International Journal of Education and Humanities
ISSN: 2770-6702 | Vol. 24, No. 2, 2026

Construction Experience of Strategic Scientific and Technological Strengths in Developed Countries and Advanced Domestic Regions

Weiqi Cao*

School of Economics and Management, Southwest Petroleum University, Chengdu, Sichuan 610500, China
* **Corresponding author**: Weiqi Cao (Email: 13382725343@163.com)

Abstract: In 2021, General Secretary Xi Jinping clearly pointed out at the 10th National Congress of the China Association for Science and Technology that competition among world scientific and technological powers hinges on national strategic scientific and technological strengths. In recent years, China has issued a series of policies including the *Outline of the National Innovation-Driven Development Strategy* and the *Outline of the 14th Five-Year Plan and the Long-Range Objectives Through the Year 2035*, which set clear goals and tasks for strengthening the development of national strategic scientific and technological strengths. In July 2024, the Second Plenary Session of the 20th Central Committee of the Communist Party of China incorporated deepening the reform of the science and technology system into the strategic arrangement of comprehensively deepening reforms and advancing Chinese modernization. It proposed reinforcing national strategic scientific and technological strengths, improving the national laboratory system, and optimizing the positioning and layout of national research institutions, high-level research universities, and leading tech enterprises. These statements and policies reflect China's high priority on boosting national strategic scientific and technological strengthst.

Keywords: Strategic Scientific and Technological Strengths, National Laboratories, Research Universities, Leading Tech Enterprises, Innovation System.

1. Construction Experience of Strategic Scientific and Technological Strengths in Developed Countries

1.1. Experience in National Laboratory Construction in Developed Countries

1.1.1. Institutionalized Scientific Teams and Mature National Laboratory Systems

Following the Bush Report, the United States gradually built a scientific and technological innovation system consisting of federal research institutes, universities, enterprises and non-profit research organizations to meet national strategic demands, alongside its renowned national laboratory system[1]. Centralizing high-quality resources, this system has delivered breakthroughs in core bottleneck technologies and key core technologies, and has been widely emulated worldwide with remarkable results [2].

Germany has established a complete national research system integrating major institutions including the Max Planck Society, Fraunhofer Society, Helmholtz Association and Leibniz Association, achieving breakthroughs in nuclear fusion technology. The United Kingdom has built an innovation system combining research institutes, research centers, national laboratories, university key laboratories and Catapult technology and innovation centers, yielding major advances in quantum technology and materials science.

1.1.2. Flexible Personnel Administration and Complete Scientific Research Infrastructure

World-class overseas national laboratories adopt flexible personnel management mechanisms. Apart from permanent staff, they recruit global outstanding talents on fixed-term contracts for research, administrative management and technical support positions, and adjust subsequent cooperation based on personal willingness and work performance.

Take U.S. Department of Energy national laboratories as an example. Their total workforce of 70,000 includes fewer than 30,000 technical researchers, accounting for less than 50%. Postdoctoral researchers, graduate students and undergraduate students sponsored by laboratories add up to over 36,000 people. The remaining staff comprises 247 senior leaders, 4,962 technical managers, 3,144 operation managers and 25,061 operational support personnel [3]. Most laboratories are equipped with top-tier comprehensive infrastructure. The Argonne National Laboratory operates the world-leading Argonne Leadership Computing Facility, which applies artificial intelligence to predict large-scale transportation patterns. The European Organization for Nuclear Research (CERN) hosts the world's largest and highest-energy particle accelerator for exploring fundamental matter structures. The RIKEN's quantum photonic computer in Japan boasts the world's strongest computing power, promising breakthroughs in cryptography and quantum technology.

1.1.3. Massive Financial Input and High Per Capita R&D Funding

National laboratories primarily serve major national strategic demands, which necessitate substantial fiscal investment. U.S. R&D expenditure grows year by year. Germany pledged an additional USD 18 billion investment in scientific institutions by 2030, while the UK government plans to raise annual research grants from the current USD 11 billion to USD 26.9 billion.

The Jet Propulsion Laboratory (JPL) under NASA held a fiscal year 2024 budget of approximately USD 2.3 billion, with roughly 5,000 researchers receiving an average of USD 460,000 per capita in R&D funds. Established in 1943 under the Manhattan Project, Oak Ridge National Laboratory had a fiscal year 2021 budget of USD 2.4 billion, employing 5,700 scientists and engineers from over 60 countries covering more than 100 disciplines, with per capita R&D funding reaching USD 420,000.

