
| Manpower training                 | 18.38  | 7.67      | 17.53  | -4.62     | 22.41  | 27.84     | 23.91             | 6.69      | 22.34  | -6.57     |
| Environment improvement           | 11.61  | -35.43    | 12.39  | 6.72      | 14.04  | 13.32     | 14.08             | 0.28      | 14.05  | -0.21     |
| Administration & management       | 0.57   | -1.72     | 0.59   | 3.51      | 0.57   | -3.39     | 0.57              | 0.00      | 0.58   | 1.75      |
| Payments to the national treasury |        |           | 50.00  | 100.00    |        | -100.00   |                   |           |        |           |
| Surplus/shortfall for period      | -17.24 |           | -67.02 |           | -8.50  |           | -9.00             |           | -25.50 |           |

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

<sup>2</sup> The 2013 Executive Yuan National Science and Technology Development Fund budget has not yet been passed by the Legislative Yuan.

#### Annual MOST final income figures, 2010-2014

Units: NT\$1 m

| Item                                    | 2010         |                           | 2011         |                           | 2012         |                           | 2013         |                           | 2014         |                           |
|---|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|
|   | 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                  | 16.39        | 5.01                      | 46.79        | 34.22                     | 18.73        | -0.37                     | 27.94        | 3.94                      | 32.91        | 18.05                     |
| Fee income                              | 45.87        | -15.41                    | 31.64        | -28.74                    | 35.24        | -23.27                    | 18.40        | -23.52                    | 16.85        | -20.89                    |
| Property income                         | 34.33        | -2.18                     | 27.18        | -6.87                     | 41.13        | 3.26                      | 62.05        | 17.99                     | 82.32        | 3.93                      |
| Operating revenue and enterprise income |              |                           | 5,000.00     | 0.00                      |              |                           |              |                           |              |                           |
| Other income                            | 52.90        | -2.13                     | 50.01        | -0.47                     | 51.53        | -15.89                    | 53.21        | -9.32                     | 55.40        | 7.92                      |
| Total                                   | 149.49       | -6.09                     | 5,155.62     | -1.86                     | 146.63       | -36.27                    | 161.60       | -10.91                    | 187.48       | 9.01                      |

unexpected increase in overdue delivery fine income at NARLabs and NSRRC.

MOST's final executive expenditure figure for 2013 was NT\$43.66 billion, which represented a decrease of NT\$380 million compared with the budget number. This decrease was chiefly attributable to surplus personnel expenditures, surplus funds from procurement cases involving MOST contributions to NARLabs, exchange rate difference fluctuations, and the sinking of the Ocean Researcher V, which terminated the vessel's operations and fuel oil purchases, etc., so that the funding was not implemented during the year.

The Science and Technology Development Fund had a final surplus of NT\$628 million at the end of 2014, which was NT\$3.18 billion more than the expected budget shortfall of NT\$2.55 billion. This difference was chiefly attributable the large number of funding applications with nonconforming content or strategies for the National Research Program for Biopharmaceuticals, National Energy Programs, Applied Research Incubation Projects, Industrial Fundamental Technology Projects, and Academic Summit Program, as well as to the lower number of approved projects and funding amounts following proposal review.

#### Annual MOST executive final expenditure figures, 2010-2014

Units: NT\$100 m

| Item                        | 2010         |                           | 2011         |                           | 2012         |                           | 2013         |                           | 2014         |                           |
|-----------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|
|                             | 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                        | 370.01       | -1.36                     | 388.98       | -1.01                     | 415.03       | -1.18                     | 419.65       | -2.99                     | 402.86       | -2.65                     |
| HSPB and subordinate units  | 14.06        | -1.16                     | 11.76        | -0.85                     | 14.75        | -0.47                     | 17.14        | -0.61                     | 11.19        | -0.62                     |
| STSPB and subordinate units | 13.29        | -0.33                     | 13.02        | -0.29                     | 9.57         | -0.40                     | 8.80         | -0.44                     | 11.02        | -0.06                     |
| CTSPB and subordinate units | 16.97        | -0.15                     | 12.03        | -0.66                     | 11.30        | -0.56                     | 10.94        | -0.63                     | 11.56        | -0.47                     |
| Total                       | 414.33       | -3.00                     | 425.79       | -2.81                     | 450.65       | -2.61                     | 456.53       | -4.67                     | 436.63       | -3.80                     |

#### Final budget numbers of the National Science and Technology Development Fund, 2010-2014

Units: NT\$100 m

| Item                              | 2010         |                           | 2011         |                           | 2012         |                           | 2013         |                           | 2014         |                           |
|-----------------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|
|                                   | 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                   | 316.17       | 3.86                      | 323.79       | 5.79                      | 348.72       | 2.31                      | 357.52       | -2.20                     | 345.88       | 2.24                      |
| Government appropriations         | 298.00       | 0.00                      | 304.02       | 0.00                      | 330.17       | 0.00                      | 341.60       | 0.00                      | 327.46       | 0.00                      |
| Other <sup>1</sup>                | 18.17        | 3.86                      | 19.77        | 5.79                      | 18.55        | 2.31                      | 15.92        | -2.20                     | 18.42        | 2.24                      |
| Fund uses                         | 326.43       | -3.12                     | 369.94       | -15.08                    | 324.96       | -29.95                    | 330.59       | -38.13                    | 339.60       | -29.54                    |
| Promotion of development          | 293.58       | -5.41                     | 288.09       | -16.42                    | 293.37       | -24.52                    | 297.02       | -33.14                    | 305.82       | -26.35                    |
| Manpower training                 | 22.48        | 4.10                      | 22.19        | 4.66                      | 21.69        | -0.72                     | 23.00        | -0.91                     | 21.89        | -0.45                     |
| Environment improvement           | 9.74         | -1.87                     | 9.17         | -3.22                     | 9.40         | -4.64                     | 10.05        | -4.03                     | 11.32        | -2.73                     |
| Administration & management       | 0.63         | 0.06                      | 0.49         | -0.10                     | 0.50         | -0.07                     | 0.52         | -0.05                     | 0.57         | -0.01                     |
| Payments to the national treasury |              |                           | 50.00        | 0.00                      |              |                           |              |                           |              |                           |
| Surplus/shortfall for period      | -10.26       | 6.98                      | -46.15       | 20.87                     | 23.76        | 32.26                     | 26.93        | 35.93                     | 6.28         | 31.78                     |

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



## **Chapter 2 Promoting National S&T Development**

- **National R&D Trends**
- **Science and Technology Research Results**
- **Science and Technology Development Advisory Board**
- **Enhancing Citizens' S&T Literacy**
- **Integration of National Disaster Prevention Research**



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## I National R&D Trends

### A. National R&D Expenditures

Taiwan's total research and development expenditures in 2009 were NT\$367.2 billion, and this figure increased steadily to NT\$454.9 billion in 2013. Expenditures grew at an annual rate of 5.5% in 2013, and the private sector's R&D expenditures grew at a rate of 7.3% compared with 2012, reaching NT\$348.2 billion. This represented an increase in private expenditures as a share of overall national R&D expenditures to 76.5% from 75.2% in 2012. In contrast, the government's R&D expenditures fell by 0.1% to NT\$106.7 billion, and the government's share of national R&D expenditures dropped to 23.5% from 24.8% in 2012.

Apart from 2010, when it benefited from the global recovery, Taiwan's economic growth rate reached a new high for the past ten years in 2014. R&D expenditures as a share of GDP have increased

steadily in recent years. However, in 2010, because the GDP growth rate surged to a record high in the previous decade, which was higher than the national R&D expenditure growth rate, R&D expenditures as a share of GDP fell slightly by 0.03% compared with 2009. In 2013, Taiwan's R&D expenditures accounted for 2.99% of GDP in 2014 (the Directorate General of Budget, Accounting & Statistics, Executive Yuan announced revised GDP data for past years on November 28, 2014, and MOST has accordingly retroactively adjusted R&D expenditures as a share of GDP for the previous years).

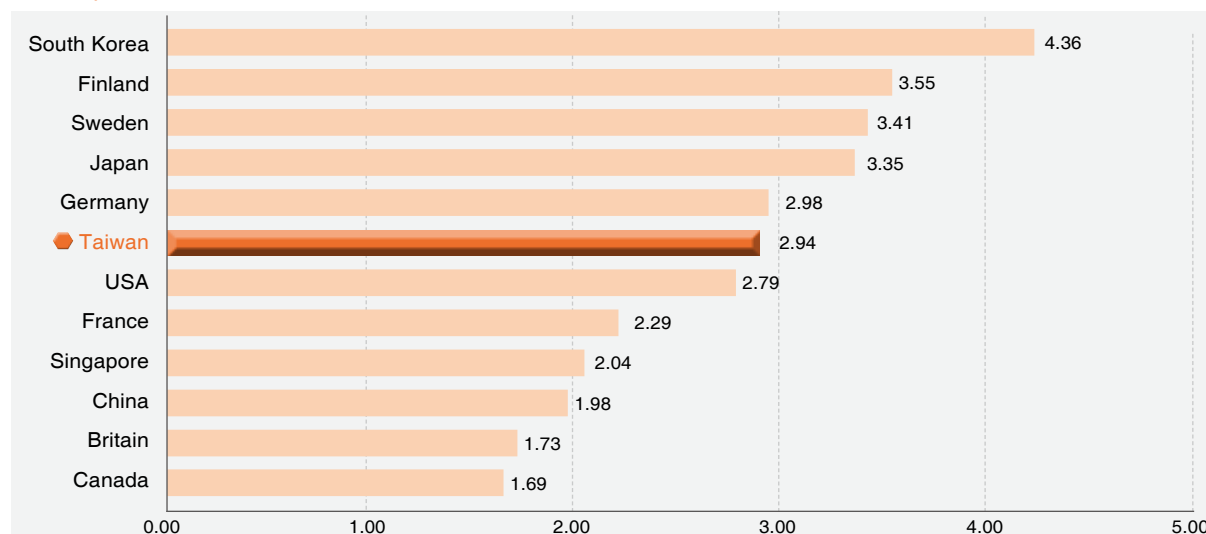
When compared with other countries in terms of R&D expenditures as a share of GDP, Taiwan lags behind South Korea, Finland, Sweden, and Germany, but is ahead of the US, France, Singapore, China, Britain, and Canada.

National R&D expenditures, 2009-2013

| Item                                  | 2009  | 2010  | 2011  | 2012  | 2013  |
|---------------------------------------|-------|-------|-------|-------|-------|
| National R&D expenditures (NT\$100 m) | 3,672 | 3,950 | 4,133 | 4,313 | 4,549 |
| Percentage of GDP (%)                 | 2.83  | 2.80  | 2.89  | 2.94  | 2.99  |
| By funding source (%)                 |       |       |       |       |       |
| Government                            | 28.9  | 27.5  | 26.2  | 24.8  | 23.5  |
| Private sector                        | 71.1  | 72.5  | 73.8  | 75.2  | 76.5  |

Source: *Indicators of Science and Technology*, ROC, 2014, MOST.

R&D expenditures as a share of GDP in various countries, 2012



Source: 1. Various countries: *Main Science and Technology Indicators*, 1/2014, OECD.  
2. Taiwan: *Indicators of Science and Technology*, ROC, 2014, MOST.

## B. National 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 personnel for many years, and accounted for 60.2%-61.1% R&D personnel during the most recent five years. The number of researchers grew over the most recent five years from 119,185 FTE (full-time equivalent) persons-years in 2009 to 140,124 FTE in 2013; technicians grew from 65,444 FTE in 2009 to 80,604 FTE in 2013; and supporting staff grew from 12,264 FTE in 2009 to 12,150 FTE in 2013.

The number of female researchers rose from 23,245 FTE in 2009 to 29,199 FTE in 2013. The number of women researchers as a share of all researchers rose from 19.5% in 2009 to 20.8% in 2013.

The number of research personnel per 1,000 employed population in Taiwan hit 12.8 person-years in 2013, which was less than the figure for Finland, the same as for South Korea, but higher than the equivalent figures for Sweden, Singapore, Japan, France, Canada, the USA, Germany, Britain and China during the 2011-2012 period.

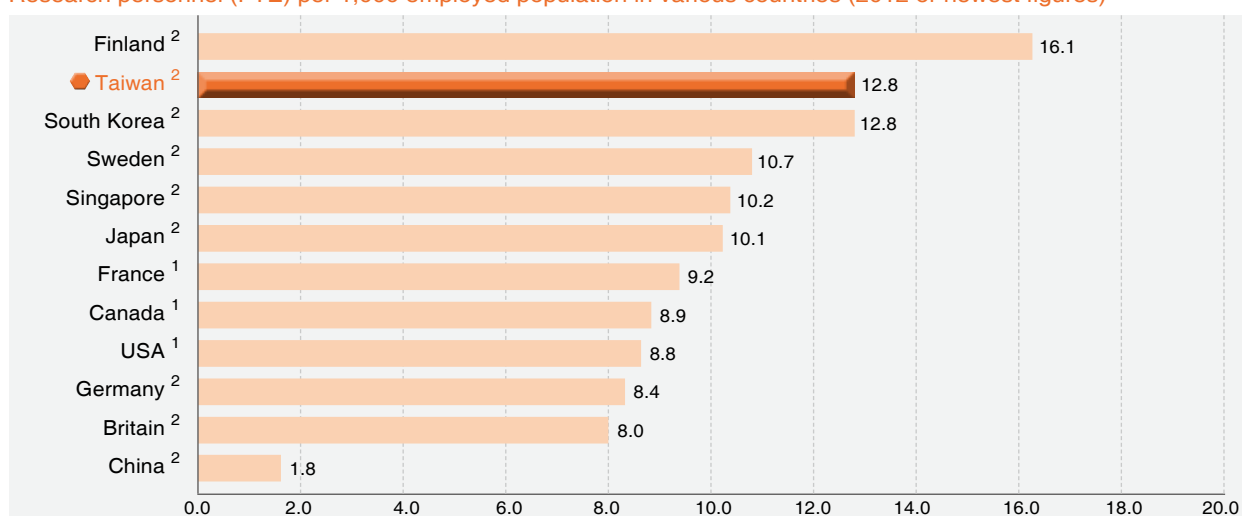
### R&D personnel in Taiwan, 2009-2013

| Item   | 2009    | 2010    | 2011    | 2012    | 2013    |
|--|---------|---------|---------|---------|---------|
| FTE R&D manpower (person-years)                                    | 196,893 | 210,678 | 221,371 | 227,976 | 232,879 |
| Researchers  | 119,185 | 127,768 | 134,048 | 139,215 | 140,124 |
| Technicians  | 65,444  | 70,576  | 74,376  | 77,224  | 80,604  |
| Supporting staff   | 12,264  | 12,335  | 12,947  | 11,537  | 12,150  |
| FTE female research personnel FTE (person-years)                   | 23,245  | 25,392  | 27,457  | 28,811  | 29,199  |
| Female research personnel as a share of all research personnel (%) | 19.5    | 19.9    | 20.5    | 20.7    | 20.8    |
| Number of research personnel per 1,000 employment (person-years)   | 11.6    | 12.2    | 12.5    | 12.8    | 12.8    |

Source: *Indicators of Science and Technology*, ROC, 2014, MOST.

Note: Because of rounding, the sum of the given figures may not be equal to the total in some cases.

### Research personnel (FTE) per 1,000 employed population in various countries (2012 or newest figures)



Source: *Main Science and Technology Indicators*, 1/2014, OECD.

<sup>1</sup> 2011 data.

<sup>2</sup> 2012 data.

## II

## Science and Technology Research Results

A total of 27,699 research papers by authors from Taiwan were cited in *Science Citation Index (SCI)* in 2013, giving Taiwan a world rank of 16<sup>th</sup>. A total of 24,415 research papers from Taiwan were cited in *Engineering Index (EI)* in 2013, giving Taiwan a world rank of 12<sup>th</sup>. In order to provide a clearer picture of the quantity and quality of Taiwan's research output, the following sections compare Taiwan with eight major industrialized countries and the leading Asian countries in terms of the three indicators of number of *SCI*-cited papers per million people, *SCI* impact factor, 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 most recent five years. Taiwan's 1,028 *SCI*-cited papers per million people in 2009 had risen to 1,185 by 2013, putting Taiwan behind Singapore, Canada, Britain, Germany, and the US, but ahead of France, South Korea, Italy, Japan, Russia, China, and India. The best performer in this category, Singapore, increased its output from 1,688 cited papers in 2009 to 2,155 in 2013. Although China's output still remains far behind most of the other countries, its cited papers grew at the fastest average rate between 2009 and 2013 (14.2%). And while South Korea has lagged behind Taiwan, its output rose from 767 cited papers per million people in 2009 to 1,017 cited papers in 2013, giving it an average growth rate of 7.28% for this period.

Number of *SCI*-cited papers per million people and five-year average growth rate in various countries, 2009-2013

Units: papers

| Country     | 2009  | 2010  | 2011  | 2012  | 2013  | Average growth rate, 2009-2013 (%) |
|-------------|-------|-------|-------|-------|-------|------------------------------------|
| Singapore   | 1,688 | 1,822 | 1,919 | 2,049 | 2,155 | 6.30                               |
| Canada      | 1,644 | 1,673 | 1,719 | 1,765 | 1,786 | 2.09                               |
| Britain     | 1,491 | 1,537 | 1,595 | 1,644 | 1,701 | 3.34                               |
| Germany     | 1,074 | 1,116 | 1,173 | 1,244 | 1,269 | 4.25                               |
| USA         | 1,113 | 1,134 | 1,170 | 1,189 | 1,198 | 1.84                               |
| Taiwan      | 1,028 | 1,076 | 1,175 | 1,185 | 1,185 | 3.61                               |
| France      | 994   | 1,006 | 1,032 | 1,055 | 1,071 | 1.89                               |
| Italy       | 871   | 890   | 932   | 982   | 1,036 | 4.43                               |
| South Korea | 767   | 840   | 916   | 987   | 1,017 | 7.28                               |
| Japan       | 601   | 593   | 606   | 610   | 616   | 0.64                               |
| Russia      | 200   | 194   | 203   | 198   | 203   | 0.27                               |
| China       | 95    | 104   | 121   | 139   | 162   | 14.20                              |
| India       | 33    | 36    | 38    | 39    | 41    | 5.48                               |

Source: 1. *SCI*-cited papers: *InCites*, Thomson Reuters (May 2014)

2. Population figures: World Bank: <http://www.worldbank.org/>

3. Population of Taiwan: Statistical Yearbook of the Ministry of the Interior: <http://sowf.moi.gov.tw/stat/year/list.htm>

## 2. *SCI* impact factor

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 that period. Among the countries compared here, the European and North American countries generally have high impact factors, and Britain, the US, Singapore, Germany, Canada, France, and Italy all had impact factors higher than 6 in 2013. Taiwan's impact factor rose from 3.74 in

2009 to 4.55 in 2013, which shows that the quality of Taiwan's academic papers is improving, although it still lags behind that of the leading European and North American countries and Japan. In comparison with Singapore, China and India, the quality of Taiwan's academic papers has been improving at a relatively slow rate, and China's *SCI* impact factor rose from 3.46 in 2009 to 4.50 in 2013, putting it on a par with Taiwan.

*SCI* impact factors of various countries, 2009-2013

| Country     | 2009 | 2010 | 2011 | 2012 | 2013 |
|-------------|------|------|------|------|------|
| Britain     | 6.89 | 7.12 | 7.39 | 7.61 | 7.71 |
| USA         | 7.23 | 7.34 | 7.47 | 7.62 | 7.70 |
| Singapore   | 5.46 | 5.72 | 6.33 | 6.94 | 7.60 |
| Germany     | 6.67 | 6.85 | 7.12 | 7.36 | 7.47 |
| Canada      | 6.27 | 6.49 | 6.72 | 6.97 | 7.11 |
| France      | 6.06 | 6.27 | 6.57 | 6.81 | 7.03 |
| Italy       | 6.03 | 6.18 | 6.44 | 6.68 | 6.82 |
| Japan       | 5.02 | 5.15 | 5.28 | 5.40 | 5.47 |
| Taiwan      | 3.74 | 3.88 | 4.08 | 4.33 | 4.55 |
| South Korea | 3.76 | 3.87 | 4.09 | 4.31 | 4.55 |
| China       | 3.46 | 3.70 | 4.00 | 4.28 | 4.50 |
| India       | 2.98 | 3.14 | 3.33 | 3.56 | 3.78 |
| Russia      | 2.60 | 2.62 | 2.68 | 2.81 | 2.88 |

Source: *InCites*, May week4, 2014, Thomson Reuters

### 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 five-year period. Among the countries compared here, Singapore's citation rate was the highest during the most recent five years, followed by that of Taiwan and then Canada. Taiwan's *EI* citation

output rose at an annual rate of 6.36% from 816 papers per million people in 2009 to 1,045 papers in 2013. While the number of papers per million people in 2012 was behind only the figure for Singapore, Taiwan's average growth rate over the previous five years was the lowest of any of the countries included in this comparison.

Number of *EI* citations per million people and five-year average growth rate in various countries, 2009-2013

Units: papers

| Country   | 2009  | 2010  | 2011  | 2012  | 2013  | Average growth rate, 2009-2013 (%) |
|-----------|-------|-------|-------|-------|-------|------------------------------------|
| Singapore | 1,044 | 1,192 | 1,196 | 1,243 | 1,922 | 16.48                              |
| Taiwan    | 816   | 877   | 983   | 889   | 1,045 | 6.36                               |
| Canada    | 560   | 592   | 612   | 629   | 915   | 13.05                              |
| Britain   | 388   | 426   | 447   | 458   | 750   | 17.90                              |
| Germany   | 357   | 398   | 442   | 471   | 739   | 19.89                              |
| Korea     | 444   | 493   | 545   | 578   | 733   | 13.32                              |
| France    | 346   | 375   | 405   | 414   | 697   | 19.13                              |
| USA       | 323   | 400   | 412   | 420   | 601   | 16.75                              |
| Italy     | 292   | 321   | 343   | 366   | 578   | 18.61                              |
| Japan     | 324   | 346   | 359   | 357   | 462   | 9.28                               |
| China     | 131   | 154   | 187   | 189   | 206   | 12.03                              |
| Russia    | 79    | 86    | 95    | 97    | 147   | 16.72                              |
| India     | 17    | 21    | 26    | 29    | 35    | 19.25                              |

Source: 1. *EI*-cited papers: *EI Compendex*, Elsevier Inc., USA, Oct. 2014

2. Population figures: World Bank: <http://www.worldbank.org/>

3. Population of Taiwan: Statistical Yearbook of the Ministry of the Interior: <http://sowf.moi.gov.tw/stat/year/list.htm>



## Science and Technology Development Advisory Board

In order to provide the Minister with recommendations and consulting services concerning S&T research and development, the Science and Technology Development Advisory Board has been established in accordance with MOST's operating rules. The Advisory Board has one chairperson position, which shall be filled by the Minister of Science and Technology, and one executive secretary position, which shall be filled by the MOST deputy minister. The executive secretary is responsible for taking orders from the chairperson and managing the

Advisory Board's affairs. To encourage excellence and innovation in research, and strengthen linkage between academic research results and the needs of industry, the Advisory Board has established an advisory conference on academic research and an advisory conference on industry-academic promotion, and has engaged in domestic and foreign experts from industry, academia, and the research community to serve as Board members and provide recommendations to MOST concerning academic R&D and industry-academic linkage.

### **A. Advisory conference on academic research**

In order to continue to improve academic research policy and academic assistance mechanisms, MOST established the advisory conference on academic research in March 2014, specially arranged for Academia Sinica President Wong Chi-Huey to serve as a deputy chairman, and invited the heads of domestic universities and representative experts and scientists in various fields of study to serve as members of the 17-person conference. The advisory conference's chief mission is to submit strategic recommendations concerning MOST's academic research and development policy, current funding mechanisms, and strategies and focal points for the funding of international academic frontier research. The advisory conference specifically seeks to address how to use limited resources to support outstanding scientists, and how research results can best be used to stimulate international academic frontier research and contribute to the nation's society and economy.

The two conferences held in 2014 reviewed MOST's project funding mechanisms, results assessment, and key R&D fields, and sought to direct attention to the needs of society and the economy. Furthermore, the advisory conference also completed review and revision of MOST's academic ethics review system, and is continuing to discuss and analyze indicators used to assess academic papers in Taiwan.

### **B. Advisory conference on industry-academic promotion**

In order to establish a mechanism for the systematic discovery of research results with practical potential, the extension of such results to mid- and downstream areas, and encouragement need-oriented innovative R&D, with the goal of strengthening industry-academic linkage, MOST established the

advisory conference on industry-academic promotion in March 2014. This advisory conference provides consulting services concerning industry-academic linkage strategies and assistance mechanisms, and the promotion of forward-looking technology R&D strategies in industry. The Minister of Science and Technology serves as the chairperson of the advisory conference, the MOST deputy minister serves as executive secretary. MOST has invited prestigious domestic and foreign scholars and scientists familiar with the industry-academic development and affiliated with industry, venture capital, academia, research organizations, and government agencies to serve as members of 18-person conference.

The three conferences held in 2014 provided numerous recommendations and views concerning the practical application of R&D results, formation of startups, academic understanding of industry's development and needs, and the training of industrial manpower. After considering the conference's findings, MOST drafted the "Trial Program to Rely on Research Institutes to Promote Industry-Academic Collaboration," which will take advantage of the Industrial Technology Research Institute's experience and capabilities to add value to R&D results and pair industry partners with academic researchers. The areas of electronics, information, and communications, National Program on Networked Communications, National Program for Intelligent Electronics, and National Program for Nanoscience and Nanotechnology have been selected as the initial targets of the program, which will conduct an inventory of R&D results, assess practical potential, promote university patent evaluation and marketing, provide consulting concerning the application of R&D results, perform matchmaking with industry partners, train specialists in intellectual property practice, and draft cooperation mechanisms for research organizations and schools.

## IV

## Enhancing Citizens' S&amp;T Literacy

In order to increase citizens' S&T literacy, 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 2014:

#### A. Popular science activities

MOST has promoted various popular science activities via a wide range of channels, and has encouraged domestic scientists, either by themselves or in partnership with companies, foundations, academic groups, or associations, to use innovative, diverse, accessible, and interesting methods to hold workshops, hands-on activities, demonstrations, performances, guided readings of articles offline and online throughout the country. A total of 1,418 popular science activities were held throughout 2014, and attracted 257,000 participants.

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 monthly visits since September 2014. Apart from setting up a Facebook fans page and a Google+ page, the website has established its own YouTube channel, and has uploaded several hundred short popular science videos provided or licensed by academic personnel and multimedia companies. As of the end of 2014, the Sci-Tech Vista Facebook fans page had received 15,500 "likes," and the YouTube channel had been viewed a total of more than 2.5 million times.

In order to enhance online dissemination of S&T news, MOST has continued to call for proposals for "Projects for Implementation of New Media for Popular Science," which are meant to encourage interdisciplinary academic cooperation, introduce new S&T knowledge in the form of special reports, or provide of full-scale, in-depth reports of major news events or facts. The public can view reports and quickly obtain information using their computer or mobile device, enabling the projects to promote understanding of science and boost citizens' scientific literacy. Funding was provided to six projects in August 2014, and the selected topics included

medicine, insects, food nutrition and safety, intelligent living S&T, cloud S&T, and environmental changes. The projects' implementing teams will produce at least 280 popular science articles with a year's time, and will rely on the Sci-Tech Vista website and Facebook posts to help the public to obtain new S&T knowledge in a convenient manner.

MOST held over 100 lectures of the popular science lecture series "Prospect" 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 23,000 students and members of the public took part in these events. In order to give students living in remote areas near-live access to these fascinating lectures, some production teams also provided live broadcasts via the Internet, including online Q&A sessions. A total of 62 lecture recordings were placed on the Knowledge Lecture Hall and Sci-Tech Vista websites, letting the public view the lectures online at any time or place; the lectures have been viewed online more than 29,000 times.

#### B. The Development of Taiwan Science Communication Industry Project

This project seeks to provide citizens with superior domestically-produced science programs and thereby achieve the goal of promoting scientific literacy, while promoting cooperation between the media industry and domestic scientists. Since 2014, the project has relied on an industry-academic collaborative to produce and broadcast popular science content. During 2014, funding was provided to 14 projects in which domestic scientists assisted the production of popular science videos, animation/manga, dramas, illustrated books, short films, and extension activities. Thus far, three public organizations (National Applied Research Laboratories, Academia Sinica, and the National Museum of Natural Science) and ten universities (including National Taiwan University and National Tsinghua University) have signed industry-academic collaboration contracts with 13 partners (including Sanlih TV, Formosa Television Culture, Dong Tai Communication, Rabbit Theater Group), and these

collaborative efforts are expected to produce 41 popular science videos (with a total length of 1,442 min.), 22 popular science animated programs (with a total length of 219 min.), three science manga, and 20 popular science drama episodes, which include illustrated books and micro-films. This plan places emphasis on both theory and practice; a sixth volume of collected papers on scientific broadcasting was published in 2014, and 16 papers were accepted for publication.

In the area of extension, popular science programs continued to be broadcast on FTV at regular times in order to get the public in the habit of viewing. A total of 104 hours of programming was broadcast throughout the year; the programs' highest viewing rate exceeded 0.5 (and averaged 0.1-0.2), and they had a cumulative reach of roughly 30 million person-times. In particular, the Saturday morning "Science Discovery" show, which was broadcast on the FTV News channel, regularly had a viewing rate of over 0.2; a survey found that the show's viewers tend to consist of middle-aged individuals with relatively high incomes, which reveals the show's influence.

In terms of quality, science programs produced with funding from this plan have been finalists at the Golden Bell Awards for seven consecutive years. The two programs winning prizes at the 2014 Golden Bell Awards consisted of "Hello Brain," which won the best science program award, and "100 Secrets of Seeds," which won the best animated program award. This project has accumulated a total of nine Golden Bell Awards thus far, which displays the high level of quality of the project's outputs.

In the area of manpower training, eight scientific communications manpower training classes and workshops encompassing both theoretical and practical aspects were held in 2014; these sessions included popular science animation and other practical training. In addition, 19 universities in northern, central, and southern areas of Taiwan conducted 49 sessions of 17 classes concerning scientific communications, which provided training more than 3,400 person-times.

In the area of international cooperation, cooperation with senior foreign production companies helped production teams in Taiwan to produce science videos for the international market. For instance, production of the first episode—"Power of Body and Movement"—of the "Hello, Brain!" brain science series involved the combined efforts of Taiwanese and French brain scientists and artists, and relied on contemporary artists' views of physical aesthetics and scientists' tests to investigate the inner world of the brain. The production team included personnel from Shih Hsin University, domestic media production firms, Britain's Screen House, and France's BDL Production House. The second and third episodes respectively focused on the topics of the brain and sound and the brain and food. This collaborative efforts won the best science program award at the 2014 Golden Bell Awards, and was broadcast by foreign media. Apart from obtaining international publicity for the results of scientific research in Taiwan, the efforts have also contributed to the improvement of scientific program production capabilities in Taiwan, which are now close to approaching international levels.

## V

## Integration of National Disaster Prevention Research

The National Science and Technology Center for Disaster Reduction (NCDR) bears responsibility for a mission that involves planning, coordination, policy drafting, technical support, and realization of applications. NCDR's overall objective is "To promote and integrate disaster prevention and relief R&D capabilities, apply various disaster prevention and relief technologies, formulate disaster adaptation strategies, help government enhance its disaster prevention and relief performance and boost the

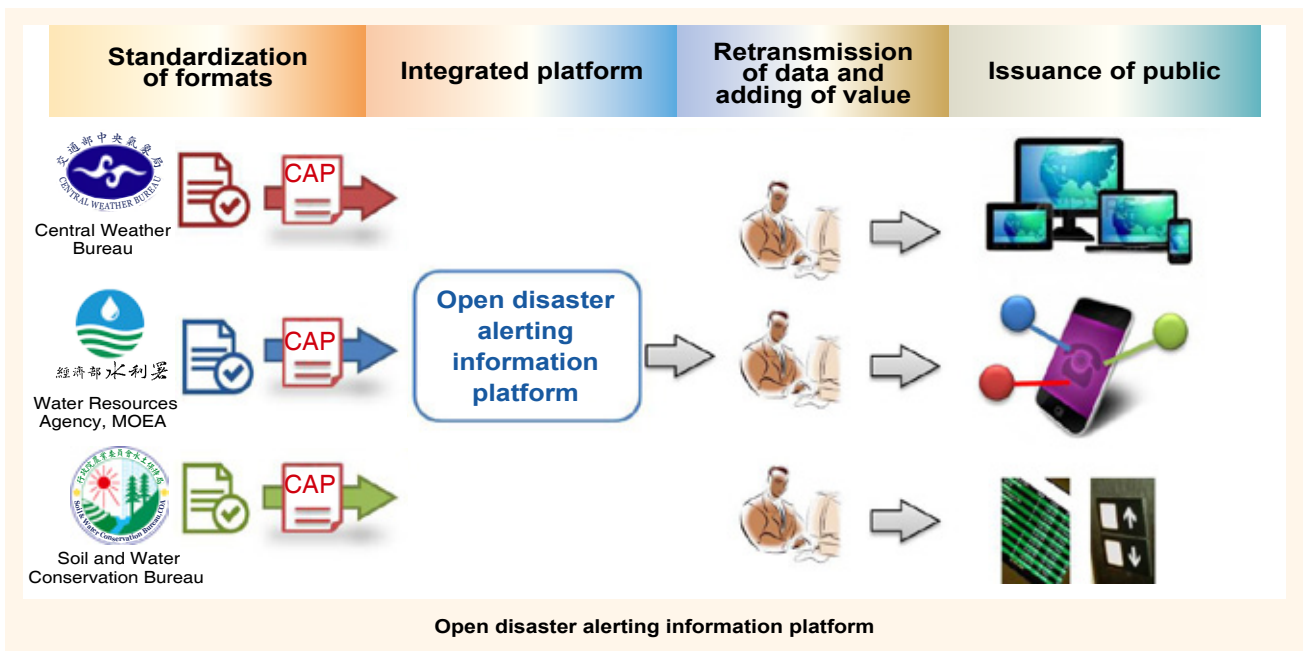
disaster resilience of society as a whole, and mitigate the impacts and losses caused by natural disasters."

Because disaster situations can be extremely fast-changing, and may involve massive amounts of information, NCDR has sought to enhance the value and transmission efficiency of disaster information by combining real-time monitoring data, early warning models, and geographical information system technologies. It has also employed joint warning

protocols and an open warning data platform to integrate disaster warning data from various disaster prevention units, which allows it to quickly provide necessary data for value-adding use by various parties. Furthermore, the disaster response decision-making assistance system developed by NCDR allows disaster response personnel to perform their mission—both on a routine basis and during an actual disaster—using common disaster images. The following is an explanation of relevant platforms and systems:

When typhoons, floods, or mudslides occur, the issuance of warning information is the responsibility of different competent authorities. However, the fact that different agencies have established independent warning issuance mechanisms causes many difficulties for users. Accordingly, NCDR is cooperating with other government agencies in the adoption

of common internationally-recognized Alerting protocols, and has established an "open disaster alerting information platform" (<https://alerts.ncdr.nat.gov.tw>) providing standardized, one-stop disaster warning services. This platform has helped facilitate diverse applications and the rapid transmission of information. After formally going online in 2014, the disaster warning platform has been adopted for use by more than 40 units, including various universities, all city and county governments, the armed forces, central government agencies, consulting companies, telecommunications companies, foundations, Google, and app development companies. The system interface receives an average of 10,000 queries each day. By providing many real-time services to the public and disaster relief personnel, the platform has reduced losses by speeding up response efforts.



