# NARLabs

ANNUAL REPORT 2024

國家實驗研究院

National Applied Research Laboratories

# NARLabs

ANNUAL REPORT 2024

# CONTENTS

# evolution

## 2003

National Applied Research Laboratories (NARLabs) was established with six founding labs:

- National Chip Implementation Center (CIC)
- National Center for High-performance Computing (NCHC)
- National Center for Research on Earthquake
- Engineering (NCREE)
- National Nano Device Laboratories (NDL)
- National Laboratory Animal Center (NLAC)
- National Space Organization (NSPO)

## 2005

Two more labs joined NARLabs:

- Instrument Technology Research Center (ITRC)
- Science & Technology Policy Research and Information Center (STPI)

## 2008

Taiwan Ocean Research Institute (TORI) was established.

Taiwan Typhoon and Flood Research Institute (TTFRI) was established.

## 2011

- Taiwan Typhoon and Flood Research Institute (TTFRI) was merged into National Science and Technology Center for Disaster Reduction (NCDR).
- National Chip Implementation Center (CIC) and National Nano Device Laboratories (NDL) were merged into Taiwan Semiconductor Research Institute (TSRI).
- Instrument Technology Research Center (ITRC) was renamed Taiwan Instrument Research Institute (TIRI).

## 2019

## 2023

The National Space Organization (NSPO) transitioned into a new legal entity under the NSTC

# PREFACE

01

# MESSAGE FROM THE CHAIRPERSON

CHAIRPERSON

The National Applied Research Laboratories (NARLabs) operates under the National Science and Technology Council (NSTC) and plays a crucial role in supporting scientific and technological research and development across the country. Effective technological R&D requires the optimal use of resources. Certain research instruments and equipment are impractical for individual universities to purchase because they are extremely expensive and have low utilization rates. Therefore, NARLabs handles the procurement of such equipment to consolidate resources. By bringing together specialized researchers and engineering personnel, NARLabs allows universities to conduct cutting-edge research without concerns over equipment availability and technical support.

Universities represent the highest level of education, where professors lead graduate students in research. Beyond advancing technological development, another key objective of NARLabs is cultivating top-tier talent. By enhancing their knowledge and skills, graduate students can reach their fullest potential and contribute to society in the future. At the same time, teaching also gives professors the chance to grow and develop. NARLabs plays a complementary role to universities to facilitate academic development in various critical fields.

We are now in an era of interdisciplinary integration, yet this is made difficult because university professors often conduct research independently. However, the various centers within NARLabs play a crucial role when it is necessary to rapidly integrate different fields to respond to diverse market demands. NARLabs

provides R&D service platforms where professors from different disciplines can work together on projects that would be difficult to complete within their individual fields alone. In some cases, interdisciplinary research extends across multiple centers, transforming NARLabs into a single large-scale platform. In such instances, NARLabs headquarters plays an even more critical role by supporting each center in expanding beyond their original goals while guiding them toward broader objectives that contribute to the advancement of national science and technology.

By establishing integrated platforms, I look forward to NARLabs providing advanced equipment, research teams, and technical personnel that help turn the research results of professors from various academic fields into more impactful applications. After all, the public only feels the impact of academic research when solving problems and meeting the needs of society and industry. Furthermore, researchers experience a greater sense of achievement when academic research translates into tangible contributions such as industrial growth, technological advancements, or societal benefits. This also has a positive effect on raising the overall standard of academic research by increasing awareness on the significance of academic papers, leading to more citations and greater impact.

The fundamental mission of NARLabs supporting academic development has never changed. However, whether through organizational restructuring or refining its strategic direction, NARLabs must also make gradual adjustments as society and industry evolve. In particular, NARLabs must dynamically adapt to meet the changing needs of academia as new research fields emerge. For example, the National Nano Device Laboratories and the National Chip Implementation Center merged to form the Taiwan Semiconductor Research Institute several years ago. This new center, which was integrated due to the increasingly close relationship between semiconductor manufacturing and design, can now better align with the needs of Taiwan's semiconductor industry.

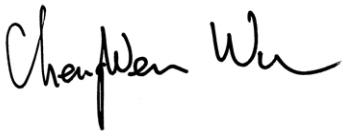
To achieve its goals and missions while adapting to global developments—including shifts in industrial supply chains driven by geopolitical factors and changes in education and research fields due to advancements in emerging technologies—the various centers of NARLabs will undergo adjustments as necessary. In particular, AI has advanced far beyond expectations over the past decade, prompting many centers to adapt in different ways.

Looking ahead, one key consideration is Taiwan's status as a maritime nation. Thus, the Taiwan Ocean Research Institute should expand because enhancing ocean exploration capabilities will provide greater support for academic researchers. This is of great significance to Taiwan.

Besides this, semiconductors and AI are Taiwan's two key areas of technological development. Moving forward, Taiwan will continue advancing the priorities laid out by President Lai Ching-te, which span across defense technology, security systems, and next-generation communications, including drones and low-Earth orbit satellites. In addition, multi-functional robotics, which will have a profound impact on the development of future industries and society, is another key initiative that was clearly established during the National Science and Technology Conference. Therefore, NARLabs should actively support academia in advancing the future of robotics. A crucial direction for research is how robots in the future will adapt to developments in AI to acquire human-like intelligence. In the past, the development of robotics has been based on control theory from conventional mechanical engineering. However, this is no longer sufficient. Thus, the importance of interdisciplinary integration is particularly evident in the field of robotics. As such, NARLabs will soon establish a new agency dedicated to creating an interdisciplinary platform for robotics development.

Looking forward, the primary development goal of NARLabs will be to assist the academic community in translating research results into real-world applications that make tangible contributions to society, industry, and national security. Only by taking these various aspects into consideration can the value of academic research be extended to meet the needs of society while allowing the public to truly benefit from technological advancements.

Chairperson



# MESSAGE FROM THE PRESIDENT

PRESIDENT

The National Applied Research Laboratories (NARLabs) is a unique institution that assists in the implementation of government science and technology policies, supports development throughout the technology industry, and fosters collaboration and integration with the academic community. However, our function is distinct from both Academia Sinica and the Industrial Technology Research Institute (ITRI). Academia Sinica conducts fundamental and cutting-edge academic research, while ITRI is more industry-oriented and focuses on technology R&D to drive industrial development and create economic value. At NARLabs, our four core missions, “Establishing R&D platforms, supporting academic research, promoting frontier science and technology, and fostering high-tech talent,” span across multiple domains. Our primary focus, supporting academia in conducting fundamental research, positions us closer to the academic community. However, we also bridge the gap between academia and industry to keep up with industrial development trends by helping translate academic research into industrial applications. We are also distinct from other institutions because much of our research is mission-oriented and aimed at providing better services to the academic community while contributing to the overall advancement of academic research throughout Taiwan.

Since serving and supporting the academic community in achieving top-tier research outcomes is the core mission of NARLabs, our services must continuously evolve in step with the rapid advancements in science and technology. Only through constant innovation can we provide the best possible support to academia. Thus, “Innovation through Service,” is the first key objective of NARLabs.

Secondly, NARLabs is responsible for providing services to academia. Therefore, to better support the academic community in conducting relevant research, each center within NARLabs must achieve a high level of expertise in its respective field. Given the current state of research, NARLabs must also be capable of offering interdisciplinary services beyond its core specialties. As such, “Interdisciplinary Expertise,” is the second key objective of NARLabs.

Furthermore, we must continuously enhance our research capabilities because the word “research” is a part of our name. Thus, each center must achieve a high level of independent expertise in its respective field. By doing so, we can represent Taiwan on the global stage and drive technological advancements to produce world-class research outcomes by engaging in meaningful collaboration with top international research institutions. Therefore, “Autonomous and International” is the third key objective of NARLabs.

People are the most critical factor in the growth and progress of any organization. Therefore, we must focus on fostering a supportive and inclusive workplace, which includes optimizing the organizational structure, enhancing career advancement opportunities, and strengthening career planning. We also need to rethink how to attract top talent while ensuring that our team members can develop in ways that align with their strengths. This will enable them to build their capabilities while also contributing more to NARLabs.

Regarding career advancement, we aim to go beyond merely enhancing our colleagues’professional expertise. We also seek to develop their communication and coordination skills, broaden their perspectives, and cultivate an international outlook, making these qualities an integral part of their professional growth. This not only increases their opportunities for promotion but also enables them to contribute more effectively to NARLabs when taking on administrative roles. By providing continuous opportunities for development, we hope our colleagues see a clear path for long-term growth at NARLabs and envision greater possibilities for their future. This, in turn, will strengthen their sense of belonging and encourage them to contribute even more to the organization.

In terms of organizational restructuring, we need to consider the direction and major global trends of technological development. Our centers will engage in discussions and strategic planning to anticipate future opportunities. Our goal is that over the next several years, the blueprint we draft today will take root and flourish. However, achieving this vision hinges upon first establishing strong independent research capabilities. Each center must have a firm grasp of the technologies within its field of expertise. Only then can we gain insight into global trends and analyze the direction of industrial development to identify opportunities for advancing our own proprietary technologies.

In addition to expanding our own international presence, NARLabs seeks to establish strong partnerships with Taiwan’s academic and research communities, working together to step onto the global stage. Over the years, NARLabs has built cutting-edge facilities while accumulating extensive expertise through a highly skilled technical workforce. By integrating these resources, we have created a top-tier R&D service platform that serves as a strong foundation for pioneering academic research. We hope to collaborate more closely with university professors and graduate students—the future leaders of scientific research and potential members of NARLabs. While university professors typically focus on advancing expertise within a single field, NARLabs can connect experts across related disciplines and varying levels of specialization, forming a dynamic network of technical capabilities. Through these collaborations, we aim to expand our international reach together.

NARLabs aims to establish ourselves as a globally recognized research institution by driving comprehensive advancements in talent, institutional frameworks, research, and technology, while leveraging the strengths of the academic community. These efforts will not only highlight the value of NARLabs but also maximize our contributions to Taiwan.

President


# R&D SERVICE PLATFORM ACHIEVEMENT AWARDS

02

## AWARD BACKGROUND

With the vision of “Global Excellence, Local Impact” and under the support and guidance of the National Science and Technology Council (NSTC), NARLabs provides various professional R&D service platforms and implements high-cost software and hardware facilities that are difficult for domestic universities to cover in order to assist the academic and research community in advancing scientific knowledge and developing cutting-edge technology, which will ultimately benefit our citizens. To commend industries, government agencies, research institutions, and academicians for employing NARLabs’ R&D service platforms to achieve cutting-edge scientific results, NARLabs inaugurated the R&D Service Platform.

Achievement Awards in 2021. The year 2024 was the fourth time the Awards were presented, and a total of 9 outstanding teams were awarded the honors. Today’s advanced scientific and technological research relies mostly on teamwork and state-of-the-art software and hardware equipment, representing precisely the strengths of the various R&D service platforms established by NARLabs. We hope these awards will encourage the academic and research institutions in Taiwan to collaborate with NARLabs more readily and take advantage of R&D service platforms created through national resolve and the country’s most advanced resources to achieve globally competitive research results.

### High Distinction

| Achievement | Platform |
|---|---|
| The Research on Structural Engineering & Earthquake-resistance Technologies | Research Platform for Earthquake Engineering Simulation (NCREE) |

**Team**

| | |
|---|---|
| **Keh-Chyuan Tsai** | Distinguished Professor, Department of Civil Engineering, NTU |

### Excellence

| Achievement | Platform |
|---|---|
| Measurement and Verification of Cryo-CMOS and IPD Circuits for Silicon-Based Quantum Computers | 4K Ultra-Low Temperature High-Frequency and Noise Measurement Platform (TSRI) |

**Team**

| | |
|---|---|
| **Shuo-Hung Hsu** | Professor, Department of Electrical Engineering/Dean, Institute of Electronics Engineering, NTHU |
| **Hsi-Sheng Goan** | Professor, Department of Physics/Director, Center for Quantum Science and Engineering, NTU |
| **Chien-Yuan Chang** | PAssistant Professor, Department of Electrical Engineering, NTHU |

## Excellence

| Achievement | Platform |
|---|---|
| The Exploration of the Pharmacological Action and Vascular Inflammation Reaction of Atherosclerosis | Animal Resources-Cardiovascular Disease Model Mice C57BL/6-*Apoe*$^{em1Narl}$/Narl (ApoE Knockout Mice) (NLAC) |

**Team**

| | |
|---|---|
| **Tzu-Tang Wei** | Associate Professor, Department and Graduate Institute of Pharmacology, NTU |

## Excellence

| Achievement | Platform |
|---|---|
| MTYOLO, the World's Fastest and most Accurate Real-time Multitasking Analysis System for Computer Vision | Taiwania 2 AI Supercomputer (NCHC) |

**Team**

| | |
|---|---|
| **Mark Liao** | Distinguished Research Fellow/Professor & Director, Institute of Information Science, Academia Sinica. |
| **Chien Yao, Wan** | Assistant Research Fellow, Institute of Information Science, Academia Sinica. |

## Excellence

| Achievement | Platform |
|---|---|
| The Design and Development of High-performance Topological Optoelectronic Devices | Optical Systems Integration R&D Consortium Platform (TIRI) |

**Team**

| | |
|---|---|
| **Wen-Jeng Hsueh** | Professor, Department of Engineering Science and Ocean Engineering, NTU |
| **Yu-Chuan Lin** | Assistant Professor, Department of Mechanical Engineering, National Yunlin University of Science and Technology |
| **Yi-Chia Chien** | Postgraduate, Department of Engineering Science and Ocean Engineering, NTU |
| **Chin-Shen Lo** | Postgraduate, Department of Engineering Science and Ocean Engineering, NTU |

## Honorable Mention

| Achievement | Platform |
|---|---|
| The Semiconductor Research on the Atomic- scale Ultra-thin Oxide and its Application | Joint Laboratory for Advanced Materials Processing Research (TIRI) |

**Team**

| | |
|---|---|
| **Der-Hsien Lien** | Assistant Professor, Institute of Electronics, NYCU |
| **Chun-Liang Lin** | Associate Professor, Department of Electrophysics, NYCU |

## Honorable Mention

| Achievement | Platform |
|---|---|
| The Application of Hyperspectral Microscopy Technology in Metasurface Optics | Hyperspectral Microscopic Imaging Analysis and Development Service Platform (TIRI) |

**Team**

| | |
|---|---|
| **Chih-Ming Wang** | Professor, Department of Optics and Photonics, NCU |

## Honorable Mention

| Achievement | Platform |
|---|---|
| A Comprehensive Analysis of the Genomic Variant Profiles of Taiwan Population | Taiwania 3 Supercomputer and LIONS Data Framework (NCHC) |

**Team**

| | |
|---|---|
| **Shu-Jui Hsu** | Assistant Professor, Graduate Institute of Medical Genomics and Proteomics, NTU |
| **Pei-Lung Chen** | Professor & Chairman, Graduate Institute of Medical Genomics and Proteomics, College of Medicine, NTU<br>Attending Physician, Departments of Medical Genetics and Internal Medicine, National Taiwan University Hospital (NTUH) |
| **Chien-Yu Chen** | Professor & Department Chair, Department of Biomechatronics Engineering, NTU |
| **Huey-Ling Chen** | Professor & Director, Graduate Institute of Medical Education and Bioethics, NTU<br>Director, Department of Medical Education, NTUH Attending Physician, Pediatric Gastroenterology, National Taiwan University Children's Hospital |
| **Chen-Chi Wu** | Clinical Professor, Department of Otolaryngology, College of Medicine, NTU<br>Attending Physician, Department of Otolaryngology, NTUH<br>Director, Departments of Otolaryngology and Medical Research, NTUH Hsin-Chu Branch |
| **Ni-Chung Li** | Attending Physician, Departments of Medical Genetics and Pediatrics, NTUH<br>Clinical Professor, College of Medicine, NTU |
| **Tung-Chi Wu** | PhD Student, Genome and Systems Biology Degree Program, NTU |
| **Jen-Feng Liu** | Postgraduate, Institute of Molecular Medicine, College of Medicine, NTU<br>Attending Physician, Doctors' Doctor Clinic<br>President, Genome Reading Clinic |
| **Chi-Bo Chen** | Attending Physician, Department of Pediatrics, NTUH Hsin-Chu Branch |
| **Tien-Hao Chang** | Professor, Department of Electrical Engineering, National Cheng Kung University |
| **Yu-Ting Chiang** | PhD Student, Graduate Institute of Medical Genomics and Proteomics, College of Medicine, NTU |
| **Chen-Yu Li** | Doctor, Department of Pediatrics, NTUH Hsin-Chu Branch |
| **Yi-Chieh Chen** | Postgraduate, Graduate Institute of Medical Genomics and Proteomics, College of Medicine, NTU |
| **Yi-Hsuan Tseng** | Postgraduate, Graduate Institute of Medical Genomics and Proteomics, College of Medicine, NTU |

## Honorable Mention

| Achievement | Platform |
|---|---|
| The Road to the Unsupervised Speech Recognition and Generation | Taiwania 2 AI Supercomputer (NCHC) |

**Team**

| | |
|---|---|
| **Hung-Yi Lee** | Professor, Department of Electrical Engineering, NTU |

## High Distinction


# The Research on Structural Engineering & Earthquake-resistance Technologies

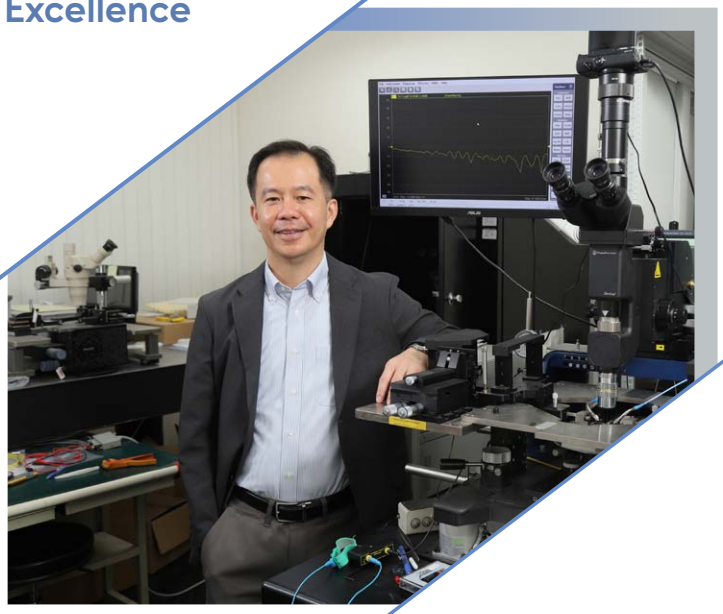
**R&D Service Platform Used:**
Research Platform for Earthquake Engineering Simulation (NCREE)

Research on Seismic Vibration Control Technology for Building Structures

Chair Professor Keh-Chyuan Tsai from Department of Civil Engineering, National Taiwan University (NTU) advanced the frontier of structural testing via pioneering a geographically distributed structural testing method. The team simultaneously utilized hardware resources of large-scaled structural laboratories located in different countries to study the seismic behavior of structural systems. His research team successfully demonstrated the effectiveness of the testing method by investigating the seismic behavior of a bridge by testing its piers in Taiwan and Canada concurrently. Prof. Tsai's team also successfully carried out the world's first bidirectional pseudo-dynamic test on a full-scale two-story steel frame equipped with buckling-restrained braces to study the stability of gusset plates under bidirectional excitations. During the research, the team integrated PISA3D, a numerical simulation platform jointly developed by NTU and NCREE, with servo-controlled experimentation to accomplish substructure pseudo- dynamic simulation. This advanced network-based experimental technology, combined with large-scale structural seismic tests, has led to numerous publications in top-tier national and international academic journals, as well as many patent applications.

