Industrial Innovation in China

Operation, Performance and Prospects for China's Industrial Innovation System: Impact of Reform and Globalization

The LEVIN Institute

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The Neil D. Levin Graduate Institute of International Relations and Commerce was created by The State University of New York to enrich the SUNY system through our work on the dynamics of globalization. The Levin Institute is a new academic enterprise that offers the skill sets offered by schools of management as well as the world view and global knowledge of schools of international relations.

A prime focus is on training students and working professionals to manage organizations effectively and ethically across borders and cultures. This in turn calls for research on and development of new approaches to learning across boundaries. At the center of this mission is the individual, the human talent working with technologies, which together drive the process of globalization. In 2005 we held an international conference on "The Evolving Global Talent Pool." This conference on "Industrial Innovation in China" focused on China's efforts to move to the forefront in the critical fields of science and technology. We think you will find the information, discussions and conclusions of great value.

Paul Tagliabue
Chairman

From our inception, The Levin Institute has placed an important emphasis on emerging economies and markets, and their impact on globalization. The rise of China as an economic force is unprecedented in speed and scale. Although most foreign attention and investment have been directed toward China's manufacturing and financial sectors, a key factor in China's ability to sustain its growth and competitive edge will depend on its success in moving into knowledge intensive industries. This in turn will depend on China's ability to produce the human talent to fuel these new industries.

This is why The Levin Institute has focused on, and developed an expertise in, the development of science, technology and innovation and the related talent needs in the PRC. And that is why we were happy to partner with the Ministry of Science and Technology and the Council on Foreign Relations to hold this conference. Organized by The Levin Institute's Provost, Dr. Denis Simon, and his colleagues, the conference and related events brought together government officials, academics, policy specialists, business figures and media representatives to evaluate China's potential to emerge as a major force in science, technology and innovation. The implications of this for the United States and the industrialized world are evident.

Garrick Utley
President

Industrial Innovation in China: Putting the Conference in Perspective

Dr. Denis Fred Simon
Provost and VP for
Academic Affairs

China's top leaders and members of its technical community have placed great faith in the development of Chinese science and technology in the 21st century. The science and technology system has undergone two decades of extensive structural reform. The human resource base of the S&T system has been expanded and improved as a result of domestic educational reforms and extensive overseas study programs. And, the inputs into formulation and implementation of science and technology policy have become more sophisticated and globally oriented. After a long period of underinvestment in science and education, China is now committed politically and economically to increase its funding of both such that these expenditures represent an increasing percentage of an expanding GNP. Multinational corporations now see it in their strategic interests to have a research presence in China as indicated by increasing numbers of MNC R&D centers being established. Chinese scientists and engineers are becoming important participants in the global science and technology system and are contributing an increasing share of papers to the world's scientific and technical literature. In many ways, it appears as if 20+ years of preparation for national scientific and technological distinction are beginning to come to fruition, with China poised to become a major international player in science and technology if not, in the longer run, a scientific and technological superpower.

It was against this backdrop that over 50 experts from China, the US, Europe and Asia came together in July 2006 to examine the current and future trajectory of the Chinese industrial innovation system. For two and one-half days, intensive and extensive discussions were held in and around the issues of China's innovative capacity and potential. The Chinese leadership sees ongoing progress in science, technology and innovation as critical to addressing three of the most important policy problems facing the country: national security, competitive success in the global economy, and the creation of the conditions for ecologically sustainable development. These also are policy problems that engage China's international partners and competitors, including the United States. Coming to a better understanding of the challenges facing future Chinese scientific and technological development is thus of considerable importance for evaluating and managing the prospects for China's political, economic, and social evolution in the coming decades. This point was reinforced several times throughout the meeting, especially in terms of the remarks offered by Vice-Minister of Science and Technology, Shang Yong. Vice-Minister Shang used the occasion of his welcome speech as well as his keynote speech at lunch during the first day to emphasize the strategic importance of China's continued engagement with the global innovation system and evolving international knowledge networks.

The significance of the conference quickly became apparent during the initial sessions as even the most seasoned Western and Asian observers of China's innovation system expressed concerns about the uneven performance of the country's R&D-to-production nexus. Even though there has been much hype about China's potential emergence as some sort of "techno-superpower," the reality that surfaced from the presentations and discussions suggested something much different—at least in the short term. Various presenters commented on the apparently complex nature of such vexing problems as the country's immature capital markets and underdeveloped Chinese regime for developing and protecting intellectual capital. Other issues that drew attention had to do with the problems of talent availability and utilization. The notion that China actually might have a serious talent shortage in terms of qualified scientists and engineers appeared strange to many in view of the huge number of young people being trained in Chinese universities, especially since 1999. Yet, the talent issue is one of the greatest limitations on the country's innovation potential. Not only are many graduates coming out of the university ill-equipped in terms of advanced technical skills to take on the needed assignments inside Chinese companies and research institutes, but they also lack the type of creative, entrepreneurial instincts that lie at the heart of innovation success in places such as Silicon Valley in California and Route 128 in Massachusetts. Finally, the PRC innovation system remains confronted by the stark reality that it is trying to attack a steadily and rapidly moving target; the so-called cutting edge of innovation—technological, organization, and business innovation—is shifting and evolving at break-neck speed as the imperatives of international competition have moved innovation capacity to center stage in the globalized economy of the 21st century.

The announcement in January 2006 of China's new 15 Year Medium-to-Long-term Science and Technology Plan highlights the fact that Chinese leaders realize that they cannot be complacent or adopt a passive attitude about these global changes at any time in the near future. Chinese participants emphasized the strategic nature of the new plan, and suggested that this was China's most

ambitious step forward in science and technology since the "1956 12-Year S&T Plan" launched under the leadership of Nie Rongzhen. The new plan is conspicuous by the fact that it tries to merge two visions together into one action program. First, there are those aspects that are designed to ignite greater attention and activity in and around the performance of industrial R&D and the commercialization of new know-how. According to this vantage point, the "enterprise" must become the new focal point at the heart of the Chinese innovation system. The shift in focus to the enterprise represents the on-going efforts to make enterprises more responsive to the growing demands of markets and their customers. Yet, at the same time, the plan also is conspicuous by the fact that it does not depart from the big government driven, mega-project philosophy manifested in the "liangdan yixing" (two bombs and one satellite) mentality, that is often seen as the key success formula for China's early military progress in the 1950s and 1960s. Government clearly sees a role for itself in helping to integrate, coordinate, manage and monitor progress towards building "a truly innovative nation."