1.1.4. Prioritization of Talent Team Development

Top overseas national laboratories attract global outstanding talents to build high-caliber teams, with replicable practices in talent training, incentive and deployment.

Many countries have developed comprehensive training systems tailored to talents at all stages. Oak Ridge National Laboratory in the U.S. launched programs for K12 students including the Next Generation STEM Internship Program, Next Generation Computational Science Pathway Program, and Accelerating Young Women in Science Program, alongside more than 20 summer internship projects for undergraduates and postgraduates. These programs provide diverse learning and practical opportunities with outstanding outcomes. Statistics show that 96% of participants continue engaging in STEM research after training, and 16% secure employment or maintain research partnerships with Oak Ridge National Laboratory [4].

Laboratories adopt mature and flexible talent evaluation systems. Lawrence Berkeley National Laboratory independently sets evaluation standards and conducts annual staff assessments, covering research outputs, published papers, funding acquisition, social contributions and academic influence, with peer-recognized achievements weighted heavily in performance reviews. The Max Planck Society in Germany implements a multi-dimensional evaluation framework focusing on academic impact, application value and teamwork, prioritizing research quality and long-term influence.

Laboratories also provide comprehensive welfare packages. Idaho National Laboratory supports remote work and offers new hires more than three weeks of personal leave, alongside maternity/paternity leave, family visit leave, 10–30 days of paid annual leave (length tied to tenure), medical, dental and life insurance, and spousal employment support.

Top global research laboratories extensively pursue research collaborations with universities. The Italian National Institute for Nuclear Physics runs multiple laboratories and co-founded 20 branches with university physics departments to integrate laboratory and university talent resources. The GSI Helmholtzzentrum für Schwerionenforschung in Germany and Ludwig-Maximilians-Universität München launched a joint postgraduate training scheme, allowing students to conduct research and attend courses at both institutions. Permanent Max Planck researchers may hold part-time professorships at universities after completing collaborative projects.

1.2. Construction Experience of High-Level Research Universities in Developed Countries

1.2.1. Emphasis on Basic Research

Basic research underpins the entire scientific system. As core components of strategic scientific and technological strengths, high-level research universities serve as the main force of basic research and the engine of major scientific breakthroughs. Germany attaches great importance to basic research investment, generating numerous world-influential original achievements.

Massachusetts Institute of Technology (MIT), renowned for independent academic innovation, established the Lincoln Laboratory with U.S. Department of Defense support after World War II, shifting its focus to basic research closely integrated with industrial production. It delivered remarkable outcomes, acting as the birthplace of numerous modern electronic products and triggering the formation of microelectronics high-tech industrial clusters.

1.2.2. Response to Practical Demands and Deep Industry-University-Research Integration

Stanford University laid the foundation for Silicon Valley as a global innovation hub, nurturing high-tech enterprises including Hewlett-Packard, Apple, Google and Tesla. The parallel rise of Stanford and Silicon Valley stems from an industry-university-research ecosystem centered on top universities and startups, built on a culture of free innovation featuring mutually beneficial collaboration between all participants.

Stanford functions as the core of the Silicon Valley ecosystem. It established external technology licensing and cooperation mechanisms, alongside an internal technology transfer service system to cultivate top faculty and talents. The university supports faculty and student entrepreneurship via market, capital and technical resources. Beyond the linear industry-university-research model of university research and corporate commercialization, Stanford maintains diversified multi-stakeholder collaboration with Silicon Valley firms through joint research, commissioned research, joint talent training, corporate consulting, data sharing and equipment leasing.

1.2.3. Promotion of Interdisciplinary Research to Boost Knowledge Innovation and Sharing

Knowledge innovation and sharing are critical drivers of technological progress, collaborative innovation and the development of strategic scientific and technological strengths. As the source of knowledge and innovation, high-level research universities break disciplinary barriers through interdisciplinary research to foster open innovation environments.

Institutions including MIT and Princeton University have set up numerous interdisciplinary research centers and programs to advance cross-disciplinary integration, yielding landmark achievements in artificial intelligence and new energy. World-class Western universities carry out interdisciplinary research targeting industrial demands and complex practical challenges. France’s higher education reforms promote disciplinary integration via supra-institutional faculties, creating platforms for large-scale interdisciplinary projects and complex multi-disciplinary research to avoid fragmentation of basic academic organizations. A matrix structure combining horizontal cross-college and vertical cross-departmental coordination strengthens systematic, coordinated and socially integrated scientific and technological innovation. University consortia combine educational and research capacity with tech industries to accelerate R&D and commercialization.