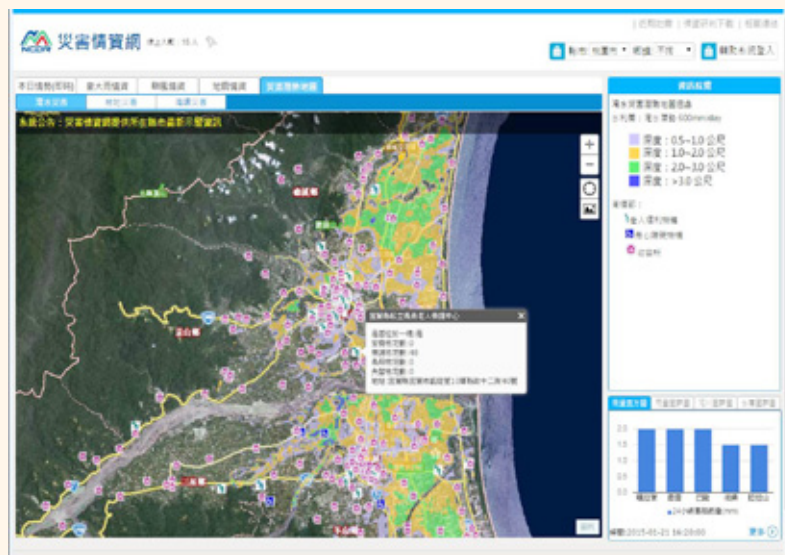
NCDR has expanded the use of its disaster response decision-making assistance system to local disaster prevention and response personnel. The system's e-mail notices ensure that central government, city, and county disaster prevention and response personnel simultaneously obtain the fastest possible disaster information. The system provided services to response personnel more than 6,000

person-times during the several typhoons that struck Taiwan during 2014.

Furthermore, the "Disaster Information Website" (<http://eocdss.ncdr.nat.gov.tw/ncdrwebv2/>) allows users to monitor nationwide natural disaster information at all times. This website received more than 14,000 visits between June 2014 and the end of December.



Disaster response decision-making assistance system



Disaster information website



## **Chapter 3 Support for Academic Research**

- **Funding Research Projects**
- **Research and Development Performance**
- **Recruiting and Cultivating S&T Personnel**
- **Research Awards**
- **International Cooperation in Science and Technology**
- **Cross-strait S&T Interchange**
- **Improving the Research and Development Environment**
- **Management and Extension of R&D Results**
- **Publications**



## I Funding Research Projects

### A. Funding Principles and Methods

By supporting S&T research work at universities and research organizations, MOST's specific-topic research project funding 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 general expenses, equipment funding, or foreign travel expenses based on the real needs of their research. Furthermore, in order to encourage long-term, in-depth research, MOST also promotes multi-year projects, and accepts applications for multi-year project funding in the fields of natural science, engineering and applied technology, and life science/medicine/agriculture.

After a specific-topic research project funding 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 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 must 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 encompass 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 19,460 specific-topic research projects were implemented during 2014 (including 13,890 newly-approved 2014 projects, 3,557 second-year projects of multi-year projects approved in 2013, 1,977 third-year projects of multi-year projects approved in 2012, 35 fourth-year project of multi-year projects approved in 2011, and five fifth-year projects of multi-year projects approved in 2010). Total implemented funding was NT\$22.42 billion, of which 64.91% went for research at public universities and colleges, 20.34% went for research at private universities and colleges, and 14.75% went for research at

Numbers of specific-topic research projects and approval rate, 2010-2014

| Item                 | 2010   | 2011   | 2012   | 2013   | 2014                |
|----------------------|--------|--------|--------|--------|---------------------|
| Project applications | 30,142 | 30,743 | 29,856 | 29,484 | 28,870              |
| Approved projects    | 14,463 | 14,167 | 14,831 | 14,265 | 13,890              |
| Approval rate        | 47.98% | 46.08% | 49.68% | 48.38% | 48.11%              |
| Implemented projects | 20,635 | 20,398 | 20,487 | 19,603 | 19,460 <sup>1</sup> |

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

<sup>1</sup> Projects implemented in 2014 included projects approved in 2014, second-year projects of multi-year projects approved in 2013, third-year projects of multi-year projects approved in 2012, fourth-year projects of multi-year projects approved in 2011, and fifth-year projects of multi-year projects approved in 2010.

government research organizations and other units. Basic research projects accounted for 52.35% of the total, applied research projects accounted for 38.32%, and technology development projects accounted for 9.33%. By research field, natural science projects accounted for 19.8% of the total, engineering and applied science projects accounted for 32.75%,

life science/medicine/agriculture research projects accounted for 27.71%, humanities and social science projects accounted for 13.21%, science education projects accounted for 5.0%, and other projects accounted for 1.53%. By research period, one-year projects accounted for 18.07% of the total, and multi-year projects accounted for 81.93%.

#### Numbers of specific-topic research projects at different types of organizations and funding, 2010-2014

Units: NT\$1 m

| Item                              | 2010          |                  | 2011          |                  | 2012          |                  | 2013          |                  | 2014 <sup>1</sup> |                  |
|-----------------------------------|---------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|-------------------|------------------|
|                                   | Projects      | Funding          | Projects      | Funding          | Projects      | Funding          | Projects      | Funding          | Projects          | Funding          |
| Public universities               | 12,291        | 13,807.82        | 12,408        | 13,585.21        | 12,419        | 13,846.52        | 12,023        | 13,986.18        | 12,008            | 14,552.40        |
| Private universities              | 6,325         | 4,737.57         | 5,948         | 4,428.52         | 5,982         | 4,688.94         | 5,514         | 4,446.46         | 5,334             | 4,560.66         |
| Military/police schools           | 233           | 204.59           | 243           | 187.49           | 217           | 175.95           | 228           | 204.24           | 229               | 203.34           |
| Government research organizations | 939           | 1,656.19         | 952           | 1,518.14         | 963           | 1,577.15         | 914           | 1,549.90         | 907               | 1,532.61         |
| Academic research organizations   | 239           | 440.00           | 241           | 573.73           | 290           | 635.37           | 282           | 618.96           | 325               | 822.12           |
| Teaching hospitals                | 600           | 629.57           | 597           | 590.99           | 608           | 636.83           | 638           | 710.02           | 655               | 743.59           |
| Other                             | 8             | 356.35           | 9             | 204.31           | 8             | 122.80           | 4             | 57.75            | 2                 | 3.19             |
| <b>Total</b>                      | <b>20,635</b> | <b>21,832.09</b> | <b>20,398</b> | <b>21,088.38</b> | <b>20,487</b> | <b>21,683.57</b> | <b>19,603</b> | <b>21,573.51</b> | <b>19,460</b>     | <b>22,417.91</b> |

<sup>1</sup> 2014 statistics are to January 10, 2015.

#### Numbers of funded basic research, applied research, and technology development projects and funding, 2010-2014

Units: NT\$1 m

| Item                   | 2010          |                  |             | 2011          |                  |             | 2012          |                  |             | 2013          |                  |             | 2014 <sup>1</sup> |                  |             |
|------------------------|---------------|------------------|-------------|---------------|------------------|-------------|---------------|------------------|-------------|---------------|------------------|-------------|-------------------|------------------|-------------|
|                        | Projects      | Funding          | Funding %   | Projects      | Funding          | Funding %   | Projects      | Funding          | Funding %   | Projects      | Funding          | Funding %   | Projects          | Funding          | Funding %   |
| Basic research         | 10,619        | 11,749.06        | 53.81%      | 10,747        | 11,280.53        | 53.49%      | 10,767        | 11,438.23        | 52.75%      | 10,418        | 11,399.41        | 52.84%      | 10,379            | 11,737.81        | 52.35%      |
| Applied research       | 8,830         | 8,411.28         | 38.53%      | 8,452         | 8,055.97         | 38.20%      | 8,477         | 8,446.15         | 38.95%      | 8,051         | 8,363.62         | 38.77%      | 7,892             | 8,592.26         | 38.32%      |
| Technology development | 1,186         | 1,671.75         | 7.66%       | 1,199         | 1,751.88         | 8.31%       | 1,243         | 1,799.20         | 8.30%       | 1,134         | 1,810.48         | 8.39%       | 1,189             | 2,087.83         | 9.33%       |
| <b>Total</b>           | <b>20,635</b> | <b>21,832.09</b> | <b>100%</b> | <b>20,398</b> | <b>21,088.38</b> | <b>100%</b> | <b>20,487</b> | <b>21,683.57</b> | <b>100%</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> |

<sup>1</sup> 2014 statistics are to January 10, 2015.

## Numbers of funded specific-topic research projects in each research area and funding, 2010-2014

Units: NT\$1 m

| Item                                    | 2010          |                  | 2011          |                  | 2012          |                  | 2013          |                  | 2014 <sup>1</sup> |                  |
|---|---------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|-------------------|------------------|
|   | Projects      | Funding          | Projects      | Funding          | Projects      | Funding          | Projects      | Funding          | Projects          | Funding          |
| Natural science                         | 2,575         | 4,668.63         | 2,574         | 4,342.56         | 2,520         | 4,164.30         | 2,356         | 3,950.25         | 2,444             | 4,440.60         |
| Engineering                             | 7,371         | 6,240.35         | 7,278         | 6,440.37         | 7,428         | 6,878.11         | 6,886         | 6,513.72         | 6,740             | 7,343.21         |
| Life science, medicine, and agriculture | 4,589         | 6,460.24         | 4,538         | 6,046.62         | 4,412         | 5,951.85         | 4,274         | 5,939.49         | 4,398             | 6,212.24         |
| Humanities and social sciences          | 5,044         | 3,035.43         | 5,066         | 2,721.59         | 5,147         | 2,821.55         | 5,120         | 3,001.91         | 4,948             | 2,963.12         |
| Science education                       | 1,033         | 1,013.74         | 888           | 955.52           | 896           | 922.42           | 850           | 815.10           | 905               | 1,122.23         |
| Other                                   | 23            | 413.69           | 54            | 581.72           | 84            | 945.34           | 117           | 1,353.05         | 25                | 336.51           |
| <b>Total</b>                            | <b>20,635</b> | <b>21,832.09</b> | <b>20,398</b> | <b>21,088.38</b> | <b>20,487</b> | <b>21,683.57</b> | <b>19,603</b> | <b>21,573.51</b> | <b>19,460</b>     | <b>22,417.91</b> |

<sup>1</sup> 2014 statistics are to January 10, 2015.

## Numbers of one-year and multi-year specific-topic research projects and funding, 2010-2014

Units: NT\$1 m

| Item                                    | 2010          |                  | 2011          |                  | 2012          |                  | 2013          |                  | 2014 <sup>1</sup> |                  |
|---|---------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|-------------------|------------------|
|   | Projects      | Funding          | Projects      | Funding          | Projects      | Funding          | Projects      | Funding          | Projects          | Funding          |
| <b>One-year projects</b>                |               |                  |               |                  |               |                  |               |                  |                   |                  |
| Natural science                         | 934           | 1,072.55         | 934           | 999.37           | 1,072         | 1,139.26         | 1,058         | 1,137.35         | 1,122             | 1,432.15         |
| Engineering                             | 4,128         | 2,681.55         | 4,052         | 2,637.78         | 4,115         | 2,874.95         | 3,753         | 2,693.54         | 3,673             | 2,946.23         |
| Life science, medicine, and agriculture | 640           | 1,171.73         | 1,255         | 1,323.73         | 1,297         | 1,292.78         | 1,289         | 1,263.81         | 1,217             | 1,293.44         |
| Humanities and social sciences          | 2,995         | 1,569.93         | 2,815         | 1,212.18         | 2,848         | 1,307.52         | 2,778         | 1,353.22         | 2,655             | 1,308.25         |
| Science education                       | 413           | 398.99           | 351           | 362.88           | 346           | 314.76           | 378           | 277.73           | 377               | 248.93           |
| Other                                   | 13            | 257.25           | 12            | 264.99           | 27            | 221.51           | 65            | 587.94           | 21                | 260.72           |
| <b>Subtotal</b>                         | <b>9,123</b>  | <b>7,152.00</b>  | <b>9,419</b>  | <b>6,800.93</b>  | <b>9,705</b>  | <b>7,150.78</b>  | <b>9,321</b>  | <b>7,313.59</b>  | <b>9,065</b>      | <b>7,489.72</b>  |
| <b>Multi-year projects</b>              |               |                  |               |                  |               |                  |               |                  |                   |                  |
| Natural science                         | 1,641         | 3,596.08         | 1,640         | 3,343.19         | 1,448         | 3,025.03         | 1,298         | 2,812.90         | 1,322             | 3,008.45         |
| Engineering                             | 3,243         | 3,558.81         | 3,226         | 3,802.59         | 3,313         | 4,003.17         | 3,133         | 3,820.17         | 3,067             | 4,396.98         |
| Life science, medicine, and agriculture | 3,949         | 5,288.52         | 3,283         | 4,722.90         | 3,115         | 4,659.08         | 2,985         | 4,675.67         | 3,181             | 4,918.80         |
| Humanities and social sciences          | 2,049         | 1,465.50         | 2,251         | 1,509.40         | 2,299         | 1,514.03         | 2,342         | 1,648.69         | 2,293             | 1,654.87         |
| Science education                       | 620           | 614.75           | 537           | 592.65           | 550           | 607.66           | 472           | 537.37           | 528               | 873.30           |
| Other                                   | 10            | 156.44           | 42            | 316.73           | 57            | 723.83           | 52            | 765.11           | 4                 | 75.79            |
| <b>Subtotal</b>                         | <b>11,512</b> | <b>14,680.10</b> | <b>10,979</b> | <b>14,287.46</b> | <b>10,782</b> | <b>14,532.79</b> | <b>10,282</b> | <b>14,259.92</b> | <b>10,395</b>     | <b>14,928.19</b> |
| <b>Total</b>                            | <b>20,635</b> | <b>21,832.09</b> | <b>20,398</b> | <b>21,088.38</b> | <b>20,487</b> | <b>21,683.57</b> | <b>19,603</b> | <b>21,573.51</b> | <b>19,460</b>     | <b>22,417.91</b> |

<sup>1</sup> 2014 statistics are to January 10, 2015.

Numbers of male and female principal investigators of specific-topic projects, 2010-2014

| Item   | 2010         |            | 2011         |            | 2012         |            | 2013         |            | 2014         |            |
|--------|--------------|------------|--------------|------------|--------------|------------|--------------|------------|--------------|------------|
|        | person times | percentage | person times | percentage | person times | percentage | person times | percentage | person times | percentage |
| Female | 4,469        | 21.66%     | 4,438        | 21.76%     | 4,469        | 21.81%     | 4,429        | 22.59%     | 4,488        | 23.06%     |
| Male   | 16,166       | 78.34%     | 15,960       | 78.24%     | 16,018       | 78.19%     | 15,174       | 77.41%     | 14,972       | 76.94%     |
| Total  | 20,635       | 100%       | 20,398       | 100%       | 20,487       | 100%       | 19,603       | 100%       | 19,460       | 100%       |

## II

## Research and Development Performance

### A. General Specific-topic Research Projects

#### 1. Natural Science

Natural science research chiefly takes the form of basic scientific research, and encompasses the five main areas of mathematics/statistics, physics, chemistry, and earth science (which includes geology, geochemistry, atmospheric science, oceanography, sustainable development, disaster prevention and response, and spatial information). In order to strengthen interdisciplinary research involving the natural sciences and other areas of science and technology, while also taking into consideration international academic research trends, MOST has been actively planning and implementing focused research in relevant areas, and has sought to achieve the goals of promoting the long-term cultivation of natural science manpower and the pursuit of academic excellence in research. The following were among some of the most significant research results of the year:

(1) Application of GEE long-term tracking data analysis to the selection of models in situations when data is missing

Long-term tracking is widely used in research in such fields as sociology, biology, and medicine. In long-term tracking research, each research subject is observed at multiple points in time, and the data obtained from this long-term tracking allows researchers to understand how each responding variable of interest (such as body weight, disease status, and number of times an event occurs) changes

with time and other dependent variables (such as frequency of movement, type of medication used, and initial number of times that an event occurs), and also the correlation between dependent variables at each point in time. The generalized estimating equation (GEE) method is a widely used approach that can be used to analyze the relationship between a responding variable and dependent variables at different points in time, and is a form of marginal regression analysis of long-term tracking data. The main feature of GEE analysis is that it examines the correlation structure of the responding variable at each point in time, and because it still can establish the consistent estimation of the variable's regression parameter on the assumed correlation structure of incorrect responding variables, it possesses statistical inferential robustness.

The long-term tracking data analysis model selection method proposed by the research team in this project represents the first systematic study in the literature of the question of regression model selection when observation of data is incomplete. The methodology developed in this project can be further extended to more general types of missing data. The statistical method proposed by the research team has provided an effective model selection tool for long-term tracking research, which is commonly plagued with data gaps and measurement errors.

(2) Research on the mechanism of fluorescence quenching when graphene oxide adsorbs transition metal ions

In recent years, research has indicated that

two-dimensional nanomaterials such as graphene, graphene oxide, and metal chalcogenides possess the distinctive characteristic-photoluminescence. For instance, graphene oxide, which forms excellent suspensions and solid films, has been proven to exhibit red fluorescence in the 600-1100 nm near infrared (NIR) waveband. Research involving the treatment of graphene with oxygen plasma indicates that graphene possesses luminescence in a wavelength range of 400-800 nm. Furthermore, when reduced graphene oxide and graphene quantum dots were excited by using UV radiation, it was found that they possess blue light fluorescence. In contrast to an inorganic metallic chalcopyrite semiconductor (molybdenum disulfide), graphene oxide has relatively high solubility in water, and possesses greater mechanical strength and a high degree of chemical modifiability. Because of this, the surface of graphene oxide can be modified with various chemical groups used as sensor elements for small molecules, with changes in the optical properties of the graphene oxide surface when it adsorbs other chemical substances serving as a sensing mechanism. This characteristic of graphene oxide can greatly facilitate the development of new sensing platforms, particularly platforms able to directly test for the presence of target molecules in water solution.

Use of the photoluminescence of two-dimensional nanomaterials has considerable potential in optoelectronics applications. The light-emitting characteristic of graphene oxide is chiefly due to energy band defects caused by the presence of several types of oxygen-containing functional groups. Observation of the fluorescence quenching efficiency of graphene oxide when different metal ions are added has revealed that the fluorescence quenching efficiency is correlated with the number of unfilled d orbitals in the metal ion, and fluorescence quenching efficiency proceeds in the order  $\text{Fe}^{2+} > \text{Co}^{2+} > \text{Ni}^{2+} > \text{Cd}^{2+} > \text{Hg}^{2+}$ .

### (3) Taiwan neutrino experiment: Searching for dark matter

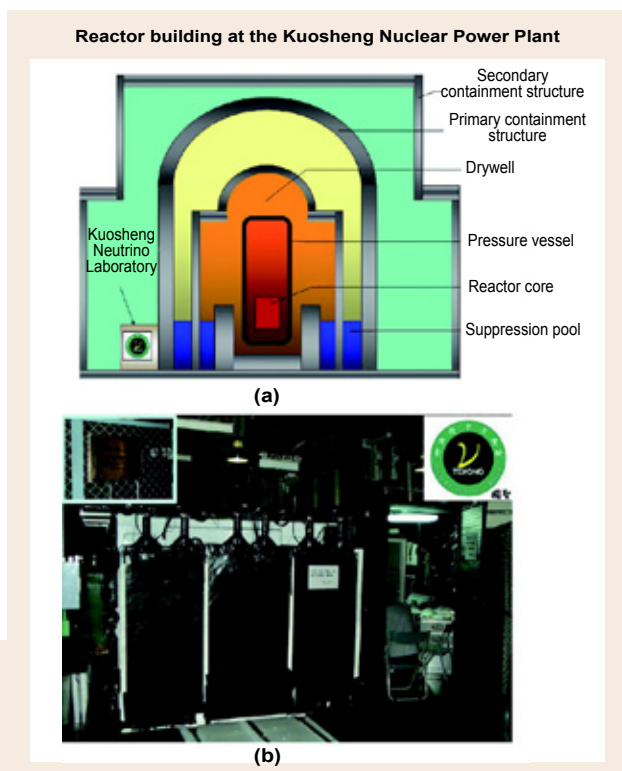
What are dark energy and dark matter?—This is one of this century most important questions in basic science. Taiwan began participating in experimental research in particle physics at the end of the 1980s, when science teams from Taiwan started playing

**Kuosheng Nuclear Power Plant and neutrino laboratory: (a) Schematic diagram; (b) view of the laboratory—the shielding and control room are visible.**

Photo source: Researcher Wang Tzu-ching, Institute of Physics, Academia Sinica

roles in research projects at leading international laboratories, and won applause from their international peers for their technical and organizational skills. The preliminary work done by the "Taiwan Experiment On Neutrino" (TEXONO) team has proven that Taiwan's Kuosheng Neutrino Laboratory has the ability to participate in other "rare event experiments." The TEXONO team has successfully explored the sub-keV energy band and found a low-mass dark matter window; this mass range is becoming a focal area of international dark matter research. The team's current research emphasis is on the development of new point-contact germanium detector (PCGe) technology that can perform measurements at extremely low energy levels (below 100 eV!). The team's current goals include performing the first observation of neutrino-nucleus coherent scattering and the detection of dark matter.

While the foreign CoGeNT experiment has uncovered unexplained events in the sub-keV energy band, because the CoGeNT experiment employs the same PCGe detector technology as used by the Taiwan team, the data from both experiments can be compared independently, which can allow the influence of theoretical model and analytical method to be eliminated. The research team's results have shed light on insufficient processing of the foreign experimental data, and suggest that the foreign



detection of unusual events is actually caused by S->B efficiency calculation errors, and cannot be the sign of dark matter.

#### (4) Climate change: Revealing the secrets of typhoons and torrential rain in Taiwan

In view of the fast pace of environmental changes and global warming, the world's governments are focusing extensive research and development efforts on the environment and climate change, and regional climate change has been one of the chief research challenges. This work involves the use of comprehensive model sets, where the ideal models consist of high-resolution global system models. These models must not only possess spatial resolution of several kilometers, but must also be able to completely simulate the various positive and negative feedback processes affecting climate systems (including the atmosphere, the sea, ice & snow, land, and ecological and human factors), as well as extreme weather and climate characteristics.

Statistics for the past 52 years indicate that typhoons in the vicinity of Taiwan display significant interdecadal changes. Furthermore, while the amount of rainfall in the Taiwan area does not have a significant correlation with typhoon strength, it does have a positive correlation with the amount of time typhoons remain in the Taiwan area. Slow-moving typhoons tend to drop large amounts of rain. In addition, slow-moving typhoons that make landfall in northern Taiwan may tend to move in a circle prior to reaching land, which will extend the rainfall time. This phenomenon occurs chiefly because slow-traveling typhoons are affected by Taiwan's Central Mountain Range after they make landfall in northern Taiwan, with convective rainfall occurring as the typhoon lingers on the southern Taiwan, and the asymmetric convection further reducing the typhoon's speed, which causes rainfall to increase even more. This positive rainfall feedback mechanism is a major causative factor in torrential rains that occurs before and after a typhoon makes landfall. Because the Central Mountain Range is the controlling factor, the signal of climate change may be concealed by topographical effects. When a typhoon is leaving land, the total rainfall may be determined by the water vapor flux carried by the southwest monsoon and the length of the typhoon's stay; the intensity of a typhoon's rainfall will thus be affected by the typhoon track and the southwest monsoon. As for changes in rainfall intensity during the three stages (before, during, and after landfall) during the prior and latter 26-year period, there has been an increase in the

average rainfall intensity of typhoons after leaving land, and this can be partly attributed to an increase in the number of typhoons traveling along path 3 in south-central Taiwan. Because Taiwan is only approximately 400 km in length from north to south, changes in the point at which typhoons make landfall along Taiwan's East Coast cannot readily be blamed on climate change, but the increased intensity of the southwest monsoon is a significant climate change signal.

In summary, the increased rainfall amount and rainfall intensity of typhoons that have moved offshore from Taiwan cannot be solely attributed to the greater strength of the southwest monsoon. In addition, while interdecadal changes in the intensity of the southwest monsoon may be due to changes in ocean temperature, this is not a signal of the well-known weakening of tropical atmospheric circulation caused by global warming. These types of interdecadal climatic variability and changes in extreme weather events attributed to climate change are largely the result of the interaction of atmospheric systems at multiple temporal and spatial scales. The mechanism by which these interactions cause meteorological changes is a challenging and important research topic awaiting further investigation by atmospheric scientists.

#### (5) Undersea cold springs and mud volcanoes near Taiwan: storehouses of energy and biology

A joint Taiwan-German oceanography research team used advanced instruments to explore the biological resources and energy-rich gas hydrates deposits in the waters to the southwest of Taiwan. This research project employed a high precision multi-frequency depth sounder to obtain data on the topography of the seabed in the research area, along with a high-resolution underwater towed camera to determine the precise position of gas seeps within each area. A 3D P-cable seismic detector was also employed to gain a clearer understanding of gas and fluid migration paths.

This project found approximately 30-50 gas vents on an area of the seabed occupying 10 square kilometers, and detected the movement of gas up through deep undersea sediment layers to the underwater vents. The large-scale emission of methane and other gases in the research area indicates that biogeochemical reactions are occurring beneath the seafloor, and are responsible for the emissions of large amounts of greenhouse gases.

In addition, an extensive chemosynthetic biological community has been fueled by the gas releases, and mussels reach a density of 600 individuals/m<sup>2</sup>/layer. The sediment contains large amounts of methane, ethane, and propane, and methane concentrations reach as high as 46,000  $\mu$ L/L. This indicates that the gas has originated from pyrolysis. The 3D P-cable seismic survey results further suggest that gas and fluid migration paths provide the methane and other gases routes from deep sediments to the seabed.

The findings of this project verify that the seabed to the southwest of Taiwan not only possesses rich and diverse biological communities, but also has widespread leaks of methane, which passes through the numerous gas transmission channels in the undersea sediments. The correlation between biogeochemical effects and gas hydrates suggests that the seabed in this area possesses large deposits of gas hydrates.

Number of natural science specific-topic research projects and funding, 2014

Units: NT\$1 m

| Category  | Applications |                 | Approved     |                 | Implemented  |                 |
|---|--------------|-----------------|--------------|-----------------|--------------|-----------------|
|   | Projects     | Funding         | Projects     | Funding         | Projects     | Funding         |
| Mathematics & Statistics  | 506          | 356.17          | 291          | 158.10          | 403          | 247.81          |
| Physics   | 479          | 1,672.46        | 270          | 558.19          | 552          | 954.80          |
| Chemistry   | 601          | 2,112.56        | 319          | 599.93          | 556          | 1,090.64        |
| Earth science, Atmospheric science, Oceanography                                  | 658          | 1,376.46        | 372          | 548.69          | 425          | 668.47          |
| Interdisciplinary research: Frontier physics, Food safety, Geospatial information | 79           | 704.82          | 70           | 138.13          | 70           | 138.14          |
| National Program in Nanotechnology  | 40           | 267.18          | 37           | 204.00          | 37           | 204.00          |
| National Science and Technology Program-Energy                                    | 18           | 1,202.91        | 14           | 418.63          | 14           | 418.63          |
| Geospatial information  | 91           | 76.97           | 43           | 24.92           | 43           | 24.92           |
| Disaster prevention and Mitigation science and technology                         | 286          | 313.27          | 151          | 143.86          | 151          | 143.86          |
| Sustainable development research  | 193          | 267.51          | 110          | 115.18          | 130          | 135.90          |
| Science Vanguard Program  | 24           | 344.99          | 22           | 157.40          | 22           | 157.40          |
| Novel materials   | 19           | 141.07          | 12           | 57.35           | 15           | 70.24           |
| Academic Summit Program   | 7            | 128.00          | 7            | 92.30           | 7            | 92.29           |
| Technology and Capacity improvement project                                       | 19           | 190.09          | 14           | 68.30           | 14           | 68.30           |
| Other   | 0            | 28.24           | 0            | 0.00            | 5            | 25.19           |
| <b>Total</b>  | <b>3,020</b> | <b>9,182.70</b> | <b>1,732</b> | <b>3,284.98</b> | <b>2,444</b> | <b>4,440.59</b> |

## Research manpower in natural science specific-topic research projects, 2010-2014

Units: person-times

| Item                |                      | 2010   | 2011   | 2012   | 2013   | 2014 <sup>1</sup> |
|---------------------|----------------------|--------|--------|--------|--------|-------------------|
| Research personnel  | Professors           | 1,500  | 1,514  | 1,431  | 1,303  | 1,431             |
|                     | Associate professors | 736    | 749    | 692    | 694    | 755               |
|                     | Assistant professors | 841    | 856    | 759    | 682    | 685               |
|                     | Lecturers            | 6      | 9      |        | 6      |                   |
|                     | Other                | 668    | 724    | 708    | 664    | 704               |
| Subtotal            |                      | 3,751  | 3,852  | 3,590  | 3,349  | 3,575             |
| Research assistants | Full-time assistants | 810    | 863    | 833    | 803    | 892               |
|                     | Part-time assistants | 107    | 85     | 73     | 39     | 30                |
|                     | Graduate students    | 9,356  | 9,318  | 8,901  | 8,563  | 9,088             |
| Subtotal            |                      | 10,273 | 10,266 | 9,807  | 9,405  | 10,010            |
| Total               |                      | 14,024 | 14,118 | 13,397 | 12,754 | 13,585            |

<sup>1</sup> 2014 data is as of January 19, 2014

## Numbers and percentage of one-year and multi-year specific-topic research projects in natural science, 2010-2014

| Year | All projects | One-year projects (%) | Multi-year Projects (%) |
|------|--------------|-----------------------|-------------------------|
| 2010 | 2,575        | 934 (36.27)           | 1,641 (63.73)           |
| 2011 | 2,574        | 934 (36.29)           | 1,640 (63.71)           |
| 2012 | 2,520        | 1,072 (42.54)         | 1,448 (57.46)           |
| 2013 | 2,356        | 1,058 (44.91)         | 1,298 (55.09)           |
| 2014 | 2,444        | 1,122 (45.91)         | 1,322 (54.09)           |

## 2. Engineering

Research in the field of engineering and applied science encompasses 18 disciplines in the three major areas of electronics/information/communications, mechanical engineering/electrical engineering/energy, and chemical engineering/materials/consumer applications, and also includes academic collaborative projects in applied technology. The chief goal of this field is to promote basic research in engineering technology and train high-level R&D manpower needed by industry in the future via the funding of specific-topic research projects, and to promote the upgrading of Taiwan's industrial technology through the extension of research project results. In addition, MOST is encouraging the development of major technologies improving people's lives and livelihoods in an effort to improve public health and welfare, foster interdisciplinary joint research involving

different research teams, and integrate knowledge and applications in different fields.

The following are some of most important research results achieved during 2014:

### (1) Fast, precise, stable automatic focusing technology

Capturing clear images chiefly depends on the speed and performance of a camera's automatic focusing system, and the biggest impediment to this is that it is usually difficult to simultaneously reduce noise and increase focusing speed. With assistance from MOST, a research team at National Taiwan University developed unique image processing technology that has even been used in Hollywood movies.

This research team proved that causing a focusing curve to undergo a monotonically increasing

or decreasing transformation will boost anti-noise ability without affecting the focusing accuracy. The team took advantage of this characteristic to propose a reciprocal transformation method enabling a lens to effectively lock on to the focal position, which reduced back-and-forth motion of the lens, overcame the problems of photography in low-illumination and short-distance situations, and greatly boosted image capture quality. This fast, accurate, and stable core technology has already been integrated into monitoring cameras, movie cameras, smartphones, and ordinary cameras, has received two US and Taiwan patents, and has been licensed to a domestic monitoring firm. In addition, the team won first place in the ROC Image Processing and Pattern Recognition's 1st IPPR Technological Innovation and Industrial Application Award out of 60 participating teams. The movie *The Hobbit* was made using cameras employing this technology.

**(2) An ultra-high speed (10 Gbps) visible light communications transmission system**

In line with steadily-increasing communications distance and transmission rate demands, transmission distance and rate have increased steadily as early coaxial cables gave way to today's fiber-optic communications, and optical communications has already become a mainstream communications technology. Apart from its display and lighting applications, visible light can freely transmit optical signals in air, and has become a key element in wireless optical communications with the development of solid-state illumination technologies. In contrast with microwave wireless communications, optical communications relies on visible light as a transmission medium, and the transmission process does not produce any electromagnetic interference. As a result, optical communications can be used instead of microwaves in situations where radio waves are prohibited (such as hospitals, aircraft cabins, and oil refineries, etc.), which ensures that the living environment is more comfortable and safer.

In view of the foregoing advantages, optical communications has become the subject of R&D campaigns conducted by numerous teams around the world, and particular effort is being devoted to achieving progress and breakthroughs in the areas of transmission rate and long-distance free transmission in the air. But while R&D teams in many countries are using LEDs as light sources for visible light communications systems, LEDs' inherent illumination bandwidth and power restrictions limit their application in research on transmission rate and long-distance

free transmission in the air (LEDs have a maximum transmission rate of approximately 3.75 Gbps and a maximum transmission distance of roughly 15 cm). In order to overcome these limitations, a research team at National Taipei Institute of Technology employed a visible light (red light) laser as a light source, which enabled them to create an all-new, innovative, feasible ultra-high speed visible light communications transmission system. Overcoming the inherent limitations of high-brightness white light LED illumination, this system has achieved a transmission rate of as high as 10 Gbps, and can freely transmit signals in air to a distance of as far as 17.5 m. As an example, a 1.5-hour movie requires a transmission capacity of approximately 4.5 Gbit, and can therefore be completely downloaded in only 0.45 sec. via a 10 Gbps ultra-high speed visible light transmission system. Apart from its display and illumination functions, visible light thus has practical value as a means of transmitting optical signals through space.

**(3) An undisturbed auditory feast: Development of high-fidelity in-ear active noise cancellation headphones**

What is meant by noise? Simply put, sounds that one does not like can be termed noise. So how does one get rid of unpleasant noise? Headphones are the most common and simplest means of eliminating noise. But headphones can only keep out high-frequency noise, which is known as passive noise cancellation. In the case of low-frequency, long-wavelength noise, such as the noise of heavy traffic, trains, or even the sounds within a sealed aircraft cabin, passive noise cancellation is of little use. Active noise cancellation is a more effective alternative, and many new portable or wearable electronics products boast of possessing active noise cancellation, which involves key technologies in the hands of foreign firms.