With the central government mobilized and with China's enterprises in the innovation driver's seat, one also can see a tremendous amount of activity occurring at the local and regional level across the Chinese S&T system. With 53 nationally approved high tech parks around the country as the catalyst, China's localities are taking a deeper interest in meeting the demands for more indigenous innovation. Cities such as Tianjin and Jinan along with Qingdao and Dalian were identified at the conference as the new hubs of innovation for everything from biotechnology to software development. Local governments are going abroad to scout Chinese talent, providing attractive offers to attract persons with several years work experience and overseas education to return to China to play a leading role in helping China to move to a higher innovation trajectory. The search for this type of talent has already proven successful in a number of cities and has helped to jump start local technological entrepreneurship across a variety of industries.

One more place where innovation also seems to have become the new watchword is inside the Chinese Academy of Sciences in the form of the Knowledge Innovation Program, which originally was launched in late 1998. The CAS, which traditionally has been at the center of China's basic research effort, is seeking to enhance its capabilities in basic science while at the same time play a more active role in helping to create new, commercially-relevant know-how that can be linked to the development of new products and services. Towards that end, the CAS has gone through a major restructuring effort that has included closing down several institutes and the merging of several others to enhance overall R&D efficiency and mission effectiveness. And, like many of the local S&T agencies, the CAS too has been engaged in a major talent recruitment campaign overseas to ensure an adequate talent pool to meet the expectations of those who look to the CAS to play a more dynamic role in China's national innovation system. Of course, one of the CAS's strengths will continue to be its linkages with overseas counterpart organizations and the individual relationships developed between foreign and Chinese scientists, including those ethnically-Chinese who have assumed permanent residence or citizenship in the US, Europe, etc. The proliferation of Chinese articles in foreign, refereed journals and the higher representation of Chinese cited articles in the Science Citation Index all suggest that in fields such as nanotechnology, biotechnology, etc. we are bound to see China start assuming a more critical role in the global knowledge networks that form the underpinning for the international S&T community.

The conference participants, Chinese and foreign, were all cognizant of the large role played by foreign technology over the last two decades in helping to fortify the economy and advance the state of Chinese technological know-how and equipment. Without the benefit of foreign technology, it is clear that China's domestic innovation system would have not been able to make up the gap that would have been left in terms of enhanced productivity, better process engineering and quality control systems, and the upgrading of the overall industrial infrastructure to support the rapid growth of the last twenty-plus years. However, with some exceptions such as Huawei, Haier and Lenovo, it also is clear that the presence of foreign technology, while not necessarily stunting the development of an indigenous local R&D effort, has allowed for a more modest level of activity regarding local R&D spending inside most Chinese enterprises. This is the case despite the launch and implementation of high-level government programs such as the Torch Program and the 863 Program. Everyone at the meeting seemed to agree that for China to achieve a breakthrough in terms of IPR, technical standards, general brand building, and overall economic competitiveness, it will have to change the current state of affairs and stimulate more indigenous innovation on a sustained basis.

This is what makes the Medium-to-Long-Term Plan so critical to the future growth of the Chinese economy. If all of the major policy initiatives contained in the MLP get carried out to fruition, China will be positioned for a rather significant re-configuration of its domestic innovation system. The combination of proposed tax and financial incentives and benefits, supplemented by the injection of increased government spending on R&D and the step-up in training for scientists and engineering talent will help to incentivize new behaviors and ideally new thinking about the critical role of innovation. Whether or not China can pull this off is the major burning question as it is clear that the MLP is not just another government-driven plan for promoting science and technology. At stake is the future course of Chinese economic and technological development and the nature of the role China will play in the evolving world order of the 21st century. If the MLP is largely successful, it will offer benefits on both the civilian and military sides to the Chinese nation, thereby strengthening the foundations of growth for the future. Moreover, as the comments by Vice-Minister Shang Yong suggested in his main speech to the conference, the course of the MLP will help define and shape the quality and nature of Chinese economic growth in the coming years as well. From the perspective of energy, environment, and resources utilization, the consequences have implications far beyond the confines of China's political borders.

Most critical, however, as the respective presentations by Mel Horwitch (on global innovation and competition) and Leonard Lynn (on global innovation and cooperation/collaboration) suggested very early on in the meeting, China's rise as a more innovative nation could change the dynamics regarding new knowledge creation and commercialization on a global scale simply because of the huge market power and talent base that China can bring to the table. The conference helped to highlight some of those fields and areas where Chinese influence could make itself felt sooner rather than later. Even more significant, however, the conference served to give pause to those who have started to see China as some unstoppable industrial or technological goliath capable of asserting unlimited influence across the international system. Clearly, China's innovation system has many problems to overcome before it can claim to be "an innovative nation." We need to know much more about the operation of the Chinese innovation system before we can offer confident assessments about what is working and what is not. We need to understand more about the interplay between civilian and military R&D, especially regarding issues surrounding budgets, R&D performance, and talent availability. And, we need to better understand the potential for actually fostering the emergence of a more creative society, and how President Hu Jintao's call for forming a harmonious society relates to and interfaces with his similar calls for China to become an innovative nation.

Nonetheless, that said, China indeed is on the march. The underlying motivations driving the MLP and other innovation related initiatives are pointed in the direction of enhancing appreciably China's role as a source of new IP and as a more influential player in global negotiations on international technical standards. Whether movement in these directions suggests that China might play a more disruptive, even more acerbic role in the future remains to be seen. Based on policy pronouncements coming out of Beijing since the early 1980s, there was never any doubt or lack of clarity in terms of China's strong intentions to close the technological gap with the West and Japan. As the overall discourse at the conference indicated, China remains firmly committed to maintaining its cooperative approach to its international S&T relationships and partaking of the benefits that globalization has to offer. As noted by many of the Chinese presenters, the call for more "independent" or indigenous innovation (zizhu chuangxin) in no ways implies a return to the self-reliance policies of the 1960s and 1970s.