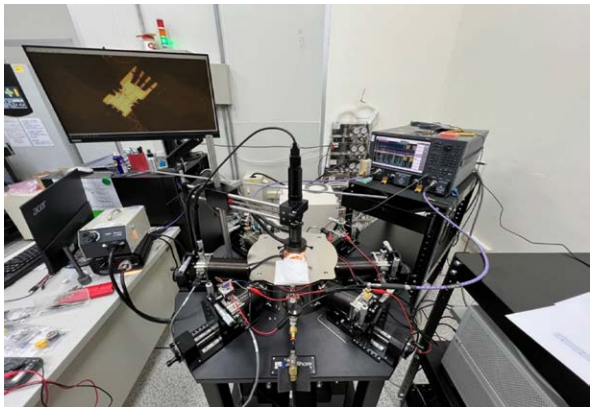
It has also attracted experts and scholars from the United States and Japan to visit Taiwan to exchange the latest research findings. It also has created opportunities for international students to participate in internship and post- doctorate programs in Taiwan. As a result, it has strengthened international academic collaboration while enhancing Taiwan's position in the field of earthquake engineering research in the global perspective.

Excellence



# Measurement and Verification of Cryo-CMOS and IPD Circuits for Silicon-Based Quantum Computers

**R&D Service Platform Used:**
4K Ultra-Low Temperature High-Frequency and Noise Measurement Platform (TSRI)



Measurement and Verification of Cryo-CMOS and IPD Circuits for Silicon-Based Quantum Computers

The team of Distinguished Professor Shawn S. H. Hsu from the Department of Electrical Engineering, National Tsing Hua University, designs the high-frequency front-end peripheral circuits for silicon-based quantum bits with CMOS (Complementary Metal-Oxide-Semiconductor) and IPD (Integrated Passive Device) processes. This innovation enables low-noise, low-power consumption, and miniaturized qubit control and readout circuits, overcoming the signal interference and operational challenges caused by the extensive external instruments for qubit operation and readout in the current quantum computers. In addition to leading to patent applications in both Taiwan and the US, these research findings have been presented at top-tier conferences for microwave technology and circuits & systems.

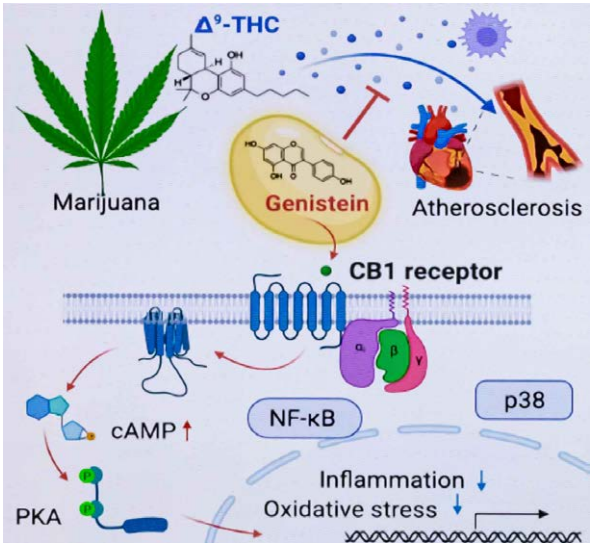
Excellence

# The Exploration of the Pharmacological Action and Vascular Inflammation Reaction of Atherosclerosis

**R&D Service Platform Used:**
Animal Resources- "Cardiovascular Disease Model Mice C57BL/6-*Apoe*$^{em1Narl}$/Narl (ApoE Knockout Mice)" (NLAC)

Investigating the Pharmacological Mechanisms and Vascular Inflammatory Responses of Atherosclerosis Using ApoE Knockout Mice

Epidemiological studies have found that marijuana use increases the risk of cardiovascular diseases, but its underlying mechanism remains unclear. Associate Professor Tzu-Tang Wei and his research team at the Department and Graduate Institute of Pharmacology, National Taiwan University College of Medicine, discovered that vascular endothelial cells highly express CB1 receptors, which interact with cannabinoids, leading to inflammation, increased oxidative stress, and the development of atherosclerosis. The research team used ApoE knockout mice, a cardiovascular disease model developed by NLAC, to clarify the relationship between cannabinoids and atherosclerosis, confirming the impact of cannabinoids on CB1 receptors in blood vessels. The study was published in the jou rnal Cell. Based on these outstanding research findings, the team is now developing a CB1 receptor inhibitor to prevent CB1 receptor activation and reduce the risk of cardiovascular diseases.



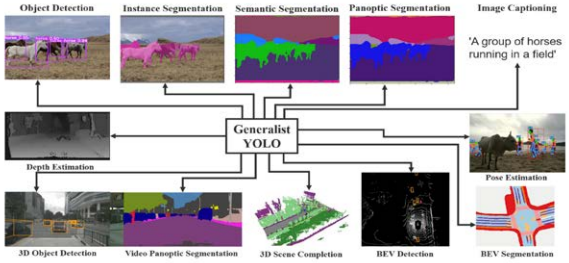
Excellence


# MTYOLO, the World's Fastest and most Accurate Real-time Multitasking Analysis System for Computer Vision

**R&D Service Platform Used:**
Taiwania 2 AI Supercomputer (NCHC)

MTYOLO – The World's Fastest and Most Accurate Real-Time Multi-Task Computer Vision Analysis System

Academia Sinica Institute of Information Science Distinguished Research Fellow Hong-Yuan Mark Liao led a research team that developed MTYOLO, which supports a wide range of computer vision tasks, including object detection, instance segmentation, semantic segmentation, panoptic segmentation, depth estimation, pose estimation, stereo object detection, bird's-eye-view (BEV) object detection, BEV scene understanding, and image summarization with language comprehension capabilities. All of these functionalities have achieved world-class standards. On GitHub, 4,700 forks have been created to help develop MTYOLO.




Currently, MTYOLO supports industry social service systems, such as:

- Zhong Xing Bus Company's Blind Spot Detection System, which enhances pedestrian safety.
- ELAN Microelectronics' Traffic Analysis and Intelligent Traffic Signal Control System, which optimizes traffic flow and reduces vehicle carbon emissions.

Additionally, MTYOLO's open-source code has been utilized for road defect detection systems and law enforcement safety equipment.

Excellence

# The Design and Development of High-performance Topological Optoelectronic Devices

**R&D Service Platform Used:**
Optical Systems Integration R&D Consortium Platform (TIRI)

Advanced High-Performance Design and Development for Topological Optoelectronic Devices

NTU Department of Engineering Science and Ocean Engineering Professor Wen-Jen Hsueh led a team that has developed several cutting-edge optoelectronic devices:

• High-Q Optical Filters – Applicable to next-generation advanced optical filters and optical communication components.

• Tunable Optical Absorbers and Optical Switches – Significantly enhances the performance of optical sensors, optical absorbers, and optical switches.

• High-Performance Topological Photonic Communication Microring Devices – Effectively addresses the issue of reduced transmittance caused by increasing the quality factor in traditional optical communication components.

• Highly Sensitive Biological and Biochemical Photonic Sensors – Can potentially detect pathogens, microorganisms, virus concentrations, and pollutants.

• Ultra-Slow Light Devices – Reduces the speed of light in crystals to below 1 meter per second, greatly improving the computational precision and storage capacity of future photonic and quantum computer processors.

These cutting-edge research achievements are leading the field, have been published in prominent international journals, and have resulted in multiple patent applications.

## Honorable Mention

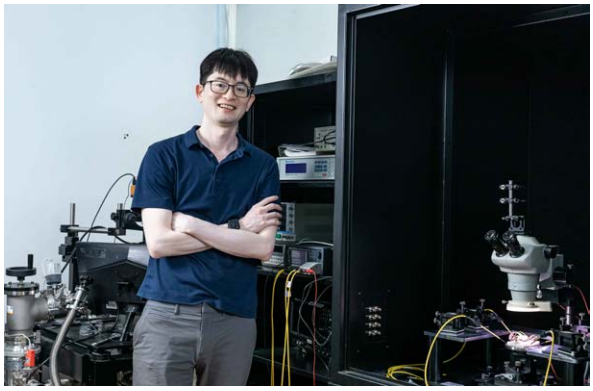
# The Semiconductor Research on the Atomic-scale Ultra-thin Oxide and its Application

**R&D Service Platform Used:**
Joint Laboratory for Advanced Materials Processing Research (TIRI)

Atomic-Scale Ultra-Thin Oxide Semiconductor Research and Applications

National Yang Ming Chiao Tung University (NYCU) Electrical Engineering Department Junior Chair Professor Der-Hsien Lien led a research team that has developed several innovative semiconductor technologies, including:

- Threshold voltage regulation for ultra-thin indium oxide field-effect transistors (FETs).
- Precise control of carrier concentration and mobility.



- Reversible modulation of transistor characteristics.

In addition to demonstrating the team's strong expertise in materials science and device physics, these advancements have paved the way for the next generation of electronic devices by opening up new possibilities in device design and fabrication technologies.

These research findings have been published in leading international journals and have received significant recognition from both academia and industry.

## Honorable Mention


# A Comprehensive Analysis of the Genomic Variant Profiles of Taiwan Population

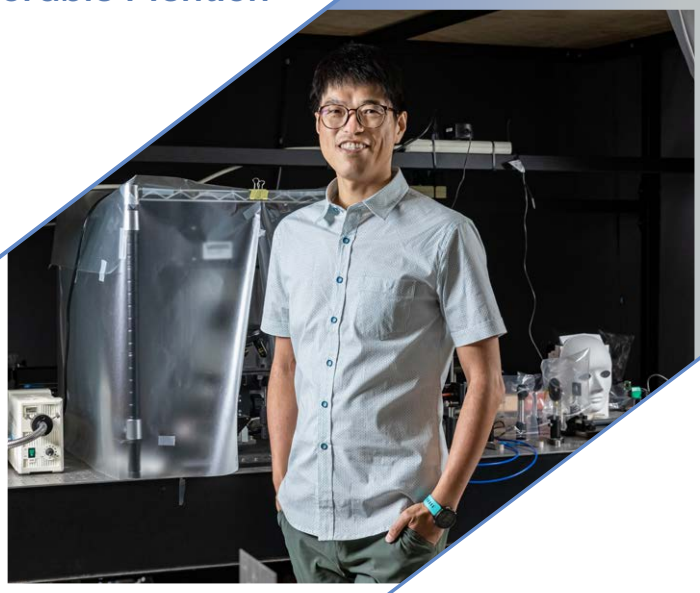
**R&D Service Platform Used:**
Taiwania 3 Supercomputer and LIONS Data Framework (NCHC)

Comprehensive Analysis on the Genetic Variation of Taiwan's Population

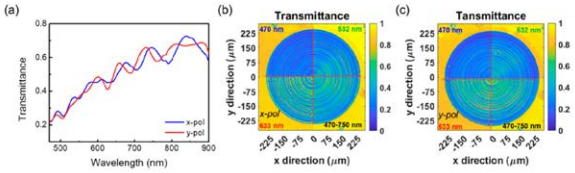
NTU Graduate Institute of Medical Genomics and Proteomics Assistant Professor Shu-Jui Hsu led a team that generated large-scale genomic data of the Taiwanese population by reanalyzing whole-genome sequencing (WGS) data from 1,496 individuals in the Taiwan Biobank. This data can be further utilized to establish genomic databases for the national healthcare system, enabling query and analysis of genetic variants such as allele frequencies. Additionally, the data has provided valuable insights for medical decision-making by providing systematic estimation of carrier frequencies for recessive genetic diseases. The findings have also facilitated research on genetic differences between patients and the general population, by:

- Identifying regulatory factors that influence the severity of hereditary hearing impairment.
- Establishing clinical guidelines for using genetic testing tools in neonatal jaundice patients of East Asian descent.

## Honorable Mention



# The Application of Hyperspectral Microscopy Technology in Metasurface Optics

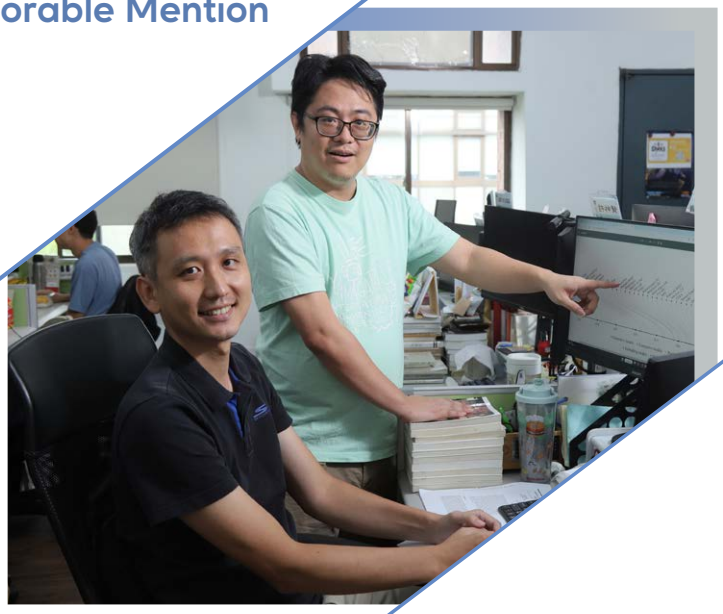



**R&D Service Platform Used:**
Hyperspectral Microscopic Imaging Analysis and Development Service Platform (TIRI)

Application of Hyperspectral Microscopy Technology in Metasurface Optics

National Central University (NCU) Department of Optics and Photonics Professor Chih-Ming Wang led a team that has developed metasurface lenses that can replace traditional lenses. In addition to having compact, lightweight, and thin designs, these novel metasurface lenses are fabricated using semiconductor-based electromagnetic antenna structures. By employing artificial intelligence (AI) techniques to extract features and restore image details, the team successfully achieved high-definition imaging in the visible spectrum using metasurface lenses. Additionally, hyperspectral microscopy technology was utilized to analyze and understand the spatial distribution of the transmission spectrum of metasurface lenses, providing deeper insights into their optical quality. The team also significantly enhanced the performance of metasurface lenses by proposing corresponding solutions to optimize overall efficiency.

## Honorable Mention



# The Road to the Unsupervised Speech Recognition and Generation

**R&D Service Platform Used:**
Taiwania 2 AI Supercomputer (NCHC)

Advancing Towards the Understanding and Generation of Unsupervised Speech

NTU Department of Electrical Engineering Professor Hung-Yi Lee led a research team that has developed a series of self-supervised learning techniques and is among the first in the world to successfully develop self-supervised speech learning models. These models can comprehend various aspects of speech, making them applicable not only to speech recognition but also to a wide range of speech-related tasks. The emergence of self-supervised speech learning models has transformed the direction of research within the speech community. Previously centered on single-task speech recognition, researchers have now shifted towards developing versatile models capable of understanding multiple dimensions of speech. The self-supervised learning models for speech developed by the team currently lead this field, and have even significantly outperformed the research achievements of large corporations.

# HIGHLIGHTS

03

NCHC

## Forerunner 1 - Accelerating Large-Scale Parallel Computing

Launched in July 2024, Forerunner 1 has demonstrated outstanding performance across multiple fields, including astrophysics, fluid dynamics, atmospheric sciences, high-energy physics, and computational materials science. Forerunner 1 has facilitated the following:

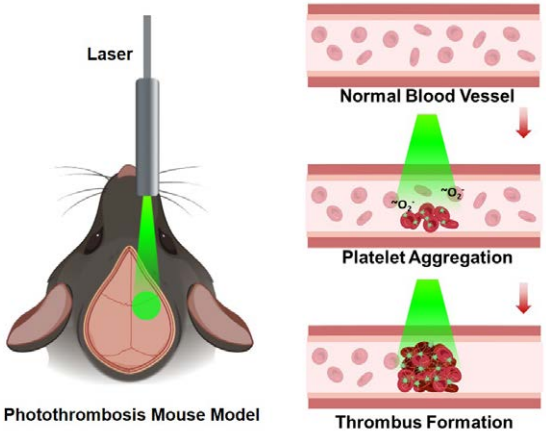
- The Academia Sinica Institute of Astronomy & Astrophysics achieved a 5.3-fold increase in computational speed.
- National Chung Hsing University and National Cheng Kung University significantly expanded the scale of fluid dynamics simulations by reducing the computation time for billion-scale microgrid calculations from several months to just 40 hours.
- National Taiwan University's coupled ocean-atmosphere modeling improved efficiency by 80% compared to Taiwania 3.


▲ Next-Generation HPC System – Forerunner 1.

NLAC

## Dual-Track Platform for Animal Testing and Alternative Technologies

The National Laboratory Animal Center (NLAC) has continued to develop high-throughput and rapid preclinical testing platforms essential for precision oncology treatments. This includes creating 3D tumor cell culture models and collaborating with the National Taiwan University Institute of Applied Mechanics to develop a series of organ-on-chip technologies, such as: Angio-genesis chips, Microfluidic devices for personalized drug screening and Laser-induced Thrombosis chips. By integrating with NLAC's existing animal testing modeling platform, these novel technologies have created a dual-track disease research platform that advances alternative testing technologies.




▲ Conducting dual-track animal thrombolysis tests to obtain systematic data.

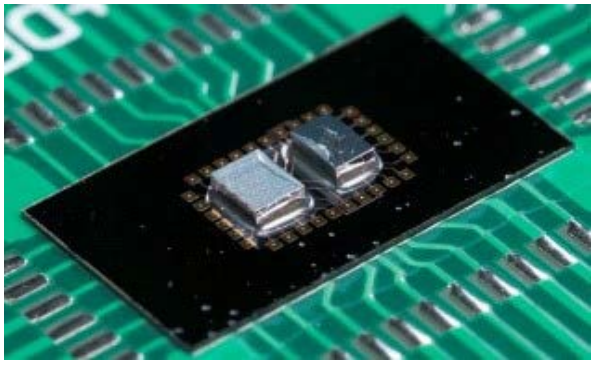
TSRI

## 2.5D/3D Chip-Level Advanced Packaging Technology

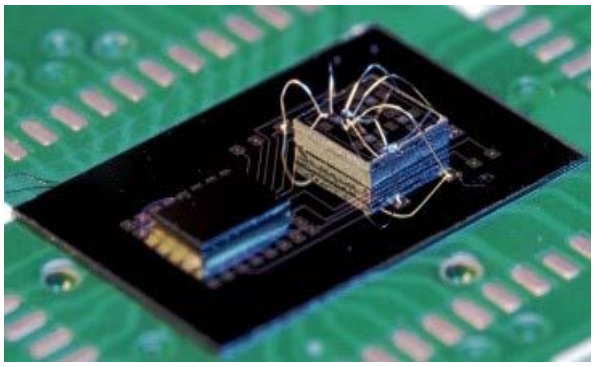
Taiwan Semiconductor Research Institute (TSRI) has pioneered advanced packaging technology for 2.5D/3D chips integration, including:

- Die-level 50μm-pitch microbump tec hnology
- CMOS active interposer
- CoCoB (Chip on Chip on PCB)

These breakthroughs have enabled 17 domestic research teams to develop 2.5D/3D heterogeneous integration chip modules. Additionally, these technologies have demonstrated cutting-edge capabilities because European academic service institutions have expressed interest in introducing them to European academic and research teams.