An R&D team at Feng Chia University has teamed up with the international headphone manufacturer Merry Electronics to develop very technologically-challenging in-ear headphones. This team has thus far completed development of three key technology projects, namely "Development of Fast-response Active Noise Cancellation Technology," "Low-power High-efficiency Chip Design and Production," and "Product Anti-noise Characteristic Assessment Platform Establishment." In conjunction with 3D scanners and 3D printers, the team has developed prototype new-generation high-performance active noise cancellation in-ear headphones through the fusion of industrial and

academic theory and practice. The team has applied for several invention and utility model patents on the basis of its results, and has published a number of papers in international journals. Furthermore, the team's completion of comprehensive adaptive active noise cancellation R&D and systems integration will not only facilitate the technological upgrading of the domestic electroacoustic industry, but also help the cooperating firms to achieve innovation and breakthroughs in product technology. Since global demand for high-end headphones is projected to be

40 million units annually, the economic benefit of this work may exceed NT\$500 million – NT\$1 billion in product value. Active noise cancellation technology can also be used in other kinds of wearable products, mobile devices, multimedia systems, audiovisual entertainment systems, and healthcare products (such as hearing aids). In an effort to boost Taiwan's electroacoustic technology, the team will continue to apply this technology to the development of various other types of electronics products.

Numbers of engineering specific-topic research projects and funding, 2014

Units: NT\$1 m

| Category  | Applications  |                  | Approved projects |                 | Implemented projects |                 |
|---|---------------|------------------|-------------------|-----------------|----------------------|-----------------|
|   | Projects      | Funding          | Projects          | Funding         | Projects             | Funding         |
| Electrical/mechanical/energy <sup>1</sup>             | 2,856         | 2,771.74         | 1,412             | 1,070.07        | 1,810                | 1,450.86        |
| Chemical/materials/consumer applications <sup>2</sup> | 2,847         | 3,825.30         | 1,328             | 1,284.79        | 1,917                | 1,932.78        |
| Electronics/information/communications <sup>3</sup>   | 3,429         | 4,230.35         | 1,703             | 1,549.85        | 2,236                | 2,111.60        |
| National science and technology programs <sup>4</sup> | 893           | 2,709.50         | 461               | 1,109.32        | 512                  | 1,164.14        |
| Special projects                                      | 343           | 1,137.84         | 159               | 475.10          | 174                  | 517.06          |
| Interdisciplinary research                            | 17            | 113.22           | 14                | 50.79           | 18                   | 66.75           |
| Academic technology development programs              | 19            | 47.69            | 19                | 38.24           | 19                   | 38.25           |
| Atomic energy and applied radiation technology        | 34            | 33.83            | 20                | 16.16           | 20                   | 16.16           |
| Gender mainstreaming technology projects              | 10            | 6.78             | 4                 | 2.22            | 4                    | 2.22            |
| Other   | 42            | 62.28            | 30                | 43.39           | 30                   | 43.39           |
| <b>Total</b>  | <b>10,490</b> | <b>14,938.53</b> | <b>5,150</b>      | <b>5,639.93</b> | <b>6,740</b>         | <b>7,343.21</b> |

<sup>1</sup> Includes aviation technology, remote sensing, machinery static forces, production, and stress, shipbuilding engineering, electrical engineering, industrial engineering, production 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 polymer engineering.

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

<sup>4</sup> Includes national programs on energy and intelligent electronics.

## Research manpower in engineering specific-topic research project, 2010-2014

Units: person-times

| Item                |                      | 2010   | 2011   | 2012   | 2013   | 2014 <sup>1</sup> |
|---------------------|----------------------|--------|--------|--------|--------|-------------------|
| Research personnel  | Professors           | 4,648  | 4,714  | 4,771  | 4,606  | 4,980             |
|                     | Associate professors | 2,891  | 2,750  | 2,826  | 2,593  | 2,598             |
|                     | Assistant professors | 2,733  | 2,572  | 2,532  | 2,276  | 2,062             |
|                     | Lecturers            | 80     | 50     | 66     | 30     | 25                |
|                     | Other                | 496    | 529    | 638    | 660    | 774               |
| Subtotal            |                      | 10,848 | 10,615 | 10,833 | 10,165 | 10,439            |
| Research assistants | Full-time assistants | 377    | 484    | 461    | 446    | 778               |
|                     | Part-time assistants | 82     | 49     | 54     | 68     | 52                |
|                     | Graduate students    | 23,304 | 22,913 | 24,608 | 22,923 | 23,683            |
| Subtotal            |                      | 23,763 | 23,446 | 25,123 | 23,437 | 24,513            |
| Total               |                      | 34,611 | 34,061 | 35,956 | 33,602 | 34,952            |

<sup>1</sup> 2014 data is as of January 19, 2014.

## Numbers and percentage of one-year and multi-year specific-topic research projects in engineering, 2010-2014

| Year | All projects | One-year projects (%) | Multi-year Projects (%) |
|------|--------------|-----------------------|-------------------------|
| 2010 | 5,947        | 4,128 (69.41)         | 1,819 (30.59)           |
| 2011 | 7,278        | 4,052 (55.67)         | 3,226 (44.33)           |
| 2012 | 7,428        | 4,115 (55.40)         | 3,313 (44.60)           |
| 2013 | 6,886        | 3,753 (54.50)         | 3,133 (45.50)           |
| 2014 | 6,740        | 3,673 (54.50)         | 3,067 (45.50)           |

### 3. Life Science

Life science encompasses 14 disciplines within the three main areas of biology, agriculture, and medicine. MOST's primary mission in life science includes planning and implementation of research and development projects in the areas of biology, agriculture, and medicine, with a goal of boosting research quality and R&D capabilities in the life sciences, training outstanding research manpower, promoting the formation of research teams, creating a superior academic environment, allocating research funding as effectively as possible, fostering pursuit of academic excellence, encouraging S&T interchange and cooperation, and realizing the development of biotechnology.

The following were among some of the most important research results of the year:

#### (1) Biology

Epigenetic control mechanisms participate in the response to environmental stresses and microbial attack in the "environmental stress-disease-resistance" phenomenon, and can facilitate the breeding of new disease-resistant crops. The autophagy of nurse cells will result in the gradual phagocytosis of oil droplets, facilitating important metabolic functions in response to lack of nutrition or aging. mRNA transport of protein complexes to the outside of the nucleus will accelerate cellular senescence and produce telomere DNA recombination in order to escape cellular aging.

A research project studied the right-left asymmetric glands of the lancelet *Branchiostoma lanceolatum* in order to understand their development

mechanism. Research using zebra fish studied the pathogenic ability of *Candida albicans*, and its interactions with drugs and host.

Supporting the establishment of the Taiwan Biodiversity Information Facility (TaiBIF), MOST promoted the collection and integration of biodiversity data. In conjunction with global trends and national policy, apart from establishing a national biodiversity information website and integrating databases in order to provide an information technology framework for TaiBIF, MOST also established a biodiversity research resource sharing platform. Beyond providing a standard structure for biodiversity data, it is hoped that the website will become a portal to integrated international data of a similar nature.

A research project examined how global warming affects the competition between invasive and native species via ecological mechanisms (such as the effect of higher temperature on individuals' growth and development). Research on the competition between the invasive butterfly *Pieris rapae* and the local species *P. Canidia* on their chief food plant *Rorippa indica* found that climate warming can speed the development of the larvae of both butterfly species, the native *P. Canidia* faces intense intra-species competition, and can even maintain an inter-species advantage over the invasive *P. rapae* (in terms of faster larval growth rates and greater pupa weight). Furthermore, in comparison with the invasive *P. rapae*, the native *P. Canidia* also enjoys a competitive advantage for the food species *Rorippa indica*, although this advantage may disappear as warming continues.

## (2) Agriculture

In an effort to obtain a superior variety of Echinacea with uniform characteristics and high yield through selective breeding, researchers developed an F1 hybrid with large-scale commercial potential. This Echinacea variety will provide raw material for processed products, pharmacological assessment, and clinical trials.

Researchers sought to develop a heat absorption device through the use of suitable heat-absorbing materials in order to boost drinking water supplies and improve Taiwan's water problem. Another research team designed and developed a post-harvest dryer for agricultural products powered by solar radiation; by enabling the convenient drying of agricultural products, this dryer will contribute to the improvement of international food security.

A science team successfully developed a new

method of separating polysaccharides on the basis of their molecular weight; this method will open new areas in research on polysaccharide and supercritical fluid applications.

Researchers found that natural phenolic acid can prevent vascular dementia in rats, indicating that it will be worthwhile to research and develop applications of phenolic acid in foods, biotechnology, and pharmaceuticals, which will have the added potential benefit of increasing the value of this substance.

Research results verified that offspring generations of inbred transgenic pigs with two copies of the BDD-hFVIII gene indeed express the protein BDD-hFVIII in milk at different lactation stages, and this protein has coagulation activity. A study employing hemophiliac mice as an animal model confirms that treatment using recombinant human coagulation factor VIII can increase coagulation in hemophiliac mice with the FVIII KO gene deleted.

Analysis of the synergistic effects between fisheries and climate change found that life history characteristics and geographic affinities can explain only part of species' responses to climate change among commercially important fishes, and concluded that changes may also be mediated by other factors, such as interspecies interactions.

A project established a detailed soil information system that will facilitate greater understanding of soil ecosystems and the genomes of soil microbes, assist the development of remediation technologies for contaminated and degraded soils, and enable the determination of soil quality assessment indicators reflecting both soil productivity and environmental health.

Research on biological control methods for pests and diseases integrated knowledge and technological expertise in the areas of insect and pathogen collection and sampling methods, genetic engineering, gene structure and analysis, nutritional needs, and microbial technologies. This project emphasizes the promotion of mature plant protection techniques, development of field application methods, effectiveness assessment, product improvement innovation, and cost-effectiveness, and seeks to develop integrated management systems for harmful organisms in order to effectively control pests and diseases while protecting safety and the environment.

## (3) Basic medicine

A research project employed non-invasive acoustic radiation force impulse (ARFI), MR

Elastography, and MRI with a specific agent (Primovist) to study liver function, liver fibrosis, and cirrhosis. In particular, this project investigated whether early diagnosis and early treatment of cirrhosis of the liver can block further cirrhosis and transformation to liver cancer.

Research on the role of mesenchymal stem cells in tumor growth and angiogenesis, and their application to the elimination of tumors when carrying oncolytic viruses, found that, through the release of various factors, bone marrow mesenchymal stem cells can promote initial tumor formation, angiogenesis, and tumor growth.

When packaged in liposomes, the two substances curcumin and bisdemethylcurcumin can effectively reduce osteoclast activity and maintain osteoblast function, which confers a protective effect against osteoporosis. It is expected that the results of this experiment can be applied to clinical diagnosis.

Researchers employed a lentivirus system to transmit genes to the bladder epithelium via bladder irrigation, and thereby perform superficial bladder cancer gene therapy. The results of this project indicate that the lentivirus system causes no significant irritation of the bladder, and may be useful in bladder gene therapy.

Melatonin was found to effectively increase proliferation of Schwann cells, which caused regenerated nerves to regain the ability to control their target muscles. The results of this project suggest that melatonin can be used in clinical treatment of injuries to the peripheral nerves.

Research discovered that arsenic can inhibit the differentiation of bone cells into bone marrow stromal cells, and cause bone loss, via the ERK-dependent signal transmission pathway. As a consequence, inorganic arsenic may be an environmental risk factor for osteoporosis.

Researcher found that the drug Amiodarone, which is widely used to treat arrhythmia, may inhibit the growth of bladder cancer cells through the induction of cellular autophagy. This project not only found that Amiodarone serves as a cancer treatment, but also preliminarily discovered the mechanism by which it suppresses tumor growth.

Research on the novel small molecule drugs AR-12 found that it can be used in conjunction with existing aminoglycosides antibiotics to fight Salmonella. The findings of this study may facilitate the development of new strategies for treating bacteria with multiple drug resistance.

Responding to a new surge in AIDS cases resulting from intravenous drug use, the government implemented a harm reduction program providing clean needles and alternative treatment on a nationwide basis. A research project studying this program found that it yielded outstanding results, and greatly reduced AIDS virus transmission and risky injections among intravenous drug users. The project's scientific, empirical results can provide important guidance for AIDS prevention policies worldwide.

Research discovered that a single-nucleotide polymorphism located on chromosome 16q22.1 may be a susceptibility gene for diabetic kidney pathologies among type II diabetes patients of Chinese descent.

A research project recommended that government units actively assist caregiver organizations to plan future care methods for aging persons with mental disabilities, and help caregivers employ appropriate social services.

Researchers confirmed that chlorella has a strong ability to protect beta cells in the pancreas, and proposed that animal models or human experiments can be used in future research on this subject. It is believed that chlorella may be used as a nutraceutical food able to regulate blood glucose and help prevent and treat diabetes.

#### (4) Clinical medicine

Research investigating the cellular and molecular biological mechanisms of atrial fibrillation discovered that the ZFHX3 gene may play an important role, and may potentially serve as an indicator and therapeutic target for atrial fibrillation.

Infection with Hepatitis B will increase likelihood of cirrhosis and liver cancer. Relevant research found that the concentration of the hepatitis B virus antigen HBsAg and hepatitis B virus DNA can be used to assess risk of disease progression in hepatitis B carriers. It was also found that mutations in the Basic Core Promoter (BCP) gene in Taiwanese carriers will increase the probability of cirrhosis. The foregoing discoveries will facilitate the location of high-risk chronic hepatitis B carriers and enable early prevention and aggressive treatment.

Research on the genetics of spinocerebellar ataxia in Taiwan successfully developed a genetic testing method, shed light on the pathogenic mechanism, and developed a specific treatment method.

A research project employing mass spectrometry

to perform selected reaction monitoring and develop peptide biological markers with plasma Con-A capture post-translational modification (PTM) for use in early detection of lung cancer discovered that 10 PTM peptides yielded statistically significant results. The resulting markers can be linked to carcinoembryonic antigen (CEA) for use as biological markers of lung cancer.

Research on stem cell angiogenesis potential in breast cancer proved that breast cancer stem cells possess vascular mimicry, and are regulated by epidermal growth factor receptors and heat shock protein phosphorylation signals. The study further discovered natural drugs that can inhibit breast cancer stem cell vascular mimicry, and determined the mechanism of their action. The findings of this research can provide a scientific foundation for the development of drugs targeting vascular mimicry in breast cancer stem cells.

Idiopathic nephrotic syndrome is a commonly seen kidney disease in children. A research project successfully established a C5a-induced animal proteinuria model, and used this model to explore the molecular mechanism of idiopathic nephrotic syndrome. An understanding of this mechanism will facilitate clinical research and control applications targeting C5a-regulated signal transmission in proteinuria.

Research verified that histamine N-methyltransferase and glutathione S-transferase participate in the formation of breast cancer, and their genes are the chief pathogenic genes causing a poor prognosis in

the case of triple-negative breast cancer. As a result, these genes may serve as new therapeutic targets and markers of treatment effectiveness in triple-negative breast cancer patients.

Research involving animal experiments verified that stem cell binding genes can be used to treat amyotrophic lateral sclerosis.

Research verified that Cav3.2 and Nav1.6 can be used as target genes for chronic pain caused by nerve damage.

A long-term tracking cohort study investigated the infection process of the hepatitis B virus, and discovered that variations in individuals' immune antigen gene sequence are closely correlated with viral quantity and risk of liver cancer.

When vitamin intake is sufficient, specific vitamins (especially vitamin A) confer protection against asthma and allergies. In addition, many predictive factors are correlated with asthma control and asthma sufferers' quality of life. Because of this, avoiding or minimizing exposure to risk factors can achieve effective control of asthma and raise quality of life among individuals with asthma.

Research found that while injection of glutamine into the abdominal cavity before or after enteritis can both reduce inflammation in the intestinal tract, the preventive use of glutamine prior to enteritis can regulate immune cells and achieve even better control of inflammation, while also reducing tissue damage and promoting repair of the intestinal tract mucus membrane.

Numbers of life science specific-topic research projects and funding, 2014

Units: NT\$1 m

| Category                   | Applications |           | Approved |          | Implemented |          |
|----------------------------|--------------|-----------|----------|----------|-------------|----------|
|                            | Projects     | Funding   | Projects | Funding  | Projects    | Funding  |
| Medicine                   | 3,913        | 8,464.02  | 1,706    | 1,975.16 | 2,981       | 3,601.51 |
| Biology                    | 463          | 1,206.25  | 212      | 347.42   | 362         | 571.90   |
| Agricultural science       | 729          | 1,471.88  | 322      | 411.35   | 578         | 754.37   |
| Special projects and other | 418          | 1,209.16  | 304      | 633.39   | 310         | 644.48   |
| Sustainable development    | 1            | 1.40      | 0        | 0.00     | 0           | 0.00     |
| Environmental protection   | 227          | 1,274.02  | 167      | 639.99   | 167         | 639.99   |
| Total                      | 5,751        | 13,626.73 | 2,711    | 4,007.31 | 4,398       | 6,212.25 |

Research manpower in life science specific-topic research project, 2010-2014

Units: person-times

| Item                |                      | 2010   | 2011   | 2012   | 2013   | 2014 <sup>1</sup> |
|---------------------|----------------------|--------|--------|--------|--------|-------------------|
| Research personnel  | Professors           | 2,798  | 2,896  | 2,830  | 2,824  | 2,976             |
|                     | Associate professors | 1,560  | 1,591  | 1,578  | 1,630  | 1,629             |
|                     | Assistant professors | 1,770  | 1,751  | 1,558  | 1,385  | 1,438             |
|                     | Lecturers            | 132    | 114    | 68     | 55     | 60                |
|                     | Other                | 2,666  | 2,879  | 2,795  | 2,924  | 3,075             |
| Subtotal            |                      | 8,926  | 9,231  | 8,829  | 8,818  | 9,178             |
| Research assistants | Full-time assistants | 2,812  | 2,536  | 2,625  | 2,687  | 2,938             |
|                     | Part-time assistants | 58     | 42     | 22     | 25     | 23                |
|                     | Graduate students    | 6,380  | 6,100  | 5,559  | 5,321  | 5,396             |
| Subtotal            |                      | 9,250  | 8,678  | 8,206  | 8,033  | 8,357             |
| Total               |                      | 18,176 | 17,909 | 17,035 | 16,851 | 17,535            |

<sup>1</sup> 2014 data is as of January 19, 2014.

Numbers and percentage of one-year and multi-year life science specific-topic research projects, 2010-2014

| Year | All projects | One-year projects (%) | Multi-year Projects (%) |
|------|--------------|-----------------------|-------------------------|
| 2010 | 4,589        | 640 (13.95)           | 3,949 (86.05)           |
| 2011 | 4,538        | 1,255 (27.66)         | 3,283 (72.34)           |
| 2012 | 4,412        | 1,297 (29.40)         | 3,115 (70.60)           |
| 2013 | 4,274        | 1,289 (30.16)         | 2,985 (69.84)           |
| 2014 | 4,398        | 1,217 (27.67)         | 3,181 (72.33)           |

#### 4. Humanities and Social Sciences

The humanities and social sciences encompass 17 disciplines in the three major areas of the humanities (literature, history, philosophy), the social sciences (law, political science, sociology, education, and psychology), and management. The following is an overview of major research efforts, implementation plans, and database projects during 2014:

##### (1) Major research efforts

###### a. Integrated Research Project on Health Information

This project consists of eight subprojects, which include: (a) A subproject developed biomedical literature mining technology based on supervised learning; this technology can uncover hidden, unknown, and meaningful links between biomedical concepts (such as relationships between drugs and diseases) from large quantities of biomedical

literature. (b) A subproject proposed an incremental classification algorithm able to design solution modules based on object addition and attribute addition perspectives; the researchers hope this algorithm can find decision rules meeting decision-makers' expectations, and can be applied to dynamic databases that have frequent updates and changes. (c) It was found that health social media data can be mined using flexible methods when patient profile, medical terminology, mood, and strength are taken into consideration. This subproject helped doctors, patients, and healthcare providers improve therapeutic quality, communication, and collaboration. (d) Researchers relied on analysis of big data to establish correct connections between diagnoses, medication use, and medical procedures, and thereby enhance the efficiency of the treatment system and medical

management; this subproject established a dynamic model of personal health, and developed a dynamic data-oriented health status model able to provide individualized forecasts of major health events. (e) After assessing the economic implications of medical information asymmetries and medical social media, researchers took patients' personal information into consideration, and designed an effective medical resource allocation mechanism for a situation in which patients can share information via a social network. This mechanism also allows service providers to transmit quality signals to patients in an environment where both parties have access to each other's personal information. (f) An effort to resolve the problem of over-specialization of recommendations when making content-based recommendations analyzed citation information in user preference files, and attempted to find possible topical information in user preferences files that could be used to assess recommendation articles. (g) Researchers proposed a novel social media analysis tool that can help consumers obtain health information, analyze their individual healthcare needs, and assist in making health decisions. This subproject included systematic implementation, collection of real data, and empirical assessment of the effectiveness of technology. (h) Different research methods were used to find key human resources-related factors affecting efficiency, which enabled assessment of the efficiency of various activities at hospitals, and provided managers with a full-scale hospital human resources management policy planning tool.

b. Technological risk, assessment of environmental impact, and the democratization of science

The disposal of low-level radioactive waste, the dispute concerning the construction of a dry waste storage facility for nuclear fuel at the Nuclear Power Plant No. 1, and plans for the future decommissioning of nuclear power plants all involve scientific uncertainty and disputes concerning scientific knowledge, and underscore the complexity of nuclear energy's back-end problems. How to expand social participation in scientific decisions and make systemic reforms increasing the democratization of science are important issues. This research project adopted analysis of the literature, in-depth interviews, and focus group methods to conduct dialogue with concerned parties and local residents. The project sought to promote positive interaction between various policy implementers, reflect on the different parties' existing assumptions and scientific blind spots,

assess the shortcomings of existing institutional systems, review system reform strategies, and facilitate policy learning and the development of democratization of science.

c. "Sociology of disaster: From Chinese society to a global perspective" book project

This project examines social fragility in the wake of a disaster and developed a relevant account of political institutions. Recent research on disasters has discovered that social factors such as social stratification and gender are the chief factors causing differences in distribution of natural disaster risk. Nevertheless, the social mechanisms causing uneven distribution of risk remain unclear. Furthermore, the project discovered through international comparisons that political institutions, especially political power and national capabilities, exert a huge effect on organizational efficiency and fairness of resource allocation during the disaster rescue, resettlement, and reconstruction stages. The project collected as much data as possible and established a database analyzing Chinese society and global disasters. The information in this database can provide a basis for research on disasters in Taiwan and international comparisons.

d. Effect of teachers' critical comments on students and their peers in a Confucian cultural context

While Western societies assert that achieving goals depends on talent and ability, empirical research results show that feedback praising students' ability has many negative effects. On the other hand, it is commonly believed in Confucian societies that, compared depending on one's ability, working hard to overcome the limitations of one's ability and thereby achieve one's goals is extremely commendable. Because of this, adults' critical comments toward children may differ from those in the West, and these comments may have a different impact on children, which is a topic that still remains to be studied. This research attempted to construct a provisional theoretical framework explaining the differences between teachers' critical comments in Confucian cultures and in the West, and the effect of these comments on the concerned students and the students' peers. This project sought to highlight the effect of Confucian culture on education, and, on a practical level, provide teachers with a theoretical basis for their critical comments.

e. The moral careers of the physically and mentally disabled

This project tracked the psychological

experience of patients with mental illnesses and invalids with physical disabilities in Taiwan's social environment, and proposed a correlation between rehabilitation and growth model and development of moral career among persons with physical and mental disabilities. This project established a mutual understanding process for body mind interaction, and then constructed a theoretical model of psychological reconstruction featuring contextual harmony and developed a clinical implementation plan.

## (2) Active promotion of planning projects

### a. Humane innovation and social practice

Starting on July 1, 2013, MOST has provided funding to National Chengchi University, National Chi-Nan University, National Cheng Kung University, and National Dong Hua University for implementation of three-year school-wide projects exploring the various regional social problems currently faced by universities from an angle of humane innovation and social practice. These projects underscore the contributions that the humanities and social sciences may make to the cause of social reform in such areas as supporting local practice, provision of relief to the poor and underprivileged, highlighting Taiwan's regional features, creation of a high-quality living environment. MOST completed review of the various schools' implementation results and performed assessment of the first-year projects during May and June of 2014.

### b. Multi-Ethnic Studies and Indigenous Community and Social Development Research

In a multi-ethnic society that possesses diverse cultural features, the society as a whole must strive to instill mutual respect and appreciation among ethnic or cultural groups. This program encourages scholars to formulate research projects from different humanities and social science perspectives, probe the origins of Taiwan's multi-ethnic outlook, and examine the current state of social practice and contemporary/future developmental issues, with the goal of establishing respect for multi-ethnic culture and a healthy social environment. The integrated program "Multi-Ethnic Studies and Indigenous Community and Social Development Research" included research on indigenous groups, Hakka, and other social groups. After soliciting project proposals, this program established nine multi-ethnic cultural research topics and ten indigenous community and social development topics. The program as a whole seeks to explore the origins

of Taiwan's multi-ethnic outlook, and examine the current state of social practice and contemporary/future developmental issues, with the purpose of establishing respect for multi-ethnic society and a sound social environment, and foster the multi-ethnic development of Taiwan's society.

### c. Brain and mind science core facilities and joint use service project

To ensure that domestic research on the humanities and social sciences keeps up with international trends, provide instruments and equipment needed for this research, and boost the standards of research in the humanities and social sciences, this project is acquiring brain magnetic resonance imaging (MRI) and magnetoencephalography (MEG) equipment for use by researchers. The National Yang Ming University/National Chengchi University team has provided a cumulative total of 3,362 hours of service to instrument facilities, and these service hours accounted for 85.9% of the facilities' open time. The amount of service is increasing every year, and instrument services totaled 1,844 hours in 2014. These teams have issued 11 journal papers and 32 conference papers thus far.

The National Cheng Kung University team's instruments went online in October 2014, and the team has provided a total of 1,464 hours of service, which accounted for 96% of the instrument center's time open. The team has published two journal papers and ten conference papers.

The National Taiwan University team began testing after completing MRI and MEG installation. The MRI unit was opened for trial use in October 2014, and has logged a total of 196 service hours thus far.

Apart from providing instrument services, the three teams have provided consulting services and also held various workshops and instrument safety lectures. Workshops and activities have included talks on neuronal aging, a symposium on clinical neuroscience, a touring workshop on cognitive neuroscience, a workshop on neuroscience and the humanities & social sciences, a functional MRI workshop, a functional MRI imaging data analysis workshop, research experience sharing forums, advanced MEG training, and cognitive neuroscience training.

### d. Projects for brain imaging research in mind science

This project seeks to sow the seeds of brain research in the humanities and social sciences. Because of this, it hopes to establish broad

research topics that will induce those scholars of the humanities and social sciences entering this area to enter a field of brain research connected with their own original issues of concern. Research fields receiving funding under this project include psychology, language, philosophy, education, special education, economics, management, art (music), religion (Buddhism), physical education, neurology and psychology, and electronic/computer engineering. Research topics encompass all levels of brain activity, and include cognition, perception, personality, social interaction, mood, motivation, and individual differences. In contrast to the broader promotion that characterized the first stage of this project, the second stage is focusing on the establishment of distinctive domestic cognitive brain imaging research directions, and has therefore announced the research topic of "Investigation of Mental Activity in Connection with Various Sociocultural Contexts and Personal Traits and Relationship with Brain Function" in hope that projects on this topic will make effective use of currently-available instruments and equipment. The project is seeks to promote interdisciplinary research, and looks forward the rise of a multi-directional dialogue between the humanities & social sciences and such fields as basic science, biomedical science, and engineering. This project's ultimate goal is to effectively incorporate humane concern and human needs in research and development, and thereby make a real contribution to society.

e. Digital humanities

In order to promote fusion of digital technology and humanities research, and encourage diversified cultural creativity research and development efforts, MOST issued a call for "Research Projects in the Digital Humanities" in 2012, and 48 projects were selected after review of the 150 applications. A second call for proposals went out in August 2013, and 36 projects were chosen out of 144 applications. The topics of the chosen projects included "Forging New Tools: New Directions in Humanities Research Supported by Digital Technology," "Exploring New Phenomena: Reflecting on Digital Technologies Embedded in the Context of Life from the Perspective of the Humanities and Social Sciences," and "Building New Cultures: Use of Design Science to Create Digital Worlds." A third stage of this project will get underway on August 1, 2015.

f. Taiwan's Election and Democratization Study

A total of 157 domestic and foreign applications

to use data from Taiwan's Election and Democratization Study (TEDS) study have been made thus far. As of the end of December 2014, TEDS data had been cited an impressive 837 times in academic papers, which shows that the TEDS database is widely used and much highly regarded by domestic and foreign researchers. The TEDS database was included among the databases of the Inter-university Consortium for Political and Social Research (ICPSR) by the University of Michigan in early 2014 (ICPSR 35094 <http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/35094>). Furthermore, the Taiwan's Election and Democratization Survey Symposium was held March 22-23 in 2014 after publicly soliciting papers, and was entitled "The Many Aspects of Citizen Participation: Analysis of TEDS2013 Survey Data." Twenty-one papers in Chinese and English were issued at this event, which also announced the initial results of this project. In accordance with past experience, it is expected that many more journal articles and books will be published following review, and will significantly enhance Taiwan's academic visibility and influence.

g. Promotion of a research ethical review system

Four public hearings on the research ethical review system were held during 2014, including a hearing held on March 28 at National Cheng Kung University in southern Taiwan, a hearing held on April 14 at National Taiwan University in northern Taiwan, a hearing held on October 8 at National Chungshing University in central Taiwan, and a hearing held on November 3 at National Taitung University in eastern Taiwan. Furthermore, in order to review the human research ethical review system, MOST called together experts and specialists in various fields at two sessions of a research ethics consulting committee conference; apart from reports on the state of implementation by relevant personnel, these conferences also included reports by academic association representatives concerning observations of the research ethical review system over the past few years, which provided MOST with a reference for institutional reform measures.

(3) Establishment, maintenance and management of databases

a. Social change survey database

The fifth survey of the 6<sup>th</sup> stage of the Social Change Survey has been completed, and there is now cumulative data from 54 surveys. This survey is not only the chief source of data for social

research, but is also the survey with the largest sample of any social survey in the world. All survey data is released one year after it is collected and organized. Most domestic users querying and downloading Social Change Survey data use it for academic survey research, and there has been a steady increase in users citing information from the survey in their journal or conference papers.

b. Communications survey database

This communications survey database project, which got underway in 2012, seeks to establish a communications database platform employing survey data and focusing on the areas of media topic qualifications, Internet and new media behavior, and entertainment and social communications. This platform encourages the release of survey data, and provides academic and industry-related information, basic data for communications researchers and professors, and written works and articles for communications scholars. As a result, this platform has become an important means of interaction and interchange in the communications community. Looking ahead to the next two years, survey efforts will focus on political and citizens' communications, and risk and crisis communications. In terms of methodology, the 5<sup>th</sup> survey will track the respondents of the 3<sup>rd</sup> survey, which will provide an understanding of possible influences on media usage and remedy

the problem of inferring cause and effect in past cross-sectional studies.

c. Taiwan Database for Empirical Legal Studies

The Taiwan Database for Empirical Legal Studies website has been visited 64,312 person times, and saw a significant growth in 2014. It is evident that this database is gradually finding increasing usage among researchers in various fields.

d. Academic Survey Research Database

This project collected data, established a database, and drafted error-checking and data procedures. The database is available via a Chinese-English website (<http://srda.sinica.edu.tw>), and contains 50 quarterly volumes of the Academic Survey Research Database bulletin and 251 volumes of a biweekly e-bulletin. The database contains 1,599 items of academic survey data, and 1,259 of these have been released for use; the 1,116 data items consisting of research projects funded by MOST account for 88% of the database's content. The Academic Survey Research Database has a membership system, and there is a browsing questionnaire on the website. If it is necessary to further analyze any reports, etc., they materials can be downloaded for use. As of September 30, 2014, a total of 8,959 persons had registered to use the website, and users had downloaded data files on 5,998 occasions.

Numbers of humanities and social science specific-topic research projects and funding, 2014

Units: NT\$1 m

| Category   | Applications |                 | Approved     |                 | Implemented  |                 |
|--|--------------|-----------------|--------------|-----------------|--------------|-----------------|
|  | Projects     | Funding         | Projects     | Funding         | Projects     | Funding         |
| Literature/history/philosophy <sup>1</sup>                                     | 1,653        | 956.43          | 762          | 426.19          | 1,012        | 570.38          |
| Law/political science/sociology/education/psychology <sup>2</sup>              | 1,842        | 1,476.50        | 801          | 468.44          | 1,212        | 763.86          |
| Management/economics <sup>3</sup>  | 2,827        | 1,833.11        | 1,335        | 711.78          | 1,707        | 991.51          |
| Mass communication, regional studies & geography, gender studies, and religion | 848          | 591.00          | 351          | 196.69          | 439          | 269.46          |
| Art, physical education, library science                                       | 748          | 545.81          | 312          | 185.30          | 381          | 233.07          |
| Digital humanities   | 144          | 157.21          | 36           | 24.48           | 69           | 50.32           |
| Taiwan's development in a global context                                       | 54           | 89.49           | 15           | 8.35            | 90           | 54.01           |
| Indigenous communities and social development                                  | 76           | 68.57           | 27           | 20.31           | 27           | 20.31           |
| Taiwan Economic Empirical Survey Database and Data Analysis                    | 12           | 11.00           | 4            | 1.56            | 4            | 1.56            |
| Other  | 24           | 17.24           | 5            | 6.74            | 7            | 8.63            |
| <b>Total</b>   | <b>8,228</b> | <b>5,746.36</b> | <b>3,648</b> | <b>2,049.84</b> | <b>4,948</b> | <b>2,963.11</b> |

<sup>1</sup> Includes literature of China and Taiwan, Hakka literature, indigenous literature, foreign language literature, history, and anthropology.