Still, should Beijing's worst fears come to pass and the world does become more protectionist, perhaps in response to the Chinese ascendancy in economic, scientific and technological terms, the character of the PRC's engagement with the world might take on a different, less positive tone. This would be highly unfortunate as the net addition of Chinese "brainpower" to the world of scientific inquiry and technological problem-solving holds great potential in terms of improving the overall human condition. Therefore, as the conference participants concluded, it is rather clear that encouraging China to become more fully committed, fully engaged, and fully participating in (and contributing to) the global innovation system as a productive member is a much better response to the PRC's rise than policies and actions that might be aimed at constraining or limiting the Chinese place in the emerging new technological order over the coming years.

Defining Innovation

In any study or analysis, the definition of key terms is a useful first step. From the very start of the conference, participants launched into a wide-ranging and candid discussion of the operation, performance and prospects for China's industrial innovation system. But at several points over the three days of discussion, they did stop to consider the meaning of innovation—both as a general concept and in the Chinese context. This was crucial since the term is so widely employed in the discourse of globalization that it is now a buzzword, commonly viewed as something of a silver bullet that kills off old-economy thinking and revives stagnant societies and economies by driving new growth.

Yet for such an easily and casually uttered word, nailing down a precise definition was not so straightforward. In opening remarks, China's Vice Minister of Science and Technology Shang Yong defined innovation in terms of its potential benefit for his country. It would be "the new engine and driving force to propel economic growth," he believed. In a luncheon address later, Shang outlined what he called the "three principal aspects of building an indigenous innovation capability," essentially three ways to innovate. First is the capability to "absorb, digest and improve" imported technology and "recreate" intellectual property based on the original. This basic form of innovation may not result in anything truly new. The second method is to integrate existing or emerging technology and inventions to produce new intellectual property. Third is the purest sort of innovation: scientific discovery or invention. To achieve each successive level of innovation requires more skills, more knowledge and, typically, more investment.

For Robert Shelton, who leads the innovation practice for consulting firm PRTM, innovation can be applied not just to a product or service, but could just as well pertain to business models or management organization. The iPod would not have been a meaningful innovation without the business model change that the iTunes online platform represented, he pointed out. Innovation is all about new ways of learning, working and operating, Shelton reckoned. "Collaboration and partnerships are the major currency of innovation," he remarked. "The unit of measure of innovation is the partnership."

Innovation, it seems, is something intangible that is hard to define but is recognizable when one sees it. It can mean many things to many people—from a mere idea to a whole new organization. On the conference's third day, Denis Simon, Provost and Vice-President for Academic Affairs at

The Levin Institute, managed to break the concept down. Innovation, he said, is "the process that transforms ideas into commercial value." Adapting comments made by previous speakers, Simon outlined six different types of the innovation process. The capture of commercial value is what distinguishes invention from innovation, he suggested.

That is an appropriate and valuable point. After all, innovation is not an altruistic pursuit. The fascination with the concept in China and anywhere else where the unrelenting pressures of globalization are driving reform has everything to do with finding new ways to generate economic growth and create wealth. "Everybody today is worried about their innovative capability," said Simon. "The key issue is where to get the resources and assets to drive the innovation machine. Who has the global talent? And is China building an innovation system that will allow it to be successful in the 21st Century?"

That was the overarching question that conference participants sought to answer.

What is Innovation?

- Transformation of ideas into commercial value
- Introduction and commercial sale of a new or improved product, e.g. the Remington typewriter, the tungsten filament light bulb, the Pentium chip, the Apple iPod
- Introduction and commercial use of a new method of production, e.g. the steam engine, the Pilkington float glass process, Henry Ford's production line
- Introduction of a new form of business organization or management method, e.g. franchising, cooperatives, joint ventures, co-production and outsourcing agreements, just-in-time inventory management, regional sourcing
- New uses for existing products, e.g. among the first uses of the electronic computer was in military applications such as the calculation of cannon trajectories
- New markets for existing products, e.g. the doughnut was invented in Germany and then spread across the world
- New channels for commercial transactions and distribution, e.g. catalog sales, overnight air courier service, e-commerce, phone banking

Invention vs Innovation
Invention is the creation of a new idea or concept, while innovation is the process of turning the new concept into a commercially viable product, service, procedure or application

Innovation System
A set of distinct institutions that contribute to the development and diffusion of new technology in an organization (e.g. a company), country or region

Session 1
China and the Global Innovation System

Speakers

Globalization and Industrial Innovation: New Patterns and Practices

Dr. Mel Horwitch
Polytechnic University

Chinese Innovative Firms and the Industrial Innovation System

Prof. Chen Jin
Zheijiang University

Comparative Perspectives on US-China Innovation Systems

Dr. Kathleen Walsh
Naval War College

China's Evolving Position in the Global Technology System

Dr. Leonard Lynn
Case Western Reserve University

Moderator

Dr. Denis Simon
The Levin Institute

Shang Yong
China's Vice Minister of Science and Technology

China's main economic challenge over the next decade is to shift from its longstanding export-led, low-cost manufacturing growth model to one based on domestic consumption and the power of creativity. The traditional focus on development through exports and heavy fixed-asset investment must give way to more productive, higher quality growth driven by innovation. At the same time, as it restructures, China must avoid a hard landing and maintain social stability. The overcapacity in many industries, the soaring use of natural resources, and the staggering savings rate of over 40% of GDP cannot be maintained. "After several decades of strong economic development, China is at a crossroads," Shang Yong, China's Vice Minister of Science and Technology, told participants in a luncheon address. "Obviously, the old growth pattern is not sustainable."

The current five-year plan outlines the government's approach: stimulate domestic demand, shift resources away from industries with too much capacity such as automobiles and steel, and shore up the financial system so that it can better absorb savings and mobilize capital for productive purposes. A key focus is the promotion of innovation. A 15-year science and technology development blueprint—a national innovation strategy—was launched in 2006. The plan calls for R&D spending to rise from 1.2% of GDP to more than 2.5%, which is slightly above the average for OECD nations, by 2020. As a clear sign of its commitment, the government allocated more than $8.5 billion to invest in science and technology in 2006 nearly 20% more than in 2005. Chinese industries are to become modern, globally competitive, and energy efficient. "Industrial development is undergoing a strategic transformation," said Shang. "The next two decades will be crucial."