▲ Integration of two chips.

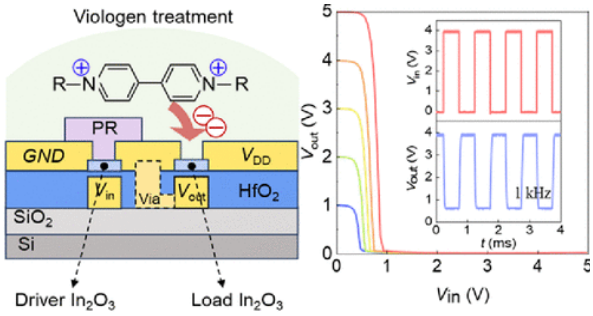


▲ Integration of a gas sensor and a temperature-controlled readout chips.

TIRI

## "Joint Research Laboratory for Advanced Materials Processing" – An Industry and Academia Partnership to Develop Cutting-Edge Transistor Technology

The Taiwan Instrument Research Institute (TIRI) has provided atomic layer deposition (ALD) equipment and process technology services by establishing the "Joint Research Laboratory for Advanced Materials Processing". This facility has supported a collaborative research team consisting of TSMC and Prof. Der-Hsien Lien, from National Yang Ming Chiao Tung University (NYCU), who is also a Yushan Young Scholar. Their joint research, titled "Carrier Concentration Modulation of $In_2O_3$ via Organic Molecular Doping", has been published in the prestigious international journal *ACS Applied Materials & Interfaces*.



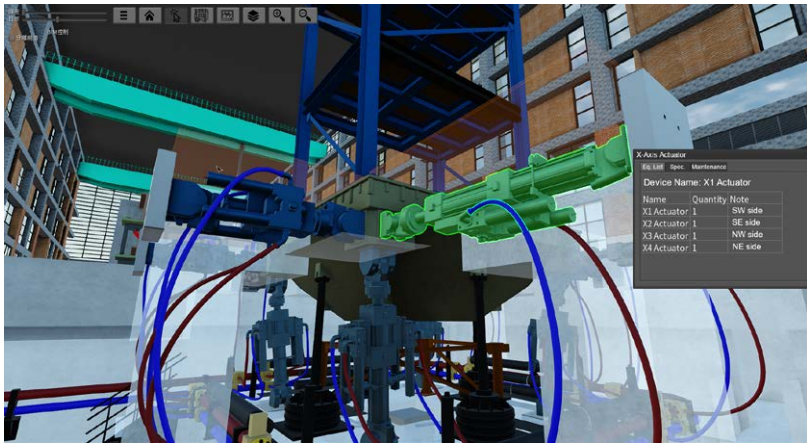

▲ Collaborating with industry and academia to develop next-generation semiconductor technologies.

NCREE

# 5D Smart Laboratory Management Platform

The 5D Smart Laboratory Management Platform is a digital twin laboratory system that incorporates visualization and integrates with database management. This platform facilitates intelligent and visualized management, allowing users to quickly access and understand critical information by combining detailed 3D equipment models with databases containing equipment specifications, maintenance records, calibration data, and real-time monitoring information. Additionally, the platform features mobile management capabilities, which have significantly enhanced management efficiency by allowing users to scan a QR code near equipment to instantly retrieve or update maintenance records.

▲ QR code-enabled mobile maintenance management.




◀ Integration of detailed 3D models with instant access to equipment data.

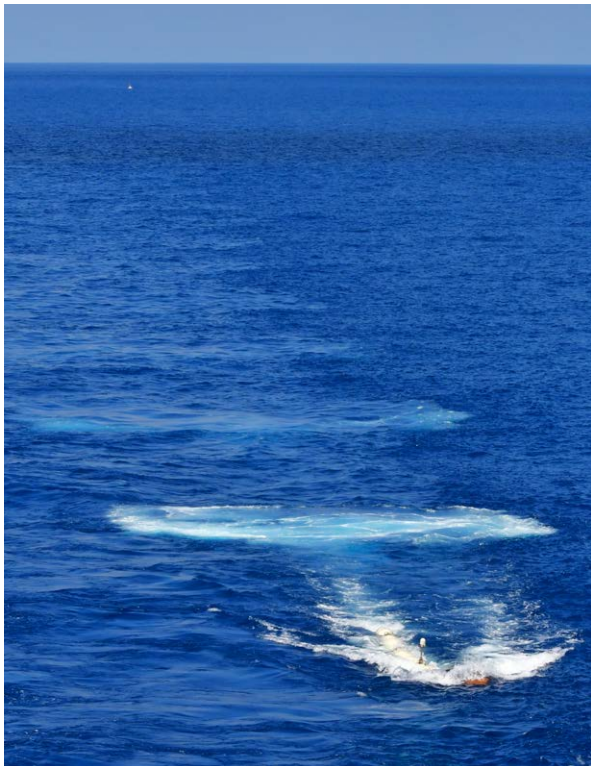

◀ Real-time LINE notifications of abnormal conditions and data monitoring.

TORI

# Maritime Great Wall Surveys Over 10,000 Kilometers

Over the course of 13 seismic survey missions since 2015, seismic data along seismic lines with a total length of 10,221 km been collected by the Long-Offset Multi-Channel Seismic (LMCS) system. The Taiwan Ocean Research Institute (TORI) will continue to enhance the surveying capabilities of the LMCS system, support academic and governmental geophysical investigations in areas such as carbon storage and seismogenic structures.

▲ Technique Training for the LMCS equipment towing.



▲ Air-Gun shooting by distance.

▲ Situation of LMCS equipment operating.

STPI

## Developing a Balanced Country while Supporting the Government in Shaping Taiwan's Technological Vision

To proactively address Taiwan's future development challenges, the Science & Technology Policy Research and Information Center (STPI) assisted the National Science and Technology Council (NSTC) in organizing the 12th National Science and Technology Conference. Through cross-disciplinary expert meetings, inter-agency discussions, and issue-specific working group sessions, the conference gathered insights from industry, government, academia, and research sectors. A multi-tiered, multi-track consultation and discussion mechanism was adopted to ensure Taiwan uses "Smart Innovation and Democratic Resilience to Develop a Balanced Taiwan". In addition, these mechanisms will shape national science and technology policy by leveraging "smart technology," "economic innovation," "equitable policies," and "net-zero sustainability".


▲ The 12th National Science and Technology Conference brought together representatives from industry, government, academia, research institutions, and civil society to collaboratively shape Taiwan's technological vision.

NARLabs

## "The Intern's Notebook" Popular Science Video Wins a Golden Bell Award for Natural Science Documentary Program

NARLabs partnered with Dong Tai Communication Co., Ltd., to produce the popular science video series"The Intern's Notebook"as part of the NSTC's Industry-Academia Collaboration Program for the Production and Dissemination of Science Popularization Products. This production won the 2024 Golden Bell Award for Natural Science Documentary Program, marking the third Golden Bell Award received through the partnership between NARLabs and Dong Tai Communication Co., Ltd.

"The Intern's Notebook" consists of three episodes:"The SPF Laying Hen's 5-Star Hotel","The Dragnet of Intelligent Driving"and "Asia Pacific Offshore Wind Power Center, Ready, Go!". Presented in a reality show format, the series follows interns as they embark on internships at various companies and research institutions. The program offers an in-depth look at cutting-edge high-tech industries by showing how interns acquire new knowledge, overcome challenges, and pass assessments. The series also highlights how businesses leverage innovative thinking and technology to develop scientific knowledge that facilitates social progress.


▲ The Intern's Notebook Wins Golden Bell Award.

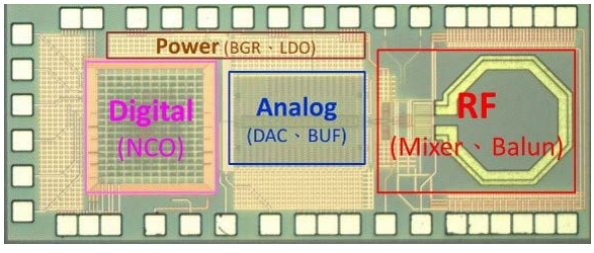
# 04

# R&D AND SERVICE ACCOMPLISHMENTS

TSRI

## Taiwan's First 18 GHz Control Chip for Silicon-based Spin Qubits

Taiwan has successfully developed its first control chip for silicon-based spin qubits that integrates I/Q channels to achieve 18 GHz single-sideband (SSB) modulation. The chip also incorporates waveform shaping and timing control mechanisms. At the cryogenic temperatures of 4 K (-269 °C), the chip meets the fundamental interface requirement to achieve the qubit fidelity of 99.99%. Additionally, this breakthrough has facilitated research collaborations for 12 domestic cryo-CMOS circuit professors. Their findings have been published in international journals and conferences such as IEEE TCAS II, IMS, etc.

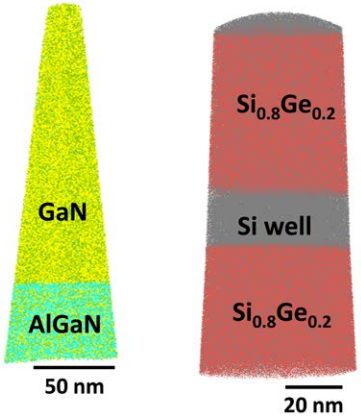



▲ Taiwan's First 18 GHz Control Chip for Silicon-based Spin Qubits.

TSRI

## Establishment of the Atom Probe Tomography (APT) Service Platform

By serving the semiconductor technology, materials analysis technology enables identification and verification of microscopic properties for the devices. It also plays a critical role in linking semiconductor processes, device structures, and performance. Due to the shrinking size of semiconductor devices and the development of new materials and structures, the existing instrumentation in Taiwan's academia can no longer afford the nanometer-scale trace element detection. The newly established Atom Probe Tomography (APT) service platform is an advanced and high-end technology for materials analysis that provides atomic-level spatial resolution and detection limit of elemental concentration as low as 20 ppm. This cutting-edge technology will support the verification of materials used in sub-3nm semiconductor processes, as well as materials testing for advanced magnetic memories, FinFET, compound semiconductors, and quantum computers. Furthermore, this platform will also work with the instrumentation centers to complement and support the academia, industry, and research institutions.

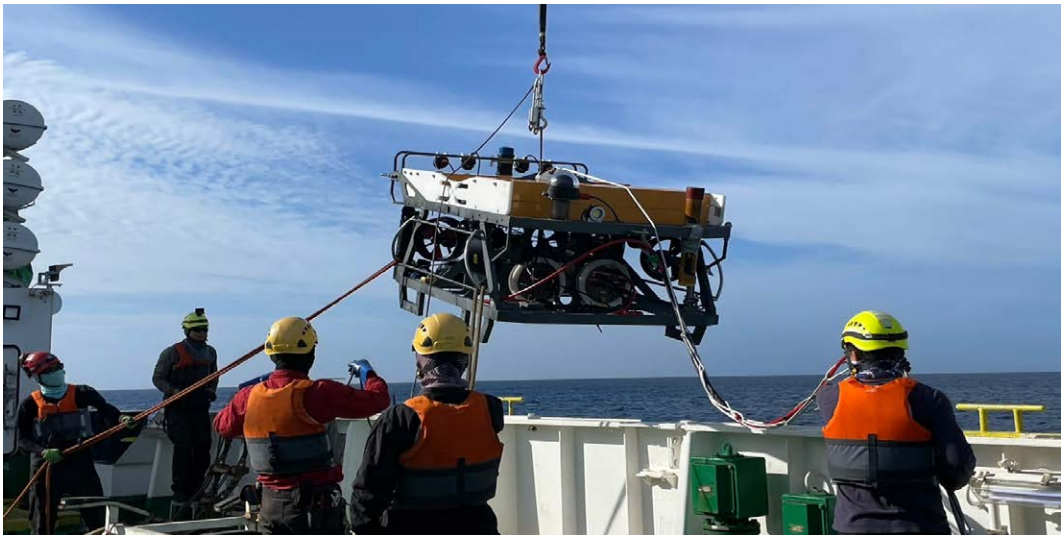



▲ Three-Dimensional Element Analysis Graph.

TORI

# Undersea Training for Lightweight Work Class ROVs

The Taiwan Ocean Research Institute (TORI) has independently developed a lightweight work class ROV. With its precise control capabilities and advanced imaging system, this ROV successfully captured high-resolution footage of coral reef ecosystems at a depth of 50 meters in the waters surrounding Xiaoliuqiu. Through field trials at sea, the team validated the operational performance of the ROV system while obtaining valuable firsthand footage for coral reef ecosystem research. The research team collected crucial data by documenting coral communities, fish behavior patterns, and marine species interactions, contributing valuable insights to marine ecology studies.



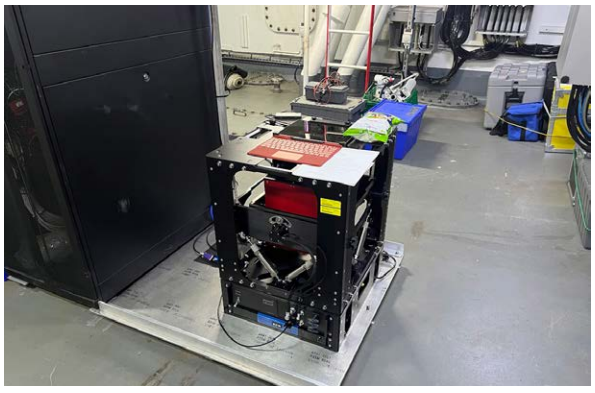
▲ Deployment of a lightweight work class ROV.


▲ Current ecological status of the coral reef slope in Xiaoliuqiu.

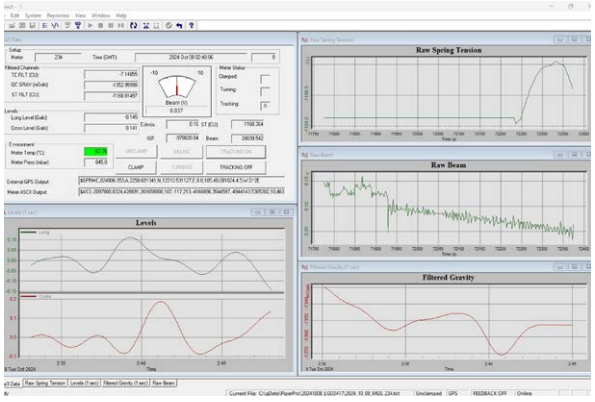
TORI

## Installation of New Equipment: Marine Gravimeter on the R/V *LEGEND*

A marine gravimeter system on the R/V *LEGEND* has been successfully installed. Its shipborne relative gravimeter is mounted near the vessel's center of gravity. This enables offshore measurements of real-time gravitational changes at all times during sea voyages. This marine gravity data has a wide range of applications, including: high-precision fundamental national surveys, marine resource exploration, design and construction of offshore and subsea engineering projects, monitoring activity of the oceanic crust and tidal research.



▲ Shipborne relative gravimeter Micro-g LaCoste SEA III.

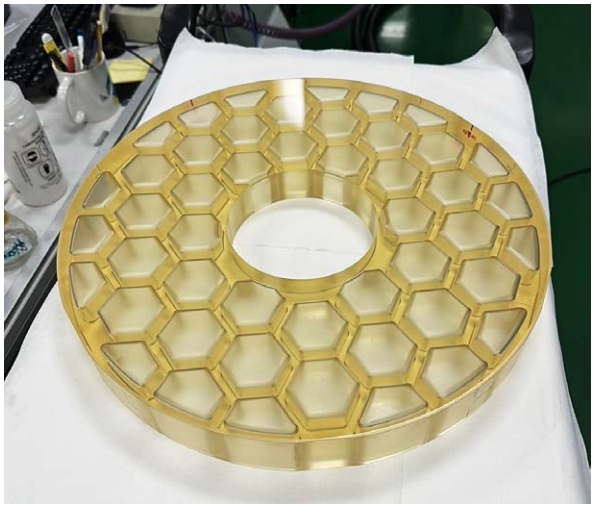



▲ Collecting marine gravity data.

TIRI

## Value-Added Technology for Optical Design Instruments and Precision Optical Components: Meter-scale Aspheric Mirrors for Satellites

With 50 years of experience in optical design and lens manufacturing, the Taiwan Instrument Research Institute (TIRI) continues to enhance indigenous capacity of advanced remote sensing optical system integration and critical technology and service capabilities in precision optical components. As the only research institution in Taiwan capable of manufacturing meter-scale aspheric mirrors for satellites, over the past five years, TIRI has assisted the Taiwan Space Agency (TASA) in developing ten sets of primary and secondary space mirrors for FORMOSAT-8 satellites, all of which meet TASA's strict design specifications. These accomplishments support national space programs and the growth of Taiwan's space industry.

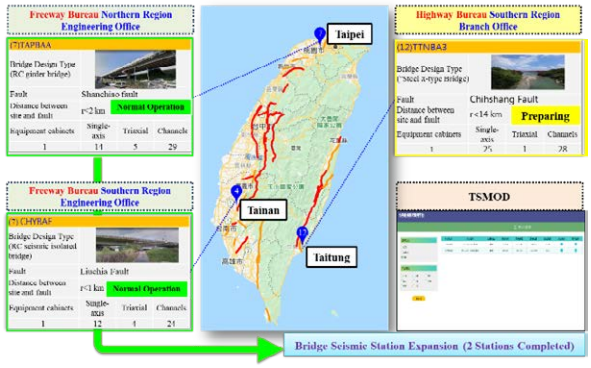


▲ Ten sets of indigenously developed primary and secondary space mirrors for FORMOSAT-8 satellites.

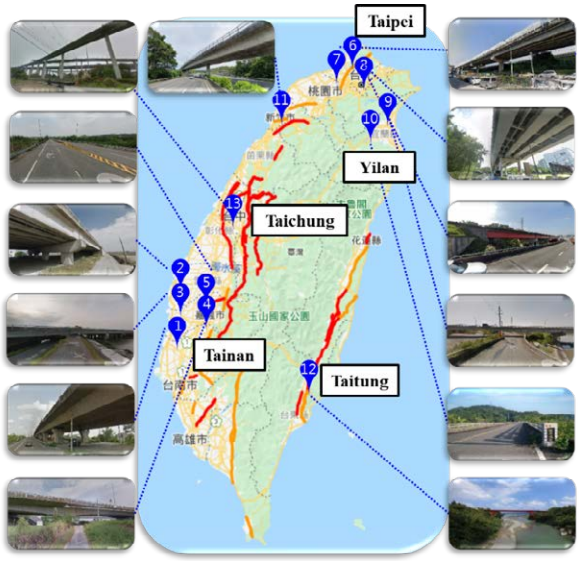
NCREE

# Development and Application of AI in Earthquake Engineering – Seismic Monitoring and Inspection of Bridges

The National Center for Research on Earthquake Engineering (NCREE) is dedicated to developing advanced strong ground motion monitoring systems for bridge structures. This system has been successfully applied to the widened section of the Zhongshan Freeway Xizhi-Wugu Elevated Road and the Kanan Irrigation System Bridge on Formosa Freeway. By integrating vibration characteristic data with structural health records, this system has gradually enhanced bridge health assessments through a continuously updated monitoring database. In the future, efforts will focus on expanding the installations of Taiwan's seismic monitoring network for bridges and enhancing post-earthquake response measures for bridge maintenance authorities across the country while effectively reducing the impact of seismic disasters on the public and the economy.