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

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

## Research manpower in humanities and social science specific-topic research project, 2010-2014

Units: person-times

| Item                |                      | 2010   | 2011   | 2012   | 2013   | 2014 <sup>1</sup> |
|---------------------|----------------------|--------|--------|--------|--------|-------------------|
| Research personnel  | Professors           | 1,823  | 1,827  | 1,912  | 2,027  | 2,082             |
|                     | Associate professors | 1,807  | 1,815  | 1,885  | 1,912  | 1,884             |
|                     | Assistant professors | 2,288  | 2,249  | 2,142  | 1,929  | 1,734             |
|                     | Lecturers            | 71     | 63     | 43     | 34     | 22                |
|                     | Other                | 436    | 444    | 435    | 447    | 431               |
| Subtotal            |                      | 6,425  | 6,398  | 6,417  | 6,349  | 6,153             |
| Research assistants | Full-time assistants | 811    | 614    | 538    | 625    | 650               |
|                     | Part-time assistants | 309    | 162    | 108    | 136    | 108               |
|                     | Graduate students    | 9,913  | 9,877  | 10,452 | 10,383 | 9,926             |
| Subtotal            |                      | 11,033 | 10,653 | 11,098 | 11,144 | 10,684            |
| Total               |                      | 17,458 | 17,051 | 17,515 | 17,493 | 16,837            |

<sup>1</sup> 2014 data is as of January 19, 2014

## Numbers and percentage of one-year and multi-year humanities and social science specific-topic research projects, 2010-2014

| Year | Total projects | One-year projects (%) | Multi-year projects (%) |
|------|----------------|-----------------------|-------------------------|
| 2010 | 3,898          | 2,995 (76.83)         | 903 (23.17)             |
| 2011 | 5,066          | 2,815 (55.57)         | 2,251 (44.43)           |
| 2012 | 5,147          | 2,848 (55.33)         | 2,299 (44.67)           |
| 2013 | 5,120          | 2,778 (54.26)         | 2,342 (45.74)           |
| 2014 | 4,948          | 2,655 (53.66)         | 2,293 (46.34)           |

## 5. Science Education

Science education research seeks to improve the academic standards of science education, enhance the quality of science education, and increase the efficiency of instruction. Science education research should seek to resolve problems in science education, respond to social changes and global environmental trends, and should actively realize research results in the form of practical applications. The following were among some of the most significant research results of 2014:

- (1) Professional development of mathematics teachers and teacher educators: Construction of an integrative theory and practical applications

The focus of international mathematics

education research has shifted from students to teachers, and further to teacher educators, with the times at which these parties receive the education staggered at intervals of 20 years. Today's research emphasizes that students, teachers, and teacher educators are all learners, and asserts that effective learning originates from active participation and active thinking. A research project examined a professional growth workshop in which teacher educators helped in-service teachers to develop teaching plans, and the research results included:

- a. Established a theoretical framework and standards for teacher education. In this framework, three levels of learners share three channels, which consist of reasoning, linkage, and communication. This finding suggests that as teacher educators

provide assistance, they also coordinate the incorporation of their research and practical experience in teachers' (students') interactive learning behavior. Employing this framework, the project employed dual methods consisting of case studies and self-investigation to deepen understanding of the skills and knowledge demonstrated by the teacher educators in their practice and their real-time interaction with teachers. The project revealed that the characteristics of effective teacher education include the following: The teacher educators achieved linkage between research and practice through active reflection and blending of multiple roles when creating educational phenomena and actions and communicating with teachers.

- b. Investigation of the teacher education knowledge of the teacher educators achieved the following insights concerning a matter of contemporary international concern: Analysis of seven teacher educators' two-dimensional framework consisting of their "theoretical knowledge type" and "assistance approach" when providing assistance to teachers tracked each teacher educator's assistance pathways as he or she assisted the same teacher during six sessions over the course of a semester, and discussed issues concerning the teacher educators' education knowledge. It was found that the key to the design of effective teacher education intervention is initially helping teachers maintain their role and effectiveness with regard to the "theory of mathematics instruction" during their teaching growth. At a teacher educator workshop held by this project, 45 teacher educators discussed their theoretical role.
- c. Research on teacher educators' professional growth included completion of "Case Studies of Professional Growth among Beginner Teacher Educators," which employed a dual-layer overlapping socially constructed activity framework to describe the evolution of the teacher educators' assistance tool designs as they provided assistance at two schools during two periods, and used the resulting findings to guide the teacher educators' professional growth.

## (2) Effect of science information reading comprehension on the thinking and decision-making process

A research project examined the textual comprehension and mental models of university and high school students after reading scientific and mathematical information, and analyzed the linkage between reading performance and thinking and

decision-making behavior regarding relevant scientific issues. This project consisted of the three subprojects on the following topics:

- a. Use of eye-tracking technology to investigate the logical thinking process of high school and university students in Taiwan.
- b. Use of eye-tracking analysis to investigate reading comprehension and the process of scientific thinking with regard to scientific information in different textual formats.
- c. Use of eye-tracking analysis to research the students' online search strategies and decision-making process when investigating science-related disputes and questions. The project's most important findings included the following: a. The logical thinking performance of the high school and university student subjects was not as good as expected. b. Academic specialty influences the eye-movement model of students when reading science information. c. Male and female students employed different information-processing models. d. Scientific thinking performance is correlated with attention when reading elements of scientific argumentation. e. Students' visual fixation on data effectively reflected their screening of online information and decision-making process. f. Knowledge cognition and belief play important roles in textual reading and screening of online information.

## (3) Promotion of a digital learning classroom fostering subject performance, key skills for the new century, and affective aspects: Example of mathematics

This project developed the "Math Island" game-based digital mathematics classroom platform, which uses games to promote autonomous math learning. By encouraging the incorporation of individuals' own concepts, the software platform allows students to arrange their own learning progress based on their learning ability. Every time a student completes a learning task, Math Island will construct the corresponding building, and the appearance of the buildings reflect the students' learning performance, which encourages the students to put effort into learning.

This approach enables the potential of students with higher learning capacity to be realized without restriction, and ensures that the students can learn at a steady pace. The platform thus gives teachers more time to help students with poor learning capacity to lay strong foundations. A trial of the platform involving 228 second-grade elementary school students found that

not only did all the students complete the prescribed course progress, 53% of the students exceeded the standard progress, and 13% exceeded the standard progress by at least one semester. Even the slower students achieved a first-time correct answer rate of close to 70%, and attained a correct rate of 90% after self revision. The project also developed a small game able to teach the four fundamental operations of arithmetic; this game allowed students to strengthen their arithmetic skills while playing the fun game.

The project's findings revealed that, apart from the fact that practicing basic arithmetic operations in the course of the game strengthened the students' arithmetic ability, the accomplishment of tasks in the game increased the students' confidence in their arithmetic skills. Even more importantly, practice via this approach achieved an especially significant improvement in the case of students with low mathematics achievement.

#### (4) Innovative cloud-based English instruction and assessment

This project developed a cloud-based English teaching platform (the eCard platform) taking advantage of the convenience and multimedia interaction capabilities of mobile devices to assist English instruction. Cloud technology was employed to share teaching resources, and multimedia interactive functions not only enable teachers to realize innovative "one to one device" instruction, but also increase students' in-class practice and after-school review opportunities. Even more importantly, the platform facilitates routine practice of listening, speaking, and reading skills, which are crucially important in English learning, but difficult to effectively practice. This project achieved (a) development of the eCard platform, (b) development of source teaching materials, (c) and development of cloud verbal English assessment technology.

The eCard platform includes a cloud server, user-end iOS, and Android apps. Source materials include a variety of eCards, including first and third-year junior high school vocabulary cards, Chinese-English sample sentence cards, pronunciation practice cards, and grammar sentence pattern cards, as well as 100 reading texts of varying difficulty and accompanying quizzes. With regard to verbal English evaluation technology, the platform can automatically assess the quality of students' spoken English. A preliminary teaching experiment indicated that the implementation of an innovative "one to one device" mobile learning plan enabled a significant improvement in students' spoken English self-efficacy,

and students spoke English with greater ease and self-confidence. It was further discovered that the platform helped students with relatively low English ability to an even greater degree than students with high English ability.

Experiments also revealed that students exhibited a significant increase in learning motivation after they started using the eCard app in conjunction with a mobile device. The experimental data further indicated that students went from being too shy to speak out at the beginning to looking forward to the eCard instructional activities, and the participating teachers verified that the students became braver in speaking out in other classroom activities. The platform is being used in teaching experiments at seven junior high schools during the current academic year.

#### (5) Design of interactive digital teaching materials and application in teaching

This project investigated how interactive technologies can be applied in the design of cloud-based digital teaching materials, and can stimulate interaction and discussion in the classroom. The project successfully developed cloud learning resources that can be used outside the classroom, as well as a seamless mechanism for interactive discussion in the classroom.

Employing a contextual learning mechanism, the project incorporated interactive elements in the design of cloud-based digital teaching materials. By making the teaching materials vital and appealing, the researchers enhance students' willingness to actively engage in online learning. The multicontextual teaching materials chiefly employed a high-resolution MP4 format, and the cloud-based digital teaching materials were designed so that students could readily access them from mobile devices.

In the multicontextual design model, the first stage provided multiple retrievable signal input mechanisms, and software technology ensured that the teaching material designers could easily express a multicontextual instructional format similar to that within a real classroom. An open-source image library was used to convert the multicontextual content into raw graphic format. The second stage included use of the prevailing signal conversion technology to change the RGB data into the high-resolution MP4 format. This process of repeated data format conversion and integration was extremely challenging.

This project had two major innovative aspects, which included classroom activities that can be

guided by the teacher and use of multiple activities situations. Taking a case discussion as an example, the teacher can design a number of screens, including case briefings, the teacher's and students' video, and guided classroom teaching activities, and the setting of a discussion can appear in front of the students. As a result, students and teachers can enjoy even more seamless interaction, and students can benefit from a peer learning effect.

#### (6) Cloud Flying Squirrel Village Science Game Picture Book

A project completed the "Cloud Flying Squirrel Village Science Game Picture Book," which provides schoolchildren with multicultural cloud science learning situations crossing time and space. The project's method consisted of using material from the "Indigenous Science Animation 3D Element Digital Collection Database" to create a "World-view Oriented Learning Framework" (WOLF).

The resulting learning process framework contains four major units, namely picture book reading, science animation, science games, and culture and science knowledge tests. The story framework is taken from six episodes of the "Flying Squirrel Village Indigenous 3D Science Animation" TV series, which won the Golden Bell Award. The Cloud

Flying Squirrel Village Science Game Picture Book is currently one of very few electronic picture books in Taiwan that accommodates the outlook and learning needs of indigenous schoolchildren.

This resource not only provides kids with an electronic picture book experience, but also enables indigenous children to call up their cultural background on a touch-control screen, and provides a new way of learning science through hands-on manipulation. During the R&D process, the researchers invited indigenous and non-indigenous individuals from different age groups to participate in trial use, particularly in places where the Flying Squirrel Village Indigenous 3D Science Animation" TV show was being publicly shown.

Trial use by viewers indicated that this interactive electronic picture book could be read by audiences after they had watched videos of the show, and would strengthen learning of cultural and scientific knowledge. Individual users' responses displayed that the picture book reading and science animation units appeals to users of all ages, and elementary-school-age users particularly enjoy the educational science games, which they can use without any extra instruction.

Numbers of science education specific-topic research projects and funding, 2014

Funding units: NT\$1 m

| Category  | Applications |                 | Approved   |               | Implemented |                 |
|---|--------------|-----------------|------------|---------------|-------------|-----------------|
|   | Projects     | Funding         | Projects   | Funding       | Projects    | Funding         |
| Science education   | 128          | 205.77          | 68         | 51.32         | 111         | 116.98          |
| Mathematics education   | 88           | 92.43           | 57         | 34.24         | 78          | 59.03           |
| Information education   | 219          | 324.86          | 112        | 89.65         | 191         | 193.08          |
| Applied science education   | 184          | 159.48          | 73         | 50.33         | 94          | 69.33           |
| Medical education   | 136          | 170.09          | 69         | 50.13         | 96          | 75.19           |
| Imagination research, practicum projects in science education   | 58           | 89.69           | 19         | 11.82         | 43          | 36.72           |
| Gender and science research   | 39           | 45.77           | 21         | 15.15         | 26          | 19.13           |
| Diversity science education   | 28           | 35.70           | 13         | 9.68          | 22          | 18.65           |
| Indigenous science education projects   | 4            | 49.58           | 0          | 0.00          | 21          | 24.43           |
| Popular science activities, popular science communication enterprise development projects, popular science communications industry-academic projects, citizens' science qualifications communications and education, public science education | 363          | 660.23          | 151        | 202.04        | 174         | 233.08          |
| Mission-oriented projects, cutting-edge international research centers, S&T risk communication projects   | 66           | 470.18          | 39         | 257.49        | 39          | 257.49          |
| Other   | 5            | 37.22           | 2          | 2.38          | 10          | 19.11           |
| <b>Total</b>  | <b>1,318</b> | <b>2,341.00</b> | <b>624</b> | <b>774.23</b> | <b>905</b>  | <b>1,122.22</b> |

Research manpower in science education specific-topic research project, 2010-2014

Units: person-times

| Item                |                      | 2010  | 2011  | 2012  | 2013  | 2014 <sup>1</sup> |
|---------------------|----------------------|-------|-------|-------|-------|-------------------|
| Research personnel  | Professors           | 810   | 758   | 779   | 771   | 786               |
|                     | Associate professors | 691   | 575   | 575   | 568   | 582               |
|                     | Assistant professors | 530   | 508   | 494   | 451   | 466               |
|                     | Lecturers            | 78    | 54    | 39    |       | 21                |
|                     | Other                | 156   | 151   | 162   | 151   | 172               |
| Subtotal            |                      | 2,265 | 2,046 | 2,049 | 1,941 | 2,027             |
| Research assistants | Full-time assistants | 314   | 352   | 416   | 378   | 414               |
|                     | Part-time assistants | 295   | 261   | 249   | 236   | 312               |
|                     | Graduate students    | 2,679 | 2,447 | 2,509 | 2,211 | 2,282             |
| Subtotal            |                      | 3,288 | 3,060 | 3,174 | 2,825 | 3,008             |
| Total               |                      | 5,553 | 5,106 | 5,223 | 4,766 | 5,035             |

<sup>1</sup> 2014 data is as of January 19, 2014.

Numbers and percentage of one-year and multi-year science education specific-topic research projects, 2010-2014

| Year | Total projects | One-year projects (%) | Multi-year projects (%) |
|------|----------------|-----------------------|-------------------------|
| 2010 | 1,033          | 413 (39.98)           | 620 (60.02)             |
| 2011 | 888            | 351 (39.53)           | 537 (60.47)             |
| 2012 | 896            | 346 (38.62)           | 550 (61.38)             |
| 2013 | 850            | 378 (44.47)           | 472 (55.53)             |
| 2014 | 905            | 377 (41.66)           | 528 (58.34)             |

## B. National Science and Technology Programs

### 1. Intelligent Electronics

In line with Executive Yuan policy, this program, which will extend from 2011 to 2015, seeks to promote electronics and semiconductor technologies in the "MG+4C" fields (medicine: medical electronics; green: green energy electronics; 3C: computers, communications, and consumer electronics; and cars: auto electronics). The program's goal is to "create integrated electronic technologies and applications promoting industrial upgrading," and it seeks to bring together S&T development capabilities at different agencies for the purpose of jointly promoting interdisciplinary technological integration and pursuing an ultimate vision of improving life and the environment.

The program's seven major subprojects consist of a medical electronics subprogram, which emphasized the development of common platform technologies for cost effective high-end medical instruments and medical electronics; a green energy electronics subprogram developing autonomous photovoltaic clean energy and key vehicle-grade chip technologies; a 4C electronics subprogram developing lightweight, miniaturized, high-performance electronics with highly intended functions, including 3D IC chip and ultra-low power/ultra-low voltage circuit design technologies; a forward-looking research subprogram guiding academic researchers in the development of essential, innovative, and integrative technologies for forward-looking intelligent electronic systems, establishing a design environment for intelligent electronics, and using bridging projects to promote

the derivative benefits of industrialization of academic R&D results; a manpower training subprogram seeking to establish heterogeneous integrated teaching platforms, train outstanding interdisciplinary electronics manpower, and encourage individuals to participate in international competitions in order to enhance the international visibility of Taiwan's technological human resources; an industrial promotion subprogram creating a superior industrial development environment, encouraging development of forward-looking products, and researching and developing novel incubation and industry service models, with the goal of supporting Taiwan's emerging intelligent electronics industry; an MG+4C vertical integration promotion subprogram seeking to rely on semiconductor industry clusters based in Taiwan's science parks, as well as the industry's ecology and division of labor, to promote vertical integration and horizontal alliances, encourage innovation and value-added applications of intelligent chip technology, and thereby boost the global competitiveness of Taiwan's electronics industry.

Agencies participating in this project include the MOEA, MOST, and MOE. During 2014, the Legislative Yuan approved funding of approximately NT\$1.7 billion. Thanks to the efforts of the participating agencies and implementing units, technology licensing income and the value of technical service contracts reached NT\$194.6 million during the year, and the project induced NT\$1.36 billion in corporate R&D investment. As of the end of 2014, the project had generated a total of NT\$607 million in technology licensing fees and technical service contracts, induced R&D investment of NT\$10.9 billion, encouraged the formation of five startups in MG+4C fields, and induced the establishment of six new business departments. The following is a summary of major results in each subprogram:

#### (1) Medical electronics subprogram

In the area of optical coherent tomography (OCT) technology, researchers developed a small OCT system for oral/dental applications, along with a disposable/cleanable miniaturized probe design able to avoid cross-contamination. Taiwan's first domestically-developed ophthalmological OCT system was used in a human clinical trial approved by an institutional review board. Furthermore, the core ultrasound technology developed in this project was licensed to a major domestic systems firm for use in handheld wireless ultrasound systems. This is the world's first ultrasound imaging system using a flat panel/touch-control/wireless control technology;

if it can be effectively developed, this technology will facilitate the development of a high-end medical instrument industry in Taiwan.

#### (2) Green energy electronics

In the field of photovoltaic (PV) technology, researchers have developed a 300 W PV micro inverter with an efficiency of over 96% and a power density of 0.25 W/cm<sup>3</sup>. This device also overcomes PV control chip reliability and conversion performance issues. In the area of auto electronics, following the successful development of Taiwan's first 600V/20A silicon carbide Schottky diode, joint support from the MOEA's Department of Industrial Technology, ITRI, and domestic firms enabled a semiconductor manufacturer to successfully upgrade to the new products and establish a high-power element design startup.

By bringing about the establishment of an unbroken power electronics industry chain in Taiwan, this project will give Taiwanese firms an opportunity to achieve the highest international standards in wide band gap power element materials, design, and processing. The company in question participated in the Taipei AutoTronics 2014 for the first time, and was awarded the gold medal for innovative products on the basis of its high-power 650 V 120 A silicon carbide Schottky diode. In addition, Taiwan's first auto-grade motor control chip passed AEC-Q100 reliability testing, and received ISO 26262 ASIL (Automotive Safety Integrity Level) D from Germany's SGS (Societe Generale de Surveillance) and TUV (TUV Rheinland); this chip has passed electric vehicle testing, and has been used in road vehicles. An insulated gate bipolar transistor (IGBT) power system module has been used to replace the gate turn-off thyristor (GTO) originally used on Taipei Metro trains.

#### (3) 4C electronics

This subprogram developed an innovative 3D IC heat transmission testing chip and measurement technology; this is currently the world's sole heat transmission testing chip that is stackable, has active hot spot simulation, and support array design. In the area of through silicon via (TSV) technology, researchers completed universal memory capacity platform 3D memory verification on a 3D IC universal memory platform testing chip. Use of this testing chip can reduce product costs and increase design flexibility, and the chip was verified using the world's most advanced technology. In addition, this subproject helped a major international firm develop a new-generation memory framework and license the

technology to Company A for a signing fee of NT\$7.2 million. The international firm also helped perform technology assessment for a planned 12" wafer plant, and assisted Company A in winning approval for a US\$44.8 million investment in plant construction and a sensor packaging production line.

#### (4) Forward-looking research

This subprogram involved 51 teams pursuing forward-looking academic research in MG+4C circuit and system chip design and development. In 2014, these teams published 156 papers in major international journals and 411 papers in other domestic and foreign journals and at conferences. The National Chip Implementation Center provided advanced chip process services to domestic academic researchers, assisting in the production of 774 chips in 2014, while providing training to IC design personnel. Furthermore, with regard to bridging projects, apart from providing consulting service concerning intellectual property law, market analysis, industry-academic collaboration, entrepreneurial strategies, and medical laws, the subprogram additionally encouraged the establishment of 43 industry-academic collaborative projects, which resulted in licensing fees totaling NT\$50.8 million, and employed focused technology placement activities to bring about 21 technology licensing cases, which earned licensing fees of NT\$15.6 million.

#### (5) Manpower training

This subprogram established seven inter-university alliance projects, five interdisciplinary platform projects, and five high-end applications processor topic series course projects, formed 27 interdisciplinary teams consisting of university instructors, and continued to hold relevant competitions, including international CAD contests, aimed at training chip design and systems integration personnel. The subprogram also joined forces with industry to establish a core wizard training project for a topical learning platform. This project strengthened students' practical abilities, promoted cooperation between academic researchers and industry, and trained manpower needed by industry, and the number of participating companies, schools, and students have grown rapidly. A patent portfolio and document writing training workshop was held for the first time in 2014, and provided comprehensive training covering such aspects as document consistency, logic, and feasibility.

In the area of industrial in-service manpower training, the Intelligent Electronics Institute implemented

the "Innovative Forward-Looking Leadership Personnel Workshop Project," which provided long-term formative training classes, employment assistance, and matchmaking sessions aimed at steering trainees to intelligent electronics-related industries. A total of 317 persons received training in mid-term formative training classes, 241 persons found employment in fields connected with intelligent electronics (employment rate of 76%), and 3,107 persons received in-service training in short-term formative training classes.

#### (6) Industrial promotion

This subprogram helped a cumulative total of 35 companies to occupy the Nangang Incubation Center by the end of 2014. These companies have developed intelligent electronics applications including wireless image transmission and movement sensing technology, a High Speed Rail wireless communications and control system, a wireless stethoscope, an EEG sensor, and 8K/4K high-resolution image technology. Among these new products, an intelligent mattress sensing system that can prevent patients from falling out of bed and detect bedsores has already entered the mass production stage, and there are still no competing products on the market. Two new startups occupied the Nangang Incubation Center in 2014, and had total paid-in capital of NT\$57.5 million. An additional six companies at the incubation center increased their capital by a total of NT\$205 million, and had total paid-in capital of NT\$263 million, which is approximately 5.7 times the project funding contributed by the government.

With regard to participation in the drafting of international standards, this subproject helped companies from Taiwan to join the JEDEC Solid State Technology Association and assume important roles, provided a platform for the exchange of technical information, and enabled eight companies to obtain profit of NT\$8.8 billion derived from the drafting of JEDEC standards.

#### (7) MG+4C vertical integration promotion

This subprogram approved four industry-academic collaborative technology development projects in 2014; these projects respectively focused on a wireless modular home sleep physiology monitoring system, an intelligent transnasal gastroscope system, an RGB-D 3D depth image identification sensor, and an integrated sensor and circuit low-power high signal-to-noise ratio micro-electromechanical microphone. In order to strengthen

extension of project results, MOST held the 2014 Industrial Innovation Results Announcement and Technology Matchmaking Conference in December 2014, and invited outstanding teams participating in the Science Park Bureau's "MG+4C Vertical Integration Enhancement Projects" and "Piloting Cooperation Projects between Industries and

Academia at Science Parks," and the MOEA-funded "New Leading Product Development Program" and "Intelligent Electronics Industry-Academic Bridging Projects" to announce and demonstrate their R&D results. This event also provided an opportunity to find companies interested in technologies developed in industry-academic collaborative projects.

#### Important achievements of the National Project for Intelligent Electronics in 2014

| Category                          | Item                             |          | Total     |
|-----------------------------------|----------------------------------|----------|-----------|
| Journal papers                    | Foreign                          |          | 199       |
|                                   | Domestic                         |          | 33        |
| Conference papers                 | Foreign                          |          | 349       |
|                                   | Domestic                         |          | 75        |
| Manpower training                 | Ph.D. students                   |          | 368       |
|                                   | M.S. students                    |          | 1,075     |
| Patents                           | Received                         | Domestic | 74        |
|                                   |                                  | Foreign  | 44        |
|                                   | Pending                          | Domestic | 42        |
|                                   |                                  | Foreign  | 70        |
| Technology licensing              | Cases                            |          | 54        |
|                                   | Signing fees (NT\$1,000)         |          | 94,441    |
| Corporate investment promoted     | Amount of investment (NT\$1,000) |          | 1,364,235 |
|                                   | Companies                        |          | 17        |
| Academic activities (sessions)    |                                  |          | 63        |
| Technological activity (sessions) |                                  |          | 25        |

## 2. Nano Technology

The second stage of the National Program on Nano Technology (2009-2014) focused on the six main areas of forward-looking nanotechnology research, biomedical/agricultural applications, energy and environmental technology, development of instruments and equipment, nanometer electronics/optoelectronics technology, nanomaterials, and applications of nanotechnology in traditional industries. In addition, various agencies are implementing important strategic projects in the areas of environmental/safety/health issues, manpower training, nanotechnology standards, a nanometer mark, and industry promotion. The overall intent of the program is to focus resources on industrial applications that are expected to take root and develop in Taiwan, and foster the industrialization of nanotechnology.

### (1) Nanometer electronics applications

a. ITRI has cooperated with the Career Technology Co. during the most recent five years in a project

involving technology licensing fees and corporate investment exceeding NT\$32.2 million, and the project has enabled the company to successfully obtain orders from Apple. Career Technology originally focused on conventional PI design and process technology; with ITRI's help in the form of technology transfer and technical assistance (including SiP electrical design and process assistance), the company has been able to complete the world's thinnest (300  $\mu$ m) 8-layer PI module substrate, and has overcome technological obstacles to win orders from Apple and greatly increase its earnings.

b. ITRI's Materials and Chemical Engineering Laboratory developed a broadband decoupling device with a unique patented electrode structure and patented leadframe, which can shorten the element's circuit transmission pathway. This element also possesses an additional  $\pi$ -shaped filter, and can achieve high-frequency filter performance surpassing that of competing Japanese products. This element technology has

been licensed to the solid-state V-chip capacitor firm Matsuki Polymer, and that company has established a new business division and invested NT\$300 million in developing a mass production ability.

#### (2) Application of nanometer biomedicine to cancer treatment

The "Re-188-liposomes" developed by the Atomic Energy Council has been reviewed and approved by the Food and Drug Administration, Ministry of Health and Welfare, and has entered clinical trials. This is the world's first internal radioactive nanometer cancer drug to begin human trials; the Atomic Energy Council has completed Phase I clinical trials, and embarked on Phase II trials in October 2014. Furthermore, to ensure that this research will continue to obtain funding support following the end of the National Science and Technology Program for Nanoscience and Nanotechnology, the Atomic Energy Council has applied for funding under the National Research Program for Biopharmaceuticals in 2015.

#### (3) Nanometer energy applications

The development of a "self-terminated oligomer with hyper-branched architecture" (STOBA) at ITRI represents a key technological breakthrough in the lithium battery industry, and this achievement was recognized with the 2009 R&D 100 Award. The technology can effectively prevent lithium battery explosions, and can also enhance battery life. In 2014, ITRI licensed the technology to Mitsui Chemicals, and hopes that the "STOBA inside" label will boost the international visibility and competitiveness of Taiwan's battery industry.

#### (4) Academic excellence results

A research team at National Chung Cheng University research team employed nanometer particles such as carbon nanocapsules, metal-containing carbon nanocapsules, carbon nanotubes, nanometer diamonds, and nanometer metal particles as lubricating oil additives, and found that the addition of nanometer particles enables the contact surface of mechanical elements to withstand stress, reduces direct surface contact, and yields a significant bearing effect." In addition, nanometer particles possess a self-repair effect, while graphene (graphite sheet) has a strong lubricating ability; after nanometer graphene particles are destroyed, the graphene forms a lubricating and protecting film on contact surfaces, and fills abrasion pits. This two-in-one lubricating effect, which includes strengthening the surface and reducing interface abrasion, can

greatly prolong the service life of lubricating oil. The technology from this project will significantly boost domestic nanotechnology capabilities and provide new energy conservation methods. The participating firm Tai Hua Enterprise invested NT\$200 million in the development of "hollow carbon nanocapsules and graphene preparation and applications technology" and relevant products in 2014.

#### (5) Nanometer Mark

Starting in 2004, this program has promoted the world's first "Nanometer Mark" public certification system. It is hoped that this mark can protect consumers' rights and interests, encourage companies to produce superior nanotechnology products, and foster the sound development of the nanotechnology industry. Responding to the termination of the program at the end of 2014, the Industrial Development Bureau, MOEA actively promoted the upgrading of the current nanometer product certification system to part of the Chinese National Standards (CNS), and has already selected "antiseptic processed goods: antiseptic testing method and antiseptic effect" for inclusion within national standards, and has drafted relevant recommendations. Furthermore, the Industrial Development Bureau has also announced that the Nanometer Mark will complete the first stage of its mission on December 31, 2016, and afterwards will be a service of the Taiwan Nanotechnology Industry Development Association.

#### (6) 2014 Taiwan Nano

The "Taiwan International Nanotechnology Week and Nanotechnology Project Results Exhibition," which was organized by the project office, was held October 2-4, 2014 at the Taipei World Trade Center. This event—Taiwan's largest nanotechnology trade show—was held for the 12<sup>th</sup> time, and was expanded this year in conjunction with the end of the nanoscience and nanotechnology program. The total of 200 booths at the event attracted roughly 19,700 visitors. The theme pavilion had a topic of "nanotechnology: looking back and forward," and the show was accompanied by a series of diverse, enriching activities, including the "International Symposium on Nanotechnology Pharmaceutical Laws and Management Policies," "Symposium on Nanoscale Medical Equipment Management Laws," "Conference on Application of Nanotechnology to Medical Equipment: Safety and Risk Assessment Awareness," "Taiwan-Austria Symposium on Nanotechnology," "Explanatory Meeting on Nanotechnology Product Opportunities," "Forum on Nanomaterials in Traditional Industries

and Matchmaking Meeting," and "Nanotechnology Workshop: Hands-on Nanometer Fun." At these activities, the organizer invited experts affiliated with domestic and foreign industry, government,

academia, and the research community to talk about future nanotechnology development trends, and share nanotechnology development results and experience.



Distinguished guests at the opening ceremony of 2014 Taiwan Nano

#### (7) Joint international research

In 2011, the European Union Framework Programme agreed to admit Taiwan to the EU's Eureka organization, and invited Taiwan to participate in the 2012 M-era.Net Kick-off Conference. Representatives of this program have since participated in M-era.Net operations. In July of 2014, the European Union Framework Programme issued M-era.Net Call 2014, and Taiwan submitted 17 projects; nine of the projects passed preliminary review, and have entered the follow-up review stage.

#### (8) Participation in international results exhibitions

a. "Nano Korea 2014," which was organized by the Nano Technology Research Association of Korea, has now been held 12 times, and this program has

been invited to conduct exhibits at this event for the past two years. In 2013, principal investigator Wu Chung-yu attended and signed a MOU with Korea. In July of 2014, the program office, bridging project, and human resources training teams jointly attended this event.

b. The program office and nanometer bridging project office, National Project for Intelligent Electronics office, and intelligent electronics bridging project office jointly participated in the ComPaMED trade fair in Düsseldorf, Germany, and manned a "Taiwan National Program Pavilion." In addition, two academic research teams and four companies participating in relevant projects also displayed their projects at this event.

### State of funding implementation for the National Science and Technology Program for Nanoscience and Nanotechnology in 2014

| Agency   | Budget number (NT\$1,000) | Implemented figure (NT\$1,000) | Implementation rate |
|--|---------------------------|--------------------------------|---------------------|
| Department of Industrial Technology            | 1,509,153                 | 1,509,056                      | 99.99%              |
| ITRI   |                           |                                |                     |
| Chung Shan Institute of Science and Technology | 73,320                    | 71,206                         | 97.12%              |
| Industrial Development Bureau                  | 35,483                    | 35,351                         | 99.63%              |
| Bureau of Standards, Metrology and Inspection  | 22,350                    | 22,340                         | 99.96%              |
| National Science Council                       | 656,912                   | 656,912                        | 100.00%             |
| Atomic Energy Council                          | 53,527                    | 50,002                         | 93.41%              |
| Environmental Protection Administration        | 9,477                     | 9,190                          | 96.97%              |
| Department of Health                           | 148,981                   | 147,380                        | 98.93%              |
| Council of Labor Affairs                       | 21,282                    | 19,450                         | 91.39%              |
| <b>Total</b>                                   | <b>2,530,485</b>          | <b>2,520,887</b>               | <b>99.62%</b>       |

### Performance indicators of the National Science and Technology Program for Nanoscience and Nanotechnology, 2014

| Item                     | Quantity                          |           |
|--------------------------|-----------------------------------|-----------|
| Academic achievements    | Journal papers                    |           |
|                          | International                     | 955       |
|                          | Domestic                          | 70        |
|                          | Conference papers                 |           |
|                          | International                     | 352       |
|                          | Domestic                          | 155       |
| Manpower training        | Ph.D. students (persons)          | 664       |
|                          | M.S. students (persons)           | 2022      |
| Technological innovation | Patents                           |           |
|                          | Applications                      | 389       |
|                          | Patents obtained                  | 384       |
|                          | First-stage technology licensing  |           |
|                          | Cases                             | 72        |
|                          | Amount (NT\$1,000)                | 91,837    |
| Technology licensing     | Cases                             | 164       |
|                          | Amount (NT\$1,000)                | 168,577   |
| Economy benefits         | Promotion of corporate investment |           |
|                          | Cases                             | 234       |
|                          | Amount (NT\$1,000)                | 4,488,708 |

### 3. Energy

Based on research conducted during the first phase of the National Science and Technology Program-Energy (2009-2013), the second phase (2014-2018) seeks to promote promising research efforts that can be realized as industrial applications within 5-10 years and can enhance Taiwan's energy intensity by at least 2%. As a result, the program has

combined some research items in order to achieve the nation's sustainable energy development vision of "establishing an energy supply and demand system promoting safe, stable, efficient use of clean, environmentally-friendly energy, creating a development environment fostering energy conservation and reduction of carbon emissions, and achieving energy conservation and emissions

reduction targets." As a result, the program seeks to realize the three major objectives of (1) enhancing energy autonomy, (2) reducing greenhouse gas emissions, and (3) creating an energy industry. In the area of energy security, the government hopes to stabilize energy sources and distribution channels, ensure balanced energy supply and demand and the normal functioning of energy supply systems, and improve system risk management. Efforts in the area of efficiency will include improved energy use management, increased energy conversion, distribution, and use efficiency, and increased energy use added value. Efforts in the area of clean energy will include development of low-carbon energy, application of low-carbon technology, and reduction in the impact of energy development in use on the environment.

Funding for the second phase of the project will total NT\$25 billion, and it is expected that the program will achieve the following goals: (1) Enhancing energy use efficiency and reducing dependence on imported energy; (2) boosting the competitiveness of alternative energy-related industries; (3) development of a smart grid technology industry and helping establish a smart grid system in Taiwan; (4) development of an offshore wind power and marine energy technology industry, and strengthening development of offshore wind power so as to achieve 2,100 GWh of power domestically and reduce carbon emissions by 1.3 million tons by 2020; and (5) development clean geothermal energy.

Apart from promoting basic research on energy technology, this program has also emphasized the creation of an energy industry, and seeks to verify the feasibility of the industrialization of energy technologies, which can be advanced to the development stage in conjunction with the MOEA's green energy industry upgrading projects, which are aimed at the energy industry. In terms of division of labor, MOST bears responsibility for front-end development of applications, and the MOEA is in charge of promotion of back-end industrialization. For example, after MOST invested in the development of smart grid technologies, the Bureau of Energy, MOEA planned and implemented a Penghu smart grid demonstration project. In addition, in the area of new energy development, MOST sponsored pioneering generating unit R&D in an industry-academic collaborative project seeking to generate power from the Kuroshio current; if this technology proves to be feasible, the MOEA will provide support to the industry, and expand efforts to promote the energy industry's peripheral manufacturing industries

and system services.