A National Innovation Strategy for China

In early 2006, China convened a National Science & Technology Summit that issued the Outline of the National Medium- and Long-Term Science and Technology Development Plan 2006-2020. Premier Wen Jiabao has spearheaded the plan's formulation, with the participation of 20 ministries and over 2,000 experts. According to Shang Yong, Vice Minister of Science and Technology, "a distinct feature of the Plan is the adoption of innovation as a new national strategy and the goal of advancing China into the ranks of innovation-oriented countries by 2020." As Chinese President Hu Jintao put it at the landmark Summit, "innovation is the core of the nation's competitiveness and the strategic motif of China's science and technology development."

The main goals of the Plan are:

- To enhance indigenous innovation to strengthen global competitiveness, create more Chinese intellectual property, and enhance national security and prosperity.
- To increase investment in R&D from 1.2% of GDP to more than 2.5% by 2020.
- To boost the contribution of science and technology from 39% to GDP to 60%, while lowering the dependency on foreign technology to 30%.
- To rank China among the top five countries holding patents and Science Citation Index (SCI) papers.

Key elements of the strategy include the following:

- Top priority will be placed on R&D in the fields of energy, water resources development and environmental protection to address bottlenecks in China's economic and social development. Efforts will go into upgrading productivity and energy efficiency, as well as developing clean energy sources.
- Policies will be "people oriented." In other words, science and technology development will focus on improving people's living standards and health. This will include the development of biotechnology and information technology to combat disease and produce cutting-edge medicines and treatments. Particular emphasis will be placed on traditional Chinese medicine.
- A key focus will be on the development and application of "common" technologies to support small and medium-sized enterprises.
- Basic and pioneering research by Chinese scientists in collaboration with overseas counterparts will drive innovation.
- Institutional innovation is crucial to the sustainable implementation of the innovation strategy.
- Both large and small enterprises will play a major role in promoting innovation, particularly through investments in China's 53 high-tech industrial zones.
- The government's main job must be to create the right environment or economic ecosystem to foster innovation and entrepreneurship. It is critical that administrative reforms be deepened to change the state's role from intervention to facilitation.
- The government will introduce incentives to stimulate innovation. These will include appropriate legal and social frameworks for enterprises to flourish, including intellectual property rights protection regimes that are adequately enforced.

Mel Horwitch
Chair of the Department of Management, Polytechnic University

Leonard Lynn
Professor of Management Policy, Case Western Reserve University

To be sure, this nation of 1.3 billion people has already achieved much progress in developing science and technology. Its fast-growing telecommunications sector, for example, is now one of the world's largest, with more than 400 million mobile phone users and about 130 million Internet surfers. The implementation of the national innovation strategy, however, will usher in a new phase of development in which innovation will drive growth. "Our industrial structure will be upgraded in the process," Shang predicted. "Domestic industries will be integrated into global supply chains to create greater opportunities."

Indeed, China's shift to embrace innovation and boost R&D cannot be understood or assessed in isolation but must be considered in the context of globalization and the emergence of a global innovation system. The pressure is on. The challenge for China, said Mel Horwitch, Chair of the Department of Management at Polytechnic University in New York, is that it must execute this crucial growth-model switch and expand its knowledge base and capacity for innovation in a decade or two, much more quickly than the US managed its transition. The key will be collaboration. "There is still a big gap between China and developed countries like the US," Shang acknowledged. "It is inevitable that China will be fully involved in international cooperation, from basic research to the development of innovative technology."

Shang's remarks indicate that China recognizes the advantage of collaboration in fostering innovation, that it must balance nationalist tendencies with the benefits of a global outlook. "Firms and countries that did best in the past century tended to be those that freed themselves of the mercantilist mentality that the country with the most gold wins," said Leonard Lynn, Professor of Management Policy, Case Western Reserve University. "Firms and countries that will do best in coming years will be those that free themselves of 'technological mercantilism', the idea that the winner is the one who is dominant in all technology." Added Lynn: "National technology policies can mobilize resources in positive ways but appeals to nationalism can be dysfunctional."

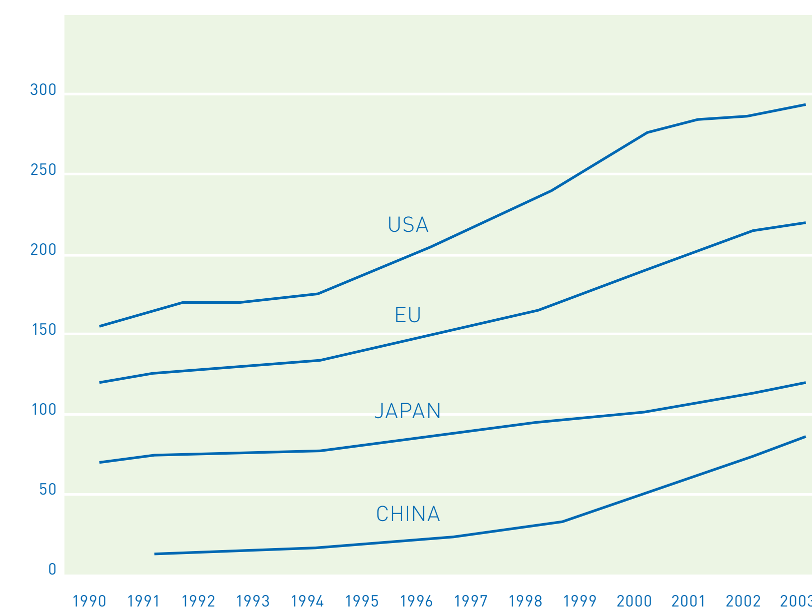
While the advantages of collaboration may be evident, both new and existing barriers to cooperation will be hard to overcome. Many foreign companies keep core technologies out of China, assigning only routine work to their Chinese operations or partners. Even if trust is established between the foreign and local sides, overseas investors worry about intellectual property rights violations and the

consequences of the high employee turnover typical of the China operations of multinationals and joint ventures.

Nevertheless, as it moves from borrowing ideas to coming up with its own, China is undoubtedly becoming an integral part of the "emerging and increasingly complex" global value creation system, said Horwitch, who also serves as Director of Polytechnic's Institute for Technology and Enterprise. He described a world in which global hubs and regional clusters of innovation are emerging. "Countries like China have to develop global cities as well as traditional high-tech clusters," he explained.