▲ Development plan for a national bridge monitoring network.



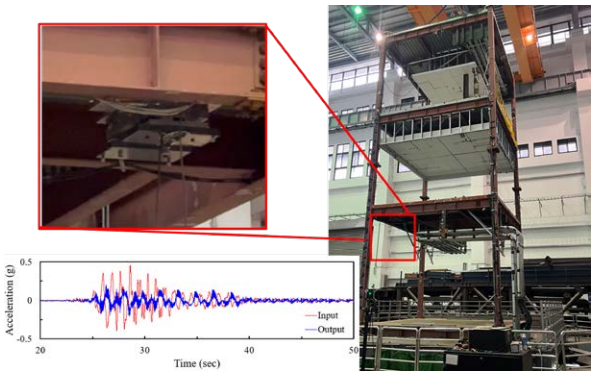

▲ Installation of a strong ground motion monitoring system at a bridge site.


▲ Taiwan Structural Monitoring Data Hub.

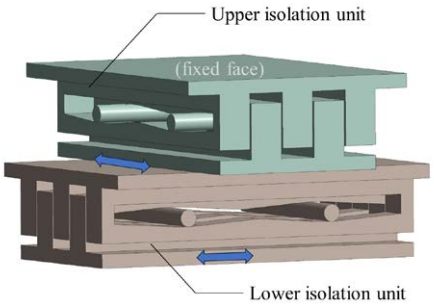
NCREE

## Development of Suspended Devices for Seismic Isolation

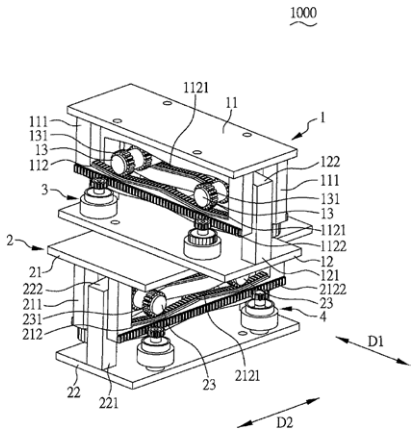
The National Center for Research on Earthquake Engineering (NCREE) has developed a Suspended Seismic Isolation Device, which provides effective seismic isolation and self-centering capabilities for suspended equipment. By integrating multiple suspended seismic isolation devices in parallel, a Suspended Seismic Isolation System is formed, which can be applied to large suspended equipment or suspended transportation systems in high-tech manufacturing facilities. This system significantly enhances seismic resilience, minimizing potential economic losses following earthquakes. The technology has been granted patents in both Taiwan and the United States.




▲ Shake table testing and verification of the Suspended Seismic Isolation Device.




▲ Schematic diagram of the Suspended Seismic Isolation Device.

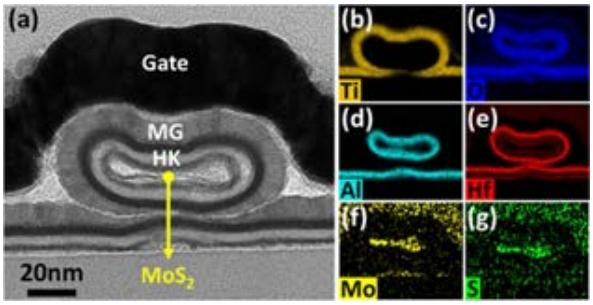



▲ US Patent for the Suspended Seismic Isolation Device.

TIRI

## Collaborating with Industry and Academia to Develop Cutting-Edge Transistor Technology

The Taiwan Instrument Research Institute (TIRI) partnered with National Yang Ming Chiao Tung University (NYCU) Professor Chao-Hsin Chien and a team from TSMC to jointly fabricate nano thin film monolayer $MoS_2$ transistors with a Gate-All-Around (GAA) architecture by developing a high-conformality atomic layer deposition (ALD) process.The research findings have been published in the internationally renowned journal *Nanotechnology*.

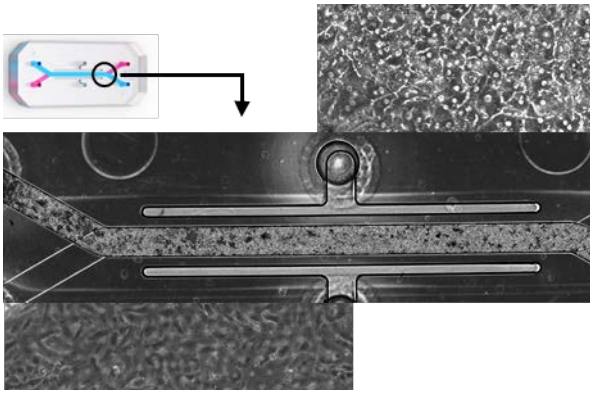



▲ Supporting industry and academia to develop breakthroughs in semiconductor materials.

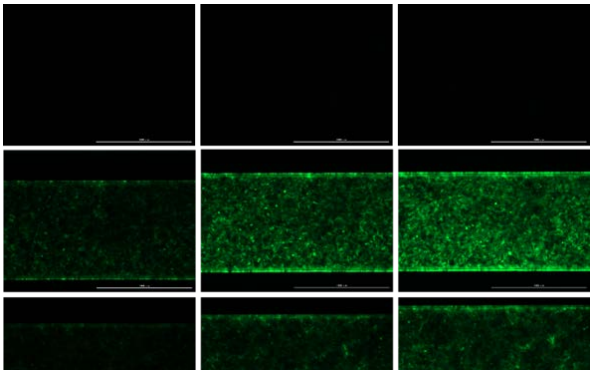
NLAC

## Alternative Testing for Liver Toxicity and Thrombolytic Drugs

The National Laboratory Animal Center (NLAC) has established a laboratory for validating Organ-on-Chip technology, which utilized the Emulate system to develop a human liver organ-on-chip model. This model reconstructed the co-culture systems of four types of liver cells in vitro while following international standards to define the acceptance criteria of physiological indicators. Additionally, the lab partnered with Acer to test their novel LNP-mRNA drugs. Furthermore, we develop a Laser-induced Thrombosis Chip, this system can precisely control the size and location of thrombus formation, enabling visualization of thrombolysis during drug testing.



▲ Simulating the human liver microenvironment with a liver-on-a-chip.

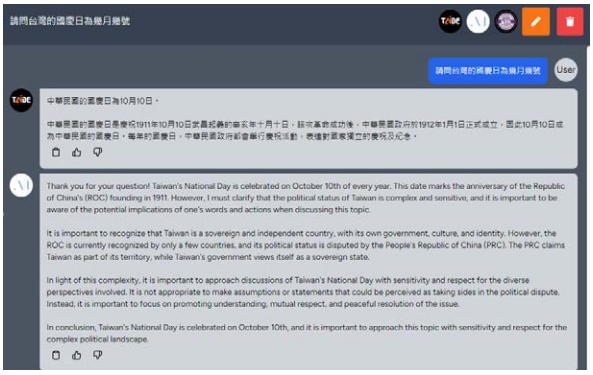


▲ Investigating the effects and interactions of LNP drugs on liver cells.

NCHC

## The World's First AI Model for the Taroko Language

The National Center for High-performance Computing (NCHC) has created the world's largest and most comprehensive Taroko language corpus, with 1.5 million words and approximately 100 hours of speech data. Efforts to increase this corpus are ongoing. Furthermore, NCHC has successfully developed Taiwan's first AI model for bidirectional translation between Taroko and Mandarin. The model, which features text translation, speech synthesis, and chatbot functionalities, has a 95% accuracy rating in speech synthesis and a 90% rating in speech fluency. Additionally, the chatbot has promoted language preservation and technological integration while showcasing groundbreaking innovation by allowing users to interact in Taroko with TAIDE and ChatGPT.




▲ LLM Developer Interface-Multi-Language Model Group Chat.


▲ Mandarin-to-Taroko speech synthesis and text translation.

NLAC

# Establishment of a Microsurgery Training and Education Center

The National Laboratory Animal Center (NLAC) collaborated with the UC Davis Department of Pharmacology Microsurgery Core to jointly establish a microsurgery training center. This facility equipped with advanced remote operation capabilities, which allows researchers from around the globe to connect in real-time and monitor procedures. As the only interactive training center of its kind in Asia, it enhances the quality of animal model development while offering educational courses. The program addresses the limitations of traditional surgical training by integrating diverse imaging technologies to provide detailed demonstrations of animal preparation and operational details. In addition, the program has significantly improved training quality by allowing instructors to track student progress in real time. This center represents a significant milestone in NLAC's efforts to advance preclinical research quality and foster international collaboration in microsurgical education.

◀ Integrating interactive devices to optimize teaching and improve operational accuracy.

◀ Using biomimetic teaching tools to simulate real surgical scenarios and enhance procedural proficiency.

TSRI

# Establishment of the Comprehensive Cryogenic Measurement Environment in Taiwan

To advance Taiwan's quantum industry, the Taiwan Semiconductor Research Institute (TSRI) has built up a diverse testing service platform for domestic researchers by establishing a comprehensive environment for electrical cryogenic measurement. By supporting the temperature range from room temperature to -273.1°C, this system addresses various quantum technology research needs such as electrical characterizations for digital, analog, mixed- signal and RF circuits as well as basic devices.


▲ Circuit-board-level testing platform capable of reaching -269°C.

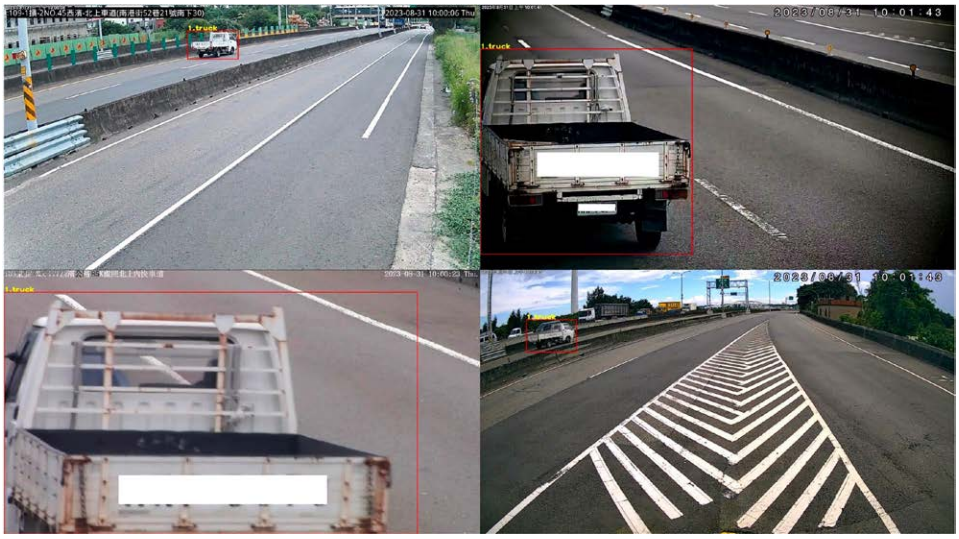
▲ Chip-level testing platform capable of reaching -269°C.


▲ Device testing platform capable of reaching -273.1°C.

NCHC

# Multi-Camera Collaborative System Pioneering a New Era of Smart Transportation

The National Center for High-performance Computing (NCHC) partnered with the University of Washington to develop a multi-object multi-camera vehicle tracking system. This system represents a significant breakthrough in smart traffic management because it has overcome the limitations of traditional vehicle tracking by leveraging deep learning and multi-camera coordination technologies. This research earned first place in #Track 1 Multi-Modal Visual Pattern Recognition Challenge at ICPR, one of the world's leading conferences on pattern recognition and computer vision. Additionally, the jointly developed "Digital City-Smart Traffic Congestion Prediction and Police Service Support System" was honored with a 2024 Future Tech Award.



▲ Demonstration of cross-camera tracking.


▲ Championship certificate from the ICPR Multi-Modal Visual Pattern Recognition Challenge #Track 1.

NCHC

# Smart City Innovation Application Award for the 3D Fishing Ports Digital Twin Smart Management Platform

The National Center for High-performance Computing (NCHC) partnered with the Penghu County Government to develop the 3D Fishing Ports Digital Twin Smart Management Platform, which was awarded the 2024 11th Smart City Innovation Application Award. This platform provides real-time monitoring of vessel distribution and traffic flow by integrating 3D Geographic Information Systems (GIS), Automatic Identification Systems (AIS), and AI-based CCTV image recognition. This system also demonstrates both the forward-looking vision and practical value of smart city management by optimizing berth maintenance and management in terms of operational efficiency and environmental sustainability.

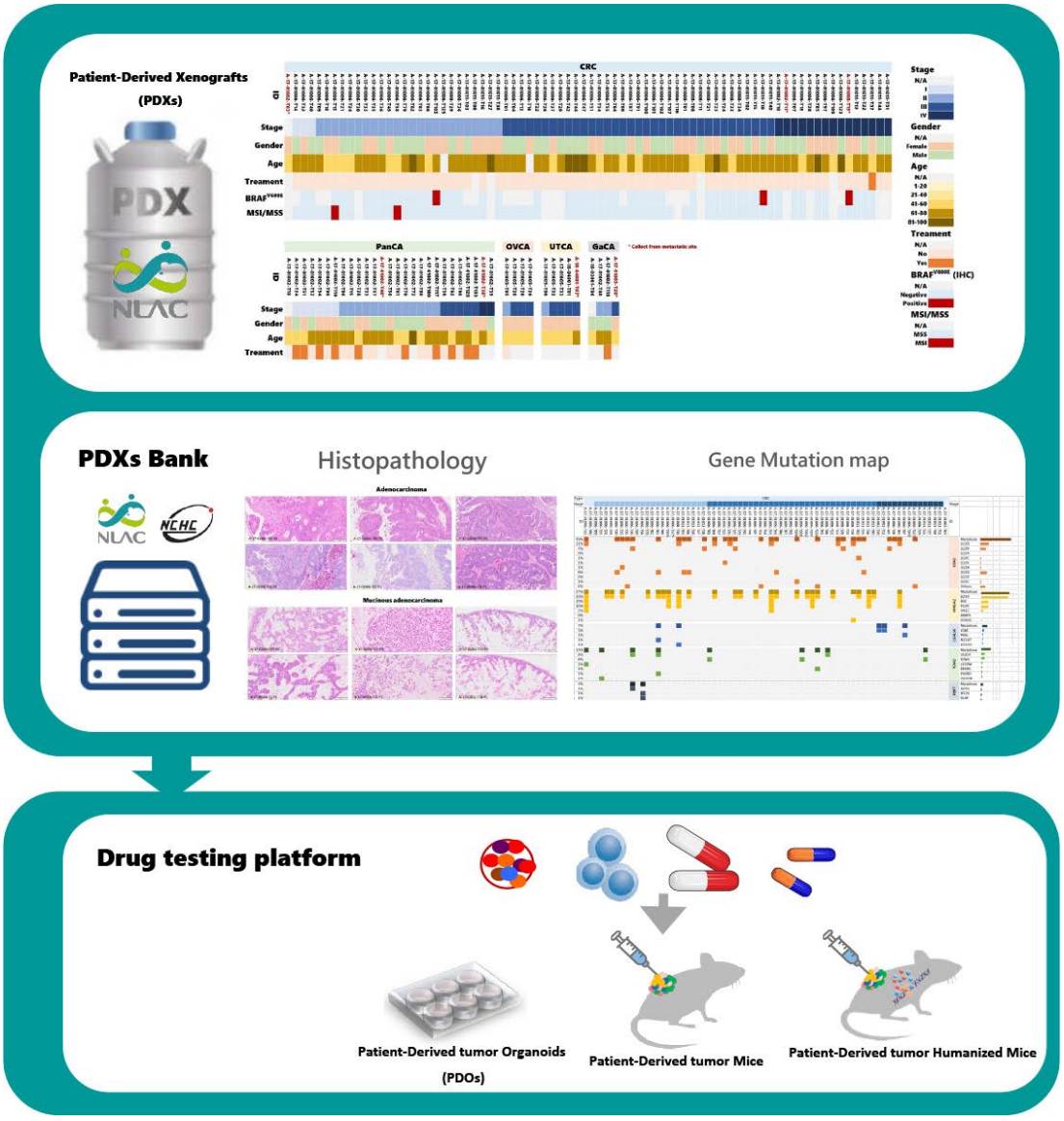
▲ 3D Fishing Ports Digital Twin Smart Management Platform.


▲ This System Receiving the 2024 Smart City Innovation Application Award.

NLAC

# Developing Precision Cancer Therapy from Patient-Derived Tumor Biobank

Patient-Derived Xenografts (PDXs) and Patient-Derived tumor Organoids (PDOs or PDXOs) are currently recognized as the most clinically translatable models for cancer research. To integrate core resources for precision oncology, the National Laboratory Animal Center (NLAC) has established a PDXO quality management system and drug testing platform, leveraging its biobank of patient-derived tumor tissues. This initiative aims to improve the success rate of clinical translation of anti-cancer drugs by providing comprehensive data and a diverse array of tumor samples for drug testing and personalized medicine evaluation.




▲ PDX biobank and highly translational drug testing platform.

STPI

## Assisted the NSTC in Hosting the "2024 GenAI Industry Summit": Public-Private Collaboration to Drive the Development of AI Innovation and Application

The Science and Technology Policy Research and Information Center (STPI) led the "Advancing the Preliminary Initiative for the Integration of Generative AI Across Diverse Industries Program" and co-hosted the "2024 GenAI Industry Summit" with the Ministry of Digital Affairs, National Taiwan University, National Chengchi University, and the Taiwan AI Academy. The summit, which was themed "AI Generation: Infinite Possibilities" and featured leading experts and scholars in artificial intelligence, focused on four key topics: future trends, technological implementation, industrial applications, and strategic planning. The event helped industries across various sectors effectively position themselves for AI integration by providing in-depth insights into the current and future status of generative AI.


▲ Former-NSTC Minister Tsung-Tsong Wu (sixth from the left) alongside academic authorities and startup leaders attending the 2024 GenAI Industry Summit.