Program results that were the subject of technology licensing in 2014 included "front collision avoidance system," "vehicle lane departure warning system," "vehicle video safety system technology," "CIGS solar cell process and verification," "nanometer silver line technology," "development of air-tight special gas process elements," and "multiple criteria charging control technology." The transfer of these technologies will encourage Taiwan's industry to commit itself to the program's six key areas. In terms of economic benefit, the program induced companies to invest more than NT\$15 billion in energy technology R&D and more than NT\$10 billion in production; actively encouraged the upgrading and transformation of the domestic energy industry; and helped bring about the establishment of four startups focusing on carbon-negative bio-butanol production technology using a cellulose biomass, advanced ultra-thin semiconductor material coating equipment and automotive optoelectronics coating, and micro/nanometer structures R&D. The following are some particularly promising areas in the program's six major technological directions:

1. Energy conservation: A project established Taiwan's first industrial low-temperature waste heat demonstration power plant; the operation of this demonstration power plant will verify the maturity of Taiwan's self-developed technology.
2. Alternative energy: (1) A miniaturized photovoltaic module achieved conversion efficiency of 35.15%, which is twice that of conventional silicon photovoltaic modules; the project team has applied for Taiwan and US invention patents for this device, which can be produced automatically and will boost reliability. (2) An energy storage system established in the Dongkeng Community, Lesser Kinmen constituted the country's first demonstration renewable energy generation and storage system based on mostly on solar and wind power and aimed at providing a stable power supply.
3. Smart grid: (1) The program established high penetration PV (400 KWp) grid-connected power system on Qimei, Penghu; this system will save more than NT\$6 million in diesel power generation costs. (2) Taiwan's first independent smart microgrid system with a demand response capability was able to provide power to public buildings within a certain area while operating independently. This smart microgrid features

remote real-time monitoring of dispersed energy sources and actual load within the system area; it can operate continuously and perform coordination of micro-turbine, energy storage, and renewable energy systems, which enables the renewable energy penetration rate to exceed 20%.

4. Offshore wind power and marine energy: The program helped complete a demonstration domestic offshore wind farm with a capacity of over 10 MW, completed bid request procedures for offshore wind farm block development, and brought about Taiwan's first offshore wind farm developer financing case.
5. Geothermal and gas hydrates: (1) Researchers developed Taiwan's first domestically-developed research grating-type onsite well temperature measuring device, which can extend the length of downwell temperature-sensing fiber-optic cable to 1,570 meters and increase temperature sensing points to five; the device can also be used to check temperature repeatability during the measurement process. (2) Using a regular array for the first time in world, researchers incorporated symmetrical boundary conditions, established mesoscale hydrodynamic methods, and analyzed the amount of thermally-stimulated methane degradation and MH pressure reduction in a dynamically-simulated sedimentary layer.
6. Clean coal: (1) China Steel established a demonstration power plant able to capture CO<sub>2</sub> using the chemical absorption method; this plant can capture 0.1 ton of CO<sub>2</sub> per day. (2) Taiwan Cement established a demonstration power plant able to capture CO<sub>2</sub> using the calcium looping method; the plant can generate 1.9 MW and capture 1 ton of CO<sub>2</sub> each day.

In the area of alternative energy, this program developed low-carbon renewable energy technologies in the promising areas of biofuels, solar energy, and energy storage. In addition, in order to boost Taiwan's energy self-sufficiency and achieve a win-win-win sustainable development vision for "energy, environmental protection, and the economy," the program relied on strategies in the Framework of Taiwan's Sustainable Energy Policy and incentive measures in the *Statute on the Development of Renewable Energy* to draft renewable energy key R&D items. Apart from seeking to develop offshore wind power and marine energy technology industries, the program is also striving to develop clean geothermal energy and survey deposits of gas



**Taiwan's first power plant capturing CO<sub>2</sub> using the calcium looping method.**

Source: ITRI

hydrates. While having the smallest possible impact on the environment, the program is committed to the sustainable management of Taiwan's terrestrial geothermal resources and utilization of marine resources, while seeking to realize the policy goals of energy diversification and self-reliance.

The new energy policy announced by the government on November 3, 2011 took "ensuring nuclear safety, steadily decreasing reliance on nuclear power, creating a low-carbon green energy environment, and gradually realizing a non-nuclear homeland" as its energy development vision and promotional strategy. The Executive Yuan is actively implementing various measures to conserve energy, reduce CO<sub>2</sub> emissions, and stabilize the power supply while upholding the three major principles of ensuring no power shortages, maintaining reasonable power prices, and fulfilling international CO<sub>2</sub> reduction pledges. The Executive Yuan hopes that this will improve the country's energy use structure and boost Taiwan's overall competitiveness. Since global energy prices and need to reduce CO<sub>2</sub> emissions will remain high throughout the foreseeable future, all interested parties must work hard to find ways of realizing the ideals of "ensuring nuclear safety, steadily decreasing reliance on nuclear power, creating a low-carbon green energy environment, and gradually realizing a non-nuclear homeland" under circumstances in which domestic energy self-sufficiency and renewable energy technology urgently require enhancement. The government hopes that the program which is being jointly implemented by MOST and MOEA, will enable Taiwan to achieve the goal of making renewable

energy account for 12% of installed generating capacity by 2020.

#### 4. Biopharmaceuticals

The National Research Program for Biopharmaceuticals has the overall objective of strengthening mid-stream development work, employing pre-clinical trials or clinical trials to perform verification and add value, and promote the industrialization of R&D results. The program has a short-term goal of establishing and integrating R&D systems and capabilities, a mid-term goal of putting the management of research results and promotion of industrialization on a solid basis, and a long-term goal of cultivating superior biotechnology pharmaceutical manpower and companies possessing international competitiveness, and ensuring that Taiwan's R&D capabilities and results receive due international attention. The following major results were achieved in 2014:

##### (1) Research group: Mission-oriented research projects

- a. A research team developed the drug MPT0E028, which was shown to better inhibit tumor growth than such commercially-available drugs as Zolanza, Tarceva, and Sorafenib. After animal efficacy experiments employing animal models with eight types of cancer (including prostate cancer, lung cancer, colon cancer, breast cancer, liver cancer, pancreatic cancer, leukemia, and lymphoma), it was found that both oral and intravenous MPT0E028 are able to inhibit tumor growth, the drug is effective in even in extremely low concentrations (nM range), and cytotoxicity toward normal bone marrow is extremely low. MPT0E028 received clinical trial review from the US FDA in March 2014 (Food and Drug Administration-Investigational New Drug, FDA IND), received IND status in Taiwan via "fast track" expedited clinical trial review procedures, and will undergo human trials at National Taiwan University and Taipei Medical University. The various stages of this case, including new drug exploration, preclinical pharmacology, pharmacodynamics, and toxicology, raw material drug production and preparation, and application for IND, have all been performed independently in Taiwan.
- b. Liver cancer has one of the highest incidences and death rates of any cancer in Taiwan. As of the present, Sorafenib is still the only drug approved for use in cases of liver cancer. A series of studies involving the recently developed liver cancer drug SC-4, which is a derivative of Sorafenib, found that SC-43 is more effective than Sorafenib at inhibiting

tumor proliferation in liver cancer cells and an in-situ animal model, and it was proposed that the mechanism of this action may involve the activation of SHP-1 followed by the inhibition of STAT3. The research team hopes to quickly confirm SC-43 as a candidate drug, is investigating appropriate biological markers and drug combination models, and is designing human trials for SC-43. In addition, the team has also synthesized numerous compounds to serve as a back-up library for SC-43, and expects to apply for IND by the middle of 2016.

- c. Huntington's chorea is a chromosomal dominant degenerative brain disease that induces chorea, dementia, and psychological symptoms in victims. The disease cannot be cured, and is currently handled solely through treatment of symptoms. The research team in this project first purified the adenosine analog T1-11 from the Chinese herbal medicine tall gastrodia tuber, and found that this substance could improve motor performance and block destruction of the ubiquitin-proteasome system in transgenic rats with altered R6/2 genes. The researchers then used this substance to treat diseases associated with expansion of trinucleotide repeats, such as cerebellar atrophy, neural degenerative disease caused by accumulation of abnormal proteins, and chronic muscle pain.
- d. Nanoparticles modified with methoxy polyethylene glycol (methoxy PEGylated nanoparticles – mPEG-NPs) have been acclaimed the third-generation "new drugs of the future." It is expected that the use of bispecific antibodies that can simultaneously bind to mPEG and tumor-specific markers (such as HER2 and EGFR) will effectively boost the binding specificity of various mPEG-NPs currently in clinical use (such as liposomes, microcapsules, and gold nanoparticles) against tumors, and thus enhance therapeutic effectiveness. A research project assessed the in vivo therapeutic effectiveness of  $\alpha$  HER2-Lipo/DOX against tumors, sought to develop the optimal dosage form, tested toxicity, and produced the bispecific antibody (mPEGxHER2).

##### (2) Preclinical development group: Drug lead assessment and candidate drug promotion projects

The goal of this project is to assess and screen promising R&D projects, implement compound preparation, general pharmacology, and in vivo imaging, perform preliminary toxicology experiments involving cells and laboratory animal, and gather

preclinical testing data, including pharmacokinetics, biosafety, and substantial equivalence data, in order to confirm whether substances can be developed as candidate drugs (the project actually includes both pharmaceuticals and medical equipment). Individualized pre-clinical trials and research can then be planned for the selected candidate drugs in order to meet clinical trial permit application needs.

In order to achieve the foregoing objectives and enhance the commercial success rate of promising cases, the project invited a team from the Taiwan Biotechnology Integrated Incubation Center to participate in topic selection, review, and assistance. The following are recent implementation results:

- a. Anti-diabetes candidate drug DBPR108: The results of this project, which was implemented jointly with a participating company under the Executive Yuan's "Promotion of Successful Biotech Investment Cases," were recognized with the 2013 National Invention Gold Medal and Lee Tien-teh Medical Technology Award; phase 1 repeated dose trials got underway in May 2014.
- b. Anti-hepatitis C candidate drug DBPR110: Pre-clinical trials began at the end of 2011, technology was licensed to a domestic firm in 2013, and application IND was made in 2014.
- c. Anti-lung adenocarcinoma candidate drug DBPR112: R&D and production of a kilogram-level quantity of the raw material drug needed for preclinical testing was completed, pharmacodynamic and metabolic research performed, and the toxic dose range in rats preliminarily determined. Preclinical toxicological testing and safety assessment, production of raw material drug needed in clinical trials, and development of a drug preparation for use in trials are now underway, and it is expected that application for IND will be made in 2015.
- d. Anti-diabetes candidate drug DBPR211: After development of a kilogram-grade amplified production process for the raw material drug and completion of pilot production, 5 kg of the raw material drug has been obtained. Preclinical toxicological testing, safety assessment, and development of a drug preparation for use in trials are now underway, and it is expected that application for IND will be made in 2015.

### (3) Clinical Group: Translational medicine and clinical trial projects

- a. There is a growing trend toward use of nanometer gel capsules in drug transmission systems, and this drug transmission method can extend product patent protection and encourage the use of old

drugs in new ways. Nanometer carrier R&D has focused on combining the molecular pathways of specific diseases with subcellular drug transmission strategies, and seeks to reduce side effects by focusing clinical treatments and enhancing effectiveness. A research project successfully used two types of binding to modify a nanometer carrier with peptide segments and glycosyl groups, and discovered that the carriers targeted the endoplasmic reticulum of immune cells. Technology developed in this project has attracted interest from firms, and licensing negotiations are underway.

- b. Ovarian cancer has one of the highest death rates of any gynecological cancer. In addition, its cause remains unclear, and the effectiveness of treatment has languished for many years. As a consequence, medical researchers believe that it is urgent to develop individualized biological markers that can be used in diagnosis and treatment. This research project is using new-generation sequencing technology uncover new methylated biological markers, which will be used to identify ovarian cancer and determine treatment prognosis. It is hoped that these markers can be used in conjunction with cervical smear testing to screen for more types of gynecological cancers and gain a better understanding of prognosis. Licensing negotiations are underway for relevant technologies, and a European company is negotiating the possibility of engaging in joint international research.
- c. A new type of composite medical dressing developed independently in Taiwan consists of an upper layer of silica gel and a lower layer of acellular porcine dermis. Apart from promoting wound healing, preventing infection, and preventing loss of protein and electrolytes, this highly biocompatible product can also significantly reduce immune rejection of the dressing by the wound. Companies are interested in this dressing, and are studying its applications and benefits.
- d. Psoriasis is a very common non-infectious inflammatory skin condition, may occur repeatedly, and is very difficult to eradicate. In addition, psoriasis can influence patients' quality of life, and often has a very detrimental effect on their appearance. Research has verified that an ointment made using the Chinese herbal preparation *qingdai* is safe and effective against psoriasis. However, the distinctive odor and color of *qingdai* often leaves patients' skin and clothing discolored and with a strange odor; these problems affect people's

willingness to use the ointment. Researchers performed clinical trials of an improved dosage form—oil extract *qingdai* ointment—and found that it was generally as effective as the original *qingdai* ointment; the results of this project have been licensed to the French firm Galderma Pharmaceutical.

- e. Ischemic femoral head necrosis usually takes the form of a series of bone tissue abnormalities resulting from the loss of blood supply due to external injury or disease. A surgical instrument set designed in this project for use in repair of femoral head necrosis has been tested in experiments using large animals, and use has been found to be safe. Further work will verify that the implantation carrier is clinically effective in bone. Clinical trials of this technology in knee joints and other limb joints have yielded very good results, and the technology has been licensed to Exactech.

(4) Resource center: Providing technical services and consulting

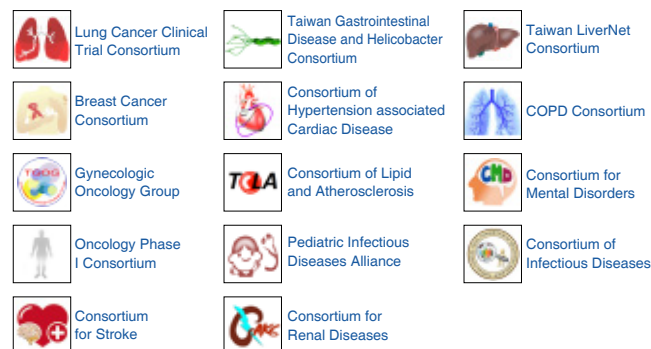
The program resource center chiefly strives to help find and confirm disease targets, perform drug screening and design, synthesize lead drugs, establish animal models, perform animal experiments, offer legal consulting, and conducting clinical trials of candidate drugs.

The program has further established the Taiwan Clinical Trial Consortium (TCTC) to employ a bottom-up approach to encourage and coordinate medical center personnel with abundant working experience and many clinical trials under their belts to join disease trial consortiums. TCTC is effectively coordinating and integrating domestic clinical resources, promoting cooperative implementation of multi-center trials, and training international multi-center and domestic inter-hospital clinical trial teams.

To date, TCTC has established 14 clinical trial consortiums targeting specific diseases, and these consortiums have conducted more than 200 international clinical trials, including over 60 in which they have played important roles. Domestic firms have also commissioned close to 70 trials. In order to enhance the quality and efficiency of clinical trials, ensure that trials can be speedily completed, and increase the pace of new drug R&D, the program office also provides consulting and assistance services concerning clinical trial laws and regulations, and has established a joint ethical review committee and mechanisms to expedite clinical trial contract signing.

## Taiwan Clinical Trial Consortium (TCTC)

<http://tc2.ntu.edu.tw>



The 14 disease trial consortiums established by the Taiwan Clinical Trial Consortium (TCTC)

(5) Industrialization promotion and international cooperation group

a. Industrialization promotion performance

This group completed 12 technical market assessment reports/case analysis reports, 18 patent retrieval reports/patent analysis reports, 14 patent/technical market consulting service reports, assisted with application for 18 patents and nine US provisional patents. Furthermore, the group used the Intellectual Property Management Database to monitor the IPR status of cases supported by the program, and established 50 intellectual property management platform cases during the year. The group further held two IPR committee meetings and two case R&D results explanatory meetings, promoted 58 industry-academic collaboration/technological collaboration/technology transaction cases, helped bring about the establishment of two startups and assisted one company increase capital, and completed 25 commercial and legal service cases. These efforts brought about approximately NT\$88.4 million in corporate investment and created 10 industrial jobs.

b. International cooperation and training:

The group promoted international R&D cooperation, strove to foster participation by domestic and foreign companies, academic researchers, and research organizations in order to achieve the commercialization of R&D results. In 2014, the group joined forces with the International Union of Biochemistry and Molecular Biology, Federation of Asian and Oceanian Biochemists and

Molecular Biologists, and International Union of Biochemistry and Molecular Biology to hold the 15<sup>th</sup> International Union of Biochemistry and Molecular Biology Symposium," which focused on the topic "Biochemistry and Molecular Biology in Transition: from Basic to Translational." International experts and scientists in various areas of biochemistry and molecular biology were invited to share their discoveries at this event, which was attended by over 1,000 specialists, scientists, students, and biotech and pharmaceutical company personnel, including 350 foreign visitors. The symposium included a poster competition featuring 350 poster papers, and biotech firms were invited to present exhibits. The symposium provided a platform allowing domestic academic researchers to meet face-to-face and engage in discussion with foreign scientists.

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

- a. This group continued to implement the revision of the *Human Biobank Management Act* after gaining an understanding of, and helping resolve, conflicts encountered by research personnel when seeking to comply with the *Statute For Human Body Biological Database Management and Act on Human Subjects Research*.
- b. Assisted the Taiwan Clinical Trial Consortium to resolve technical and legal issues connected with different trial stages, and continued to implement joint ethical review mechanisms, enhance the multi-center clinical trial proposal review efficiency, reduce waste due to the redundant production of review documents, and lessen the time needed for transmission of review documents.
- c. Planned and produced brochures and booklets aimed at educating the general public and transmitting information among the public, government, industry, and academic researchers.
- d. Held training classes, roundtable expert conferences, and public forums.

### C. The National Synchrotron Radiation Research Center

After four years and six months of construction, and four months of testing and optimization, the electron beam in the storage ring of the Taiwan Photon Source (TPS) synchrotron accelerator at the National Synchrotron Radiation Research Center (NSRRC) has achieved its design energy of 3.0 billion eV, and the storage current is over 1 mA. Trial operation on December 31, 2014 was successful, and

TPS emitted its first beam of synchrotron radiation. An inaugural ceremony for TPS held on January 25, 2015 also marked the start of a new era in synchrotron radiation technology.

Thanks to Taiwan's mastery of accelerator technology, TPS has exhibited excellent performance, and it is expected that be Asia's brightest synchrotron light source. The successful development of this large, interdisciplinary common research facility comes in the wake of Taiwan's construction of Asia's first advanced third-generation synchrotron, and again demonstrates to the world Taiwan's impressive achievements in this area of technology. Apart from completing TPS, NSRRC has also maintained the effective operation of its existing light source, and provides high-quality, advanced radiation services to domestic and foreign research teams engaging in basic and applied scientific research.

For instance, researchers from Taiwan's Academia Sinica and National Tsinghua University, and Switzerland's Federal Institute of Technology Lausanne, are using NSRRC's synchrotron radiation X-ray microscope facility and technology to observe fireflies' light-emitting organs; the results of this research were published as the cover article in the prominent physics journal *Physical Review Letters*. In addition, NSRRC has also promoted the industrial applications of synchrotron radiation, and has cooperated with numerous domestic universities, research organizations, and companies in the development of next-generation semiconductor microlithography technology, which has tangibly enhanced Taiwan's industrial competitiveness.

#### 1. Accelerator facility

The existing TLS accelerator light source continued to operate stably 24 hours a day. Over the course of 2014, the accelerator achieved an operating efficiency of 99.4% and an electron beam stability index of 98.3%, which exceeded the target values for the year. NSRRC continued to maintain the synchrotron accelerator's magnet, low-temperature, vacuum, and precision mechanical positioning systems, and conducted regular inspection, service, and functional improvement of the beamline vacuum, mechanical, water/gas/power, and interlock systems, ensuring that the accelerator facility was kept in an optimal operating state.

#### 2. Peripheral experimental facilities

NSRRC continued to operate, maintain, and upgrade beamlines throughout 2014; beamline

energies included infrared, UV, soft X-rays, and hard X-rays. The center currently has 26 beamlines open to users (including 24 at the NSRRC site and two at Japan's SPring-8). NSRRC has also been establishing highly advanced beamlines and experiment stations to prepare for the impending opening of TPS to users. NSRRC began construction of new seven peripheral facilities starting in 2011; these include protein crystallography, resonant soft X-ray scattering, submicron soft X-ray spectrography, coherent X-ray scattering, submicron X-ray diffraction, and X-ray nanoprobe experimental facilities. At present, NSRRC is performing drawing design and specifications drafting for standardized beamline mechanical elements. Many of these beamline elements have been designed in-house by NSRRC personnel; apart from offering performance equivalent to or better than those of similar commercial products, beamline elements designed in-house can dramatically reduce construction costs and enhance maintainability during operation.

### 3. User extension and scientific research

A total of 1,586 pioneering research projects (11,381 person-times) used NSRRC's light source during 2014; these projects were conducted by 106 domestic and 198 foreign organizations. Research at NSRRC 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 335 SCI-cited papers in prominent international scientific journals, including 116 papers published in prestigious journals with impact factors in the top 10%, and 54 papers published in journals with impact factors in the top 5%. Notable papers included "Platinum in Platinum-based Composite Nanoparticles: Interfacial Effects in Iron-nickel Hydroxide-Platinum Nanoparticles Enhance Catalytic Oxidation Performance," which was based on work done at the X-ray absorption spectroscopy experiment station (17C1), and was published in *Science*; "Chemical Modeling of Kuiper Belt N3 Ice Crystals in the Laboratory," which used experiment station 03A1, and was published in *Astrophysical Journal Supplement Series*; "Use of Self-Assembled Nanostructures in Giant Magnetoresistive Effect Design," which used the light absorption and magnetic circular dichroism spectroscopy experiment station/ four-ring X-ray diffractometer experiment station (stations 11A1 and 17A1), and was published in *Advanced Materials*; and "Determine of a Novel Glutaminyl Cyclase Structure Provides a New

Direction in Alzheimer's Disease Drug Design," which used protein crystallography experiment station 13C1, and was published in *Acta Crystallographica Section D: Biological Crystallography*.

NSRRC holds annual user conferences in order to promote domestic and foreign academic interchange and strengthen communication with users. During 2014, Prof. Mou Chung-yuan of the Chemistry Department at National Taiwan University was invited to present the keynote speech at the NSRRC Annual Users' Meeting, which held five seminars on the topics of "High-resolution RIXS and NanoARPES," "Coherent X-ray Scattering," "Applications of Synchrotron Radiation to Structural Biology," "X-ray Nano-analysis on Condensed Matter Physics and Materials Science," and "Opportunities for Novel Research in Paleontology Using Synchrotron Radiation and Laser Technologies," and contained many brilliant talks by domestic and foreign scientists and researchers. In addition, NSRRC also held other accelerator and applications research and neutron-related conferences, including the 4<sup>th</sup> Workshop on the Operation of Large Vacuum systems, 8<sup>th</sup> Asia-Oceania Forum for Synchrotron Radiation Research, and Small Angle Neutron Scattering Workshop.

### 4. Collaboration with industry

NSRRC strives to promote the industrial applications of synchrotron radiation, and has implemented relevant projects with collaborating firms in such areas as biomedical pharmaceuticals, optoelectronics & semiconductors, energy, medical instruments, and microsystems. Among the most noteworthy projects during the year was the "TSMC Synchrotron Radiation Virtual Laboratory Project," which successfully used the most advanced synchrotron radiation technology to resolve problems facing the semiconductor industry, and directly helped one of Taiwan's flagship corporations to boost its technological capabilities and compete more effectively with rivals in the US and Korea. NSRRC has actively cooperated with a number of universities and research organizations in the development of next-generation semiconductor lithography technology, including extreme UV lithography (EUVL), as part of the National Science and Technology Program for Nanoscience and Nanotechnology.

### 5. Manpower training

In order to pass on its R&D capabilities, NSRRC has continued to collaborate with National Tsinghua University and National Chiao Tung University in

offering synchrotron radiation study programs. Furthermore, in order to promote applications of synchrotron radiation and train a cohort of outstanding young personnel, NSRRC held occasional light source technology and applications training classes, including the 2014 winter class on free electron lasers, 5<sup>th</sup> X-ray science summer school, 2014 protein crystallography training class, 2014 X-ray absorption spectroscopy summer practicum, synchrotron radiation application and summer practicum, and 2<sup>nd</sup> advanced light source summary science practicum.

### 6. New light source and outlook

Within a very short three weeks, NSRRC's Taiwan Photon Source (TPS) increased the energy of the electron beam in its booster ring from 150 MeV to 3.0 GeV, and also injected a 5 mA current into the storage ring. TPS emitted its first beam of synchrotron radiation during successful trial operation on December 31, 2014. These achievements set a record in synchrotron radiation pilot operation, and also

verified the TPS' design, construction, and precision assembly meet the world's highest standards.

On January 25, 2015, President Ma Ying-Jeou attended a "First Light" ceremony to inaugurate the Taiwan Photon Source, and representatives of industry, government, academia, and the research community bore witness to this groundbreaking technological advance. The 3 GeV Taiwan Photon Source has a circumference of 518 meters and is accompanied by major interdisciplinary pioneering common experimental facilities. It is the result of the largest construction project for an advanced common research platform in Taiwan's history. With seven cutting-edge beamlines/experiment stations, TPS' outstanding performance will give Taiwan's researchers a global competitive advantage in many fields of science and engineering, and it will ensure domestic academic research attains the highest international standards and provide many new opportunities for forward-looking scientific research.

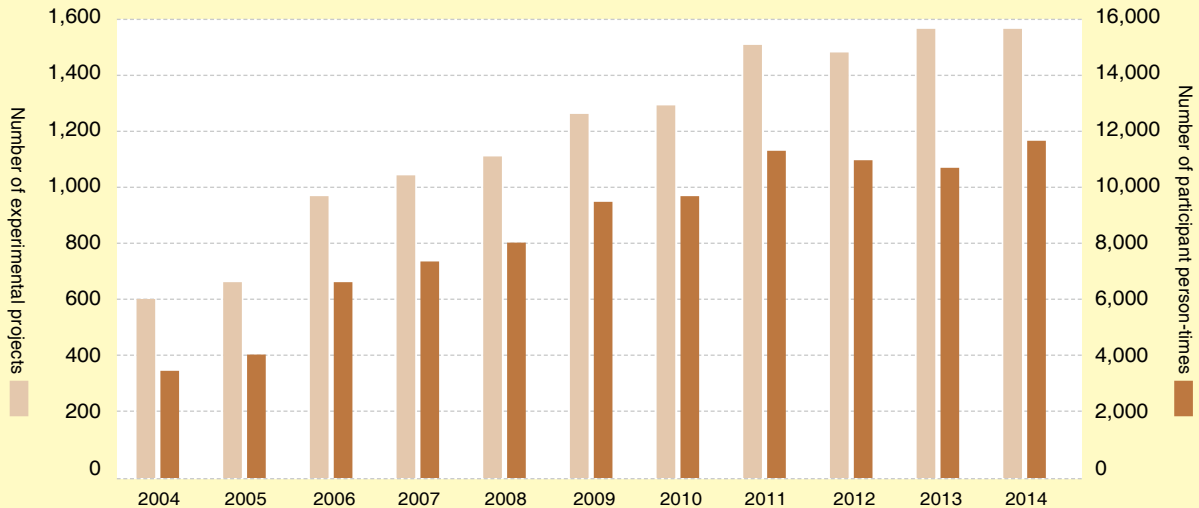


First light of the Taiwan Photon Source, December 31, 2014



President Ma Ying-Jeou (7<sup>th</sup> from right) hosts an inaugural ceremony for the Taiwan Photon Source on January 25, 2015, and presses the start-up button

Beamline experimental projects and user person-times statistics, 1994-2014



#### D. 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. With a vision of pursuing international excellence, NARLabs plays the role of an R&D platform provider training technical manpower and promoting innovation and economic benefit. The ten experimental research units under NARLabs consist of the Chip Implementation Center, Instrument Technology Research Center, National Center for High-performance Computing, National Center for Research on Earthquake Engineering, National Nano Device Laboratories, National Laboratory Animal Center, National Space Organization, Science & Technology Policy Research and Information Center, Taiwan Ocean Research Institute, and Taiwan Typhoon and Flood Research Institute. NARLabs' R&D platforms (such as global environmental science platforms, information and communications technology platforms, and biomedical technology platforms) are usually larger and more costly than any single domestic university could undertake on its own. NARLabs' R&D platforms chiefly provide academic researchers S&T research services, and enable research personnel at universities and research organizations to use superior, high-accuracy, high-efficiency instruments, facilities, and

software modeling and analytical systems to order 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 industrial needs, conveying these needs to relevant academic and research units, and employing 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' 2014 research results are summarized as follows in the four major areas of the global environment, information and communications technology, biomedical technology, and S&T policy:

##### 1. Global environment

Researchers established a mobile "dual polarization rainfall radar" able to provide early warning of torrential rains in mountain areas; this system can reduce loss of life and property damage by giving residents of areas subject to mudslides sufficient time to evacuate. A street-front building structural earthquake resistance information website provides the public tools for assessing how well their homes can withstand an earthquake. A newly-developed lightweight composite transportable bridge can be used to evacuate residents of isolated disaster-stricken areas or transfer food supplies. The National

Space Organization completed testing and assembly of key elements for the FORMOSAT-5 satellite, and the satellite bus for the joint Taiwan-American FORMOSAT-7 weather satellite constellation project entered the integrated testing stage. The Tankong-10 sounding rocket performed dynamic measurements of the ionosphere, completing a multi-stage sub-orbital research project. A "quasi-broadband ocean bottom seismometer" was deployed at depths of up to 5,000 meters; by gathering seismic data from the seafloor to the east of Taiwan, this system will enlarge the scope of earthquake monitoring around Taiwan.

## 2. Information and communications technology

Taiwan's first petabit-class earth science database collects and manages real-time and historical big data. Researchers created a digital model of the entire Shimen Reservoir area and its various engineering facilities. A project in conjunction with UMC developed the world's first mass-production 0.18  $\mu\text{m}$  micro-electromechanical process, and began providing process services. Researchers successfully produced an ultra-low power resistive memory element with an area of only 3  $\text{nm}^2$ . Semiconductor process exposure equipment modules and components developed autonomously in Taiwan passed fab testing and verification, and orders have already been received.

## 3. Biomedical technology

Researchers successfully developed CRISPR/Cas genetic modification technology and gene knockout rats that can be used in drug screening; the development of this technology in Taiwan is keeping pace with top laboratories in the US and China. Isolation operation technology was used to investigate the mechanism by which BF probiotics can relieve colitis, and confirmed that BF can maintain immune balance by inhibiting the activity of inflammation factors. NARLabs established the "NARLabs Medical Materials Value Creation Alliance" in order to advanced medical equipment testing capabilities at the Hsinchu Biomedical Park and accelerate the development of biotech medical equipment in Taiwan; the 20 members of the Alliance are able to collectively provide integrated industry chain services. In the area of applications software, a sleep apnea diagnostic program was licensed to a domestic biomedical company; this program can help doctors quickly determine whether patients suffer from sleep apnea, and assess their symptoms and level of risk. This software is the first medical platform of its kind

combining imaging, computational hydrodynamics, and a cloud system, also provides software modeling service.

## 4. S&T policy

In order to assist the government in drafting S&T policies, NARLabs addresses important policy issues (such as Taiwan's S&T manpower and environmental sustainability, etc.), regularly issues reports analyzing forward-looking technology development trends in various countries, S&T development trends, and key areas where inputs are needed. NARLabs' S&T policy research helps the government promote advanced technologies and establish R&D information platforms that can ensure R&D resources are allocated and used in the most effective manner. NARLabs further established the "Policy Research Indicators Database," which collects survey statistics and competitiveness ranking information from over 200 countries. Regular reports on patent portfolio trends in Taiwan and its main competitors have helped improve domestic industry's intellectual property distribution and portfolios, equity investment and technology licensing, and the ability to combat rights infringements, while boosting the overall intellectual property and research capabilities of industry.

NARLabs hopes actively promote integration and services functions within the country's innovation system, while encouraging knowledge innovation and S&T development. NARLabs has completed reports and papers including a 5-10 year energy development vision planning report, a 5-10 year information and communications technology development vision planning report, overall analysis of patent trends and advantages in various countries, a report on US litigation strategies from the perspective of the HTC case, and research on development strategies for the innovation ecology.

The following is a summary of major R&D results at each center in 2014:

### 1. National Chip Implementation Center

#### (1) Establishment of a wireless sensor building block system platform

The "MorSensor" wireless sensor building blocks consist of a modular multilayer integrated sensing platform that can be used to combine various types of sensors, which can be used in conjunction with cell phone or PC apps to realize various sensor applications, and include both hardware and software. Appropriate MorSensor building block elements can be employed to incorporate sensors in various types

of sporting equipment, clothing, or accessories, and the versatile building blocks can be attached to surfaces made of different materials. The Chip Implementation Center's MorSensor wireless sensor building block system platform provides academic sensing element development teams with a means of quickly performing system integration and system demonstration. In addition, the MorSensor elements come with a hardware platform, software platform, complete set of experimental teaching materials, and technical consulting services. As a result, the MorSensor building blocks can readily serve as teaching materials and instructional aids in academic classes on embedded sensor system hardware and software and Android app development.



**MorSensor-wireless sensor building blocks**

#### (2) Bridge structural safety sensing node system

National Chip Implementation Center has implemented a disaster prevention bridge safety monitoring system R&D project in conjunction with the Executive Yuan's "Science and Technology Development and Implementation Program for Strengthening Disaster Prevention." This project, which is being conducted on a bridge across the Zhuoshui River, has completed the design, development, and production of a bridge structural safety sensing node system, including a bridge body sensing node system and an underwater sensing node system. The underwater sensing node system comprises a power module and core module; the system has a network exchange with a power supply, and control workstation programs access data from the underwater sensing node system. Testing and verification of the sensing node system has been completed, and it was installed on the Zhuoshui River Bridge at the end of 2014 to perform real-time monitoring.



**Underwater sensing node system elements**

#### (3) Development of a 0.35 $\mu\text{m}$ multi-option CMOS MEMS process platform

This research has sought to integrate motion, environmental, and biomedical sensing applications, etc. in a single high-performance platform that can offer sensing functions needed by the future "Internet of Things" and intelligent living applications. As motion and posture sensing become increasingly mature, researchers have attempted to expand the scope of sensing applications to physiological and environmental attributes. Responding to the future need for low-power, miniature sensing systems combining motion, physiological, and environmental sensing capabilities, the Chip Implementation Center has developed a 0.35  $\mu\text{m}$  complementary metal oxidation semiconductor micro-electromechanical (CMOS MEMS) element process platform able to facilitate the integration of semiconductor circuit design, micro-electromechanical sensor structure, and gold and platinum electrode materials. This platform can enable even more sensing functions to be integrated in a single chip system, which will help realize the future Internet of Things and meet the needs of intelligent living.