1.3. Construction Experience of Leading Tech Enterprises in Developed Countries

1.3.1. Enterprise-Centered Innovation and Independent R&D Capacity

Mastery of core technologies relies on innovation capacity, which has become the core competitive advantage of industrial chains worldwide. Leading Western tech enterprises prioritize independent innovation. Apple integrates innovation into corporate culture, and its applied innovation model delivers continuous industry-leading upgrades [5]. As a global pharmaceutical giant and German innovation benchmark, Bayer Group drives corporate growth through scientific and technological innovation. It launched the Bayer Leap Program to address major human development challenges, conducting technical exploration in life sciences, polymers and advanced agricultural technology. Sustained R&D investment strengthens independent innovation and delivers groundbreaking inventions leading global agriculture, chemical and life science industries.

1.3.2. Cultivation of Cross-organizational Collaboration Capacity

Collaboration capacity of leading tech enterprises powers collaborative innovation mechanisms, enabling effective cooperation with all entities of strategic scientific and technological strengths, fostering positive interaction between technological innovation and socio-economic development, improving integrated coordination efficiency, and advancing the development of strategic scientific and technological strengths.

Rolls-Royce plc of the UK excels in external cross-organizational cooperation. It built a global network of university technology centers with 28 universities worldwide to recruit top global talents, share cutting-edge resources and knowledge, and focus on basic research and technical R&D to sustain corporate innovation vitality. Close partnerships with diverse suppliers expand raw material access channels and build a multi-level supply chain collaboration system.

2. Construction Experience of Strategic Scientific and Technological Strengths in Advanced Domestic Regions of China

2.1. Construction Experience of National Laboratories in China

2.1.1. Focus on National Strategic Demands with Local Developmental Characteristics

National laboratories and national key laboratories prioritize national strategic development demands and layout cutting-edge scientific fields. Meanwhile, they leverage local resource endowments and industrial advantages to conduct basic and frontier technical research, realizing win-win coordination between national strategies and regional development.

Laoshan Laboratory in Qingdao targets major national strategies including building a maritime power. Supported by marine research strengths such as Ocean University of China and the Institute of Oceanology, Chinese Academy of Sciences, and combining Qingdao's geographic location and marine resources, it carries out marine science research and technical breakthroughs. As China's sole national laboratory dedicated to marine science, it enhances China's global competitiveness in marine research while boosting Qingdao's local economic growth and industrial upgrading

2.1.2. Driven by Emerging Strategic Technologies to Upgrade Industrial Innovation

National laboratories prioritize frontier scientific research while aligning closely with national emerging strategic technologies to drive industrial innovation and upgrading through technological breakthroughs. During the 14th Five-Year Plan period, China established a batch of national laboratories covering core innovation fields including quantum information, photonics and microelectronics, cyberspace communications, artificial intelligence, biomedicine and modern energy systems. Cross-disciplinary and cross-field collaboration within these laboratories accelerates R&D, application and industrialization of new technologies, processes and products.

In information and communications, laboratories cooperate with world-class local enterprises such as ZTE and Huawei. In artificial intelligence, collaborative innovation with Harbin Institute of Technology (Shenzhen), Shenzhen Institutes of Advanced Technology and Tencent advances industrial development in Shenzhen through integrated industry-university-research mechanisms.

2.1.3. High-standard Construction to Build Original Innovation Sources

As the highest tier of national strategic scientific and technological strengths and the national research system, national laboratories adhere to high-standard, high-quality construction principles to become cradles of original innovation [6].

Top-tier talent leadership: National laboratories are led by multiple academicians, with local government chief officials serving as directors of councils or management committees during construction. For instance, Zhangjiang Laboratory's management committee was co-chaired by the then Mayor of Shanghai Ying Yong and Bai Chunli, President of the Chinese Academy of Sciences.

Advanced research infrastructure: National laboratories rely on major scientific infrastructure. The Chinese Academy of Sciences transferred major national facilities including the Shanghai Synchrotron Radiation Facility and National Center for Protein Science Shanghai to the Shanghai Advanced Research Institute to support Zhangjiang Laboratory.