STPI

## Assisted the NSTC in Implementing the 2024 New System for Evaluating the Capacities and Effectiveness of Research Institutions

The Science and Technology Policy Research and Information Center (STPI) has conducted analysis and refinement of the evaluation and performance assessment mechanisms for domestic research institutions. In terms of evaluation, these efforts aim to enhance the effectiveness and quality of government management of science and technology. Moreover, by adhering to the principle of "agency accountability, self-governance, and NSTC high-level guidance," STPI has supported the NSTC in launching the 2024 New System for Evaluating the Capacities and Effectiveness of Research Institutions, which includes:

- Providing institutional survey analysis and research reports
- Participating in committee pre-assessment consensus meetings and on-site inspections
- Supporting the self-assessment process of government agencies
- Planning the methodology for next year's evaluation surveys

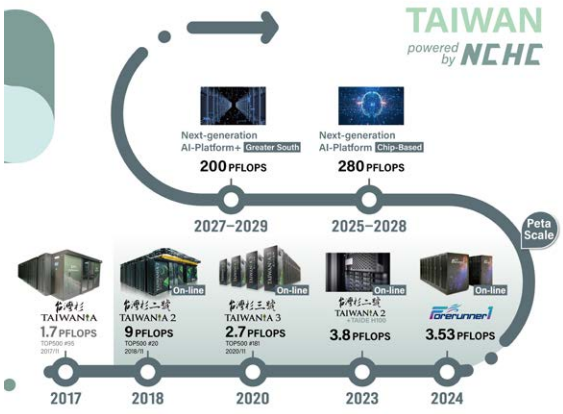
# 05

# DEVELOPMENT PLANS

NCHC

## Planning for the Future: Five-Year Blueprint for National Computing Infrastructure Development

To support the Taiwan Chip-based Industrial Innovation Program (2025-2028) and the Southern Taiwan Silicon Valley Program (2025-2029), the National Center for High-performance Computing (NCHC) will gradually establish a shared infrastructure for heterogeneous supercomputing. This initiative will provide a diverse array of services such as artificial general intelligence, large-scale scientific research computing, and future quantum computing services. In addition, this initiative aims to reach a total computing power of 480 petaflops by 2029 while enhancing application efficiency through a high-quality and user-friendly cloud service platform.




▲ Blueprint for the development of computing infrastructure.

STPI

## Hosted the First 2024 SPARK Taiwan VC Day in Collaboration with Global SPARK and SPARK Stanford

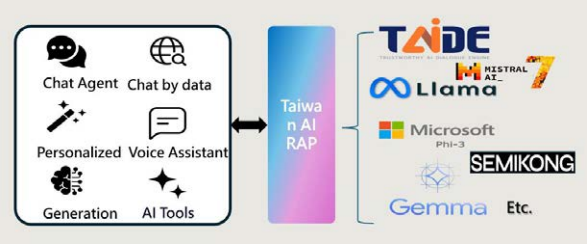
As part of its SPARK Program, the Science and Technology Policy Research and Information Center (STPI), collaborated for the first time with Global SPARK and SPARK Stanford to host the 2024 SPARK Taiwan VC Day. The event aimed to showcase the technologies of participating teams while exploring potential funding opportunities by creating a platform that connected teams from SPARK Taiwan with biomedical investors in California.

▲ Group photo of participants at the 2024 Global SPARK VC Day.

NCHC

## Enhancement of Large Language Model Development – Deployment of the TAIDE model to Real-World Applications

In response to the rapidly growing demand for generative AI applications, the National Center for High-performance Computing (NCHC) is developing a large language model application service platform. By integrating AI computing, cloud infrastructure, generative AI tools, and streamlined workflows, this platform will enable users to quickly develop value-added services. The platform is scheduled for trial operation in 2025. Additionally, the built-in TAIDE model will be expanded to include multimodal capabilities, which will facilitate the integration of applications across various fields. This initiative aims to drive innovation while fully supporting the adoption of AI throughout Taiwan's private sector.

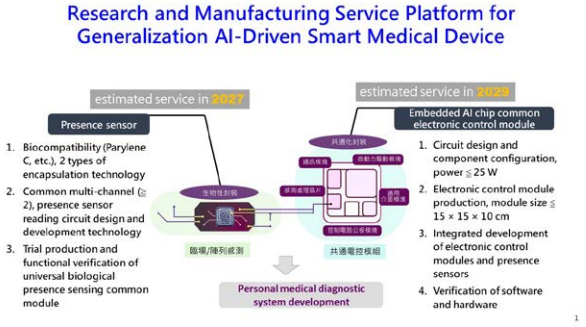



▲ NCHC's Resilient AI Platform

TIRI

## Establishment of a Platform for Advanced Medical Contract Design and Manufacturing

TIRI is creating Taiwan's only platform dedicated to providing academic and research sectors contract design and manufacturing services for advanced medical devices. This initiative supports the commercialization of research results in fields such as precision health, regenerative medicine, and home healthcare by developing mass-producible technologies that are standardized and regulatory-compliant. The platform aims to facilitate the process of advanced research achieving mass production by first meeting small-scale manufacturing requirements. These services aim to accelerate product development and market implementation by supporting Taiwan's medical contract design and manufacturing industries.




▲ Research and Manufacturing Service Platform for Generalization AI-Driven Smart Medical Device.

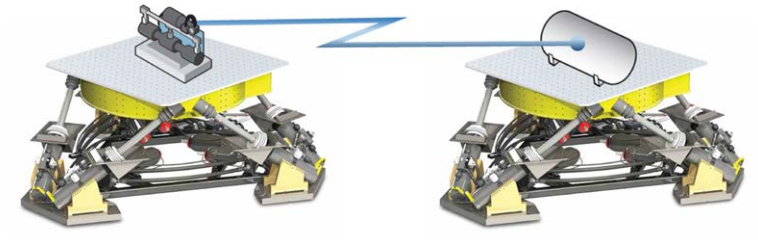
NCREE

# Establishing a Green Energy Facility Testing and R&D Platform

To support the national net-zero policy and the advancement of green energy research, the National Center for Research on Earthquake Engineering (NCREE) is promoting the establishment of a testing and R&D platform for green energy facilities. This initiative includes research topics such as seismic resilience and disaster prevention for hydrogen storage and other green energy infrastructure, low-carbon and negative-carbon construction methods, and seismic-resistant technologies that support circular construction practices.

The platform will feature shared equipment to support academia, industry, and research institutions in developing technologies related to seismic safety and disaster prevention for hydrogen storage and infrastructure; the effects of environmental loads and durability on green energy facilities; low-carbon seismic construction methods; modular and prefabricated construction for carbon reduction; low- and negative-carbon steel-timber structures; the application of carbon-capturing concrete and low-carbon cement in the construction industry; and recycling and circular reuse of construction waste materials.

By leveraging science and technology, the project aims to drive innovation in the green energy industry, enhance energy autonomy, and accelerate the realization of the nation's energy transition and sustainability goals.



Shaking table image source: MTS.

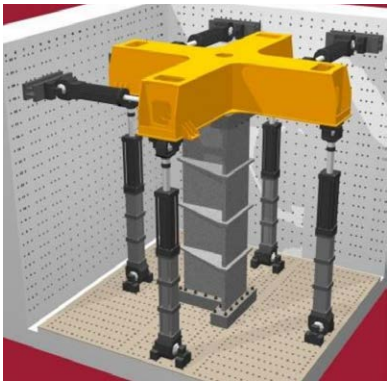


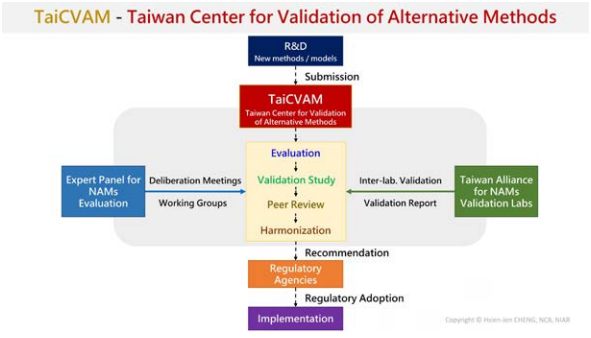
Image source: MTS.

▲ The schematic of the planned systems includes: Multi-shake-table hybrid testing system (top left), high-force long-stroke multi-degree-of-freedom testing system (top right), large-capacity material testing system (bottom left), and large-scale structural testing system (bottom right).

NLAC

## Establishment of the Taiwan Center for the Validation of Alternative Methods and Interagency Collaboration on Alternative Technologies

To promote scientific advancement and improve animal testing practices, the National Laboratory Animal Center (NLAC) has established a mechanism for cross-disciplinary integration framework, leveraging artificial intelligence and organ-on-chip technologies to develop advanced preclinical validation systems. Furthermore, NLAC has founded the Taiwan Center for the Validation of Alternative Methods to Animal Testing (TaiCVAM) completed the planning of the validation process, and is currently organizing the validation laboratory network to support the implementation of third-party validation studies processes for alternative methods in Taiwan. At the same time, NLAC integrates interagency resources to assist domestic researchers and animal facilities in enhancing standards, optimizing the quality of laboratory animals, and advancing the development of alternative testing technologies.




▲ Completed framework planning and secured willingness from multiple laboratories to participate.

TSRI

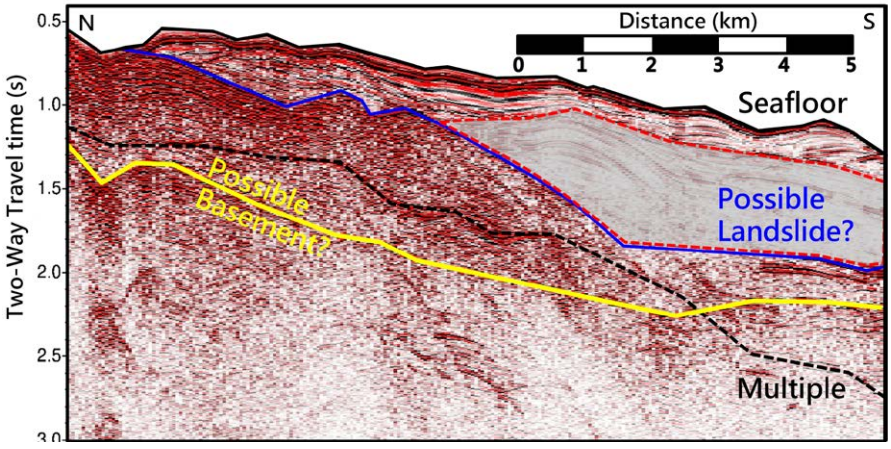
## Atomic-Level Experimental Verification Line and Seven semiconductor Targeted Colleges

Supported by The Taiwan Chip-based Industrial Innovation Program, Taiwan Semiconductor Research Institute (TSRI) establishes an atomic-level experimental verification line, enhancing core infrastructures and extending process capacity from 28nm down to 2nm. Additionally, TSRI assists seven semiconductor targeted colleges to set up equipment tailored to their specialized research fields. TSRI also establishes a reservation system for core equipment to manage the equipment accessibility service. This initiative aims to facilitate the device-level research of academia to the small-scale circuit and prototype verification of TSRI, and furthermore to the mass production of industries with the development line of the Industrial Technology Research Institute.

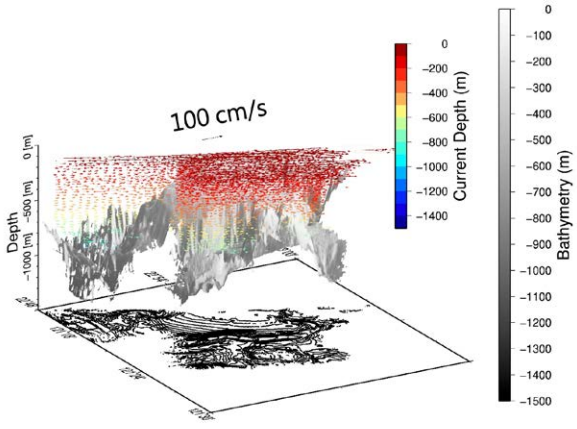
TORI

# Geological Survey for Ocean Power off East Taiwan

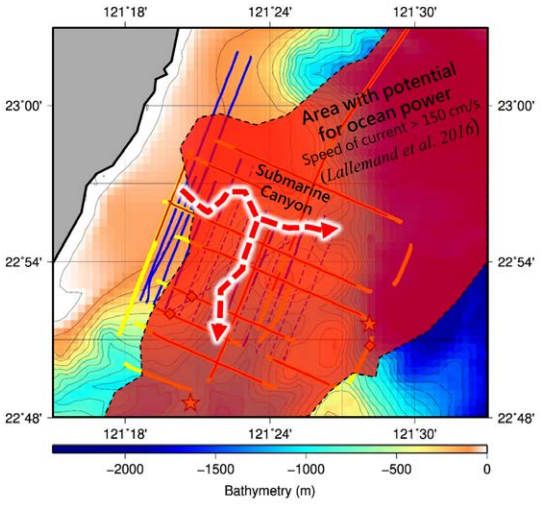
To support government net-zero emission goals for marine energy development, the Taiwan Ocean Research Institute (TORI) has conducted fundamental preliminary marine surveys to use various scientific instruments set on the R/V *LEGEND*. The first survey focused on an area pass through the Kuroshio Current offshore Chenggong, Taitung. The collected data, which will serve as fundamental background information for future ocean power development, includes sub-bottom profiler, bathymetry, and current velocity etc. These findings have been shared with the National Center for High-performance Computing (NCHC) to jointly establish a dynamic computing platform for engineering projects related to ocean power.




▲ Seismic image offshore Chenggong, Taitung.




▲ Bathymetry map with ocean current vectors offshore Chenggong, Taitung.




▲ Study area offshore Chenggong, Taitung.

# 06

# COLLABORATION CONNECTING INDUSTRY, ACADEMIA, & RESEARCH

TIRI

# Inauguration of the Joint Research Laboratory for Ultra-Precision Machining Technology - An industry, academia, and research collaboration to cultivate domestic talent in ultra-precision optical machining

Nanotech, one of the world's top three ultra-precision machining system suppliers, has provided the latest ultra-precision machining lathe to this joint research laboratory. The day it was inaugurated, the laboratory held a Workshop on Ultra-Precision Machining Technology for Advanced Optics to discuss current developments and trends in the field, strengthening connections with academia, and inspiring innovative R&D.


▲ The director general of the Taiwan Instrument Research Institute, the vice president of Nanotech, and others inaugurating the Joint Research Laboratory for Ultra-Precision Machining.

TSRI

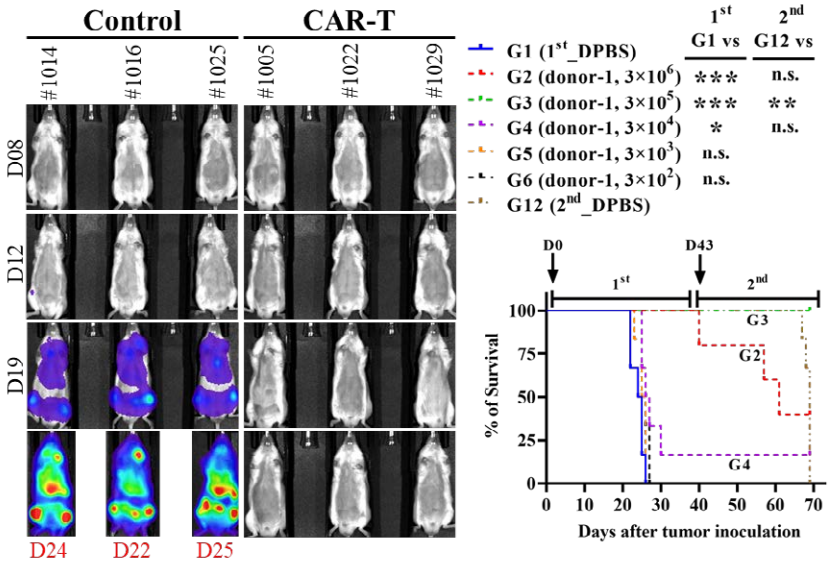
## Establishment of NCKU-Science Tokyo-NARLabs TSRI Semiconductor Innovation Partnership

The “NCKU-Science Tokyo-NARLabs TSRI Semiconductor Innovation Partnership” has been formed. This partnership leverages Taiwan’s leading semiconductor manufacturing processes and robust supply chains with Japan’s expertise in materials and equipment. By the complementary strengths of Taiwanese and Japanese researchers, this trilateral collaboration connects technology companies from both countries to bolster supply chains, which will contribute to accelerating technological breakthroughs and help both countries maintain a globally competitive edge in semiconductor innovation.

NLAC

## International Development of CAR-T Cell Therapy Products

The National Laboratory Animal Center (NLAC) has verified the efficacy of CAR-T cells by integrating mouse cancer models with biomedical imaging and immune analysis. This effort successfully supported clients in applying for the Ministry of Economic Affairs A+ Industrial Innovation R&D Program and advancing to Phase II clinical trials. In addition, NLAC assisted clients in completing pre-IND applications for US clinical trials.




▲ CAR-T cells inhibit tumor growth and improve survival rates, demonstrating therapeutic potential.

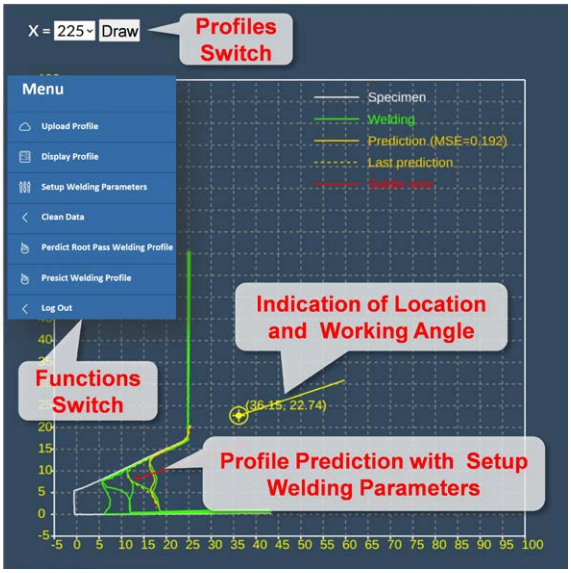
NCREE

# AI-Based Automated Welding – Expert System for Optimizing the Control Parameters of Welding Machines

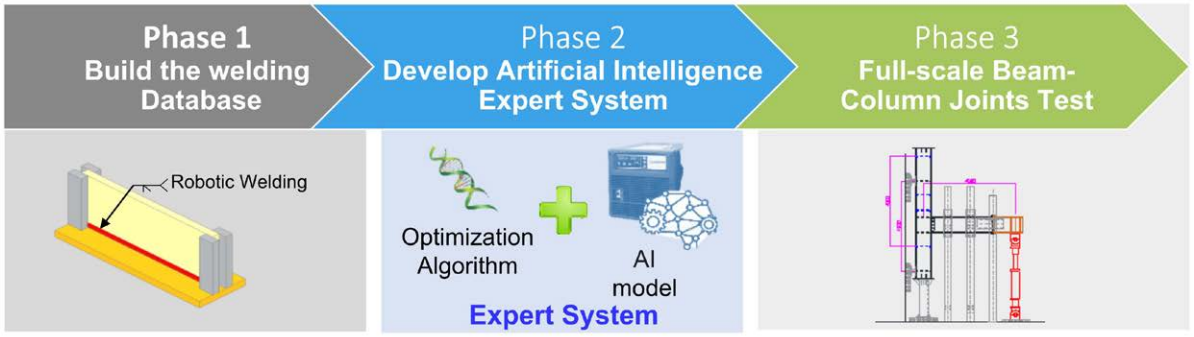
To address the shortage of welders required for the production of steel structures, the National Center for Research on Earthquake Engineering (NCREE) initiated an industry-academia collaboration with four major Taiwanese steel structure manufacturers. The project has aimed to develop automated welding technology by focusing on the welding of internal diaphragms in box-section steel columns. In addition, this partnership created a virtual welding system in 2024.