#### (4) Establishment of a chip system design cloud environment

NAR Labs has established a chip system design cloud environment and has provided electronic design automation software needed to implement a cloud computing environment. Users do not need to purchase and maintain servers, and NAR Labs provides installation and maintenance manpower. Instead, users can perform chip system design, simulation, and verification directly in this cloud computing environment, which achieves sharing of the design environment, computing resources, and information security duties, and the system can quickly identify design problems and provide technical

consulting. Furthermore, designers' data, processes, and silicon intellectual property data are protected, and offsite backups are made. This is a highly secure and accessible chip system design operating environment.

#### (5) V-Band antenna two-dimensional field measurement measure service

Due to the rise of the mobile communications industry and rapid development of semiconductor process technology in recent years, portable communications products have become an inseparable part of people's lives. This has brought demand for ever-increasing wireless data transmission speeds, which has induced industrial and academic researchers to pursue 57-64 GHz commercial band circuits and product R&D. In view of the fact that antennas are indispensable elements of wireless communications devices, in order to provide a comprehensive wireless communications chip R&D environment, the Chip Implementation Center has completed development of a 50-72 GHz band V-band antenna two-dimensional radiation field measurement system and related technology. This system, which incorporates antenna theory, mechanical design, and electrical control and measurement programs, can effectively boost the wireless communications R&D capabilities of academic researchers.

## 2. Instrument Technology Research Center

### (1) Autonomous production of optical elements for semiconductor equipment

The Instrument Technology Research Center (ITRC) has developed new optical elements needed in wafer positioning platforms on semiconductor lithography equipment, and these elements meet accurate positioning requirements and overcome the problem of deformation when optical elements are subject to heat. The Zerodur reference mirror and i-line glass lens completed at ITRC can be used in measurements involving precision positioning platforms in semiconductor equipment and in the illumination and projection lens system of semiconductor lithography equipment. ITRC has also completed an elevation pin with surface roughness of less than 30 nm for use in wafer transport devices; this pin has passed verification by semiconductor process equipment manufacturers, and ITRC continues to provide small batch production service. In addition, ITRC has completed development of a quartz light guide rod that boosts the current rectangular quartz rod production capacity from 250 mm to 450 mm. These quartz light guide rods will be

used in a lithography illumination system developed in-house. The foregoing four R&D results all involve key precision optical elements used in semiconductor process equipment, and will increase opportunities for the manufacture of localized semiconductor equipment in Taiwan.

### (2) Hyperspectral imaging technology earns international recognition

In 2014, ITRC joined forces with National Cheng Kung University and the Australian Water Quality Centre to use the underwater hyperspectral imager developed at ITRC in performing monitoring and management of the underwater environment. In May of 2014, ITRC was invited to participate in an inaugural ceremony at Saint Vincent Bay, South Australia, where the first trial of the underwater hyperspectral imager in Australia was performed. A successful case of domestic scientific diplomacy, the project received coverage on Australian TV, and was also the subject of a press conference after the team returned to Taiwan. The R&D team has obtained further funding from Australia, and plans to conduct an underwater seagrass observation project in the future as part of its plans to apply this technology to the detection and assessment of environmental changes, and implementation of restoration work.



Underwater hyperspectral imager

### (3) A high-resolution automatic optical chip defect inspection system for LEDs

Demand for automated inspection equipment able to boost QC and production performance, while cutting costs, has kept pace with the continuing miniaturization of semiconductor products. This optical defect inspection platform and technology developed at ITRC possesses high-resolution inspection and measurement capabilities needed by the semiconductor industry, and offers spatial resolution ( $1.83 \mu\text{m}$ ) and field of view ( $4.2 \times 2.8 \text{ mm}$ )

better than similar inspection systems currently on the market (3-5  $\mu$  m resolution), while also providing superior precision and lower cost. The inspection system can be used to check the surface of either wafer-form or chip-form LEDs for electrode defects and edge defects, etc. At present, ITRC is continuing to improve its prototype system, and expects the system to be able to complete defect inspection of a 4" LED wafer within 20 min. in the future. The system is expected to replace current manual inspection methods, and significantly boost the competitiveness of Taiwan's LED industry.

#### (4) Assistance to biomedical technology research teams

During 2014, ITRC's "Career Technology R&D and Verification" project sought to boost academic researchers' translational capabilities and promote the establishment of startups through the establishment of an integrated biotech incubation service platform; this project has achieved the following results:

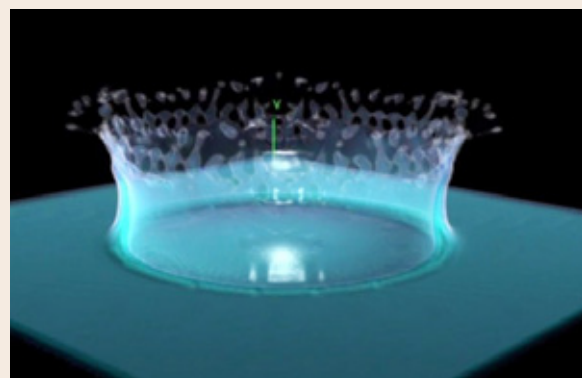
- a. In-depth assessment and selection of cases: In conjunction with MOST's incubation program, this project provided milestone funding support, sought to uncover promising cases meeting clinical needs, performed in-depth assessment and review, and strengthened attention to business models and patent links. Of the 30 cases accepted during 2014, it was recommended that eight selected cases apply for funding, and these cases subsequently received assistance from project managers and experts in an effort to speed up the commercialization of R&D results.
- b. Team incubation assistance: Seven teams received incubation assistance during 2014, and the two team "Customized Devices for Dental Implant, Oral and Maxillofacial Reconstruction Surgery" and "A Novel Neural Conduit" established startups with assistance from the project. It is also expected that the team "A Disposable Marrow Cavity Steel Pin Remote Tapped Hole Positioning Devices" will establish a startup in the near future.

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

#### (1) Simulation of 3D special effects and cloud rendering

The technological upgrading of the National Center for High-Performance Computing's (NCHC) Cloud Render Farm allows remote users to directly browse the computing nodes of the Cloud Render Farm's graphic processing unit (GPU) via a prototype cloud desktop system, and manipulate complex 3D

software operating procedures, which shortens the animation process. Furthermore, the completion of GPU-accelerated milkcrown simulation processes allows accelerated simulation of the splashing water droplets that form when a falling drop hits the water surface. This technology allows performance of from 3.2 to 5.5 times that of the CPU, and was selected for presentation at the 2014 SIGGRAPH Asia conference. In the future, the technology will be applied to the production of visual special effects involving splashing water.



**Cloud Render Farm technology results:  
GPU-accelerated milkcrown simulation**

#### (2) TWAREN management and development of SDN technology

NCHC manages the Taiwan Advanced Research and Education Network (TWAREN), and develops relevant network management methods and technologies needed to ensure high network availability. Seven new network management functions were added in 2014, including log quantitative trend statistics, flow trend charts, network one-way packet loss monitoring, domestic and foreign router monitoring and positioning, optical network real-time warning system, network flow on-demand online real-time filtering system, network equipment viability and DC power load monitoring, and a flow information on-demand sharing platform. As for software defined network (SDN) technology, NCHC has completed planning and deployment of an SDN dynamic virtual network service, and has developed the "SDN-supported cross-domain virtual machine migration method," for which ROC and US patent applications have been made.

#### (3) Big data image identification and analysis technology

The age of big data has arrived, and NCHC has developed big data image identification technology

that can facilitate big data image processing and analysis. This technology can be used in monitoring rivers, bridges, and reservoir water levels nationwide, can determine water level height and the extent of underwater areas, and can judge which areas may experience flooding on the basis of automatically-calculated areas of inundation. The system's current accuracy is approximately 85%. At present, NCHC is cooperating with the Water Resources Agency, MOEA in the development of a system that can process over 200 monitoring images simultaneously, and expects the system to be able to automatically monitor images from over 1,000 cameras in the future. This technology can also be applied to inspection of rebar, and allows users to remotely assess rebar quantities with an accuracy of 99%. The technology can further be used to estimate the number of people in dense crowds.

#### (4) Biomedical database and analysis platform

NCHC has integrated high-performance networking, computing, storage, and analytical software and databases in the development of a fruit fly brain neural gene database and new-generation sequencing data platform. These systems will help scientists extract phenotype-linked groups of genes with biological significance from huge bodies of data, and find key biological pathways and disease-causing mechanisms. The fruit fly brain neural gene database has preliminarily established nearly 4,000 items of genetic data, and will allow scientists to analyze the topology of the fruit fly brain. For its part, the new-generation sequencing data platform is providing human gene sequencing data storage and computing services to over 56 laboratories, and contains more than 160 TB of genetic data. In a major research breakthrough, a domestic team has used the platform to discover that the gene *DUNQU1* can serve as a biological marker of liver cancer, and can be used as a drug target. It is expected that this platform will facilitate the development of individualized medicine in Taiwan, and will expedite the development of testing and diagnostic reagents.

#### (5) Establishment of the Earth Science Observation Knowledgebase

NCHC has created Taiwan's first petabit-class earth science database (the "Earth Science Observation Knowledgebase," ESOK), which contains observation results extending from space and the atmosphere to the sea and the interior of the earth. Apart from safely preserving hard-won observational data in one unified earth science database, ESOK also relies on high-performance computing resources

and big data analytical techniques to offer integrated database services. Data is currently being input into ESOK at a rate of 100 TB annually, and it can process more than 18,000 high-frequency data items per second. And thanks to NCHC's integration measures, the database can enable users to make diachronic, cross-field, cross-spatial, and cross-event queries. Apart from assisting in natural disaster management, the database will also facilitate environmental and ecological sustainability research.



**ESOK—The first petabit-class earth science database in Taiwan (the photo shows use of the database to query geological exploration and marine buoy data).**

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

#### (1) A lightweight composite transportable bridge for disaster relief

Natural disasters such as typhoons, flooding, and earthquakes pose severe threats to the lives and property of the people of Taiwan. For instance, the flooding and debris flow that occurred on August 8, 2009 caused the destruction or severe damage of more than 100 bridges, which cut off numerous mountain communities from the outside world and prevented emergency disaster relief supplies and personnel from reaching these areas. In this type of situation, the "lightweight composite material transportable bridge for emergency disaster relief" can enable quick emergency access and relief, and allows a bridge that can be used by people, cars, and motorcycles to be installed within the shortest possible time. As a result, this transportable bridge can facilitate evacuation operations, enable the transport of foodstuffs to stricken areas, and minimize loss of life and property losses by allowing rescue personnel to take advantage of the golden period for relief work after a disaster strikes.

By combining the great strength and light weight of glass fiber reinforced composite material with the structural features of an asymmetrical cable-stayed bridge, this technology overcomes the time restrictions imposed in the past by the use of temporary roadways made from concrete pipes (which often take from 3 days to a week for construction) and temporary steel bridges (require approximately 1-3 weeks for installation). In contrast, this transportable bridge can be assembled within 8 hours, and possesses the advantages as follows— (a) quick assembly, (b) being used by residents for self-rescue, and (c) reusability.



A lightweight composite transportable bridge for disaster relief

## (2) Establishment of a tsunami early warning system and disaster scenario database

In light of the great loss of life and economic losses caused by the tsunami that occurred after Japan's March 11, 2011 Tohoku earthquake, in conjunction with MOST's Program on Applying Science and Technology for Disaster Reduction, the National Center for Research on Earthquake Engineering (NCREE) implemented the Project for the Establishment of a Tsunami Early Warning System and Disaster Scenario Database from 2011 to 2014 in order to strengthen Taiwan's tsunami modeling technology and establish a tsunami early warning system. NCREE uses the Cornell Multi-grid Coupled Tsunami Model (COMCOT) to perform tsunami modeling and inundation potential analysis, and employs geographical information system technology to overlay various types of information.

As a result, NCREE can provide tsunami inundation potential maps and an early warning database. Apart from being able to provide tsunami inundation potential maps for coastal cities and

counties in order to facilitate the drafting of tsunami damage control plans, when a major earthquake has occurred and a tsunami is suspected, NCREE's systems can provide information including maximum wave height, degree and area of inundation, and average water depth expected in relevant parts of Taiwan if a tsunami actually strikes. In addition, the system can also suggest alert levels for various towns, townships, and districts, which will enable more efficient response and reduce deaths and injuries.

## (3) Drafting of seismic evaluation and reinforcement guidelines for hospital buildings

A hospital designated to respond after a major earthquake must be able to provide emergency medical services. However, the experience from real earthquakes is that hospitals require seismic performance improvements addressing both their building structures and equipment if they are to provide emergency treatment and care to the large numbers of victims expected after an earthquake, and avoid the problem of some hospitals in the disaster zone needing to perform care outside, which happened in the wake of the 921 earthquake of September 21, 1999. The results of this study can provide the Ministry of Health and Welfare, hospitals, and construction enterprises guidelines for seismic evaluation and reinforcement. The content of these guidelines integrates the results of mature seismic performance evaluation and reinforcing research, and includes seismic performance improvement techniques for hospital buildings and important equipment. NCREE has also conducted a demonstration evaluation and reinforcement projects to show how to achieve the guidelines' recommended hospital structural seismic resistance goals.

## 5. National Nano Device Laboratories

### (1) Self-powered chips for the Internet of Things

It is projected that more than 2.6 billion chips specifically for the "Internet of Things" (IoTs) will be needed by 2020, and these chips will require multiple functions, low manufacturing costs, and the ability to spend much time on standby. Because of this, the National Nano Device Laboratories (NDL) has proposed low power consumption monolithic 3D-IC Epi-like transistors with heterogeneous integration, low production costs, and low power consumption. By stacking low-operating-voltage memory with SiGeC thin film ambient solar energy harvesters. The resulting low-cost, high-performance, batteryless integrated 3D-IC chips meet the requirement that Internet of Things chips remain on standby for prolonged periods in order

to remain ready for occasional use.

#### (2) Application of Sub-10 nm 2D electronic channel materials to 3D FETs

Today's advanced semiconductor production technology has already made the leap from planar elements to three-dimensional elements with varied gate structures. In order to keep up with the steadily-shrinking dimensions forecast by Moore's Law, the sub-10 nm elements of the future will inevitably incorporate materials with even faster channels. After successfully developing "double-fin FinFETs" in 2013, NDL recently incorporated novel high-speed 2D electronic materials in 3D field effect transistors (FETs). NDL's newly developed mixed-layer channel transistors produced from molybdenum disulfide on a silicon substrate are the first elements of their kind to achieve N-type/P-type complementary symmetrical operation in low-voltage operation, and they pave the way for the production of 2D N-type elements with driver currents in excess of 25%.

#### (3) Novel junction-less field-effect transistors

Junction-less transistors employ the simple concept of resistance, which is similar to when water cannot pass through a pinched hose, and use one gate to control the density of electrons or holes, which allows control of the transistor current. These transistors have an extremely simple structure, and are like tubes that can be pinched shut to stop the flow of water. And since this type of structure is easy to produce at even a nanometer scale, the transistors will be less expensive to manufacture than elements made with today's increasingly complex interface manufacturing technology. Furthermore, unlike conventional transistors, they have no current leakage, and they also offer the advantages of shorter response time and lower power consumption. However, as their size continues to shrink, junction-less transistors still face problems common to all nanometer elements, including doping instability and the short channel effect. NDL has recently developed a junction-less transistor with a novel structure. In this transistor, use of diffusion to achieve an ultra-shallow doping distribution ensures that the dopants are distributed solely on the channel surface. This design concept causes the flow of electrons to be concentrated on the outer ring channel; the design can eliminate the switching function and doping instability problems afflicting conventional junction-less transistors.

#### (4) A Si-based IR photodetector

NDL recently joined forces with the Graduate Institute of Materials Science, National Taiwan

University in using NDL's 6" process to develop a low-cost Si-based infrared photodetector that is compatible with current semiconductor processes. Not only has this result successfully overcome the difficulty of using silicon-based materials in long-wavelength optical communications, it also avoids the high cost and complex processes entailed by the use of III-V family elements. The team's research has achieved the tangible realization of academic element design concepts, and has successfully produced relevant elements using a pure silicon process for the first time in Taiwan. Compared with the efforts of other research teams worldwide, the project team has succeeded in enhancing conversion efficiency by a factor of several hundred, while also reducing process difficulty. As a result, this breakthrough could potentially change Taiwan's existing industry structure. Relevant R&D results have been published in the prominent international journal *Nature Communications*.

#### (5) 3 nm<sup>2</sup> ultra-low-power resistive memory elements

NDL has used atomic layer deposition, a sputtering system, and etching technology to successfully produce resistive memory elements for upper and lower electrodes that are smaller than 3 nm and 1 nm. These memory elements are small enough to display atomic-level properties. Compared with similar memory elements in the literature, this element is even smaller, and has a key dimension of only 3 nm<sup>2</sup>. When operated with different applied voltages, the element can emulate the state of resistance in four different elements, and can thus achieve several times the memory storage density of a standard multi-level cell (MLC). The research report "Utilizing Sub-5 nm Sidewall Electrode Technology for Atomic-Scale Resistive Memory Fabrication" was issued at the prestigious Symposium on VLSI Technology 2014, which was held in Honolulu on June 9, 2014.

#### (6) Flexible silicon thin film solar cells with a three-dimensional nanometer structure

Because solar cells convert sunlight directly into electrical power, they are the form of renewable energy that can be most easily used in everyday life applications. An R&D team at NDL used low thermal budget, high-quality film technology and heterogeneous integration capabilities in partnership with a team from Hong Kong University of Science and Technology, which contributed a flexible substrate with a light-capturing nanometer structure, to successfully develop a flexible silicon thin film solar

cells with a three-dimensional nanometer structure. The solar cells developed in this project offer the advantages of low materials costs, light weight, ease of manufacturing in large-area units, and flexibility. It is therefore expected that solar cells of this type will become an important new option for the solar energy industry; the results of this project have been published in the leading international journal *Scientific Reports*.

#### (7) Forward-looking high-frequency measurement applications and services

NDL and a team from National Taiwan University cooperatively developed and assembled a new low-noise amplifier for use in a neutrino detection project. The ARA (Askaryan Radio Array) is a large multinational high-energy physics project observing electron showers caused by neutrinos, and began collecting data using six detectors located below the Antarctic icecap starting in 2012. Three of the ARA detectors used the new amplifier developed in Taiwan. In addition, the ANITA-III (Antarctic Impulsive Transient Antenna) project is using high-altitude balloons to detect neutrino events. The third balloon launch, which was conducted in December 2014, employed 36 detectors using the new amplifier, and the balloon is expected to circle Antarctica for roughly two months. The next stage of the project will make full-scale use of the amplifier.



The ANITA-III detector is prepared for launch

## 6. National Laboratory Animal Center

### (1) Establishment of CRISPR/Cas genome editing technology accelerates new drug development

In the wave of new drug that is taking place throughout the world, genetically-modified rodents

play a key role linking biomedical R&D results with clinical drug development. How to quickly produce appropriate genetically-modified rodents and thereby accelerate the preclinical testing process has thus become an important part of new biomedical drug development efforts worldwide. While rats are the rodents most commonly used in preclinical testing, technological bottlenecks often prevented the development of genetically-modified rats in the past, and forced research organizations and pharmaceutical firms to conduct testing with genetically-modified mice.

The National Laboratory Animal Center (NLAC) has now established a CRISPR/Cas (clustered regularly interspaced short palindromic repeats and CRISPR-associated nuclease system) technique that promises to speed up the genome editing process, and has also mastered technically-challenging "rat pronuclear microinjection." These methods will not only allow the rapid production of genetically-modified transgenic rats, but also greatly improve testing efficiency and precision by overcoming barriers to the production of rats for use in drug experiments. Finally, this breakthrough also enhances the welfare of animals by reducing the number of animals needed to one-third or one-fourth of the original amount. NLAC's ultra-fast, money-saving CRISPR/Cas gene knockout mouse and rat production service can quickly produce genetically-modified rats and mice needed by researchers in Taiwan, and it hopes that its autonomous development of model animals for use in pharmacokinetics research will accelerate the development of new biomedical drugs in Taiwan.

### (2) Aged mice—A new and powerful tool for researching degenerative diseases

Taiwan's demographic structure has been changing in the wake of contemporary social development and the improvement of technology and medicine. Due to lower birth and death rates, and a longer average lifespan, the elderly population has increased sharply, and an aging society has emerged. And because aging often results in degenerative diseases caused by a gradual decline in bodily functions, researchers in academia and industry are increasingly focusing their attention on geriatric medicine. Laboratory mice with various forms of organ degeneration and tumors characteristic of aging provide excellent models of human diseases, and are used in research on hypertension, diabetes, nephrotic syndrome, chronic liver disease, cirrhosis, bronchitis, and emphysema. Naturally aged C57BL/6Jnar1 mice

with ages of from 12 to 24 months provided by the NLAC can be used in research on geriatric medicine, methods of delaying aging, and degenerative diseases. NLAC has also established an aged mice database that gathers information on the behavior of aged mice, pathological phenotypes, central nervous system gene expression, intestinal flora, metabolomics, immunology, bone density, blood stem cells, and reproductive ability (sperm quality), etc. This database is an important reference for researchers and will meet the needs of research and development on aging.

### (3) Development of gene targeted mice with high technical difficulty

In 2013, NLAC relied on its high-efficiency genetic modification technology to successfully gain entry to the International Mouse Phenotyping Consortium (IMPC), and it has continued to engage in cooperation with top-notch international research teams. Assuming the mission of overcoming technological bottlenecks, during 2014, NLAC developed 20 gene targeted mice that are urgently needed and pose great technical challenges. These mice have genetic characteristics associated with cardiovascular disease, tumors, neural disorders, and developmental and visual defects. Responding to developmental needs, NLAC has isolated high-quality embryonic stem cells from the commonly used C57BL/6N mouse strain, and has also developed blastocyst injection host from albino mice expressing green fluorescent protein. Gene targeted mice can be quickly selected on the basis of expression of the fluorescent protein, which will not only shorten the subsequent selective breeding process, and reduce animal use, but also overcome difficulties in the production of the most technically-challenging gene targeted mice. By gradually developing gene targeted mice that other laboratories worldwide cannot, NLAC will show the world Taiwan's ability.

### (4) Development of animal models with eight types of surgically induced diseases

Preclinical testing in Taiwan, including new drug development and drug target selection, urgently needs appropriate disease animal models in order to better transfer upstream R&D results to industry. NLAC has established four major animal model systems encompassing the areas of reproduction, urinary metabolism, the endocrine system, and immunity, and including surgically-induced disease models achieved via the eight procedures of castration, vasectomy, ovariectomy, ovariectomy & hysterectomy, unilateral

nephrectomy, 5/6 nephrectomy, adrenalectomy, and splenectomy. These animal models can be used in research on sexual disorders, osteoporosis, reproductive physiology and pathology, chronic kidney failure, metabolic disorders, and immunology.

### (5) Participation in the NARLabs Medical Materials Value Creation Alliance

NARLabs has established the "NARLabs Medical Materials Value Creation Alliance" in order to meet the needs of R&D teams engaged in the development of medical materials. This alliance bears responsibility for bridging the gap between upstream biomedical R&D and the downstream medical equipment industry, and is establishing Taiwan's most complete interagency support system (encompassing the Ministry of Science and Technology, Ministry of Economic Affairs, Council of Agriculture, and Ministry of Health and Welfare). In the alliance, the Instrument Technology Research Center, Science & Technology Policy Research and Information Center, and National Laboratory Animal Center play key roles in coordination/prototype production specifications and functional verification, accumulation of R&D capabilities and incubation, and preclinical animal experiments. The alliance will harness the service capabilities of industry, government, academia, and the research community, and link technological resources in the three major medical materials-related areas of medical electronics, polymer materials, and metallic materials. The division of labor and integration of the 20 alliance members will help shepherd the products developed by entrepreneurial teams from the innovation stage to the value creation stage, and significantly boost the output of the medical equipment industry.

## 7. National Space Organization

### (1) Assembly and testing of the FORMOSAT-5 satellite's optical remote sensing instrument

The National Space Organization's (NSO) FORMOSAT-5 optical remote sensing instrument consists of three subsystems: a telescope, electronic unit, and a CMOS-type focal plane assembly (FPA). The telescope was completed and calibrated in 2014. The electronic unit employs high-capacity, high-density, stacked memory to reduce volume and weight, and has passed image compression ratio and system testing. The world's first CMOS-type FPA, which includes a panchromatic capability and four multispectral chips, has now passed demanding functional and reliability (service life) testing, and

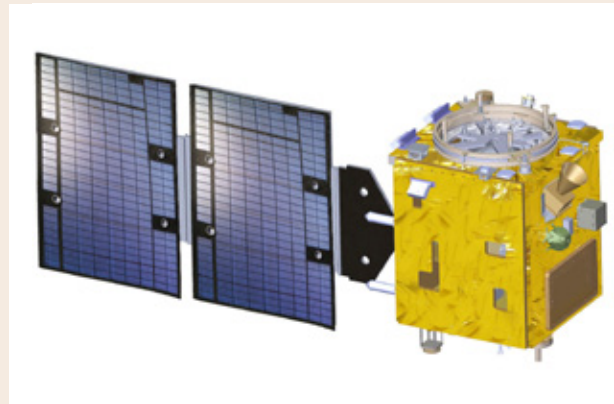
vacuum chamber integrated testing of the electronic unit and CMOS-type FPA has also been completed.

## (2) Creating the ionospheric probe with the world's highest resolution

The advanced ionospheric probe, which forms part of the scientific payload of the NSO's FORMOSAT-5 satellite, will, for the first time, measure multiple characteristics of the ionospheric plasma, including composition, density, velocity of movement, and temperature, using a single probe. In comparison with other countries' instruments, the advanced ionospheric probe developed autonomously by National Central University can employ a maximum sampling rate of 8,192 samples/second to measure the fine structure of plasma irregularities with a spatial resolution of centimeters, as opposed to the prevailing meter-grade resolution. It is expected that this instrument will yield major breakthroughs in research on the characteristics of plasma irregularities in the ionosphere. This instrument has already passed flight testing on the sounding rocket Tankong-9, and its measurement modes and functions meet requirements prior to implementing its scientific mission on the FORMOSAT-5.

## (3) FORMOSAT-7 satellite enters detailed design stage

The goal of NSO's FORMOSAT-7 autonomous satellite development program is to increase the reliability of the FORMOSAT-7's mission systems, and enable them to serve as key technology verification platforms, as well as inheritance design platforms for the National Space Organization's future small satellites (300-kg grade). The spacecraft bus completed preliminary design review and entered the detailed design stage in 2014, and design integrity and compatibility of the payload and ground system interface have been confirmed. Key satellite elements developed and produced in Taiwan include the satellite computer, power control element, fiber-optic gyroscope, navigation receiver, propulsion verification module, and satellite structure, all of which have completed detailed design and entered the hardware and software development and testing stage. Furthermore, the science payload (GNSS-Reflection), which is also being developed in Taiwan, has completed development planning and determination of payload specifications; software development and hardware production will be performed during 2015.



**The Taiwan-developed FORMOSAT-7 satellite**

## (4) Successful flight test of the Tankong-10 sounding rocket

The NSO's Tankong-10 scientific mission began at 11:10 a.m. on October 7 with the launch of the sounding rocket from the Jiupeng launch site in Pingtung County. While passing through the upper atmosphere at altitudes of between 90 and 286 kilometers, instruments on board the rocket measured changes in the coupling of the ionosphere and thermosphere. The Tankong-10 carried a science payload consisting of six ionosphere measurement instruments, and was the first domestically-developed rocket roll control mechanism. The science payload measured data on neutral particles, ions, electrons, and magnetic fields along the rocket's path; this data can be used to verify the accuracy of atmospheric data obtained by the FORMOSAT-3 and -7 satellites. In addition, the rocket's roll control mechanism reduced and precisely controlled the rocket's roll rate speed by altering its rotational inertia, and ensured that the rocket accommodated the science payload's measurement requirements.

## (5) Development of a spherical grating for a space-grade hyper-spectrometer

NSO and National Taiwan University of Science and Technology have jointly completed development of a spherical grating that will comprise a key light-splitting element in a space-grade hyper-spectrometer. This grating has a wavelength range that includes visible light, near infrared, and short-wave infrared. The grating development project—

the first of its kind in Taiwan—also facilitated the establishment of optical design simulation and aberration reduction optimization capabilities. The resulting grating has a spectral resolution of less than 3 nm, which is better than the current prevailing hyper-spectral resolution (NASA~10 nm). In addition, the grating has an efficiency of as high as 70%, which is far better than that of existing gratings on the international market and gives the grating international competitiveness. Apart from use in airborne/satellite-borne hyper-spectrometers, the grating also promises to have industrial applications, such as in optical communications and biomedical optoelectronics.

#### (6) The 10<sup>th</sup> Anniversary Results Announcement Conference for the FORMOSAT-2 Satellite

The FORMOSAT-2—Taiwan's first remote sensing satellite—was successfully launched on May 21, 2004. The satellite has made more than 50,000 orbits of the Earth, since it launched 10 years ago, and has imaged a cumulative area roughly equivalent to 30,000 times the area of Taiwan, or approximately seven times the Earth's land area. In order to thank various domestic and foreign parties for their support and assistance, NSO held the "FORMOSAT-2 10<sup>th</sup> Anniversary Results Announcement Conference" at the international conference center of NTU Hospital on May 21, 2014. The heads of domestic and foreign disaster relief organizations including the Tzu Chi Foundation, UN Operational Satellite Applications Programme, and Japan's Sentinel Asia, JAXA, were invited to this event, along with domestic and foreign users and experts. The participants gave very productive presentations concerning results in such areas as application of FORMOSAT-2 images to scientific research, disaster relief, agricultural crops, technological diplomacy, elementary and middle school education, and

environmental monitoring. In addition, the conference also announced the issuance of "Beneath the Vault of Heaven," which contains collected images taken by the FORMOSAT-2 satellite, and the images from the FORMOSAT-2 caused participants to ponder the issues of sustainability and coexistence.

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

#### (1) Strengthen technology manpower and research results service platform

Apart from continuing to collect manpower information for different fields and provide personal information management services, the Science & Technology Policy Research and Information Center's (STPI) National Profiles of Human Resources in Science and Technology (NPHRST) also integrated information on published works and performed value-adding analysis in 2014, and introduced "research history," "statistical resource website," and "NPHRST bulletin" services. In addition, NPHRST performed a first-ever Ph.D. employment survey, which elicited an enthusiastic response. Looking ahead to the future, NPHRST will implement surveys concerning Ph.D.-related issues, continue to perform value-adding analysis of data, and provide various types of statistical information, and a new knowledge notification service, to high-level manpower and persons concerned with the human resources situation throughout domestic industry, government, academia, and the research community.

#### (2) The Research Portal

The Research Portal (<http://portal.stpi.narl.org.tw/>) showcases STPI's S&T policy research results, and presents STPI's observations concerning important scientific research issues and the perspectives of research personnel. Through exploration of issues and links to resources, STPI seeks to help citizens gain a better understanding of national S&T policies and development directions, and it also hopes to increase the influence of its S&T policy think tank. The Research Portal aims its services at all citizens who are concerned about Taiwan's S&T development and S&T policy directions. Because of this, the Research Portal also offers value-added information cards concerning important terms and specific people and things often encountered in research papers, and hopes that this will help various types of readers quickly absorb background information as they read, and also find relevant online resources. In the future, the Research Portal will continue to expand its content and



A group photo of participants at the FORMOSAT-2 10<sup>th</sup> Anniversary Results Announcement Conference

services, and rich citizens' awareness and knowledge of domestic and foreign S&T activities, and help government promote the country's S&T development.

### (3) Establishment of scientific research topic selection processes and mechanisms

STPI relies on observation and analysis of trends in the external environment to implement demand-oriented forward-looking analysis aimed at uncovering future S&T development trends and directions in important fields. STPI also relies on expert opinions and evidence-based data analysis to help government agencies establish mechanisms and processes for the selection of important S&T topics. This year, STPI has helped MOST to uncover global academic development focal points and future research hotspots in the areas of electronics, computers, and communications, electrical machinery, and chemicals & materials. STPI's preliminary recommended focal points include wide band gap semiconductors, sensors, and high value-added technologies for use of non-grain biomass resources. These focal areas of scientific research possess great potential application value for Taiwan's industries during the coming three to eight years.

### (4) Patent information services-building a bridge between S&T and industry

STPI relies on patent information to monitor the evolution of different technologies and regional information, and maintain an understanding of different industries, S&T development trends, and the state of competition. STPI has also realized that its systematic, structured collections of patent statistics and data have potential interpretive value outside the boundaries of science and technology. STPI's results in 2014 included general analysis of patent trends and advantages in various countries, comparative analysis of basic industrial energy capabilities, a preliminary study of technology and standards in the solar cell industry, dye-sensitized solar cell patent barriers and strategies for overcoming them, analysis of multimedia broadcast multicast service (MBMS) technology and standard essential patents, analysis of key technologies and patents for intelligent wearable devices, examination of defensive and offensive strategies with regard to specific arguments in US patent litigation with reference to the HTC case, and analysis of the evolution of different versions of the 3GPP Beyond 4G wireless communications standards. STPI's Industrial Information Office e-Bulletin currently has more than 28,600 subscribers, and STPI issued 920 information reports concerning patent intelligence and other topics throughout 2014.

### (5) Innovation ecosystem research and planning

In line with its mission of promoting research and development concerning innovation ecosystem operation and industry-academia collaboration innovation, the establishment of effective innovation system and legal environments, assisting S&T development governance, and drafting of innovation policies and planning of relevant mechanisms, STPI achieved the following major results in 2014: the completion of research reports including the "Innovation Ecosystem Development Strategies," "Legal System Research in order to Promote Taiwan's S&T Startup Development," and "Analysis of Policy Incentive Measures Encouraging Industry, Academia, and Research Organizations to Engage in Cooperation"; implementation of projects commissioned by MOST, including the "Promotion and Planning of Innovation Development in Science Parks," "Planning and Implementation of Measures to Strengthen Industry-Academia Collaboration and Innovation in Science Parks," and "2014 International Symposium on S&T Innovation and Entrepreneurship Policies and Legal Systems"; and provision of decision-making consulting and support to MOST concerning nearly ten major development programs (including program reports at meetings of the Executive Yuan).

### (6) International Symposium on S&T Innovation and Entrepreneurship Policies and Legal Systems

Although Taiwan's entrepreneurs possess boundless creativity and innovative spirit, and have won numerous international awards of all kinds, Taiwan has found it difficult to transform its entrepreneurs and innovators energies into new industries, which has impeded Taiwan's industrial transition. In order to review the restrictions and constraints on the entrepreneurial environment posed by Taiwan's current entrepreneurship policies and legal system, STPI joined forces with America's George Washington University in Canada's Ottawa University to hold the "2014 International Symposium on S&T Innovation and Entrepreneurship Policies and Legal Systems" on October 16-17, 2014. The main conclusions of the symposium, which provided a forum for recommendations concerning Taiwan's innovation policy environment from domestic and foreign think tanks, included the establishment of an innovative startup ecosystem, relaxation of restrictions on university instructors' participation in startups accompanied by the drafting of effective rules

to prevent conflicts of interest, and establishment of a legal environment eliminating obstacles to innovation. It is believed that these recommendations will help Taiwan draft sound S&T policies promoting entrepreneurship.