Corporate innovation, Horwitch explained, is going global as demonstrated by competitive companies such as Spanish fashion house Zara and Korean electronics group Samsung. Zara has integrated its manufacturing, supply chain and retail outlets around the world, aligning them under a set of modern marketing techniques, professional management principles, and corporate values with global appeal. The result: an efficient and responsive international retail operation that delivers high value to loyal customers, with minimal advertising. Samsung, meanwhile, has combined the best science and engineering talent from across the world with best management practices to create

China's Efforts are Having an Impact
R&D Expenditures ($ Billions, PPP estimates)



Source: OECD, Main Science and Technology Indicators (various years), cited in Science and Engineering Indicators 2005

Katleen Walsh
Professor of National Security Affairs at the Naval War College in Rhode Island

an effective R&D network producing cutting-edge products and applications.

China and its enterprises aspire to achieve similar success. According to Kathleen Walsh, Professor of National Security Affairs at the Naval War College in Rhode Island, China has taken a big step forward by adopting a national innovation strategy. It has already built what she called "a pretty impressive ecosystem" for innovation in just under three decades. "China is going 'all in' on globalization," she remarked. "It is really hanging its future on the future of globalization." Because of its size and unique scope for growth, China will possess the full spectrum of innovation from low end to high. China has been wise to stress the need for overseas companies not just to transfer technology but also to provide training to local personnel—"a long-term, patient approach to learning innovation," Walsh observed. China's top-down administrative structure allows for the quick implementation of new ideas and policies, she noted.

Going forward, China faces enormous challenges such as the lack of its own core technology and brands and the absence of an independent innovation system, argued Chen Jin, Vice President of the College of Public Administration at Zhejiang University. Few Chinese firms are adept at applying the radical "disruptive innovation" needed to make waves internationally. Appliance maker Haier and telecom networks group Huawei Technologies are examples of firms that have leveraged their capacity for innovation to achieve success in the global market, said Chen, who is also Chairman of Zhejiang University's Research Center for Science, Technology, Education and Policy. Some smaller enterprises such as Cgogo, which adapted its search engine for the mobile phone, have demonstrated a knack for creativity and imaginative marketing, he pointed out.

China must promote "intangibles" such as creativity and inquisitiveness and overhaul its education system, Walsh reckoned. Universities will be critical to the development of China's long-term innovative capacity. Another priority is the need to address persistent concerns about the protection of intellectual property rights. "The impact that China-based R&D centers will have on global innovation patterns remains uncertain and will be hard to evaluate," Walsh concluded. "Independent innovation is emerging in China. But what will be China's innovation style? Will the West learn from China? And will China share its innovation style with the world?

Looking Ahead:
China's Innovation System Emerges

Advantages and Strengths

- China is at the nexus of the globalization dynamic
- Widespread investment in necessary infrastructure will continue to attract and facilitate foreign investment
- A top-down approach to innovation promotes more rapid, widespread implementation of science and technology plans
- China's new strategy to emphasize the competitive advantages of regions
- A sizeable science and engineering workforce
- National pride is a potent driving force

Challenges

- How to extend the successful development model to the rest of the country, while expanding the innovative capacity of the rich coastal regions
- Reduce redundancies due to competing priorities and efforts to attract foreign investment
- Successful implementation of the innovation strategy
- To absorb and adapt foreign innovative ideas, processes and practices successfully will require patience if China is to effectively leapfrog in technology
- Address persistent concerns among both foreign and domestic investors about intellectual property rights protection

Credit: Kathleen Walsh

Session 2
An Overview of China's Industrial Innovation System

Speakers

Industrial Innovation in China: A Stocktaking and Analysis

Prof. Zhang Zhihe
Chinese University of Geosciences

Government Policy and Industrial Innovation

Dr. Douglas Fuller
American University

The Development && Opening of Tianjin's Binhai New Area and the Biotechnology Sector in China

Li Jiajun
Director-General, Tianjin Science and Technology Commission

The Regional Innovation System in China

Xu Heping
Deputy Director General, Strategy, Survey and Research Office, Ministry of Science and Technology

Moderator

Jin Xiaoming
Ministry of Science & Technology

Li Jiajun
Director-General, Tianjin Science and Technology Commission

Understanding the workings of China's industrial innovation system is a challenge. Not just because the shift to innovation-led growth is such a new policy, or that R&D operations are not as well developed as they are in the West. There is simply a lack of knowledge about China's knowledge system and how innovation happens. Research so far is minimal, Zhang Zhihe, Professor at the China University of Geosciences in Wuhan, acknowledged. What have been done are mainly qualitative studies, not quantitative analyses, he observed. Indeed, a comprehensive view of how innovation works in China is still difficult to put together. The situation, for one thing, is highly fluid.

There are certainly many examples of regional "clusters" of innovation that have sprouted in recent years. Professor Li Jiajun, Director General of the Tianjin Municipal Science and Technology Commission, described how his city, China's third biggest, has leveraged its traditional position as one of the nation's most important industrial, commercial and manufacturing hubs into a new role as a leader in cutting-edge growth sectors such as IT, biotechnology and pharmaceuticals, environmental management, energy sciences, and herbal medicines. Tianjin is creating the right environment to foster innovation, Li argued. The municipality, for example, boasts more than 150 biotech enterprises, with combined annual sales of over RMB 10 billion, or about $ 1.3 billion. The development of the Tianjin Binhai New Area, he noted, would drive further expansion of innovative industries in the whole Bohai Bay region, in the same way that Pudong has served as a growth engine for Shanghai. The focus on Tianjin is part of a new government strategy to engineer a major transformation of this region and create a new innovation driven growth hub.

The emergence of such clusters of creativity are an important aspect of China's industrial innovation system, Xu Heping, Deputy Director General, Strategy, Survey and Research Office, Ministry of Science and Technology, agreed. Regional governments and enterprises have boosted local R&D spending. From 2000 to 2004, investment by local governments in science and technology increased by 20.1%. Between 1996 and 2004, patent awards rose 25% in the Pearl River Delta, 24.1% in the Changjiang River Delta, and 13.8% in the Bohai region. According to Xu, this suggests that even more emphasis should be placed on building innovation capacity such as information exchanges and technology transfer networks at the local level. More investment is especially needed in China's Western regions, he said.