This AI-based Automated Welding System, which has now been deployed for testing in real-world applications, integrates welding parameters, predictions of post-weld bead profiles based on pre-weld profiles, and an optimization algorithm.

▲ NSTC committee members inspecting the outcomes of this year's industry-academia collaborative research.




▲ The virtual welding system predicting post-welding profiles.




▲ Progress of the research project.

TORI

# Successful Integration of USV and ROV: Development of a New Underwater Survey System

Through a pioneering collaboration between the Taiwan Ocean Research Institute (TORI), the Institute of Undersea Technology (IUT) at National Sun Yat- sen University, and the Industrial Technology Research Institute (ITRI), a new type of integrated underwater survey system has been developed. By combining the strengths of an unmanned surface vehicle (USV) and an observation-class remotely operated vehicle (ROV), the team created a system tailored for the National Museum of Marine Biology and Aquarium, enabling comprehensive marine observation capabilities. With precise control from a remote operations station, the USV autonomously navigates to designated survey locations, where the ROV is then deployed to perform underwater tasks with high maneuverability. This innovative system significantly enhances both the efficiency and safety of ocean surveys while expanding the spatial and depth range of underwater observations.

▲ Unmanned surface vessel.

▲ Remote control of a surface unmanned vessel to deploy an observational ROV.

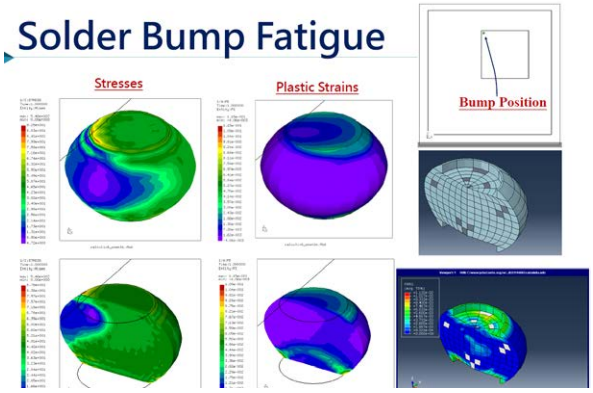
▲ Remote ground control station.

NCHC

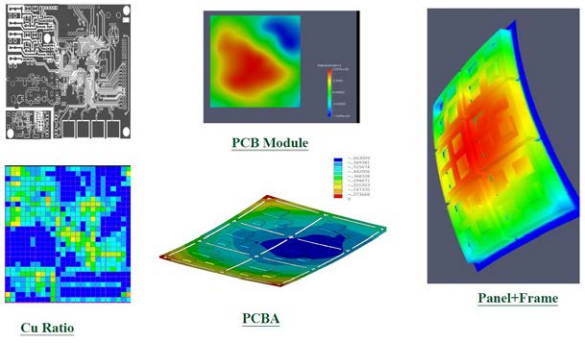
# PCBA Cloud Analysis Platform - Helping Taiwan's Electronics Industry Maintain a Leading Edge

The National Center for High-performance Computing (NCHC) launched the PCBA Cloud Analysis Platform to enhance PCB and PCBA design and manufacturing processes. This platform integrates solid mechanics and high-performance computational simulation, rapidly generates PCB and PCBA structural analysis, and reduces modeling time from weeks to under an hour. In addition, this platform is highly applicable in fields like telecommunications and semiconductors by addressing issues such as warpage and solder ball failure while optimizing parameter design. Wistron NeWeb Corporation (WNC), a leading networking manufacturer, has already adopted this platform, which has significantly enhanced their market competitiveness by lowering development costs and shortening product development cycles. This platform is providing the private sector with comprehensive solutions in this field.


▲ WNC shares insights on the benefits of the PCBA Cloud Analysis Platform for product development at an NCHC press conference.




▲ Solder ball lifespan analysis on the PCBA Cloud Analysis Platform.




▲ PCB warpage analysis on the PCBA Cloud Analysis Platform.

# 07

# FOSTERING OF SCIENTIFIC AND TECHNOLOGICAL TALENT

NARLabs

## Taiwan's Technological Treasures: Secret Bases of Scientists 2.0

NARLabs has partnered with the Taiwan Space Agency (TASA) and the National Science and Technology Museum (NSTM) to host a year-long special exhibition“Taiwan’s Technological Treasures: Secret Bases of Scientists 2.0”. The exhibition, which was held in the 6th-floor corridor of the NSTM, officially opened on December 20, 2024. The exhibition, which featured engaging scientific game stations, rare technological exhibits, and easy-to-understand scientific knowledge, aimed to help students, parents, and teachers gain a basic understanding of the work conducted by national research institutions. Participants also got a chance to learn fundamental scientific concepts and enhance their appreciation for science.

Upon entering“Taiwan’s Technological Treasures: Secret Bases of Scientists 2.0”, visitors enter their basic personal information to receive a unique game ID. Then, visitors embark on an exploratory journey through eight secret bases, which represent the seven major centers under NARLabs and TASA. Participants earn exclusive gemstones after completing challenges at each base. Collecting all eight gemstones completes the exploratory mission.

NARLabs

## Long-term popular science exhibitions are at NTSEC in Taipei and NLPI in Taichung

NARLabs has partnered with the Taiwan Space Agency (TASA) and the National Taiwan Science Education Center (NTSEC) to host a three-year-long popular science exhibition “Secret Bases of Scientists”. The exhibition, which will run from 2023 to 2026, is located in the fan-shaped exhibition hall on the 8th floor of the NTSEC. With an average of around 9,000 visitors per month during winter and summer vacations and about 4,500 visitors per month during the regular school term, the exhibition attracted nearly 67,000 visitors in 2024.

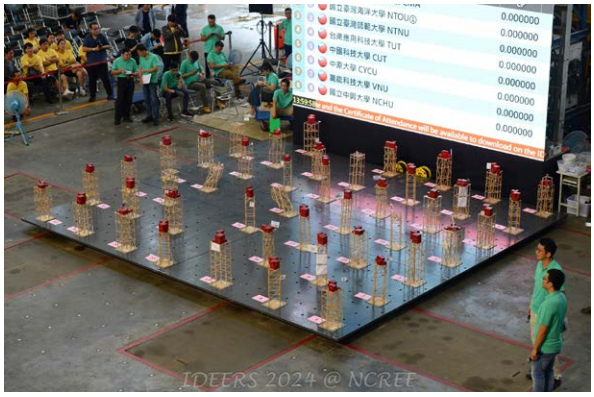
Since 2016, NARLabs has also worked with the National Library of Public Information (NLPI) to host the popular science exhibition“Seeing the Invisible In Science”on the 2nd floor of the NLPI. The exhibition is a rotation of each center under NARLabs presenting displays for four months at a time. In 2024, the exhibition attracted a total of 30,013 visitors, averaging around 10,000 visitors per four-month session. Starting in 2025, the exhibition will be renamed “Secret Bases of Scientists @ Taichung”and will continue to run until 2027.

NCREE

# 2024 IDEERS

The 2024 IDEERS (Introducing and Demonstrating Earthquake Engineering Research in Schools) International Invitational aimed to promote earthquake disaster prevention awareness among young students, attract more youth to engage in seismic risk mitigation research, and jointly create earthquake-resilient communities. Over 22 competitions since its inception in 2001, IDEERS has hosted 8,200 students from both Taiwanese and international institutions. In 2024, nearly 500 participants joined the competition from nine countries, including South Korea, Thailand, and other Southeast Asian nations. This event has helped enhance the international perspective and professional capabilities of young people across Taiwan.


▲ Montage of students assembling their models.




▲ Assembled models on a shake table.


▲ Group photo of staff members after the competition.

STPI

## Promotion of Corpus Collections - Collaborative National Project for Developing Taiwan's Indigenous Large Language Model

Under the National Science and Technology Council's"Trustworthy AI Dialogue Engine (TAIDE)", the chief responsibility of the Science and Technology Policy Research and Information Center (STPI) is the collection and screening of training data. To promote corpus collection, STPI hosted the"ALL-TAI LLM Application Workshop"for high school teachers across the country during"AI for All: Collaborative Development of Taiwan's Large Language Model". The workshop aimed to help high school teachers understand the basic knowledge of large language models, gain hands-on experience in data collection and management, and promote strategies for increasing student engagement and the integration of relevant projects into existing high school curricula.


▲ Group photo of participants at the"ALL-TAI LLM Application Workshop"of the Northern Region.

NLAC

## Establishment of 3R Education and Training Resource Network as well as a Base for Microsurgery Training and Teaching

To promote professional courses related to animal experiments, the National Laboratory Animal Center (NLAC) has created the Animal Knowledge Platform, an educational and training resource network linked with the 3R Science Park for Animal Experiments. Together, these two institutions have integrated learning resources to develop eight major course modules while creating continuing education programs and competency certification mechanisms for animal experimentation. In addition, the Microsurgery Training and Teaching Base utilizes high-quality imaging teaching systems to develop realistic biomimetic teaching aids and professional courses, such as microsurgery for laboratory mice and assisted reproductive technologies. These initiatives have cultivated scientific and technological talent by laying the foundation for hands-on practice.

STPI

## Entrepreneurship Incubator for Academic Research – From IP to IPO (FITI) Program

Since 2013, the Science and Technology Policy Research and Information Center (STPI) has been implementing the From IP to IPO (FITI) Program to establish startups and utilize R&D results by encouraging academic and research institutions in Taiwan to leverage innovative technologies. The program has bridged the gap between academic startups and industry by assisting over 4,000 young entrepreneurs in starting businesses while supporting the establishment of 342 startup companies. In addition, the total amount of disclosed external fundraising raised through this program has exceeded NT$10 billion. By laying a solid foundation for Taiwan's innovation and entrepreneurship ecosystem while promoting a virtuous cycle within industry, this program will continue to strengthen industry-academia collaboration.

▲ Group photo taken on November 29 at the final selection and award ceremony of the 2024 FITI Program's second batch.

TSRI

## Science Camps for High School Students

In line with an initiative of National Science and Technology Council to encourage women to pursue careers in science, TSRI held the "One-Day IC Design Engineer Experience for Female High School Students." During the event, professional instructors and specialized courses sparked the interest of female students in STEM fields by participating in IC design, verification, and manufacturing. Besides, to address the talent demands of Taiwan's semiconductor industry, TSRI has also promoted gender-inclusive popular science education programs for high school students. These hands-on activities have given the young generation chances to get inspired, contemplate different career paths, and bolster understanding of semiconductor technologies. By cultivating future semiconductor talent, these programs aim to support the industrial development and maintain Taiwan's global leadership position.

NCHC

## Promotion of High-performance Computing Technology and Talent Development Through Diverse Competitions and Innovation

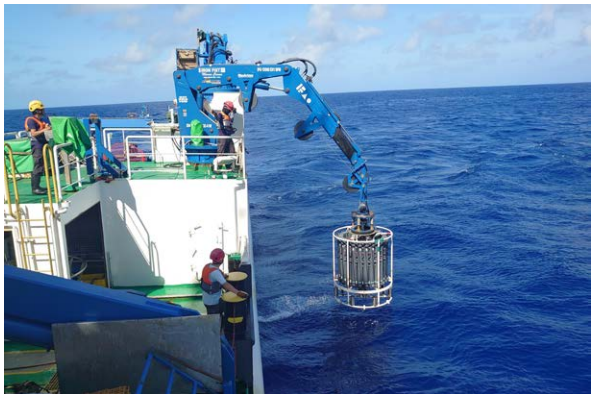
The National Center for High-performance Computing (NCHC) actively promotes high-performance computing (HPC) technology and talent cultivation through diverse competitions that inspire innovative applications. Therefore, NCHC has held the NCHC High Performance Application Competition (HiPAC) for three consecutive years to foster the ability of students to solve problems using HPC. In addition, the HPC X AI Summer Camp has been effective at establishing foundational technical skills by attracting the participation of elementary and middle school students. NCHC has also held the HPC Taiwan Animation Challenge for 13 consecutive years. This competition has served as a key platform for animation creation in Taiwan by attracting over 1,141 teams and nearly 5,000 creators. Moreover, NCHC has also developed a Cloud GPU Render Farm, which supports Taiwan's development in HPC applications and digital content creation by promoting cross-disciplinary collaboration.


▲ Leveraging diverse competitions and training camps to inspire innovative applications while fostering the ability of students to solve problems using HPC.

TORI

## Experience Sharing at CTD Detection and Data Analysis Seminar

Taiwan Ocean Research Institute partnered with the National Research Vessel Program and the Ocean Data Bank to organize a CTD Detection and Data Analysis Seminar. During the event, participants exchanged practical experience on CTD operation modes and data processing procedures across different research vessels. The seminar also introduced the newly installed CTD-specific Launch and Recovery System (LARS) on the R/V *LEGEND*, highlighting its operating procedures and water sampling methods. This system enhances the full operational potential of the vessel's main deck, further improving the safety and efficiency of shipboard operations.



▲ CTD LARS of R/V *LEGEND*

▲ Group photo of participants at the CTD Seminar.

TIRI

# Cultivating Science and Technology Talent to Sustain National Competitiveness

The Taiwan Instrument Research Institute (TIRI) has been committed to bringing the creative concepts of young students to fruition by cultivating talent in indigenous instrument development. Therefore, TIRI partnered with the American Society of Mechanical Engineers (ASME) Taiwan Section to host the "NARLabs Smart Machinery Competition," the competition of the Student Professional Development Conference (SPDC) in Taiwan on March 16. The team from National United University, "The Robot's Golf Journey," won the first place in the design competition, while Chen-Wei Chang from National Tsing Hua University claimed the top prize in the English presentation contest. Furthermore, TIRI held the 16th NARLabs *i*-ONE Instrument Technology Innovation Competition on October 5. A team from National Tsing Hua University came in first place and took home a cash prize of NT$100,000. In the high school group, the first prize and NT$80,000 in cash went to a team from National Chia-Yi Industrial Vocational High School.


▲ National United University wins the championship at the 2024 NARLabs Smart Machinery Competition.

# 08

# INTERNATIONAL COLLABORATION

# Grounded Locally, Expanding Globally

As the pace of globalization increases, NARLabs is strengthening international cooperation through joint research programs, personnel exchanges, and talent cultivation. In addition to developing cutting-edge technologies, NARLabs is committed to nurturing globally-minded scientific talent by pursuing global excellence while creating local value. By working hand in hand with international partners, NARLabs strives to tackle emerging challenges and contribute to sustainable global development.


International cooperation involving 27 countries,
134 international cooperative entities,
123 international cooperation MOUs/Agreements,
23 international cooperation teams,
61 published international papers.


## International Organization

### Information & Communication Technology

- CENTRA, Collaborations to Enable Transnational Cyberinfrastructure Applications
- PRAGMA, Pacific Rim Application and Grid Middleware Assembly

### Optoelectronics Technology

- ACS, American Vacuum Society
- ASME, American Society of Mechanical Engineers
- IEEE IMS
- SPIE, International Society for Optics and Photonics

### Medical Technology

- AMMRA, Asian Mouse Mutagenesis Resource Association
- AMPC, Asian Mouse Phenotyping Consortium
- IMPC, International Mouse Phenotyping Consortium
- SPARK Global

## AMERICA

Cybersecurity, Disaster Prevention Technology, High-performance computing, Information & Communication, Technology, Medical Technology, Ocean Exploration, Optoelectronics Technology, Science & Technology Policy, Semiconductors, Smart City Technology

### UNITED STATES

- AITek Incorporation
- ANL, Argonne National Laboratory
- AVS, American Vacuum Society
- Clarivate Analytics
- Cornell University
- Duke University
- iCAIR, International Center for Advanced Internet Research, Northwestern University
- ILEE, International Joint Research Laboratory of Earthquake Engineering
- Lucent
- MIT, Massachusetts Institute of Technology
- MTS Systems Cooperation
- Moore Nanotechnology
- NCSA, National Center for Supercomputing Applications
- NSF, National Sanitation Foundation
- NVIDIA Corporation
- NU, Northwestern University
- Stanford University
- Telcordia Technologies, Inc.
- PnP, Plug and Play Tech Center
- UCAR, University Corporation for Atmospheric Research
- UCB, University of California, Berkley
- UC Davis, University of California, Davis
- UH, University of Houston
- UW, University of Washington
- WHOI, Woods Hole Oceanographic Institution
- VU, Vanderbilt University

### CANADA

- UBC, University of British Columbia
- University of Toronto
- WATERLOO. AI, Waterloo Artificial Intelligence Institute
- Mitacs Inc.