Massive capital investment: Single construction cycles of national laboratories involve billions of RMB to sustain stable long-term research. The Hefei National Laboratory for Quantum Information Science received joint funding from the Anhui Provincial Government, the Chinese Academy of Sciences and multiple high-tech enterprises, enabling landmark breakthroughs in quantum information.

2.2. Construction Experience of High-Level Domestic Research Institutions

2.2.1. Clear Functional Positioning and Focus on Core Missions

High-level research institutions excel at clarifying their strengths and characteristics to concentrate on core missions and optimize allocation of research resources. National research institutes prioritize basic frontier research and breakthroughs in key core technologies to deliver landmark progress in specific fields. The Shenzhen Institutes of Advanced Technology, CAS, focuses on three core directions: medical imaging and scientific instruments, synthetic biology and biomanufacturing, and integrated circuit materials and packaging, integrating national demands, scientific frontiers and regional economy.

Provincial research institutions prioritize R&D and industrial application of generic regional industrial technologies to convert research outcomes into productive forces. The Jiangsu Industrial Technology Research Institute centers on industrial technology R&D and transformation, matching corporate demands via market-oriented mechanisms and establishing a regional innovation benchmark.

2.2.2. Institutional Mechanism Reform and Market-Oriented Operation Systems

Format and save your graphic images using a suitable g Many high-level research institutions have achieved remarkable results through organizational restructuring and market-oriented operational systems. In-depth structural reforms enable flexible allocation and efficient utilization of research resources, maximizing resource efficiency and research output quality. Market-oriented operation systems allow institutions to respond dynamically to market demands and realize economic and social value via technology transfer and commercialization of research outcomes.

The Jiangsu Industrial Technology Research Institute founded a corporate subsidiary in 2016 to manage state-owned assets via commercialized operations, conducting technology development, investment and park management to strengthen self-sustaining market capacity. It established a three-tier system of general institute, specialized research institutes and joint enterprise innovation centers. The general institute oversees overall management, with subordinate specialized institutes co-founding 113 joint innovation centers with leading regional enterprises across segmented industries. This “R&D plus industry” model accelerates conversion of scientific achievements into real productive forces through close corporate collaboration.

2.3. Construction Experience of High-Level Domestic Research Universities

2.3.1. Compact, Specialized and Characteristic Research University Development

High-level research universities pursue a compact, high-quality development model to build distinctive specialized institutions. Examples including Southern University of Science and Technology, Southern Medical University and ShanghaiTech University develop targeted disciplines in frontier fields such as life sciences, materials science and information technology, elevating their research capacity and contributing to national scientific and technological innovation.

2.3.2. Off-campus Research Institutes to Utilize Regional Scientific Resources

High-level research universities establish off-campus research branches such as satellite campuses and research institutes as a core development strategy. Cross-regional cooperation builds close partnerships with local governments and enterprises, deepens integrated industry-university-research application, and expands cross-regional research networks by leveraging local talent, policy and research resources.

Tsinghua University has established 16 university-local government research institutes targeting major national and regional strategies including the Beijing-Tianjin-Hebei Coordinated Development, Guangdong-Hong Kong-Macao Greater Bay Area and Yangtze River Delta Integrated Development. Representative platforms include the Research Institute of Tsinghua University in Shenzhen, Yangtze Delta Institute of Tsinghua University in Zhejiang and Tsinghua Pearl River Delta Research Institute. These institutes serve as bridges linking Tsinghua University with local governments and enterprises, driving regional economic growth and commercialization of research achievements [7].

2.4. Construction Experience of Domestic Leading Tech Enterprises

2.4.1. Favorable Innovation Ecosystem to Support Corporate Growth

The growth of leading tech enterprises relies on a comprehensive innovation ecosystem covering policy support, capital funding, talent reserves and industry-university-research collaboration. Policy support forms the foundation via tax incentives and R&D subsidies to reduce corporate innovation costs. Talents constitute the core innovation driver, as leading enterprises attract top professionals to form talent hubs. Industry-university-research cooperation accelerates commercialization of research outcomes. Complete intellectual property protection safeguards innovative achievements, mature financial services provide innovation capital, and vibrant entrepreneurship culture stimulates innovative vitality. Collectively, these elements sustain corporate competitiveness and industry leadership amid fierce market competition.