#### (7) A 4G LTE standard-essential patent database

Apart from exemplifying the continued evolution of communications technology, 4G will also provide a foundation for the Internet of Things, mobile cloud technology, and 5G technology. Companies worldwide are consequently devoting themselves to 4G R&D, and Taiwan's leading firms cannot ignore this trend. But in order to keep up with global 4G technology R&D progress, companies must step up efforts to acquire portfolios of so-called "standard-essential patents" (SEPs). SEPs refer to patents that must be used when manufacturers develop similar equipment. In the "Research Project on Telecommunications Industry Patent Trends and Patent Litigation Analysis," which has been conducted under commission to the Intellectual Property Office, MOEA, STPI has gradually assembled data on more than 3,000 4G LTE SEPs. In this project, several dozen experts and scientists read the patents, summarized their technical focal points, and noted technologies, effects, and product attributes, and uncovered the corresponding technical specifications. Relevant research results can be found online on the Intellectual Property Office's website: <https://tiponet.tipo.gov.tw/TipoMenu>. Domestic firms may freely download the results of this project for their reference.

### 9. Taiwan Ocean Research Institute

#### (1) Ocean radar observation and ocean prediction modeling—The Taiwan Ocean Predictive Modeling System

The Taiwan Ocean Research Institute (TORI) has relied on improved computing power and a theoretical basis consisting of hydrodynamics and oceanography to gradually develop ocean numerical modeling technology. Computer modeling can extend the spatial and temporal characteristics of data obtained from observation points and compensate for insufficient ocean observation data, which makes it a powerful tool for analyzing changes in the global characteristics of the sea. TORI's high-resolution ocean forecasting technology combines three-dimensional models of the sea and waves obtained via high-speed computation with data from an oceanographic observation database, data assimilation system, and value-added applications modules. This technology can be used to model and forecast currents, waves, storm

surges, and tsunamis in the waters around Taiwan. In conjunction with value-added applications technology involving marine data, TORI's technology can also be employed to maximize the value of ocean forecasting data in environmental conservation, emergency rescue, economic development, recreation, academic research, and disaster prevention and relief.

#### (2) Ocean radar observation and ocean prediction modeling—Taiwan Ocean Radar Observation System

The sea surface current observation system (TOROS) deployed by TORI provides constant, all-weather hourly surface current observation information for a large sea area. This major marine environment monitoring system will modernize the country's active promotion of its exclusive economic zone (EEZ). The system project began in 2009, and 15 individual systems have been completed thus far. It is expected that the establishment of a new monitoring system on Taiwan's Northeast Cape in early 2015 will preliminarily achieve the goal of complete observation of surface currents in all directions around Taiwan.

Starting from the third quarter of 2013, TORI implemented an 18-month TOROS system improvement project aimed at enhancing observation signal stability, correctness, and applicability. By the fourth quarter of 2014, the data output rate of 15 monitoring stations around Taiwan had been increased to more than 80%, and the surface current observation area had been expanded to over 124,896 square kilometers, which is equivalent to 3.47 times the size of Taiwan and 8% larger than before the improvement project.

In view of the fact that people are growing increasingly fond of spending their summer days enjoying ocean recreation, the current and ocean condition information provided by TORI's integrated ocean radar observation and ocean modeling platform can be provided to the competent authority for use as a reference in ocean recreation risk management. Taking the temporary experiment station at Xianan Bay as an example, a website featuring near real-time information allows the public to view ocean and environmental information including currents, waves, and wind strength. The project team has engaged in numerous discussions with Kenting National Park, the Coast Guard Administration, and local ocean recreation operators, and has revised the website's information presentation methods in order to improve the platform's value-added applications.

### (3) Use of a lidar wind profiler to perform wind field measurements

TORI uses a lidar wind profiler to study marine and inshore wind fields and the interaction between the ocean and atmosphere. This instrument can also be applied in the development of offshore wind power. TORI's lidar system consists of a second-generation WINDCUBE V2 instrument, which relies on the principle of Doppler frequency shifting of laser pulses to perform simultaneous high-resolution measurements at 12 heights within a three-dimensional wind field, and can measure wind speed, wind direction, and vertical wind speed up to a height of 290 m. While conventional mast observations require costly and time-consuming mast installation and maintenance work, lidar systems are easy to set up, and are as effective as mobile mast systems. Lidar wind profilers can be applied to wind field characteristic research, and can be used to analyze wind speed distribution characteristics within the range of wind turbine blades in a wind farm, and thus determine wind turbines' output power characteristics. A lidar system was successfully used this year to observe the wind field in a typhoon, and the data obtained in this way will help shed light on the near-ground wind field structure in typhoons, which will enable a better understanding of typhoons' environmental impact and ability to damage structures.

### (4) Operation of a bottom-moored sediment trap platform

Oceanographers current have very little observation data concerning conditions in the deep sea at depths of greater than 3,000 m. In order to effectively determine the effect of global changes on the marine environment, TORI maintains a deep-sea bottom-moored sediment trap observation platform at the South East Asia Time-Series Station (SEATS), which is responsible for long-term measurement and collection work involving sediment particles, currents, and hydrological parameters in major marine areas around Taiwan. The sediment trap resembles a large funnel deployed in the deep sea, and it stores sediment particles drifting down from above in a different bottle every eight days. The sediment bottles are recovered once each half-year, and a string of traps is then put out again to continuously capture sediment. The sediment particles mostly consist of the shells or skeletons of living organisms, atmospheric sediment particles, and particles derived by erosion from terrestrial sources, and they can be used to measure the flux of various types of matter, including

mass, organic and inorganic carbon and nitrogen, opal, aluminum, phosphorus, trace elements, carbon and nitrogen isotopes and radionuclides, and persistent organic pollutants. In general, the particles record the effect of climate change, human activity, and pollution on the ocean's ecological environment.

### (5) Investigation of marine geohazards in the Fangliao submarine canyon

In order to produce marine geohazard potential maps for the waters around Taiwan, a geology/geophysics team from TORI investigated the undersea morphology and deposits from the Gaoping Submarine Canyon to the Fangliao Submarine Canyon on two voyages. This was the first time that a domestic research vessel used a large undersea core sampler to take long piston cores. A careful examination of the resulting cores gradually shed light on marine geohazard incidents over the past millennium. A core sample of marine sediments 722 cm in length was brought to the surface from a depth of 1,022 m in the Fangliao Submarine Canyon. Researchers working in the core laboratory performed careful analysis of this rare and valuable core, and discovered the signs of 15 significant turbidity current events and several dozen laminar layers. The researchers concluded that the turbidity current layers were not the result of chance events; instead, they probably were the result of submarine landslides caused by sideslope instability or sediment liquefaction induced by environmental changes such as earthquakes.

Nevertheless, further investigation will be needed to determine whether this type of turbidity current event possesses periodicity, assess spatial and temporal variation in the occurrence of marine



Collection of piston sediment cores

geohazards around Taiwan, and appraise whether the geohazards are linked with terrestrial climate and other geological events.

#### (6) Remembering the Ocean Researcher V and looking ahead to the future

TORI's Ocean Researcher V oceanographic research vessel completed numerous important missions during its time in service. Apart from supporting academic research and participating in the country's marine energy exploration efforts, the Ocean Researcher V also undertook scientific surveys around the nation's marine frontiers, and achieved impressive results. This work included the collection of survey data concerning undersea topographic features and biodiversity research in waters around the Zhongsha Islands, on the continental shelf of the South China Sea, near Zengmu Reef, and at Zhenghe Reef. Other achievements included extraordinary underwater photographs taken near Zengmu Reef and the collection of core samples containing methane deposits from the waters to the southeast of Taiwan. Ocean Researcher V also compiled many records, including the successful deployment of a marine weather buoy at Nansha-Taiping Island—Taiwan's southernmost point—and the deepest hydrological measurements made by Taiwan (depths of 4,330 meters in the South China Sea and 5,800 meters in the Ryukyu Trench). During its short time in service, the vessel spent 417 days at sea and traveled a total of 95,723 kilometers (equivalent to 2.4 times the distance around the Earth at the equator); scientific personnel took part in research aboard the vessel a total of 1,291 person times, and collected 26,242 GB of data; and the vessel's most protracted voyage lasted 23 days, while its longest voyage took it a distance of 9,081 kilometers.

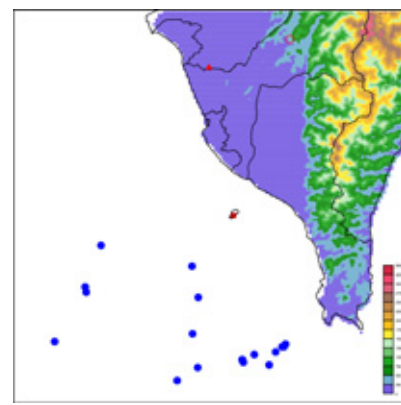
When the Ocean Researcher V was lost in an accident on October 10, 2014, the country's oceanographic survey capacity immediately suffered a severe blow. In order to quickly restore the nation's oceanographic research and exploration capabilities, the government has revised the "Ocean Researcher V Scientific Instrument Installation and Operation Plan," and TORI and MOST are jointly planning and promoting the nation's research fleet in accordance with the recommendations of MOST's December 11 report "Ocean Researcher V Incident Emergency Response Measures and Plan for Reconstruction of Taiwan's Research Vessel Capabilities," which calls for development of a future marine research fleet consisting of a mission-orientated assortment of 500-ton, 1,000-ton, 2,000-ton, and 3,000-ton research

vessels. Looking ahead to the future, TORI will refer to foreign research vessel operating models as it strives to improve its ship management mechanisms and voyage management. Beyond achieving maximum synergy from the oceanographic fleet and boosting vessel use efficiency, TORI also expects to consolidate its survey technologies and service capabilities in response to the needs of government and oceanographic researchers.

### 10. Taiwan Typhoon and Flood Research Institute

#### (1) Development of the Southwest Monsoon Atmospheric and Hydrological Integrated Observation Network

Faced with the challenges of global warming and climate change, industry, government, academia, and research units all need increasing amounts of intensive meteorological observation data. The Taiwan Typhoon and Flood Research Institute (TTFRI) has teamed up with relevant units to establish a joint observation team, and has integrated resources to conduct a large observation experiment, which has helped to improve students' observation abilities. The Southwesterlies Joint Observation Experiment, which was conducted from May 26 to June 13 in 2014 throughout southwestern Taiwan and offshore waters, implemented three series of intensive observations, which consisted of four sounding observations at fixed locations at certain times. The intensive observation work and data collection work in this project provided valuable information shedding light on the environmental characteristics shaping the southwestern monsoon, and deepening understanding of the nature and development process of mesoscale convective systems.



Locations of intensive ground-based and shipboard observation stations during the experimental period

(2) Installation of a precipitation research radar to measure rainfall in mountainous areas

TTFRI has installed an advanced dual polarization Doppler weather radar in Kaohsiung's Shanlin District. This radar unit can attain rainfall estimation accuracy at least 15% better than that of traditional radar, and can detect the development of rainfall systems in mountain areas at an even earlier times. The radar's observation range encompasses Tainan, Kaohsiung, and Pingtung; it will help researchers to analyze the causative factors and characteristics of local rainfall, and can thus enhance our ability to accurately estimate the amounts of torrential rain falling in mountainous areas. In the future, the real-time transmission of radar observation data to the Central Weather Bureau will enable better ability to prevent and mitigate natural disasters. The radar observation data can also help scientists to unravel the mechanisms triggering torrential rains, which will further their understanding of catastrophic meteorological conditions.

(3) Establishing an ensemble experiment platform to support typhoon-induced flooding early warning and response

TTFRI has joined forces with the Central Weather Bureau, National Science and Technology Center for Disaster Reduction, and academic researchers to develop a quantitative ensemble forecasting technology for rainfall, and project participants established the Taiwan Cooperative Precipitation Ensemble Forecast Experiment (TAPEX) with computing resources from the National Center for High-Performance Computing. TAPEX results for 2014 indicated that ensemble typhoon tracks are an effective means of forecasting the track of typhoons approaching Taiwan. In addition, TAPEX has also successfully forecast areas of heavy rainfall during Typhoon Matmo: the Hualien and Yilan areas of northern Taiwan and mountain areas in central and southern Taiwan. Ensemble members also yielded an appropriate rainfall signal for a heavy rainfall event occurring in southern Taiwan during early August 2014. Data from TAPEX has been provided to agencies with disaster prevention duties, including the Executive Yuan Office of Disaster Management; National Science and Technology Center for Disaster Reduction, Central Weather Bureau; Water Resources Agency, MOEA; Soil and Water Conservation Bureau; and Directorate General of Highways, for use in typhoon-induced flooding early warning and response actions.

(4) Non-contact flow observation technology R&D

TTFRI commonly uses acoustic Doppler velocity profilers (ADCPs) to observe river flow velocity and cross section information, and the resulting data can be used in conjunction with entropy theory to obtain the relationship between the surface flow velocity, cross section, and flow rate. The on-site use of surface velocity radar (SVR) to measure surface flow velocity further enables real-time estimation of cross section and flow during typhoons and torrential rain events. TTFRI has also developed a proprietary ADCP River Flow Analyzer (ARFA) with a graphic interface; this software can automatically process ADCP observation signals, boosting efficiency. The software was promoted at an ADCP workshop, and can enable hydrological personnel to conveniently perform flow observations and monitor the state of river hydrology.

(5) Acquisition of advanced weather radar data assimilation technology

Extremely short term quantitative rainfall forecasting information (0-6 hours) is very important early warning reference information in the event of flooding and landslides. In order to enhance the accuracy of its forecasting methods, TTFRI has acquired advanced foreign weather radar data assimilation technology, and has established a radar data assimilation system, which includes radar echo assimilation methods and different background field error covariant arrays. In addition, TTFRI has adjusted this system using specific local geographical conditions and radar observation restrictions; in conjunction with numerical meteorological forecasting models, the new system help provide more accurate extremely short-term high-resolution quantitative rainfall forecasts.

(6) Acquisition of a model for prediction across scales

TTFRI has acquired a model for prediction across scales (MPAS) used in high-resolution global atmospheric modeling from the United States' National Center for Atmospheric Research, and has performed localized use and long-period test forecasting. The model features an all-new grid framework that can simultaneously model meteorological phenomena including large-scale monsoons and mesoscale convection. TTFRI is currently using the MPAS system in typhoon and seasonal rainfall experiments, and is testing the system's localized modeling stability

and predictive ability. Preliminary results indicate that the system can provide effective forecasts of typhoons for periods of up to three days, and can also forecast Taiwan's spring rains. In the future, addressing

Taiwan's water resource planning needs, the system will be used in 5-10 day forecasts for reservoir watershed areas and spring rainfall forecasting applications R&D.



## Recruiting and Cultivating S&T Personnel

### A. Recruiting S&T Personnel

Scientific and technological personnel are the driving force behind S&T development and national progress, and all leading countries are therefore competing to recruit more S&T personnel. In order to strengthen research and development at academic research organizations and universities, MOST therefore employs generous subsidy measures to recruit outstanding domestic and foreign high-tech human resources. In order to establish conditions and an environment facilitating the recruiting of academic and S&T manpower, MOST not only assisted implementation of such relevant policies as the Executive Yuan's "Manpower Training Program" and "Integrated Cultivation, Retention, and Recruiting Program," but also employed the following subsidy measures during 2014:

#### 1. Effective mechanisms for recruiting S&T manpower

- (1) Establishment of bottom-up subsidy platforms for the recruiting of S&T manpower: MOST has drafted various subsidized recruiting measures, provides generous recruiting subsidies, and helps academic research organizations to recruit overseas technical manpower for work in Taiwan. For instance, in 2014, a total of 2,359 guest personnel and post-doctoral researchers were recruited to participate in S&T research projects, and 76 research scientists were recruited to implement major mid-/long-term research projects.
- (2) Assisting the professional development of post-doctoral researchers: In order to promote the careers of outstanding young post-doctoral researchers in Taiwan and train domestic academic and technical human resources, MOST has continued to provide stable research funding and independent research opportunities, and encourages early planning of research careers.

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

#### 2. Recruiting of special outstanding manpower and granting academic work awards to post-doctoral researchers

- (1) MOST promotes the *Subsidy Measures for the Recruiting of Special Outstanding Manpower by Universities* to provide funding support for the competitive recruiting of foreign elite S&T manpower by universities, and allow universities to formally incorporate recruited S&T personnel in their organization as full-time teaching and research personnel receiving monthly salaries. This will encourage outstanding international S&T personnel to accept employment in Taiwan, and will induce such persons to pursue long-term S&T research in Taiwan. A total of 32 applicant organizations obtained subsidies for this purpose in 2014.
- (2) MOST provides the Post-doctoral Researcher Academic Work Award in order to cultivate young, outstanding research manpower, 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 2014.

MOST-funded S&amp;T personnel recruiting statistics, 2010-2014

Units: person-times

| Item                   | 2010  | 2011  | 2012  | 2013  | 2014  |
|------------------------|-------|-------|-------|-------|-------|
| Guest personnel        | 190   | 179   | 134   | 133   | 136   |
| Post-doctoral research | 2,462 | 2,214 | 2,206 | 2,201 | 2,223 |
| Research scientists    | 103   | 86    | 82    | 59    | 76    |
| Total                  | 2,755 | 2,479 | 2,422 | 2,393 | 2,435 |

### B. Cultivating of S&T Personnel

In order to enhance 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 NSC—MOST's predecessor—has provided subsidies to S&T personnel wishing to study at foreign universities or perform research at foreign research organizations. Furthermore, responding to the recent drop in university and college students studying abroad, MOST has instituted the "Graduate Student Study Abroad Program" to encourage young outstanding Ph.D.-holders from Taiwan to engage in post-doctoral research overseas; this program provides funding to in-school Ph.D. students wishing to participate in 7-12 month short-term research and study programs at prominent foreign universities and research organizations.

MOST drafted the *Guidelines for Subsidies to Mission-oriented Teams Performing Overseas Study and Research* in 2012 in order to provide subsidies to teams of outstanding domestic individuals who wished to study key technologies urgently needed for Taiwan's future development, and train

R&D manpower in key total areas, at designated world-class overseas public or private research organizations. These subsidies have been issued 61 times since the program was initiated on a trial basis in 2010, and MOST provided such subsidies to 70 individuals in 22 teams studying or performing research at 14 organizations in five countries in 2014.

In addition, to encourage young persons of Taiwanese descent overseas to visit Taiwan and learn about the country's development, eight agencies (including MOST, Ministry of Foreign Affairs, Overseas Compatriot Affairs Commission, Department of Health, Environmental Protection Administration, Council of Agriculture, National Youth Commission, and the Academia Sinica), along with NARLabs and the Taiwan Foundation for Democracy, have jointly implemented the "Taiwan Tech Trek" program. This program sponsors summer trips to Taiwan by youths of Taiwanese ancestry living abroad in order to participate in internships at public and private organizations and enterprises. Ten sessions of the Taiwan Tech Trek have been implemented from 2005 to 2014, and a total of over 2,500 trainees have participated.

Manpower training statistics, 2010-2014

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 |                  |
| 2010 | 251  | 186                                   | 75                        | 268              |
| 2011 | 273  | 185                                   | 66                        | 254              |
| 2012 | 253  | 134                                   | 82                        | 298              |
| 2013 | 257  | 160                                   | 65                        | 289              |
| 2014 | 228  | 147                                   | 77                        | 276              |

## IV Research Awards

### A. MOST Awards

#### 1. Outstanding Research Award

MOST established the Outstanding Research Award in order to encourage S&T personnel with outstanding research results to engage in long-term academic or academic-industrial research, and thereby enhance the country's academic research standards and industrial technology R&D capabilities. Starting in 2014, the number of annual recipients of the Outstanding Research Award has been limited to 75, and the academic research (including a maximum of 4 interdisciplinary research projects) and industry-academic research categories are limited to 70 and 5 awards respectively. Apart from receiving a certificate from MOST, recipients receive an award of NT\$900,000. Recipients may receive this award up to three times; recipients who have received the Outstanding Research Award three times may, in accordance with relevant regulations, apply for specially-contracted research projects. A total of 72 persons received this award in 2014 (68 in the academic research category and 4 in the industry-academic research category).

#### 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. As a rule, the number of recipients is limited to 40 annually. Apart from receiving a medal and NT\$200,000 from MOST, award-winners who propose a multi-year (2-5 years) specific-topic research projects within six months after announcement of the list of award-winners will receive even more generous funding support. A total of 40 persons received this award in 2014.

Winners of this award and the Distinguished Research Fellow Award and Outstanding Research Award received their awards from the MOST minister at a research awards ceremony held on May 21, 2014.

#### 3. Technology transfer awards and incentive measures

- (1) Outstanding Technology Transfer Contribution Award: In order to recognize research personnel and research teams that have made significant contributions to the transfer of R&D results and achieved excellent performance, MOST grants public commendations and awards of up to a maximum of NT\$150,000, along with a medal to each individual, to selected outstanding research personnel and teams that have participated in technology transfer cases in which their organizations have received licensing fees and derivative benefits totaling more than NT\$1 million. A total of 13 persons in eight cases received this award in 2014.
- (2) Grants to superior technology transfer centers: Organizations implementing MOST-funded projects that have established dedicated technology transfer units, have completed five or more technology transfer cases within the most recent three years, and have earned actual income of at least NT\$1.5 million by means of technology licensing may apply to MOST for these grants. Following a performance assessment, MOST will select up to seven cases to receive grants of up to NT\$2 million each. Each project implementing organization may receive these grants up to five times. Three organizations received the grants in 2014.

### B. Other Awards

#### 1. Executive Yuan Outstanding Contribution in Science and Technology Award

The Executive Yuan drafted the *Implementation Guidelines for Recognition of Persons Making Outstanding Contributions in Science and Technology* and established the *Outstanding Achievement in Science and Technology Award* in order to recognize the country's outstanding scientists and engineers.

The award was renamed the "Executive Yuan Outstanding Contribution in Science and Technology Award" in 2006, at which time the relevant regulations were revised as the *Executive Yuan Outstanding Contribution in Science and Technology Award Implementation Regulations, Executive Yuan Outstanding Contribution in Science and Technology Award Review Committee Establishment Regulations, and National Science Council, Executive Yuan Selection Operating Guidelines for the Executive Yuan Outstanding Contribution in Science and Technology Award*, 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 work in the natural sciences, engineering, biology/medicine/agriculture, or the humanities and social sciences whose R&D results lead to outstanding inventions or innovations, and thereby make significant, groundbreaking, and original contributions to society may be nominated to receive this award. After experts and scholars engaged by MOST perform a preliminary assessment, a review committee consisting of the heads of government agencies, schools, and academic research organizations, plus experts and scholars affiliated with these units, performs a review, and the results are forwarded to the Executive Yuan for approval and conferral of awards.

In 2014, 36 nominations were received for the Executive Yuan Outstanding Contribution in Science

and Technology Award, and the award was granted to two persons following a selection process. The winners were Prof. Chou Ming-chi, in the field of natural science, and Prof. Tsai Ming-chi, in the field of engineering. The Executive Yuan held the awards ceremony on December 23, 2014.

## 2. Presidential Science Prize

In order to enhance Taiwan's international academic standing and encourage scientists who have made innovations or contributions in international academic research on mathematics, the natural sciences, life sciences, social sciences, and applied science, MOST has conducted the Presidential Science Prize selection process since 2001. The Presidential Science Prize is the nation's highest honor for scientific research, and is granted once every two years. Winners of this award receive a trophy, certificate, and NT\$2 million in prize money. In 2013, three persons were chosen to receive this award, namely Academia Sinica fellow Peng Hsuing in the mathematics and natural science section, Academia Sinica fellow Lai Ming-chao in the life sciences section, and Dr. Lu Chih-yuan, general manager of Macronix, in the applied science section. The Presidential Science Prize ceremony was held in the Office of the President on December 5, 2013. Nominations were accepted during 2014, and award winners will be selected in 2015.

### Research awards, 2010-2014

| Item  | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|------|------|------|------|------|
| Outstanding Research Award (persons)  | 89   | 74   | 73   | 72   | 72   |
| Ta-You Wu Memorial Award (persons)  | 40   | 40   | 40   | 40   | 40   |
| Executive Yuan Outstanding Contribution in Science and Technology Award (persons) | 2    | 6    | 1    | 4    | 2    |
| Presidential Science Prize (persons)  | --   | 2    | --   | 3    | --   |



At the Executive Yuan Outstanding Contribution in Science and Technology Award ceremony held on December 23, 2014, Premier Mao Chih-kuo (4<sup>th</sup> from left) is shown with then MOST Minister and Vice Premier Chang Shan-cheng (2<sup>nd</sup> from right), MOST Political Vice Minister Chien Tzung-liang (1<sup>st</sup> on left), MOST Administrative Vice Minister Chen Teh-hsin (1<sup>st</sup> on right), and the two winners of the Executive Yuan Outstanding Contribution in Science and Technology Award: Prof. Chou Ming-chi, in the field of natural science, and wife, and Prof. Tsai Ming-chi, in the field of engineering, and wife (3<sup>rd</sup> from left and 4<sup>th</sup> from right).

## V

## International Cooperation in Science and Technology

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

### A. Bilateral S&T Cooperation

In order to strengthen bilateral collaborative relationships and establish bilateral platforms for S&T interchange, MOST has stepped up the signing of scientific and technical cooperation agreements and MOUs with foreign science and technology agencies and research organizations, and is also strengthening outreach to new partners and potential areas of cooperation. A total of 111 cooperation agreements, MOUs, and other cooperation documents had been signed with 43 countries and three international organizations as of the end of 2014.

MOST signed the following bilateral S&T cooperation agreements during 2014 (including extended agreements): 1. 4<sup>th</sup> Implementation Agreement for the Taiwan-American Constellation Observing System for Meteorology, Ionosphere, and Climate (Cosmic); 2. an MOU with the Canadian Trade Office in Taipei concerning health research; 3. an MOU with the Japan Science and Technology Agency (JST) concerning the selection of candidates in Taiwan for the "Japan SAKURA Exchange Program in Science"; and 4. renewal of the MOU between MOST and Germany's Alexander von Humboldt Foundation concerning the recommendation and recruiting of German post-doctoral researchers for funded research in Taiwan.

### B. Participation in Major International S&T Organizations

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

#### 1. European Union

In 2008, MOST established the "National Contact Point in Taiwan" (NCP-Taiwan) for the EU Framework Program, and from 2007 to 2013 vigorously promoted Taiwan's participation in major multinational interdisciplinary research projects under the EU's Framework Program 7 (FP7). The NCP provides up-to-date EU FP-related information services to domestic research personnel, helps bring together domestic and EU project teams, and provides researchers in Taiwan consulting services and assistance with project application procedures, which has served to foster greater interaction and cooperation between scientists in Taiwan and Europe. The EU initiated the 8<sup>th</sup> Framework Program (2014-2020)—entitled "Horizon 2020"—in 2014. Responding to the framework of Horizon 2020, MOST has integrated the NCP, which it has located at NARLabs. This will help NARLabs, in line with its mission of funding research and training human resources, to continue to help Taiwan's R&D personnel to strengthen interchange with their European counterparts, and expand contact between NARLabs and organizations in Europe.

#### 2. Asia Pacific Economic Cooperation

MOST actively participated in APEC (Asia Pacific Economic Cooperation) activities. During 2014, apart from sending delegations to the 3<sup>rd</sup> and 4<sup>th</sup> APEC Policy Partnership on Science, Technology and Innovation (PPSTI) working group conferences, which were held in Changzhou, China and Beijing, MOST also proposed the two projects APEC Green Video Festival—which was intended to satisfy public interest in green technology and promote innovative green energy research—and "Promoting Innovative and High Value-added Bio-product Production Technologies for Sustainable Development of the APEC Region"; both of these proposals were approved by the PPSTI conferences.

In addition, during the year, MOST sent personnel to New Zealand to attend the 2<sup>nd</sup> APEC Chief Science Advisors (CSA) conference; held the 2014 APEC Typhoon Symposium and a series of workshops on use of numerical modeling in weather forecasting; and held a workshop on the use of agricultural waste to produce biology-hydrogen in which 45 trainees from five APEC economies participated.

## Major S&amp;T activities with international partners held by MOST in 2014

| Date     | Name   |
|----------|--|
| February | Joint conference on "New Opportunities of Advanced Metrology" held in Japan with Japan's National Institute for Materials Science (NIMS).  |
| March    | Signing of MOU with Japan's JST concerning selection of personnel in Taiwan to participate in the "Japan Sakura Exchange Program in Science."<br>The 7 <sup>th</sup> France-Taiwan Frontiers of Science/Domestic Incubation Forum (forums held in southern and northern Taiwan).   |
| April    | Joint project results announcement meeting for the Japanese-Taiwanese project "Bioelectronics and Biophotonics" held in Japan with JST.  |
| May      | The 2 <sup>nd</sup> conference of the Taiwan-South African Joint Committee of Scientific and Technological Cooperation held in Taiwan with the South African Department of Science and Technology.<br>Joint conference "Innovation and Commercialization" held in Taiwan with the South African Department of Science and Technology.<br>The 11 <sup>th</sup> Taiwan-US. AFOSR Nanoscience Program Review & Workshop held at National Dong Hua University.   |
| July     | July 28-30, former MOST Minister Chang Shan-cheng participates in a bilateral S&T cooperation conference in Washington D.C. with the National Science Foundation (NSF), National Institutes of Health (NIH), and National Institute of Standards and Technology (NIST), and holds substantive meetings with high officials, including Dr. John P. Holdren, Assistant to the President for Science and Technology; Dr. Kathryn D. Sullivan, undersecretary of commerce for oceans and atmosphere ; Dr. Cora Marrett, deputy director of the National Science Foundation; Mr. Michael Carr, Principal Deputy Assistant Secretary of the Department of Energy; Dr. Ralph J. Cicerone, president of the National Academy of Sciences; Dr. C. Dan Mote, president of the National Academy of Engineering; and Dr. Victor J. Dzau, president of the Institute of Medicine.<br>The joint "Nano Scale Bio Engineering and Information Security" conference was held with the Israeli Ministry of Science and Technology.<br>The annual Taiwan-Mongolian working conference was held in Mongolia in conjunction with the Mongolian Science Foundation.<br>The joint "Bio Science" conference was held in Cape Town with the South African Department of Science and Technology.<br>The 4 <sup>th</sup> Taiwan-Philippines Ministerial Conference on Science and Technology was held in Manila, and is jointly hosted by both countries' science ministers.<br>The 7 <sup>th</sup> Taiwan-Indian Joint Conference on Science and Technology was held in Taipei, and was hosted by MOST Vice Minister Chien Chung-liang.<br>A bilateral annual conference between Taiwan and Russia's RFBR was held in Moscow, and was jointly hosted by Vice Minister Lin Yi-ping and the deputy chairman of RFBR.<br>The 2014 Taiwan-Poland joint conference on energy technology.<br>Taiwan-France (MOST-ANR) bilateral joint research project progress and results discussion conference was held in Paris. |
| November | An annual trilateral S&T cooperation conference with Latvia and Lithuania was held in the Lithuanian capital of Vilnius.<br>The 8 <sup>th</sup> Taiwan-France Frontiers of Science Forum was held in Troyes, France.   |
| December | On December 10, the Taiwan-Canada (MOST-NRC) Annual S&T Cooperation Consultative Conference was held in Taipei.<br>An annual working conference was held in Japan with JST.<br>The 2014 Taiwan-Germany Academic Interchange Conference was held with joint sponsorship of the Deutsche Akademischer Austauschdienst (DAAD).  |

### C. International Academic Interchange

In order to enhance Taiwan's visibility in the international academic world, in recent years 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. Furthermore, to encourage young scientists to enter the international academic sphere at an early date, MOST provides funding to domestic graduate students for participation at international conferences allowing them to present their research results. This participation also expands graduate students'

international perspectives, sharpens their research skills, and fosters international research collaboration.

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

Funding for international academic interchange activities, 2010-2014

| Item | International collaborative research projects (projects) | Invited visits by foreign S&T personnel (person-times) | Attendance at international academic conferences (Dept. of International Cooperation projects/specific-topic research projects) (person-times) | Graduate students attend international conferences (person-times) | Attendance at international conferences by graduate students (person-times) | Participation by teams in international academic organization conferences (teams/ person-times) | Assistance in enhancing the international influence of domestic scientists |
|------|--|--|--|---|---|---|--|
| 2010 | 148  | 1,022  | 1,079 / 11,582   | 3,307   | 313   | 40 / 231  | 32   |
| 2011 | 164  | 767  | 872 / 10,968   | 2,589   | 273   | 35 / 178  | 41   |
| 2012 | 198  | 833  | 925 / 11,898   | 3,221   | 295   | 38 / 209  | 29   |
| 2013 | 138  | 856  | 982 / 12,290   | 3,314   | 345   | 42 / 223  | 34   |
| 2014 | 114  | 839  | 953 / 12,607   | 3,300   | 345   | 49 / 313  | 27   |

### D. 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, and occasionally hold seminars to

serve overseas Chinese scholars and exchange students. Eleven overseas symposia held in North America this year discussed topics including biomedical engineering, demographic aging, healthy living and nutraceutical foods, smart energy and green technology, cloud computing, and disaster prevention.

## VI Cross-Strait S&T Interchange

Complying with the government's Mainland policy guideline of "taking Taiwan's interests foremost and ensuring benefit to society," MOST has been steadily promoting constructive, in-depth cross-Strait academic interchange and collaboration. While prioritizing technological cooperation and cooperation, MOST relies on interchange at different levels to strengthen the development of systematic, routine cross-Strait S&T interchange mechanisms based on mutual trust. MOST's chief promotional approach is to recruit scientists and technical specialists in China who wish to perform research in Taiwan, support cross-Strait research projects on topics of common importance, and provide funding for relevant technical forums. The following is an overview of the cross-Strait interchange regulations drafted in conjunction with government policy and the results of their implementation during 2014:

1. Based on the *Operating Guidelines for Subsidies for the Recruitment of Visiting S&T Personnel*, 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 121 person-times in 2014.
2. Based on the *Operating Guidelines for Subsidies for the Holding of Cross-straits Academic and S&T 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 given for 64 conferences in 2014.
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 89 such visits in 2014, which were chiefly for the purpose of public lectures and participation in discussions.

4. In 2014, MOST reviewed a total of 464 applications for academic and S&T personnel from the Mainland China Area to come to Taiwan for long- or short-term academic or S&T activities.
5. In order to promote positive cross-strait academic interchange, MOST continued to fund its portion of bilaterally-funded joint research projects with China on specific issues concerning public welfare. This year's joint topics were "aquatic biological resources" and "collaborative cross-strait food research." In addition, an annual conference was held to discuss topics for 2016 and future cooperation on various new issues. Starting in 2014, MOST and National Natural Science Foundation of China have begun a new series of joint research projects on the common topics of earthquakes, torrential rain & typhoons, and biodiversity.