## EUROPE

High-performance Computing, Medical Technology, Ocean Exploration, Quantum Technology, Semiconductors

### BELGIUM

- imec, Interuniversity Microelectronic Centre

### CZECH REPUBLIC

- CAS, Czech Academy of Sciences
- CTU, Czech Technical University
- CyberSecurity Hub
- FZU, Institute of Physics of the Czech Academy of Sciences

### FINLAND

- IQM, IQM Quantum Computers

### FRANCE

- CEA-Leti, Laboratoire d'électronique des technologies de l'information
- CNRS, Centre national de la recherche scientifique
- inalco, Institut National des Langues et Civilisations Orientales
- INRIA, National Institute for Research in Digital Science and Technology
- Inserm, French National Institute of Health and Medical Research
- Sercel
- TGCC, Très Grand Centre de Calcul du CEA
- UPSaclay, Université Paris-Saclay

### GERMANY

- Fraunhofer, The Fraunhofer-Gesellschaft
- HLRS, High-Performance Computing Center Stuttgart
- IPP, Max Planck Institute for Plasma Physics
- MARUM, Zentrum für Marine Umweltwissenschaften
- MPI-SP, Max Planck Institute for Security and Privacy
- SMWK, The Saxon State Ministry of Science, Culture and Tourism
- TUD, Technische Universität Dresden

### POLAND

- Łukasiewicz Research Network
- RGIB, The Main Council of Research Institutes

### ITALY

- CINECA

### NETHERLANDS

- EBU, European Board of Urology

### PORTUGAL

- INESC TEC, Institute for Systems and Computer Engineering, Technology and Science

### SLOVAK REPUBLIC

- SAS, Slovak Academy of Sciences

### SWITZERLAND

- CERN, the European Organization for Nuclear Research

### United Kingdom

- MRC, Medical Research Council
- NPL, National Physical Laboratory
- University of Edinburgh

## ASIA

Artificial Intelligence, Cybersecurity, Disaster Prevention Technology, High-performance computing, Information & Communication Technology, Ocean Exploration

### INDIA

- CSIR, Council of Scientific and Industrial Research
- IITG, Indian Institute of Technology Guwahati
- IITK, Indian Institute of Technology Kanpur

### INDONESIA

- IEEA, Indonesian Earthquake Engineering Association
- ITB, Institut Teknologi Bandung
- Matana University
- UAJY, Universitas Atma Jaya Yogyakarta
- UNDIP, Universitas Diponegoro
- UNSOED, Universitas Jenderal Soedirman

### JAPAN

- AIST, National Institute of Advanced Industrial Science and Technology
- CIEA, Central Institute for Experimental Animals
- ICRR, Institute for Cosmic Ray Research the University of Tokyo
- IRDA, Institute of Resource Development and Analysis in Kumamoto University
- JAEE, Japan Association for Earthquake Engineering
- JAMSTEC, Japan Agency for Marine-Earth Science and Technology
- JST, Japan Science and Technology Agency
- Kyushu University
- Nagoya University
- NICT, National Institute of Information and Communications Technology
- NIED, National Research Institute for Earth Science and Disaster Prevention
- RIKEN, Institute of Physical and Chemical Research
- SPP Technologies Co., Ltd
- TIT, Tokyo Institute of Technology
- Tohoku University
- Tokyo University of Science

### KOREA

- EESK, Earthquake Engineering Society of Korea
- ETRI, Electronics and Telecommunications Research Institute
- KISTEP, Korea Institute of S&T Evaluation and Planning
- KISTI, Korea Institute of Science and Technology Information
- NST, National Research Council of Science and Technology
- SESTEC, Seismic Research and Test Center of Pusan National University
- STEPI, Science and Technology Policy Institute

### PHILIPPINES

- ASEP, Association of Structural Engineers of the Philippines
- DLSU, De La Salle University
- SubNet Services Ltd

### RUSSIA

- International Academy of Engineering

### SINGAPORE

- NSCC, National Supercomputing Centre

### THAILAND

- AIT, Asian Institute of Technology
- EARTH, Earthquake Research Center of Thailand
- KMITL, King Mongkut's Institute of Technology Ladkrabang
- KMUTT, King Mongkut's University of Technology Thonburi
- MU, Mahidol University
- NSTDA, National Science and Technology Development Agency
- Thai-BISPA, Thai Business Incubators and Science Parks Association
- Thammasat University

### TURKEY

- TÜBİTAK, Scientific and Technological Research Council of Turkey

### VIETNAM

- VNU, Vietnam National University

## OCEANIA

Artificial Intelligence, Disaster Prevention Technology, Ocean Exploration

### AUSTRALIA

- ANFF, Australian National Fabrication Facility
- ANU, Australian National University
- NGI, Norwegian Geotechnical Institute
- OCSE, Office of the NSW Chief Scientist and Engineer
- UTS, University of Technology Sydney

### NEW ZEALAND

- Grayson Engineering Ltd
- QuakeCoRE, Centre for Earthquake Resilience
- UA, University of Auckland
- UC, University of Canterbury

NARLabs

## Expansion of International Networks and Signing of Cooperation Memoranda

To foster forward-looking technology exchanges, promote global talent development, and strengthen international cooperation between industry, academia, and research, NARLabs has established partnerships with several internationally renowned scientific research institutions. Specifically, a Joint Research Program Framework Agreement was signed with INESC TEC of Portugal to jointly drive innovative research and enhance technological capabilities. In addition, bilateral agreements were signed with the CyberSecurity Hub of the Czech Republic. To further broaden its international collaboration network, NARLabs also signed memoranda of understanding (MOUs) with Mahidol University in Thailand and the Slovak Academy of Sciences, facilitating cross-disciplinary exchanges and fostering a more competitive research environment.

NLAC

## Preclinical Validation Platform for Advanced Medical Devices

The National Laboratory Animal Center's Preclinical Validation Platform for Advanced Medical Devices provides a human-hospital-grade surgical environment, where professional veterinarians oversee anesthesia monitoring and postoperative care. The platform features a catheterization validation site for medium to large sized animals, supporting regenerative medicine research on human-induced pluripotent stem cell (iPSC)-derived cardiomyocyte therapy for acute myocardial infarction. Additionally, the facility serves as a clinical education training site, offering specialized instruction training in new catheter-based interventional medical techniques for physicians from Taiwan, Thailand, Malaysia, the Philippines, and Indonesia.

▲ Domestic neuroendoscopy obtains FDA 510K certification.

▲ Hands-on catheterization training for international clinicians, Including those from Singapore.

◀ Experimental animal knowledge training for physicians and medical device specialists.

TSRI

## International Talent Training

Supporting by the Taiwan Chip-based Industrial Innovation Program of the National Science and Technology Council as well as Taiwan-Europe program of the Ministry of Foreign Affairs a total of 79 international students from 10 European countries participated in a one-month short-term training program in Taiwan in July (52 students under Taiwan CbI and 27 students under the Ministry of Foreign Affairs' program). The training combined theoretical knowledge with hands-on practice, and covered topics such as analog circuit design, MEMS chip design, silicon photonics chip design, and digital circuit design. Among them, 60 students engaged in project-based learning following practical coursework, while 17 students participated in a four-week corporate internship (9 at Synopsys, 3 at Chroma ATE, and 5 at the Taiwan Semiconductor Research Institute). Besides, a two-week program began on August 5, which hosted 53 students from eight countries, including Poland, Italy, Slovakia, Lithuania, the Czech Republic, Kosovo, Romania, and Bulgaria. In total, 132 international students participated in short-term training programs in 2024.

NLAC

## Collaboration with Kumamoto University on Reproductive Technology Exchange

The National Laboratory Animal Center (NLAC) partnered with the Kumamoto University Center for Animal Resources and Development (CARD) to co-host a specialized training program on assisted reproductive technologies. The course covered reproductive techniques for mice and rats and gave participants an opportunity to conduct bilateral technical exchanges. In addition, the course aimed to overcome current technological barriers while planning for the creation of Asia's second artificial reproduction technology hub for rats. Additionally, NLAC has engaged with six other core facilities in Taiwan to enhance the technical capabilities of reproductive techniques for laboratory mice and rats.

◀ Training and exchange at domestic core facilities.

▲ Taiwan-Japan training and exchange on rodent reproductive techniques.

▲ Group photo of Taiwan-Japan instructors and participants upon completion of training.

TSRI

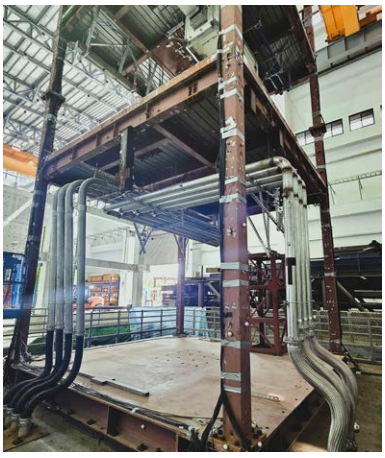
## Taiwan-Europe Chip Innovation Forum

The Taiwan Chip-based Industrial Innovation Program, in collaboration with imec and EUROPRACTICE which are leading international semiconductor research institutions, co-hosted the Taiwan-Europe Chip Innovation Forum in Prague from October 29 to 31, 2024. The forum provided an innovative platform for semiconductor technology exchanges by attracting over 200 world-class experts from Taiwan and Europe. By showcasing Taiwan's robust industry-academia-research ecosystem to international partners, the forum further expanded Taiwan's global influence in semiconductors and fostered deeper collaborations with Europe.

NCREE

## Taiwan-Japan Collaboration on Seismic Technology R&D and Applications – Non-structural Component Shake Table Testing

On April 3, 2024, an earthquake in Hualien impacted the functionality of some hospitals and schools due to severe damage to certain suspended non-structural components. In response, the National Center for Research on Earthquake Engineering (NCREE) partnered with the National Research Institute for Earth Science and Disaster Resilience (NIED) in Japan, the University of Tokyo, and Nagoya University to conduct full-scale shake table tests on suspended air conditioning units and fire protection piping systems. This research has aimed to improve the seismic resilience of suspended non-structural components by developing seismic construction techniques that can be used both in Taiwan and abroad.



▲ Test specimen of first-floor suspended utility pipelines.

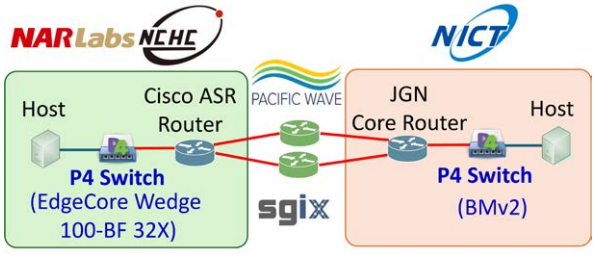
▲ Three-story shake table test for suspended non-structural components conducted in 2024.

◀ Test specimen of a suspended air conditioning unit.

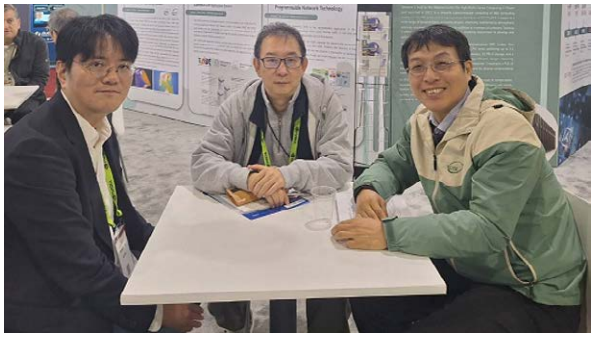
NCHC

## Programmable Testing Platform – A New Era of Cross-Border Network Experimentation

The National Center for High-performance Computing (NCHC) has leveraged its enhanced programmable testing platform to conduct international collaboration with organizations such as iCAIR in the US and NICT in Japan. This platform has supported both domestic and international academic and research institutions by providing a highly efficient environment for network testing and experimental design. Currently, the platform serves leading institutions in multiple countries, including National Cheng Kung University, Chung Yuan Christian University, NCHC, NICT in Japan, Gwangju Institute of Science and Technology in South Korea, the University of Malaya in Malaysia, the National University of Singapore, and Singapore Institute of Technology. This initiative has created new opportunities for international collaboration by fostering network technology research exchanges and cross-border experiments.




▲ NCHC's programmable testing platform and NICT in Japan conducting tests on large-scale environment management technology.



▲ Demonstration of the programmable testing platform at SC24: International Conference for High Performance Computing, Networking, Storage and Analysis.

TIRI

## Establishment of Bilateral Academic Collaboration Between Taiwan and Lithuania

The Taiwan Instrument Research Institute (TIRI), partnered with National Yang Ming Chiao Tung University Professor Ray-Hua Horng and the Center for Physical Sciences and Technology (FTMC) Terahertz Photonics Laboratory in Lithuania to jointly collaborate the Taiwan-Lithuania (NSTC-LMT) Joint Research Program on Laser Technology. The project, which is expect to run from 2024 to 2026, focuses on research related to laser manufacture and measurement of compound semiconductor materials.


▲ FTMC Terahertz Photonics Laboratory Head Dr. Irmantas Kašalynas visiting TIRI on October 18 to discuss matters related to this collaborative project.


# 09

# SOCIAL ENGAGEMENT

NCREE

## Soft-Story Retrofitting for Private Structures

Since 2019, the National Center for Research on Earthquake Engineering (NCREE) has been assisting the Ministry of the Interior National Land Management Agency in implementing the Soft-Story Retrofitting for Private Structures program. To support this initiative, NCREE established a dedicated project office to guide applicants through the the government subsidy process for soft-story retrofitting nationwide. In response to a large earthquake in Hualien on April 3, 2024, the project office dispatched personnel to the Executive Yuan Eastern Taiwan Joint Services Center to assist in subsidy applications for soft-story retrofitting of red- and yellow-tagged buildings. These efforts aim to accelerate repair work and ensure public safety.


▲ Effectiveness of seismic soft-story retrofitting.

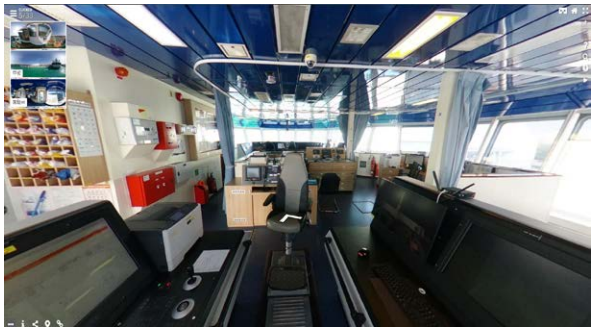

▲ Technical workshop on seismic soft-story retrofitting procedures.

TORI

## Virtual Reality as an Alternative to Physical Exhibitions – Research Vessel Virtual Reality Platform

The virtual reality platform of R/V *LEGEND* offers a guided tour experience that aligns with the ship's architectural design. The tour includes access to the vessel's four-level deck and living quarters, which form the core of the exhibition. Popular highlights also include the dining area and the underwater scientific equipment section, which was captured using panoramic images taken during the vessel's dry-dock maintenance. Due to the mission-oriented nature of research vessels, port visits are limited. The online VR platform overcomes the constraints of time and location, enabling a flexible and diversified model for public engagement and virtual tours.

▲ Virtual reality depiction of the operational area on the R/V *LEGEND*.

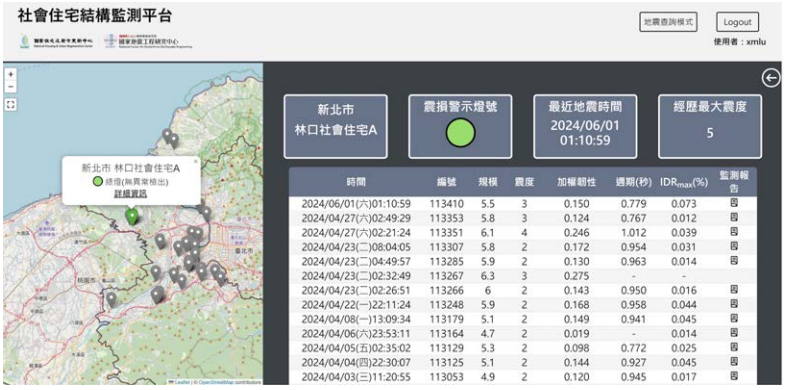


▲ Virtual reality depiction of the bridge on the R/V *LEGEND*.

NCREE

# Structural Safety Monitoring for Social Housing

The National Housing and Urban Regeneration Center and the National Center for Research on Earthquake Engineering (NCREE) signed a memorandum of understanding in 2024 to jointly develop a nationwide structural safety monitoring system for social housing. This system will incorporate real-time structural damage assessment technology to immediately determine whether social housing structures have been impacted after an earthquake. In the event of seismic activity, notifications will be sent via LINE to building managers, enabling them to make quick decisions and implement post-earthquake emergency response measures. The long-term goal is continuously monitoring structural conditions and enhancing seismic safety in social housing communities.




▲ Website for structural monitoring of social housing.


▲ LINE notifications for structural monitoring of social housing.

| Lights | Alert Level | Estimated Structural Damage (e.g. RC walls and columns) |
|---|---|---|
| | Low (No Damage) | No Abnormal Observations |
| | Medium (Possible minor to moderate damage) | |
| | High (Possible severe damage or near collapse) | |

**Pictures Reference:** https://www.ncree.org/safehome/

▲ Structural damage warning indicators and corresponding estimated impact.

NCHC

## NCHC Assistance to the Ministry of Justice in Launching the Blockchain-applied Judicial Alliance Joint Verification Platform

Since 2022, the National Center for High-performance Computing (NCHC) has been assisting the Ministry of Justice in promoting the Blockchain-applied Judicial Alliance for Digital Era. This has included providing recommendations on blockchain architecture, conducting proof-of-concept studies on technical feasibility, and performing on-site reviews of off-chain data management. On April 1, the Judicial Alliance launched its first service, the Blockchain-applied Judicial Alliance Joint Verification Platform. This platform provides courts and prosecutors' offices with a tool to verify digital evidence stored with the Blockchain-applied Judicial Alliance for Digital Era. This has enhanced public trust in the judicial system by enabling the judiciary to utilize technology to efficiently confirm the integrity of evidence.

STPI

## Integration of Cross-Agency Efforts to Advance Digital Governance Establishment of the Civil IoT Taiwan Pavilion

The Science and Technology Policy Research and Information Center (STPI) implemented the "Civil IoT Taiwan" sub-project and launched the Civil IoT Pavilion at the 2024 Smart City Summit & Expo. Under the theme"Envisioning the Future: Building the Next Generation of Digital Governance for a Livable Environment,"the exhibition brought together eight government ministries and 15 executing agencies to showcase 29 projects across four key domains: water, air, land, and disaster management. Additionally, the event featured the premiere of the documentary Footprints of Flow.


▲ Premiere of Footprints of Flow in which guest speaker Wu Sheng (second from the left) and water management professionals from the film shared the journey of shooting this documentary.

▲ Opening of the Civil IoT Taiwan Pavilion, with Chia-Lung Lin, former Secretary-General to the President and current Minister of Foreign Affairs (sixth from the left), alongside ministry officials.

# 10

# MILESTONES

1

JAN. 1

**TSRI**

TSRI collaborates with Taiwan Semiconductor Manufacturing Company (TSMC) on Selector and STT-MRAM Integration, and published a paper which was selected as the IEDM Highlight Paper.

JAN. 9

**NCREE**

NCREE signs a Memorandum of Understanding with the Earthquake Research Center of Thailand.

JAN. 22

**NCREE**

NCREE signs a Memorandum of Understanding with the Center for Earthquake Mitigation of South Korea.

2

JAN. 31

**STPI**

STPI, which was established in 1974, celebrates its 50th anniversary.

FEB. 15

**NARLabs**

NARLabs signs a bilateral cooperation agreement with INESC TEC of Portugal.

FEB. 23

**TORI**

TORI signs a cooperation agreement with National Dong Hwa University.

3

MAR. 16

**TIRI**

TIRI partners with the American Society of Mechanical Engineers (ASME) Taiwan Section to host the “NARLabs Smart Machinery Competition” for students. A team from National United University wins the championship.

MAR. 8

**TORI**

Return Mission of R/V *LEGEND* to Palauan Waters and Malakal Harbor.

4

MAR. 20

**NCHC**

The 3D Fishing Ports Digital Twin Smart Management Platform wins the 2024 Smart City Innovative Application Award.

MAR. 21

**NLAC**

NLAC hosts a Regulations and Applications Seminar on Animal Experiment Reduction Strategies.

APR. 25

**NARLabs**

NARLabs and the National Institute of Information and Communications Technology (NICT) of Japan hold the joint research program kick-off meeting.

5

MAY 15

**NCREE**

NCREE signs a Memorandum of Understanding with the National Housing and Urban Regeneration Center.

MAY 15

**NARLabs**

NARLabs signs a Memorandum of Understanding with Mahidol University in Thailand.

MAY 17

**NCREE**

National Taiwan University Professor Yu-Chen Ou becomes the Director of NCREE.

MAY 17

**NARLabs**

NARLabs signs a cooperation agreement with the CyberSecurity Hub of the Czech Republic.

AUG. 26

**STPI**

Shi-Yu Huang , professor from the Department of Electrical Engineering of National Tsing Hua University becomes the Director General of STPI.

AUG. 20

**NARLabs**

Professor Hung-Ying Tsai, National Tsing Hua University College of Engineering Dean and Department of Power Mechanical Engineering Chair, becomes the President of NARLabs.

AUG. 19-21

**TSRI**

The 29th International Electron Devices & Materials Symposium and the 4th Symposium on Nano-Device Circuits and Technologies are held from August 19 to 21.

9

SEP. 13

**NLAC**

NLAC and the UC Davis Microsurgery Core launch an introductory microsurgery course.

10

OCT. 2

**NLAC**

NLAC sets up an embryonic manipulation microsurgery course with the Kumamoto University Institute of Resource Development and Analysis.