This anecdotal evidence of pockets of innovation emerging from the grassroots, however, offers a far from complete picture of China's innovation system. There are other key characteristics. Zhang noted that high-tech industries are the main drivers of innovation. The Tianjin experience seems to support that notion. Information technology is now a critical part of the Chinese economy—as high as 16% of GDP, according to one estimate cited by Douglas Fuller, Assistant Professor, School of International Service, American University, Washington, DC. IT is also a key input for the development of many future technologies, he noted.

Meanwhile, the central government has done a lot to promote innovation among small and medium-sized enterprises, added Mu Rongping, Professor and Director-General the Institute of Policy and Management (IPM), Chinese Academy of Sciences. The Ministry of Science and Technology, he said, has coupled SMEs with larger companies that have the money to finance innovation, encouraging partners to share knowledge to facilitate the commercialization of R & D.

Dr. Douglas Fuller
American University

But what about the openness of the Chinese innovation system? Panelists in the first session of the conference stressed the importance of collaboration. Innovation is a global process these days, a pooling of comparative advantages and expertise. So it should follow that the best way forward for China is to establish a more open industrial innovation system, Zhang argued. In other words, China's indigenous innovation system will grow most robustly if it is connected to the global innovation networks and there is a free flow of exchange between them.

That was essentially the same conclusions Fuller derived from his extensive field research into the impact of different types of firms on the growth of innovation in China. Fuller conducted more than 300 interviews across China, covering foreign and domestic enterprises, government officials, NGOs and academics. The purpose: to assess the contributions of different types of firms to the upgrading of technology. He looked at neglected domestic companies that receive little financing, favored domestic firms on which the state lavishes support, regular foreign-invested enterprises (FIEs), and so-called hybrid FIEs that are registered overseas, financed well and have a clear China-based operational strategy.

The latter group made the biggest contribution to pushing China up the value chain, according to Fuller. In a ranking of the top ten enterprises in China (including the operations of multinationals such as Microsoft and Intel) according to China-originating US IT patents held, all but one (Huawei Technologies) were either FIEs or hybrids. The hybrids held the most patents by far. "China's national innovation system cannot be analyzed independent of the institutional environment," said Fuller. "The problems in China's national innovation system are often due to faults in the larger political economy." These include the misallocation of financial resources and the magnification of the problems due to dysfunctional technology and industrial policies.

Clearly, China's national innovation system remains inefficient in many ways, Fuller reckoned. While domestic firms may have a China-based strategy, their contribution to the upgrading of technology is low, even when they are well financed. Nonetheless, in this age of rapid globalization—notably the globalization of R&D in IT and pharmaceuticals—foreign firms are playing an important role in the development of China's national innovation system. This suggests a reason for optimism, Fuller concluded: China's international openness, particularly to financial institutions essential to support innovation, will be critical if it is to succeed in developing a more efficient national innovation system.

Outcomes
Firms and the Causal Chain

FIRM TYPE	FINANCE	CAPABILITIES/ INCENTIVES	MOTIVATION FROM OPERATIONAL STRATEGY	TECHNOLOGY ACTIVITIES IN CHINA	CONTRIBUTION TO UPGRADING
NEGLECTED DOMESTIC	Little finance	Low capabilities	High but irrelevant	Do not pursue	Low
FAVORED DOMESTIC	Lavish state support	Low capabilities/ low incentives	High	Few attempts and execution poor	Low
REGULAR FIES	Access to hard budget finance	High capabilities and incentives	Variable	Variable	Moderate
HYBRID FIES	Access to hard budget finance	Same as as above	High	Pursue tech in China	High

Credit: Douglas Fuller

China's Top Ten US IT Patent Holders

RANK	FIRM NAME	FIRM TYPE	CHINA-ORIGIN US PATENTS	TOTAL US PATENTS	CHINA WEIGHT
1	Hon Hai	Hybrid	510	2,807	18.2%
2	Microsoft	FIE	95	4,680	2%
3	Inventec	Hybrid	88	275	32%
4 (tie)	UMC	Hybrid	29	2,643	1%
4 (tie)	IBM	FIE	29	42,373	.068%
5	Winbond	Hybrid	27	839	3.2%
6	Huawei	Domestic	18	19	94.7%
7	Intel	FIE	17	11,419	.15%
8	SMIC	Hybrid	15	16	93.8%
9	Nokia	FIE	14	4,045	.35%
10 (tie)	Phillips	FIE	9	20,670	.44%
10 (tie)	Motorola	FIE	9	17,013	.53%

Credit: Douglas Fuller

Session 3
The Evolving Role of the Enterprise in the Industrial Innovation System

Speakers

Capacity Building for Enterprise Innovation in China

Dr. Mu Rongping
CAS

Industrial Innovation and the Role of China's SMEs

Dr. Nannan Lundin
Orebro University

Policy System on SME Innovation & Entrepreneurship

Liang Gui
Director-General, Torch Development Center, Ministry of Science and Technology

Commercialization of R&D in China: The Ecology of the Industrial Innovation System

Robert Shelton/Jack Gau
PRTM Consulting

Moderator

Dr. Mu Rongping
CAS

Dr. Mu Rongping
CAS

The key building blocks for the industrial innovation system China wants are contained in the national science and technology plan. The strategy is a response to concerns about how China will cope as traditional comparative advantages such as lower labor costs and more lax environmental standards weaken. It addresses structural challenges China is facing—a widening gap in industrial technological capability with more developed economies, the diminishing effectiveness of investment, the low value contribution of high-tech sectors, and the gap between science and technology capacity and real innovation, among others. "We still have a lot of problems to solve," said Mu Rongping, Professor and Director-General the Institute of Policy and Management (IPM), Chinese Academy of Sciences. "There is a large gap in technology capacity between China and the US"— as much as 10-15 years behind in some sectors.

China's national innovation strategy is geared towards remedying deficiencies such as insufficient investment in innovation development, the apparent shortage of R&D personnel, and a weak intellectual property rights (IPR) regime, Mu explained. The government's arsenal of policy weapons includes spending and management adjustments, the introduction of tax incentives, government procurement practices, measures to facilitate the assimilation of imported technology, strengthening of IPR protection, and more effective human resources and talent development.