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

S&T interchange with China and permit review case statistics, 2010-2014

| Item  | 2010  | 2011  | 2012  | 2013  | 2014 |
|---|-------|-------|-------|-------|------|
| Recruited S&T personnel from China (person-times)   | 135   | 113   | 110   | 109   | 121  |
| Cross-strait academic conferences   | 57    | 64    | 67    | 59    | 64   |
| S&T personnel from the Mainland China Area, Hong Kong, and Macao invited to Taiwan (person-times) | 43    | 87    | 48    | 82    | 89   |
| Professional S&T activity permits reviewed (person-times)   | 2,022 | 1,296 | 1,613 | 2,089 | 464  |

## VII Improving the Research and Development Environment

### A. Online Services

Newly-added online information services in 2014 included an instrument information query function spanning different agencies, an online application system for S&T personnel seeking funding for short-term overseas research operations, and online application procedures for review of specific-topic research project results reports and Hundred-Person Pioneer Program projects. These systems are described as follows:

1. The new "agency instrument data query function" added to the instrument service platform allows users to query information on approximately 668 instruments at the MOEA, COA, Ministry of Health and Welfare, Academia Sinica, MOE, and MOST providing services to external users; this function has been provided since November 2014.
2. The new-version online application system for "Funding of Scientific and Technological Personnel for Short-term Research Overseas" allows applicants to perform online application, reporting of funding use, report transmission, and organizational compilation; the new system has been in use since January 2014.
3. The "specific-topic research project results report

review service" allows users to submit mid-term and final specific-topic research project results reports to MOST's academic departments. This function has been in use since March 2014, and was used to submit approximately 142 reports during the year.

4. The Hundred-Person Pioneer Program was introduced on a trial basis in 2013; after submission of application proposals was cancelled in 2014, applicants can make direct applications for funding; a total of approximately 384 applications have been made via this system.

As for paperless online application for academic research grants and funding, after many years of online submission for review, the system has effectively conserved paper and postage, shortened processing time, and boosted administrative efficiency. In order to seek further improvement, MOST began use of paperless academic review fee receipts on a trial basis starting in 2013, and has used the paperless receipts on a full scale since 2014; paperless receipts were used to request funding reimbursements approximately 94,000 times during the year, and performance has been excellent.

#### Paperless online application procedure statistics, 2012-2014

| Item                                     | 2012    | 2013    | 2014    |
|--|---------|---------|---------|
| Specific-topic project funding           | 108,360 | 109,972 | 107,897 |
| International collaborative projects     | 19,232  | 19,148  | 19,356  |
| Manpower recruiting projects             | 13,845  | 16,026  | 15,468  |
| Industry-academic collaborative projects | 5,773   | 4,782   | 4,651   |

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

#### Paperless online review cases and person-times, 2012-2014

| Item  | 2012   |              | 2013   |              | 2014   |              |
|---|--------|--------------|--------|--------------|--------|--------------|
|   | Cases  | Person-times | Cases  | Person-times | Cases  | Person-times |
| Specific-topic project funding applications | 28,253 | 94,645       | 27,915 | 86,512       | 27,331 | 86,933       |
| International collaborative projects        | 8,733  | 11,377       | 8,138  | 10,543       | 8,578  | 11,661       |
| Manpower recruiting projects                | 1,432  | 2,041        | 1,472  | 2,182        | 1,690  | 3,146        |
| Industry-academic collaborative projects    | 1,776  | 4,929        | 1,327  | 3,680        | 1,406  | 4,291        |

Note: Based on online application cases submitted via the online review system.

## B. Centralized Use of Major Instruments

The major instruments program continues to provide needed instruments for research use by universities and industry. MOST provided funding to the following 17 schools as part of its major instrument joint use service program in 2014: 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, and National Pingtung University of Science and Technology. Facilities at these universities house 163 in-service instruments. Seven new (and replacement) instruments and equipment items were purchased during the year, and funding totaled NT\$191 million.

Major instrument centers provided services 380,170 times in 2014, and service time exceeded 400,497 hours. The aggregate value of instrument services amounted to over NT\$472 million.

Major instrument use center service statistics, 2014

Units: NT\$1m

| School name  | Number of instruments | Service cases  | Service hours  | Total value of experiments |
|--|-----------------------|----------------|----------------|----------------------------|
| National Taiwan University                             | 18                    | 49,369         | 66,695         | 71                         |
| National Taiwan Normal University                      | 4                     | 8,269          | 15,942         | 15                         |
| National Central University                            | 12                    | 25,485         | 25,224         | 28                         |
| National Tsinghua University                           | 29                    | 89,955         | 65,671         | 90                         |
| National Chiao Tung University                         | 24                    | 37,158         | 58,215         | 92                         |
| National Chungshing University                         | 16                    | 49,578         | 34,870         | 56                         |
| National Chung Cheng University                        | 10                    | 12,131         | 16,246         | 12                         |
| National Cheng Kung University                         | 20                    | 58,305         | 54,233         | 47                         |
| National Sun Yat-sen University                        | 17                    | 24,080         | 38,139         | 37                         |
| Self-owned instrument joint use projects ( 8 schools ) | 13                    | 25,840         | 25,263         | 24                         |
| <b>Total</b>   | <b>163</b>            | <b>380,170</b> | <b>400,497</b> | <b>472</b>                 |

Source: Major Instrument Information Management System ( 1-12/2014 )

## VIII

## Management and Extension of R&D Results

According to 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 by patenting and technology licensing, shall, as a rule, be granted to the implementing organization.

Because of the important role played by academic research organizations in developing and applying knowledge, MOST drafted the *Operating*

*Guidelines for the Management and Extension of Funded Academic Research 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, persons applying for invention patents via the implementing organization may apply to MOST for subsidies

covering 80% of patent application expenses and maintenance costs for the first three years; and when a patent has been received, the applicant may receive an incentive depending on the country in which the patent was granted. In order to better integrate academic research resources and effectively manage and extend academic R&D results, MOST revised the foregoing *Operating Guidelines* to eliminate invention patent award incentives and adjust the patent application expense subsidy ratio starting July 1, 2011. While applicants may still apply for 80% subsidies when a patent has been granted, subsidies during the application stage will cover only 40% of expenses, and a subsidies for an additional 40% of application expenses can be obtained after the patent certificate has been received. Subsidies covering

invention patent expenses were provided in 5,649 cases involving the results of funded projects during 2014.

Furthermore, to encourage technological diffusion, project-implementing organizations must pay only a certain percentage of income from R&D results to funding agencies (these payments are included in the Science and Technology Development Fund in accordance with budget procedures); this percentage is 20% in the case of agencies, 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\$55 million in 2014.

## IX Publications

|  |  |
|--|--|
| <p><i>Science Development</i></p>                                      | <p>First published in 1973, the monthly <i>Science Development</i> originally served 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. Well-illustrated reports enable general readers to understand scientific developments and achievements in Taiwan and around the world, promote stronger links between science and the humanities, and increase the public's scientific knowledge. 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.</p>   |
| <p><i>Ministry of Science and Technology Review</i></p>                | <p>Published online in Chinese and English versions, the annual <i>MOST Review</i> 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&amp;T development and its achievements.</p>   |
| <p><i>Indicators of Science and Technology, ROC (2014 edition)</i></p> | <p>The <i>Indicators of Science and Technology</i> has been published annually since 1990 in order to publicize the results of the "Survey of National Science and Technology Activity." The 2014 <i>Indicators</i> contained four major sections: The first section, "Summary Analysis," compared trends in the R&amp;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&amp;D in Taiwan and other countries. The second section, "International Comparison of S&amp;T Activity," contained relevant data concerning major S&amp;T indicators in various countries. The third section, "S&amp;T Activity in Taiwan," included a breakdown of R&amp;D funding and R&amp;D manpower across the business enterprise, government, higher education, and private nonprofit sectors, the government's S&amp;T budget and R&amp;D budget, S&amp;T results, and science park R&amp;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. (2014 edition query website: <a href="http://www.most.gov.tw/tech/index.asp">http://www.most.gov.tw/tech/index.asp</a>).</p> |

|  |  |
|--|--|
| <p><i>Journal of Biomedical Science</i></p>  | <p>This English-language 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 <i>Journal of Biomedical Science</i> 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 freely use papers via the Internet, and research personnel can share the periodical's resources in order to promote academic development. The Journal had an <i>SCI</i> impact factor of 2.736 according to the 2013 <i>Journal Citation Reports (JCR)</i>, and is one of the most representative biomedical journals in Asia.</p> |
| <p><i>International Journal of Science and Mathematics Education</i></p>           | <p>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 67% of manuscripts are from non-English-speaking countries, which makes it a very representative educational research journal presenting viewpoints from non-English-speaking countries. According to the 2013 <i>Journal Citation Reports (JCR)</i>, this journal had an <i>SSCI</i> impact factor of 0.636.</p>  |
| <p><i>East Asian Science, Technology and Society: An International Journal</i></p> | <p>First issued in 2007, this quarterly is published by a prominent international publishing company. It 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 outlooks differing from those prevailing in the West, which will in turn 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.</p>  |

All of the foregoing publications can be viewed and queried at the MOST website: <http://web1.most.gov.tw/>.



## **Chapter 4 Strengthening Academic-Industry Links and Innovation**

- **Industry-Academic Cooperative Research Projects**
- **PIONEER Grants for AIC**
- **Minor Alliance Projects**
- **From IP to IPO**
- **Industrial Fundamental Technology Projects**
- **Applied Research Incubation Projects**
- **Germination Program**



ACADEMIA  
INDUSTRY

SCIENCE

TECHNOLOGY

## I

## Industry-Academic Cooperative Research Projects

MOST has actively promoted industry-academic collaborative research projects for many years in order to harness the abundant R&D resources of the academic sector and train S&T personnel with practical experience. The model of mutually-beneficial cooperation employed in industry-academic collaborative research projects over the course of many years has supported and boosted the R&D capabilities of domestic companies, and the forward-looking technologies developed in these projects have made major contributions to domestic industrial competitiveness.

In order to make even greater use of the results of academic research and further accelerate Taiwan's S&T innovation, starting in 2013 MOST has promoted industry-oriented industry-academic collaboration models including PIONEER Grants for AIC, Minor Alliance Projects, Industrial Fundamental Technology Projects, and the Applied Research Incubation Projects.

To ensure that MOST's funding of industry-academic collaborative research projects achieves the goals of objectivity and fairness, establish guidelines for academic review, and provide evaluation personnel recusal and confidentiality

regulations, MOST drafted the *Ministry of Science and Technology Review Incentive and Funding Case Recusal and Confidentiality Guidelines* on December 3, 2014. These guidelines determine relevant recusal regulations for reviewers, principal investigators (applicants) or their interested parties, and collaborating companies and their statutory responsible persons, and prescribe that academic research organizations must establish mechanisms for avoidance of conflict of interest.

Furthermore, in order to increase companies' willingness to participate in industry-academic collaborative projects, MOST further revised the *Operating Guidelines for the Funding of Industry-Academic Cooperative Research Projects* on November 15, 2012. The main intention of this revision was to reduce the level of matching funds that a collaborating company must provide from 30% to 20% in "developmental" industry-academic cooperative projects; an agreement may be reached to eliminate the R&D results ownership proviso only if "a single collaborating company's contribution exceeds 50% of total project funding."

Implementation performance of industry-academic cooperative research projects, 2010-2014

| Item                                  | 2010   | 2011   | 2012  | 2013  | 2014  |
|---------------------------------------|--------|--------|-------|-------|-------|
| Number of projects                    | 944    | 868    | 863   | 842   | 813   |
| Funding (NT\$1 m)                     | 716.93 | 744.01 | 793   | 816   | 894   |
| Number of participating firms         | 954    | 896    | 883   | 829   | 852   |
| Corporate contribution (NT\$1 m)      | 301.63 | 349.23 | 347   | 306   | 328   |
| Manpower training (graduate students) | 2,057  | 2,037  | 2,179 | 2,081 | 2,095 |
| Approved patents                      | 65     | 75     | 130   | 130   | 110   |

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

## II

## PIONEER Grants for AIC

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

These projects channel academic R&D capabilities to industry by pairing Taiwan's finest scientists and researchers with internationally competitive companies. The benefits 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.

MOST approved two projects in 2013 (with periods of five years). As of the end of 2014, these projects had applied for approximately 30 patents in the fields of semiconductors and steel processing technology, and preliminary results were extremely promising. Three new projects were approved in 2014 (with periods of three years), and included projects in the fields of green chemical engineering technology, wireless/broadband Internet technology, and mobile communications technology. The five projects approved during the first two years of this program have attracted corporate R&D funding totaling NT\$590 million, and are expected to yield more than 100 patent applications during their first five years. By harnessing the R&D capabilities of universities and industry, and promoting joint R&D efforts in forward-looking and basic technologies, this program seeks to bring about a full-scale improvement in Taiwan's industrial competitiveness and product added value.

## III

## Minor Alliance Projects

The ample research capabilities of Taiwan's academic research sector are not applied solely to the pursuit of academic advances and the publication of papers in journals, but also to collaboration with domestic industry and the development of solutions 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 capabilities of academia, MOST began funding "academia-industry technological alliance projects" ("Minor Alliance Projects") in 2012. These projects take technologies developed by the academic sector as their subject, and employ an industry-academic alliance format to fund "technical service laboratories" spanning various industry platforms. This novel form of industry-academic collaboration can systematically diffuse

the technological capabilities of the academic sector, which will strengthen industry-academic technological linkage, and also realizing better interaction between universities and companies. The projects are aimed at enhancing industrial competitiveness, while also letting academic research personnel accumulate more practical experience, and shortening the gap between research and industry.

Implementation of the first cohort of Minor Alliance Projects got underway in February 2013; 75 projects received funding during the first year, and 92 projects received funding in 2014. Project implementing organizations include 41 public and private universities and research organizations throughout Taiwan. As of the end of October 2014,

1,045 companies were participating in alliance projects. This program has achieved its preliminary goal of establishing a platform for industry-academic collaboration, and alliances are currently being encouraged to expand their membership. It is

expected that the program will boost industry's ability to compete by achieving the goal of technological diffusion between the academic research and industrial sectors.

## IV

## From IP to IPO

To encourage young people and researchers in Taiwan to embark on startups, realize the recommendations of the 9<sup>th</sup> National Science and Technology Conference, encourage universities and research organizations to establish innovative, entrepreneurial cultures, and create an environment fostering the industrialization of R&D results and novel ideas, MOST began implementation of the "Intellectual Property to Initial Public Offering" program (also known as the "From IP to IPO" program) in March 2013. This program provides assistance to entrepreneurial teams dedicated to transforming R&D results or creative ideas into innovative products or new businesses, in the expectation that a wave of entrepreneurial activity will help channel Taiwan's plentiful R&D capabilities to industry, where they will take root, create value, and add to Taiwan's economic momentum.

This program conducts an innovative startup team selection process twice each year. In this process, startup teams consisting of students, instructors, and researchers write startup pre-proposals, and a maximum of 40 finalist teams in each session will receive assistance, which takes the form of entrepreneurial resources and guidance, monthly physical and online classes, and two startup training camps intended to impart operation planning skills and briefing technique.

This program has invited successful domestic and foreign Chinese entrepreneurs and venture capitalists to serve as entrepreneurship coaches

providing startup knowledge and experience, and NARLabs and the three science park bureaus offer supporting equipment, experimental facilities, operating space, and referral to resources. This assistance enables teams to test their concepts, produce prototypes, and receive necessary services throughout the initial startup period. After a three-stage selection process, the chosen teams are given small startup seed funding and introduction to angel investors in order to help them get their ventures up and running.

Since this program was introduced, it has garnered support from 13 companies, including Acer, TSMC, Ernst & Young, Industrial Bank of Taiwan, and Chunghwa Telecom. Stan Shih, founder of Acer, serves as honorary dean of studies; apart from providing grant money, he also serves as an entrepreneurship coach. Since 2013, four sessions of the program have gathered 853 startup proposals, provided in-depth training to 160 startup teams, assisted 964 entrepreneurs, and helped 34 teams expedite establishment of startups. Apart from directly creating 162 employment opportunities, these startups also cumulatively raised NT\$88.33 million in funds and had a total of NT\$124 million in paid-in capital (as of December 2014). Furthermore, to give the startup teams a broader international perspective and expose them to the innovative culture and experience of Silicon Valley, the program will continue to strengthen ties with a group of venture capitalists in Silicon Valley—the "Silicon Valley Taiwan Angels."

## V

## Industrial Fundamental Technology Projects

MOST is promoting "Industrial Fundamental Technology Projects" in order to enhance the basic standards of industry in Taiwan and fuse the R&D capabilities of academia and industry. This program provides funding to universities to establish basic technology R&D centers charged with developing basic industrial technologies that will have widespread uses by manufacturers, pose high technological challenges, have extensive expected economic influence, and offer broad application markets ("three highs and one broad"). The projects' industry-academic collaborative format attracts R&D resources from industry, and is intended to leverage the government budget, take advantage of universities' abundant resources, help industry boost its competitive ability, and train human resources with practical experience.

MOST provides funding of up to NT\$20 million to each project, and companies must contribute no

less than 20% of the applied-for funding. Projects are conducted in four-year stages; implementation performance is evaluated on an annual basis, and funding to poorly-performing projects may be cut off. While government funding initially predominates, corporate contributions and university resource inputs are expected to gradually increase, and it is hoped that projects can attain long-term self-sufficiency. The program was implemented in September 2012. As of 2014, 30 basic technology R&D centers had been established, and implementation results included the acquisition of 52 patents, application for 48 patents, completion of 22 technology licensing cases, NT\$13.44 million in technology licensing fees, 103 training classes, manpower training 1,335 person-times, receipt of technical licenses by 118 persons, investment of NT\$57 million by participating companies, and derivative industry-academic collaboration funding of NT\$81 million.

## VI

## Applied Research Incubation Projects

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

Although Taiwan's academic institutions and research units have accumulated many achievements

and considerable potential 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 2014, more than 100 promising proposals in the fields of pharmaceuticals and medical equipment had passed the selection process, and 45 of these had been subjected to in-depth assessment. After rigorous review and selection by domestic and foreign experts, 10 projects were approved to receive funding; assistance was also provided for the establishment of two startups.

## 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' original academic research results possessing industrial value via the planning of projects and drafting of mechanisms. Following collection of assessment recommendations during the first stage, which lasted from 2007 to 2010, the Germination Program got underway in 2011. It is hoped that this program will systematically promote the commercialization of promising scientific discoveries. The program has the following objectives:

1. To encourage universities and academic research organizations to establish innovative, entrepreneurial campus cultures.
2. To strengthen academic research organizations' capabilities and mechanisms for investigating original R&D results with potential commercial applications, and simultaneously encouraging successful projects to train manpower and embark on startups.
3. To promote the use of academic research results as the basis for startups, and foster linkage between scientific advances and commercial applications.

Implementation of this program consisted of two stages, namely the funding of university and research organization R&D results germination centers and the implementation of R&D results germination projects. Each center has organized a technology manager team to uncover potential cases, and case review and entrepreneurship coach systems help research personnel to move the research results from the laboratory to the market. This program has significantly raised the socioeconomic impact of scientific research. Six germination function centers have been established since 2011, and have recommended 145 germination cases with significant promise. Following review, funding has been provided to 33 germination projects, which have reached the technology verification and commercial development stages. The program has brought about the establishment of four startups thus far.





## **Chapter 5 Development of Science Parks**

- **Hsinchu Science Park**
- **Southern Taiwan Science Park**
- **Central Taiwan Science Park**



Taiwan's science parks were established for the purpose of attracting high-tech industries and manpower, encouraging domestic technological innovation, promoting industrial upgrading, balancing regional development, and achieving nationwide economic growth. Among the three science parks, the Hsinchu Science Park is a hotbed of the semiconductor and optoelectronics industries; the Central Taiwan Science Park specializes in

optoelectronics, aerospace, and precision machinery; and the Southern Taiwan Science Park is a stronghold of the optoelectronics industry. These three science parks are the nuclei of numerous industry clusters, form a high-tech corridor extending from north to south in western Taiwan, and are playing an active role in creating new opportunities for economic development.

## I Hsinchu Science Park

Established in 1979, the Hsinchu Science Park has been developing for over 30 years; today the park has earned international acclaim, and is recognized as one of the world's most successful science parks. The industry clusters that have formed within the park exert a strong attractive effect, and the members have achieved many successes in product R&D and international market competition. The semiconductor industry is an excellent example, and is has become a crucial supply chain member in the global market.

The Hsinchu Science Park comprises six sites, namely the fully-developed 653-hectare Hsinchu site, 129-hectare Zhunan site, and the 107-hectare Longtan site; and the under-development 38-hectare Hsinchu Biomedical Park, 350-hectare Tongluo site, and the 71-hectare Yilan site. As of the end of 2014, a total of 149,116 persons were employed at the park (excluding persons working in industrial and commercial services), and the 489 companies operating in the park had cumulative paid-in capital in excess of NT\$2.0 trillion.

These companies also had total operating revenue of NT\$1.16 trillion in 2014, and this figure represented growth of 4.57% compared with 2013. The 39 new investment cases during the year called for investment of NT\$21.5 billion, and this figure was up by 18.18% in terms of number of companies and 276.5% (in terms of investment) compared with 2013, while reaching a three-year high. As for manpower

training, academic research and educational institutions near the park were commissioned to provide in-service training classes; such training was provided 9,321 person-times. Furthermore, to accommodate the needs of industry and the country's future growth, the Science Park Bureau is actively developing the new Tongluo, Hsinchu Biomedical Park, and Yilan sites and recruiting occupants.

The Hsinchu Science Park Bureau has a vision of "creating an innovative, entrepreneurial, pioneering science park," and upholds core values of "accumulating capacity, concern, collective creativity, and accountability." Over the last few years, Hsinchu Science Park has maintained an output in excess of NT\$1 trillion, employment has set new records, and the park has successfully stimulated economic growth and acquired many innovative domestic and foreign flagship companies. Apart from the semiconductor and optoelectronics industries, which already enjoy critical international status, firms in the park are developing core technologies in such areas as the Internet of Things (IoT), digital convergence, cloud computing, big data, and B4G wireless broadband. This will ensure that the Hsinchu Science Park maintains its status as a center of high-tech industry, continues to cultivate plentiful, highly-qualified human resources and well-integrated resources, and drives the development of technological industry in Taiwan.

## Overview of Hsinchu Science Park Industries, 2014

| Industry                 | Number of firms | Number of employees <sup>1</sup> | Capital (NT\$100 m) | Revenue (NT\$100 m) | Revenue growth (%) |
|--------------------------|-----------------|----------------------------------|---------------------|---------------------|--------------------|
| Integrated circuits      | 198             | 88,316                           | 6,500               | 8,445               | 9.02               |
| Computer and peripherals | 49              | 10,083                           | 835                 | 527                 | -31.7              |
| Communications           | 48              | 7,187                            | 256                 | 306                 | 12.36              |
| Optoelectronics          | 96              | 37,061                           | 3,185               | 1,951               | 0.78               |
| Precision machinery      | 36              | 3,084                            | 80                  | 263                 | -1.37              |
| Biotechnology            | 58              | 3,099                            | 117                 | 83                  | 0.11               |
| Other                    | 4               | 286                              | 24                  | 59                  | 18.4               |
| Total                    | 489             | 149,116                          | 10,997              | 11,633              | 4.57               |

<sup>1</sup> Employment figures do not include commercial and industrial service firms.

## Growth of the Hsinchu Science Park, 2009-2014

| Item                             | 2009    | 2010    | 2011    | 2012    | 2013    | 2014    |
|----------------------------------|---------|---------|---------|---------|---------|---------|
| Revenue (NT\$100 m)              | 8,835   | 11,869  | 10,346  | 10,588  | 11,125  | 11,633  |
| Increase or decrease (%)         | -12     | 34      | -13     | 2       | 5       | 4.57    |
| Number of companies              | 440     | 449     | 477     | 485     | 481     | 489     |
| Increase or decrease (%)         | 2       | 2       | 6       | 2       | -1      | 2       |
| Employees <sup>1</sup>           | 132,161 | 136,548 | 145,537 | 148,104 | 148,608 | 149,116 |
| Increase or decrease (%)         | 1       | 3       | 7       | 2       | 1       | 1       |
| Manpower training (person-times) | 10,681  | 9,698   | 8,894   | 8,321   | 8,907   | 9,321   |
| Increase or decrease (%)         | 1       | -9      | 8       | -6      | 7       | 5       |

<sup>1</sup> Employment figures do not include commercial and industrial service firms.

## 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 were approved to occupy the park in 2014, yielding a cumulative total of 196 companies, of which 177 had already occupied sites and begun operations. The revenue earned by park companies during the year totaled NT\$639 billion, which represented growth of 3.95% compared with 2013. As of the end of 2014, 567 hectares of land in the park had been leased, and the leasing rate had reached 87.5%.

The Southern Taiwan Science Park promotes the establishment value-added, innovative startups forming industry clusters, sustainable, ecological communities, and a lifestyle emphasizing culture and art. In 2014, STSP was awarded the Gold Medal for Highest Performance in the nonprofit organization category of the Taiwan Corporate Sustainability Awards and the Sustainable Governance Award of the British Standards Institution Governance, Risk, Compliance Convention (and was the only government agency to receive this honor). The Tainan site received the Green Building Diamond Grade Ecological Community Mark in 2013, and the

Kaohsiung site received the Ministry of Culture's 4<sup>th</sup> Public Art Excellence Award in 2014.

Development of industry clusters at the Southern Taiwan Science Park:

### 1. The world's foremost dedicated foundry site

Leading dedicated foundries in STSP have gradually increased their investment to more than NT\$740 billion. TSMC has adopted a sub-20 nm process, and UMC is using a sub-28 nm process. It is expected that foundry growth will stimulate investment by peripheral up- and downstream industries, and make STSP the world's dominant 12" wafer foundry site.

### 2. The world's largest optoelectronic industry cluster

Epion Technology, which has acquired LED epi-wafer and chip production technology, ultra-fast laser producer Cyber Laser, and low-power display specialist Pervasive Displays are among the notable optoelectronics firms in this cluster. Innolux plans to establish a low-temperature polysilicon (LTPS) sixth-generation panel plant at the Kaohsiung site to produce panels for high-end cell phones; this project will require investment in excess of NT\$80 billion and is expected to employ 2,300 persons.

### 3. An increasingly complete green energy industry cluster

The 2013 "Southern Taiwan Science Park Green Energy Low-Carbon Industry Cluster Promotion Program," which aims to encourage green energy investments by companies or research organizations, provides funding of up to NT\$2.5 million. This program

helped three companies obtain NT\$37.5 million in other government resources, four companies obtain product certification, and two companies obtain venture funding. Other achievements include providing training to 1,110 persons and induced six companies to make investments totaling NT\$335 million at STSP.

### 4. Biotech/medical equipment industry cluster goes international

The second stage of the "Southern Taiwan Biotech and Medical Device Cluster Development Plan," which began in 2013, successfully established an integrated service platform promoting linkage between industry, academia, research organizations, and medicine, and performing KOL (key opinion leader) marketing, and established an innovative medical device development environment. This program induced four companies to invest NT\$450 million in STSP during 2014, including adding 50 research personnel. The program also approved funding for 34 new medical device technologies, helped five companies at STSP to obtain NT\$61.7 million in other government resources, signed MOUs with five domestic testing and certification organizations, and held one technology matchmaking conference, one creative design competition, two international business opportunity matchmaking conference, and one results announcement conference. The program also participated in three international trade shows, provided training to 374 persons, held two clinical workshops, established an exhibition room for products made by this industry cluster, and conducted an industry-academic collaboration KOL marketing trip to Vietnam.

Overview of industries in the Southern Taiwan Science Park, 2014

| Item                           | Companies | Employment | Investment (NT\$100 m) | Revenue (NT\$100 m) | Revenue growth rate (%) |
|--------------------------------|-----------|------------|------------------------|---------------------|-------------------------|
| Integrated circuits            | 16        | 21,550     | 9,855.64               | 2,806.22            | 9.76                    |
| Optoelectronics (green energy) | 56        | 46,096     | 2,745.38               | 3,158.22            | -1.35                   |
| Computers & peripherals        | 2         | 272        | 30                     | 18.91               | 4.76                    |
| Telecommunications             | 11        | 1,127      | 74.25                  | 50.29               | 77.32                   |
| Precision machinery            | 47        | 5,579      | 193.89                 | 274.60              | 10.18                   |
| Biotechnology                  | 59        | 2,082      | 225.89                 | 61.14               | -12.14                  |
| Other <sup>1</sup>             | 5         | 2,286      | 26.83                  | 25.02               | -10.01                  |
| Total                          | 196       | 78,992     | 13,151.90              | 6,394.38            | 3.95                    |

<sup>1</sup> "Other" industries include "other scientific industries" and "other park enterprises."

## Growth of the Southern Taiwan Science Park, 2010-2014

| Item  | 2010    | 2011    | 2012     | 2013     | 2014     |
|---|---------|---------|----------|----------|----------|
| Revenue (NT\$100 m)                           | 6,058.8 | 5,794.1 | 6,219.63 | 6,151.21 | 6,394.38 |
| Increase or decrease (%)                      | 31      | -4.4    | 7.34     | -1.1     | 3.95     |
| Number of companies                           | 167     | 179     | 186      | 185      | 196      |
| Increase or decrease (%)                      | 7       | 7       | 4        | -0.5     | 6        |
| Employment                                    | 56,388  | 62,344  | 64,887   | 70,896   | 78,992   |
| Increase or decrease (%)                      | 16      | 11      | 4        | 9        | 11       |
| Manpower training <sup>1</sup> (person-times) | 2,308   | 1,746   | 1,606    | 1,369    | 1,315    |
| Increase or decrease (%)                      | 21      | -24     | -8       | -15      | -4       |

<sup>1</sup> Manpower training figures do not include participation in advanced technical lectures or benchmark corporate leader lectures.



## Central Taiwan Science Park

Established in 2003, the Central Taiwan Science Park (CTSP) seeks to gather high-tech companies and manpower, encourage domestic technological 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 living in one superior industrial park.

In 2014, 25 more companies received approval to occupy sites in the park, giving it a cumulative total of 174 firms, of which 129 are already operating in the park. In 2014, firms in CTSP had total capital investment of close to NT\$2 trillion and revenue of NT\$522 billion, which represented annual growth of 13.5% compared with 2013. The Central Taiwan Science Park's chief achievements in 2014 were as follows:

### 1. Revenue reaches a new high

After breaking through the NT\$400 billion mark in 2013, companies in CTSP achieved a new revenue record in 2014. This was chiefly attributable to surging demand for mobile electronics products and steadily rising specifications, which led to a flood of orders among the wafer and chip supply chain firms. In addition, companies completed full-scale roll-out of 28 nm production lines, which also stimulated sales and production at mid-/high-end process companies.

### 2. Outstanding tenant company recruiting results

CTSP has acquired numerous domestic and foreign high-tech tenant companies in recent years, including 43 optoelectronics firms, 62 precision machinery firms, 32 biotech firms, eight integrated circuits firms, 15 computer and peripheral firms, two communications and digital content firms, and 12 other enterprises. Industry clusters in these fields are forming rapidly, and achieving a strong competitive advantage. In addition, CTSP has bolstered its R&D capabilities through the acquisition of 14 research organizations and incubation centers. In 2014, 24 new investment cases were approved (four of which were proposed by foreign companies), and called for total investment of NT\$5.89 billion. Furthermore, CTSP's Zhongxing New Village High-tech Research Park enjoyed successful recruiting of tenant firms, and ITRI began accepting tenant firms on September 15 for its "Central Taiwan Innovative R&D Park," where Taiwan Mother Cosmo and Allion Computer began operations on June 30 and October 31.

### 3. Creating a sustainable environment

Since it was established, CTSP has emphasized both industrial development and environmental sustainability. After passing an EIA in 2006, in addition to vigorously performing development work and recruiting tenant companies, the Qixing site of

the Houli campus has placed particular emphasis on upholding the public's rights and interests. After extensive communication and negotiation, a precedent-setting win-win compromise among the

concerned parties was reached on August 8, 2014 in the lawsuit concerning the third phase of CTSP development (the Qixing site of the Houli campus).

#### Overview of Central Taiwan Science Park industries, 2014

| Item                      | Firms            | Employment (persons) | Investment (NT\$100 m) | Revenue (NT\$100 m) | Revenue growth (%) |
|---------------------------|------------------|----------------------|------------------------|---------------------|--------------------|
| Integrated circuits       | 6                | 7,842                | 1,120.3                | 2,848.72            | 37.87              |
| Computers and peripherals | 10               | 1,044                | 12.97                  | 27.49               | 41.35              |
| Telecommunications        | 1                | 182                  | 0                      | 0.82                | 5.19               |
| Optoelectronics           | 36               | 17,413               | 625.78                 | 2,107.02            | -9.02              |
| Precision machinery       | 41               | 4,071                | 93.39                  | 205.49              | 17.09              |
| Biotechnology             | 23               | 1,244                | 52.68                  | 18.69               | 122.98             |
| Other <sup>1</sup>        | 12               | 464                  | 8.69                   | 12.47               | -3.35              |
| Total                     | 129 <sup>2</sup> | 32,260               | 1,913.81               | 5,220.70            | 13.52              |

<sup>1</sup> "Other" industries include "other scientific industries" and "other park enterprises."

<sup>2</sup> Number of new tenant firms

#### Growth of the Central Taiwan Science Park, 2010-2014

| Item  | 2010     | 2011     | 2012     | 2013     | 2014             |
|---|----------|----------|----------|----------|------------------|
| Revenue (NT\$100 m)                           | 3,625.37 | 2,911.12 | 3,233.26 | 4,599.08 | 5,220.70         |
| Increase or decrease (%)                      | 50.33    | -19.70   | 11.07    | 42.24    | 13.52            |
| Companies                                     | 112      | 125      | 140      | 158      | 174 <sup>3</sup> |
| Increase or decrease (%)                      | 12       | 11.6     | 12       | 13       | 10               |
| Research organizations and incubation centers | 12       | 13       | 14       | 14       | 14               |
| Increase or decrease (%)                      | 20       | 8.3      | 7.7      | 0        | 0                |
| Employees                                     | 23,329   | 26,783   | 28,751   | 31,242   | 32,260           |
| Increase or decrease (%)                      | 17.6     | 14.81    | 7.35     | 8.66     | 3.26             |
| Manpower training <sup>1</sup> (person-times) | 982      | 1,351    | 837      | 645      | 635              |
| Increase or decrease (%)                      | -8.05    | 37.58    | -38.04   | -22.94   | -1.57            |
| Manpower training <sup>2</sup> (person-times) | 1,789    | 1,664    | 1,560    | 1,255    | 1,024            |
| Increase or decrease (%)                      | 17.16    | -6.99    | -6.25    | -19.55   | -22.56           |

<sup>1</sup> Aimed at park employees

<sup>2</sup> Aimed at students

<sup>3</sup> Total number of approved firms



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