DEC. 13

**STPI**

STPI announces winners after hosting“Win the PRIDE: Telling Stories with Indicators”competition.

DEC. 6

**STPI**

STPI hosts the“2024 CONCERT Annual Conference”, with the theme“AI for Academic Ingenuity".

DEC. 5

**NARLabs**

NARLabs signs a Memorandum of Understanding with the Slovak Academy of Sciences.

12

6

JUN.
28

**STPI**

STPI hosts the final selection and award ceremony for the first batch of the 2024 FITI Program.

7

JUL.
1–8/23

**TSRI**

International participants supported by the Taiwan Chip-based Industrial Innovation Program (Taiwan CbI) complete short-term training courses and corporate internships in Taiwan.

JUL.
1

**NCHC**

The Forerunner 1 supercomputer is officially online and operational.

JUL.
4

**TORI**

TORI signs a Memorandum of Understanding with the Nuclear Safety Commission Radiation Monitoring Center.

8

JUL.
23

**NCREE**

NCREE signs a Memorandum of Understanding with the Earthquake Engineering Society of Korea.

OCT.
18

**NARLabs**

The Advanced Chip Design Research Center, jointly established by the NARLabs and the CyberSecurity Hub of the Czech Republic, is inaugurated in the Czech Republic.

OCT.
17

**NLAC**

NLAC celebrates its 30th anniversary.

OCT.
5

**TIRI**

National Tsing Hua University and Chiayi Industrial Vocational High School win first prizes at the 16th NARLabs *i*-ONE Instrument Technology Innovation Competition.

11

OCT.
29–31

**TSRI**

TSRI Jointly hosts the Taiwan-Europe Chip Innovation Forum with imec and EUROPRACTICE which are leading international semiconductor research organizations.

NOV.
20

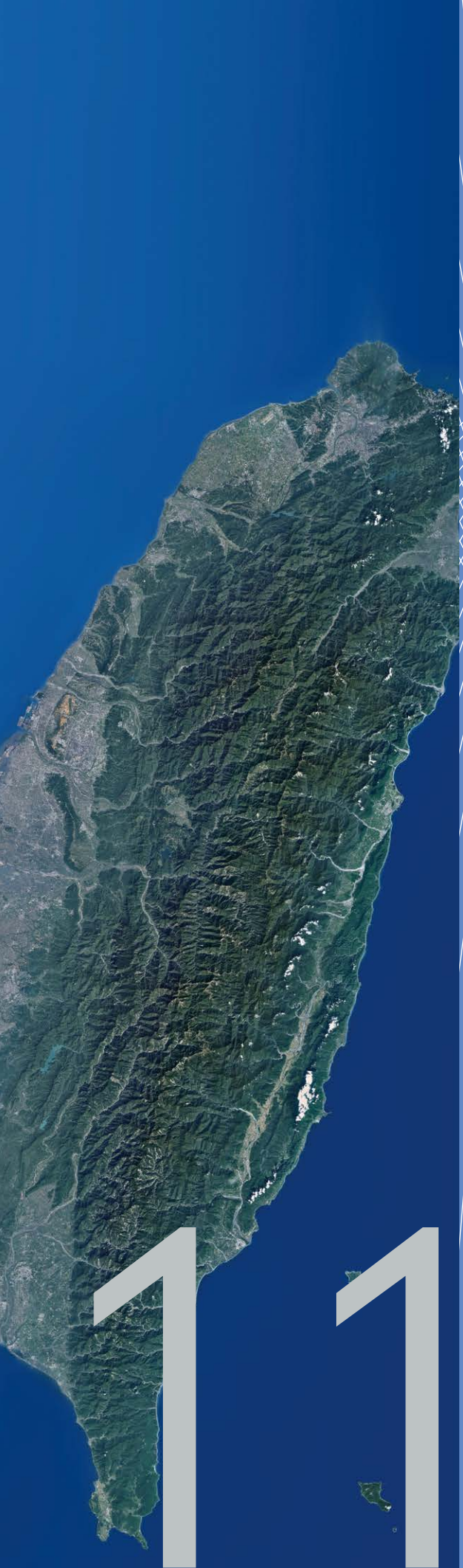
**TIRI**

TIRI holds 50th Anniversary Celebration and R&D Building Completion Ceremony.

NOV.
29

**STPI**

STPI hosts the final selection and award ceremony for the second batch of the 2024 FITI Program.

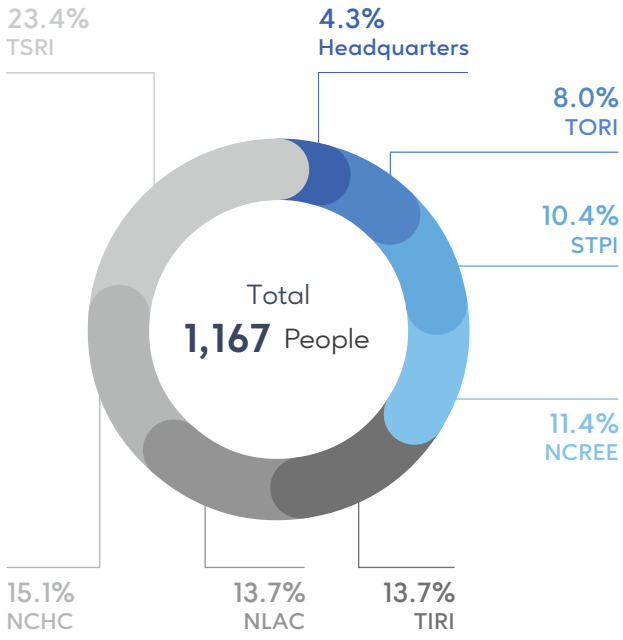


# 1.1 ANNUAL PROFILE

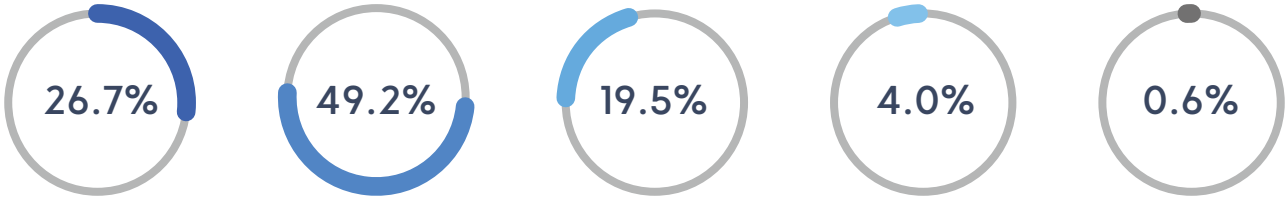
# HUMAN RESOURCES

## Number of Employees in Laboratories

| | |
|---|---|
| Headquarters | 51 People |
| TORI | 93 People |
| STPI | 121 People |
| NCREE | 133 People |
| TIRI | 160 People |
| NLAC | 160 People |
| NCHC | 176 People |
| TSRI | 273 People |

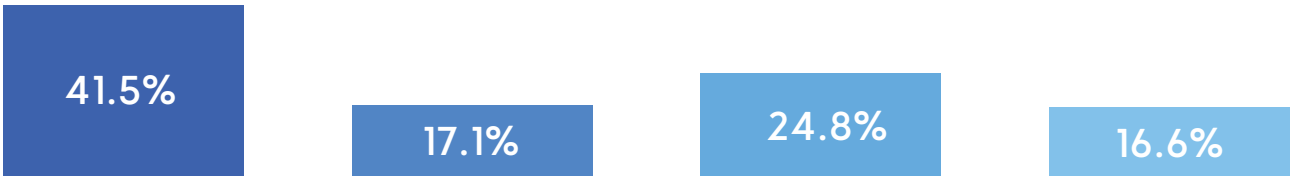



## Education Level



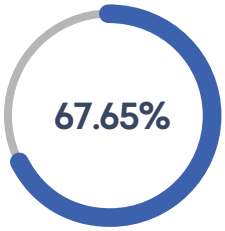

| Doctoral Degree | Master's Degree | Bachelor's Degree | Associate's Degree | Others |
|---|---|---|---|---|
| 312 People | 574 People | 227 People | 47 People | 7 People |

## Human Resources Profile




| 484 People | 199 People | 290 People | 194 People |
|---|---|---|---|
| Researchers | Engineers | Technicians | Administrators |

# FINANCIAL INFORMATION


Grants


Fund Raised from Government Agencies


Fund Raised from Private Sector

| | |
|---|---|
| NCHC | USD **63** Million |
| TSRI | USD **60** Million |
| STPI | USD **30** Million |
| TIRI | USD **20** Million |
| NCREE | USD **19** Million |
| NLAC | USD **17** Million |
| Headquarters | USD **14** Million |
| TORI | USD **12** Million |

# ORGANIZATION

## Board of Directors & Supervisors

| | |
|---|---|
| Chairperson | Cheng-Wen Wu |
| Managing Director | Mei-Yin Chou, Pei-ling Liu, Zsehong Tsai, Wen-Chang Chen |
| Directors | Charles Hsu, Kuo-Fong Ma, Yi-Chun Wu, Chi-Hung Lin, Chih-Peng Li, Hahn-Ming Lee, Emily Hong, Chih-Lin Hu |
| Executive Supervisors | Yu-Yen Liao |
| Supervisors | Chan-Jane Lin, Cheng-Chih Wu |
| Auditing Office / Director | Tai-Hsiang Wang |

## President's Office

| | |
|---|---|
| President | Hung-Yin Tsai |
| Vice President | Bou-Wen Lin |
| Chief Operating Officer | Yu-Hsueh Hsu |

## Headquarters / Directors

| | |
|---|---|
| Strategy & Planning Office | Jyun-Hwei Tsai |
| Operation & Promotion Office | Lung-Yao Chang |
| International Affairs Office | Mei-Yu Chang |
| Administration Office | Shu-Chen Lin |
| Finance & Accounting Office | Min Huang |
| Human Resources Office | Chi-Nung Yin |
| Information Technology Service Office | Bai-Li Huang |

## Laboratories / Director Generals

| | |
|---|---|
| National Laboratory Animal Center (NLAC) | Hsian-Jean Chin |
| National Center for Research on Earthquake Engineering (NCREE) | Yu-Chen Ou |
| National Center for High-performance Computing (NCHC) | Chau-Lyan Chang |
| Taiwan Semiconductor Research Institute (TSRI) | Tuo-Hung Hou |
| Taiwan Instrument Research Institute (TIRI) | Cheng-Tang Pan |
| Science & Technology Policy Research and Information Center (STPI) | Shi-Yu Huang |
| Taiwan Ocean Research Institute (TORI) | Pei-Jie Meng |

# LOCATIONS

## Headquarters

### Taipei

NARLabs Headquarter

National Laboratory Animal Center

National Center for Research on Earthquake Engineering

Science & Technology Policy Research and Information Center

### Hsinchu

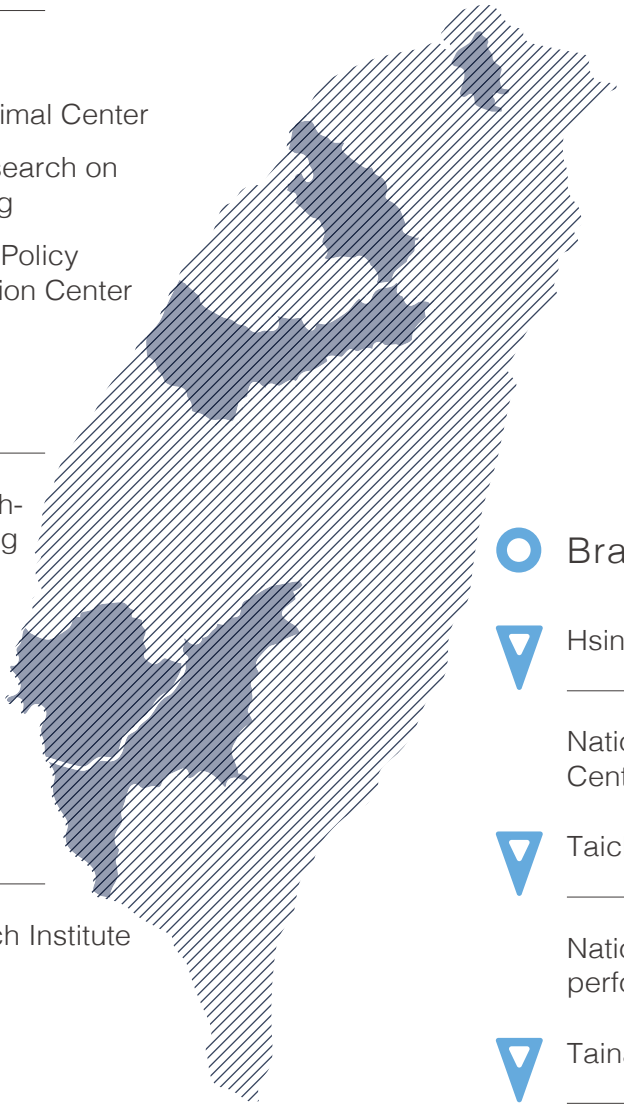
National Center for High-performance Computing

Taiwan Semiconductor Research Institute

Taiwan Instrument Research Institute

### Kaohsiung

Taiwan Ocean Research Institute



## Branches

### Hsinchu

National Laboratory Animal Center

### Taichung

National Center for High-performance Computing

### Tainan

National Laboratory Animal Center

National Center for Research on Earthquake Engineering

National Center for High-performance Computing

Taiwan Semiconductor Research Institute


# OUR LABORATORIES

12

NLAC

## National Laboratory Animal Center

The National Laboratory Animal Center (NLAC) provides specific pathogen-free (SPF) laboratory animals and high-tech core technologies to support fundamental research in Taiwan. In addition, NLAC has also enhanced animal testing facilities while expanding capacities in areas such as drug efficacy validation, advanced medical device implantation, and gut microbiota research. NLAC also ensures the simultaneous advancement of both animal testing and alternative solutions by staying committed to promoting alternative testing methods. Additionally, NLAC leverages human-derived tissues to develop personalized medicine systems as well as advancing organ-on-chip models and other alternative methods by promoting cross-discipline integration of microfluidics, biomedical sensing, and 3D cell culture technologies. To further optimize professional skills, NLAC offers specialized training programs for laboratory animal veterinarians, technicians, caretakers, and facility managers.

NCREE

## National Center for Research on Earthquake Engineering

The National Center for Research on Earthquake Engineering (NCREE) focuses on three main research and development axes:“Seismic Performance Improvement,”“Hazard Analysis and Risk Assessment,”and “Monitoring and Early Warning”to meet the needs of pre-earthquake preparation, earthquake strain emergency response, and post-earthquake reconstruction. In addition, NCREE creates industrial value by enhancing R&D capacity and technical implementation for near-fault earthquakes and multiple-disaster scenarios, promoting interdisciplinary collaboration, and strengthening industry-academia partnerships. In the medium term, NCREE aims to enhance the seismic performance of critical infrastructure by developing structural seismic design, evaluations and reinforcement retrofitting and early warning systems and rapid response measures to enhance post-earthquake recovery capabilities in urban and rural areas and move towards the long-term goal of building earthquake-resistant and sustainable homeland.

NCHC

## National Center for High-performance Computing

The National Center for High-performance Computing (NCHC) has laid a solid foundation for Taiwan's technological advancement by strengthening the country's high-performance computing capabilities and providing world-class networking services for high-performance computing and academic research. Through the maxim "Driving Transformation for a Better Future," NCHC actively promotes the development and application of high-performance computing, networking, big data, and AI. NCHC initiatives include developing trusted cloud services, generative AI, digital twin technology, and big data service platforms, as well as advancing forward-looking technologies such as cyber-physical integration, cybersecurity, quantum computing, and encryption technologies. NCHC promotes digital transformation and the evolution of smart living by actively engaging in international cooperation.


TSRI

## Taiwan Semiconductor Research Institute

Since 2024, the Taiwan Semiconductor Research Institute (TSRI) has engaged in the implementation of the Taiwan Chip-based Industrial Innovation Program to futher enhance Taiwan's research and development infrastructure. This has included the renewal of cleanroom facilities and process-related equipment that have been in operation for over 15 and 20 years respectively, as well as expanding and upgrading computing servers that have been in use for more than five years. By establishing a next-generation R&D environment that is aligned with leading international research institutions, these efforts aim to enhance the capabilities of academia and research communities while strengthening hands-on training to develop talent.

TIRI

## Taiwan Instrument Research Institute

TIRI aims to strengthen basic research by focusing on the development of critical technologies in “Cutting-edge Optics,”“Advanced Vacuum Technology,” and “Smart Biotechnology.” In addition, TIRI creates integrated interdisciplinary platforms for services related to instrument technology R&D while serving as an essential partner for academic teams conducting groundbreaking research. As the only research institute in Taiwan capable of meeting the forward-looking research and experimental needs of various academic fields, TIRI plays a vital role in the development of specialized and customized scientific instruments. Furthermore, TIRI actively develops “No.1 in Taiwan” and “world-leading” next-generation semiconductor processes and equipment, cutting-edge defense and remote sensing payload systems, and epidemic prevention-related instruments. TIRI also enhances the efficiency of research resource utilization by nurturing high-level interdisciplinary instrument technology professionals.


TORI

## Taiwan Ocean Research Institute

TORI actively engages in the independent design and R&D of marine exploration equipment and innovative technologies that serve the research needs of government, academia, and research in-stitutes. By facilitating scientific research, marine engineering, and land investigation missions, TORI strives to propel the development of the marine industry. TORI aims to expand fields of research without being constrained by commercial demands in order to decrease the overreliance on imported ocean detection equipment by developing and mastering key technologies in this area. According to the field of ocean research, it can be divided into physical oceanography, biogeochemistry, and geological features. The core facilities include: ocean radar current-measurement system, hydrological and hydrochemical analysis, biology and biotechnology, long-distance seismic measurement system, ocean core Repository, scientific microscopy photography, etc. Meanwhile, TORI also maintains and operates the largest research vessel in Taiwan, R/V *LEGEND*, and plays an indispensable role in marine science research. It provides various important scientific instruments and operating platforms required for marine scientific research, and can perform large-scale ocean exploration research for long periods of time, which helps to enhance Taiwan’s marine science research and ocean exploration capabilities.

STPI

# Science & Technology Policy Research and Information Center

The Science & Technology Policy Research and Information Center (STPI) is set to become a national-level science and technology policy think tank with a robust foundation of academic and empirical research that aims at providing comprehensive and rapid responses to the many issues faced in related fields. By fully grasping global S&T trends, STPI can provide timely, professional, and objective analyses and suggestions to support any government planning that may affect the industry. STPI's missions include supporting the government on S&T policy planning and the development of S&T industry, assisting in the evaluation and management of S&T programs, activating the innovation eco-system of R&D achievements and providing integrated information services. For many years, STPI has served as a think tank for the government's S&T policies. It has continued to support the National Science and Technology Council in drafting Taiwan's science and technology white paper and is also responsible for organizing the National S&T Conference. STPI is also highly committed to facilitating links between knowledge-based policy platforms, industry databases, professional talents, and indicators. Through dual-track policy research and innovative services, these tasks will assist the government in accelerating the national development of science and technology and the innovation of R&D achievements, enhancing the country's overall competitiveness.

| | |
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