For Liang Gui, Director General of the Torch High Technology Industry Development Center, Ministry of Science and Technology (MOST), the focus of efforts to promote innovation has to be China's small and medium-sized enterprises. SMEs already play a critical role in driving economic growth and innovation, he said. Established in 1987, the Torch Program is the sole agency commissioned by MOST to improve the environment for innovation and high-tech industrial development. Among the tools at its disposal to stimulate the growth of technology entrepreneurship include networks of sector-specific incubators and science parks, the SME promotion law that was implemented in 2004, and the SME board launched by the Shenzhen stock exchange that same year and which now has about 50 companies listed. Also available is the Innofund, a central government facility started in 1999 that by 2005 had allocated $650 million to support nearly 8,000 high-tech projects of mainly early-stage SMEs.

SMEs in China: Driving Innovation

China's small and medium-sized enterprises are a dynamic part of the economy. Of all companies registered since 1978, 99.6% are SMEs.

SMEs account for:

— 58.5% of GDP
— 68% of trade volume
— 48.2% of tax revenue
— 75% of urban employment

By the end of 2004, there were 140,000 technology-based SMEs—only 3% of the total number. These firms, 92% of which are private companies, accounted for:

— 65% of all patents
— 75% of technology innovations
— 82% of new products

The key obstacle to development and innovation that SMEs face is the scarcity of capital. External financing is restricted. Due to scale and the lack of guarantees, only 10% of SMEs can obtain bank credit. Access to capital markets is difficult. Meanwhile, risk-averse investors are reluctant to fund innovation and government money goes mainly to research institutes.

Credit: Liang Gui

Dr. Nannan Lundin
Orebro University

China's main challenges, Liang reckoned, are the lack of its own core technologies and the weak indigenous capacity for innovation. The Torch Program will play a more integral role in implementing the national innovation strategy, particularly through interaction with universities and the capital markets, he said. "There is still a lack of a driving force and an overall capacity to sustain innovation in our economy." As a result, transnational cooperation will continue to be an important positive factor, he added.

Nannan Lundin of Örebro University and the Stockholm School of Economics and her colleagues Fredrik Sjöholm, also of the Stockholm School of Economics, and Jinchang Qian of China's National Bureau of Statistics have studied the role of science- and technology-based small enterprises—firms with fewer than 300 employees, less than RMB 30 million in turnover, and less than RMB 40 million in fixed assets—in China's industrial innovation. They found that between 2000 and 2004, the proportion of small firms that are science and technology based dropped from 11% to 9%. This coincided with similar declines in the share of science- and technology-based large (from 83% to 75%) and medium-sized (from 44% to 35%) enterprises.

In 2004, according to the findings of Lundin and her colleagues, the five sectors with the highest percentage of science- and technology-based small firms were pharmaceuticals (29%), office machinery (26%), computers and communications (21%), specialized machinery (18%) and electronics (14%). While in 2000 most science- and technology-based small companies were collectives or state-owned enterprises (SOEs), in 2004 the majority by far were private. And SOEs were among the only type of small enterprise that registered a drop in jobs.

Lundin and colleagues concluded that the role of small enterprises in science and technology development is important. The position of these firms has been buttressed by increases in R&D expenditures since the beginning of the 1990s. The pressing policy challenge, Lundin said, is how to make even more small firms engage in science and technology development, in particular through international partnerships or collaboration. The aim is to enable these enterprises to create new and better jobs, especially in light of shrinking employment in the state sector.

This is not simply a matter of government policy. Promoting innovation is a major challenge for companies everywhere. Most enterprises start out with a strong core innovation system, but are unable to sustain it, said Robert Shelton, Principal and head of the innovation practice at PRTM Management Consultants. "Homegrown innovation is not sufficient to maintain a company as the environment around them changes."

As a company progresses from the initial stages of innovation development at the narrow functional or product level to the broader, more sophisticated innovation that reaches across the enterprise, each step drives its financial performance higher. Along the way, partnerships and collaborative links around the world become increasingly essential. "External collaboration and partnerships are the major currency of innovation," Shelton remarked. "The unit of measurement of innovation is the partnership."

To be innovative, a firm must work better internally, but it must also readily access new ideas and create competitive advantages through its external connections. Modern R&D centers cannot operate in isolation. As Boeing demonstrated with the development of its newest jet models, to be effective and successful, collaboration must be global. Partnerships and networks can make up for a firm's weaknesses or skill gaps and boost its competitiveness. The key, said Shelton, is openness

Robert Shelton
PRTM Consulting

For companies to be innovative, they must also look not just at the products and services they provide, but also at the way they make or deliver them. Successful business model innovation is essential, as demonstrated by companies such as Dell Computer and Southwest Airlines, which revolutionized their respective industries. Chinese enterprises, Shelton concluded, will have to combine business-model innovation with technology innovation of products, services and processes, maintaining their openness to outside ideas and practices. To achieve this, PRC companies will require visionary leadership, commercial intuition, and execution.

Consistent with the thrust of the new 15 year S&T plan, China's enterprises should be at the center of the country's innovation system, Lundin argued. The interplay between the state and the private sector as this system develops could make the difference between its success and failure. China has long struggled to balance state control with the need for a dynamic enterprise culture. Even as China seems at times to be stuck in its old command-economy ways, far from achieving a breakthrough, it can flash the potential it possesses to become a technology superpower. The question is: Is China's glass half empty—or half full?

Session 4
Regional Innovation Systems in China

Speakers

Innovation Networks in China: A Regional Perspective

Dr. Sun Wansong
Qingdao Shibei Hi-Tech Park

China's Coastal Innovation Centers: Beijing vs Shanghai vs Shenzhen

Jon Sigurdson
Stockholm School of Economics

Comparison of Industrial Development between Pudong New Area and Binhai New Area

Prof. Zhou Guirong
Tianjin University of Commerce

The Development & Innovative Environment for the Software Industry: Experience of Jinan

Wang Xu
Jinan Municipal Government

Moderator

Dr. Cao Cong
The Levin Institute

Dr. Sun Wansong
Qingdao Shibei Hi-Tech Park

Veteran investors often stress China is not a single market, but several regional markets. Its municipalities and provinces each have distinct characteristics, seemingly differing legal regimes and substantial populations. China's domestic innovation system reflects this, with variations according to region. Local clusters of innovation have emerged across the country, particularly in coastal areas—the Shenzhen Special Economic Zone adjacent to Hong Kong, the Pudong area of Shanghai, and the Bohai Basin region of Tianjin are examples. These pockets of growth are key points of contact between the global innovation system, as represented by multinationals, and China's local network. The interplay between the global and the domestic innovation systems through various types of collaboration is essential to the development of China's knowledge base. For this reason, it is important to understand how China's regional innovation clusters have evolved.