The rapid rise of the “Six Little Dragons of Hangzhou” stems from the city’s robust innovation ecosystem. The municipal government introduced tax reductions, R&D subsidies and venture capital to cut corporate innovation costs. Abundant local talent reserves provide continuous innovation momentum. Zhejiang launched the “Digital Zhejiang” strategy in 2003, fostering internet giants including Alibaba, Hikvision and New H3C Technologies and aggregating digital industry talents. The “Six Little Dragons” maintain close cooperation with local universities and research institutions, leveraging computing resources from the Zhejiang Lab and Alibaba City Brain platforms to accelerate research commercialization. Policy support, abundant digital talent and sufficient computing resources together form the innovation ecosystem enabling the rise of these enterprises in Hangzhou.

2.4.2. Increased R&D Investment to Drive Technological Breakthroughs

Leading tech enterprises continuously expand R&D expenditure to sustain advantages in core technologies. They establish dedicated R&D institutions, assemble expert technical teams and invest heavily in new technology and product development. Sustained R&D investment delivers market-competitive new products and services to maintain industrial leadership [8].

As a domestic leading tech enterprise, Huawei invested over RMB 160 billion in R&D in 2023, with cumulative R&D expenditure exceeding RMB 1.11 trillion over the past decade, accounting for more than 10% of annual operating revenue. Massive R&D investment supports global laboratory deployment, recruitment of top talents for basic and applied research, and continuous innovation in communication technologies and products. As a global leader in 5G standards, Huawei delivers convenient, efficient communication solutions worldwide. Sustained R&D investment strengthens its technical strength and generates substantial market returns [9].

3. Conclusion

This paper systematically sorts out the construction experience of strategic scientific and technological strengths from two dimensions: developed foreign countries and advanced domestic regions, covering four core entities: national laboratories, high-level research institutions, research universities and leading tech enterprises.

For developed countries, national laboratories feature institutionalized talent teams, flexible personnel systems, massive fiscal investment and comprehensive talent training and incentive mechanisms. High-level research universities prioritize basic research, deep industry-university-research integration and interdisciplinary innovation. Leading tech enterprises uphold independent innovation and cross-organizational collaborative capacity building.

For China's advanced regions, national laboratories adhere to national strategic positioning combined with local industrial characteristics, driven by emerging technologies and built to high original innovation standards. Domestic research institutions clarify functional positioning and advance market-oriented operational mechanisms. Research universities develop compact, characteristic disciplines and build cross-regional off-campus research platforms. Local leading tech enterprises rely on comprehensive regional innovation ecosystems and sustained high R&D investment to achieve core technological breakthroughs.

The summarized international and domestic experience can provide practical references for Sichuan Province to optimize the layout of national laboratories, research institutions, universities and leading tech enterprises, improve the collaborative innovation system of strategic scientific and technological strengths, and accelerate the construction of regional innovation hubs.

Acknowledgments

No funding acknowledgment.

References

[1] Editorial Department of Qiushi Journal. (2021). Boost national strategic scientific and technological strengths. Qiushi, (11).

[2] Tu, P., Cao, A., & Yi, T. (2023). Governance mechanism and enlightenment of U.S. department of energy national laboratories from the actor-network perspective. Science and Technology Management Research, 43(23), 53–62.

[3] Zhang, D., Xue, L., Liang, Z., et al. (2024). Experience and enlightenment of high-level research universities exerting the role of national strategic scientific and technological strengths. Tsinghua Journal of Education, 45(4), 46–59.

[4] Qin, P., Wang, J., & Yang, M. (2024). Experience and enlightenment of talent team construction in world-class foreign national research institutions. Chinese Journal of Science and Technology Talents, (1), 36–44.

[5] You, W. (2012). A preliminary study on the enlightenment of apple's innovation model for corporate product innovation. Oriental Corporate Culture, (15), 15–16.

[6] Bian, S., & Liu, X. (2011). Modes, classification and comparison of national laboratories — research based on innovation practices of the United States, Germany and China. Journal of Management, 8(4), 567–576.

[7] Yu, Y. (2025). University-local institute collaborative innovation model under industry-education integration. Contemporary Educational Research, (16), 133–135.

[8] You, W. (2012). A preliminary study on the enlightenment of apple's innovation model for corporate product innovation. Oriental Corporate Culture, (15), 15–16.

[9] He, X., & Guo, L. (2026). Operation mode and regional synergy of China's national laboratories. Journal of Information Science, 44(8), 71–78.