The spread of innovation clusters across China is like the V-shaped formation in which geese fly, Jon Sigurdson, Professor of Research Policy and Director of the East Asia Science & Technology and Culture Program at the Stockholm School of Economics, suggested. The coastal regions are in the lead, with other parts of the country following at a staggered pace. According to Sun Wansong, Visiting Professor, Beijing Jiaotong University, and Vice Director, Qingdao Northern Hi-Tech Park Management Committee, there are two forces driving the development of new industrial parks, key building blocks of regional innovation clusters: top-down government policies and management, and bottom-up companies and market demand, particularly in the fast-growing private sector.

The central government's strategy has been to build up growth poles to propel regional development, said Zhou Guirong, Professor at Tianjin University of Commerce. Tianjin's Binhai New Area is the latest such region to receive official impetus after Shenzhen and Pudong, she explained. Like Pudong, Binhai is focused on export-oriented industries.

Government R&D funding has guided and driven the emergence of these growth poles and the 53 national high-tech zones in the country. At this stage in China's innovation development, "the government must carry out a new round of adjustment to improve the functions of its new industrial parks," Sun said. "Unqualified parks like those using land for horse racing or those trying to get overdue tax support should be resolutely closed down.

Those in areas with a concentration of schools and scientific research institutes should be consolidated." The key is to keep upgrading established clusters as lower-grade parks and developments open further afield.

For a regional innovation cluster to succeed requires more than just an official designation. The Binhai area had been growing rapidly for years before receiving Beijing's blessing. According to Wang Xu, Deputy Secretary General of the Jinan Municipal Government, the China International ICT Innovation Park in his city has received no special treatment. "We regard the title [of 'innovation park'] as an award and encouragement, not a privilege," he said.

Critical to the growth of innovation clusters is corporate support and enterprise activity. Wang briefed participants on the success of Jinan, the capital of Shandong Province. In 2005, he noted, Microsoft signed letters of investment intent with three Chinese software firms, all of which are either based in Jinan or have links to the city. Jinan boasts the biggest software park in the country, with nine homegrown companies among the top 100 Chinese software enterprises. Two examples: the Inspur Group, the biggest server manufacturer and IT solutions supplier in China, and CVIC Software Engineering, the country's largest supplier of financial management software.

Prof. Zhou Guirong
Tianjin University of Commerce

Jinan is only one of many aspiring centers of innovation in China that are aiming to follow in the wake of the coastal "geese formation" leaders. "Every locality has the ambition to have its own science park," Sigurdson noted. Shanghai offers a powerful role model. Zhangjiang, the high-tech park in the Pudong district, is one of the municipality's notable showcases, attracting more foreign investment in R&D than any other park. The city also has a handful of other technology and science parks affiliated to major universities. Each of Shanghai's 11 districts has its own industrial park, most with a specific focus. Shanghai also has 28 incubators, at least one in each district, providing homes for some 20,000 enterprises.

Jinan has obviously learned from Shanghai and the success of Pudong. The city offers software firms many attractions, Wang explained. These include: access to talent available at its 66 universities and more than 200 research institutions; salaries of software engineers lower than in bigger cities such as Shanghai; the special character and work ethic of a society closely identified with native son Confucius; a diverse range of clients and markets; ready access to venture funding; active software industry organizations that foster collaboration; policy support and organized public services such as enterprise incubators, infrastructure, and transport links; and a pleasant, habitable environment." Jinan's advantage is not just its low cost," Wang concluded. "It also pays attention to the 'soft' aspects of development."

The positive attributes of Jinan that Wang listed mirrored the basic reasons Sigurdson gave for why multinationals have opened R&D facilities in China—access to a huge market, the abundant talent pool including scientists returning from abroad, and the lower costs. Sigurdson put the growth of China's regional innovation clusters in a global perspective. "Rapid globalization and urbanization are creating post-industrial societies," he remarked. "R&D is playing an important role." Ten years ago, few multinationals had R&D facilities in China. Today, many do. Some companies have made significant investments. Ericsson has seven Chinese R&D centers, some of which focus on the world market. About 800 employees, or 20% of the telecom group's China staff, are deployed in its R&D operations, Sigurdson said.

The blossoming of such innovation hubs as Jinan and the growing wave of multinationals using China as an R&D base indicate that connections between the global innovation system and China's are increasing, though they may not yet be substantial. As Jinan, Binhai and Qingdao have done, many other local clusters of innovation have put together the ingredients for success. "But if you take China as a whole, it is the linkages that are definitely lacking," Sigurdson observed. "This is still a very serious shortcoming." In the same way that collaboration and partnerships between foreign and domestic enterprises are essential to successful innovation development in China, equally vital are the enmeshing and coordination of local clusters of innovation into an efficient and effective national network that is more than tangentially tied to the emerging global innovation system.

Session 5
Strategic Components of China's Innovation System

Speakers

University-Enterprise Linkages and their Role in China's Innovation System

Prof. Ma Lianjie
Huazhong University of Science and Technology

China's Evolving Talent Pool and its Role in Industrial Innovation

Dr. Cao Cong
The Levin Institute

IPR, Industrial R&D and Innovative Activity in China: A Prognosis for the Future

Dr. Andrew Mertha
Washington University

The Present Status and Developing Trends in China for the Protection of IPR

Hu Zhijian
Deputy Director General, Dept of Policy,
Regulation & Reform, Ministry of Science and Technology

Moderator

Dr. Adam Segal
Council on Foreign Relations

What are the building blocks that China needs to create a competitive innovation system? There are at least three important factors: enterprises that foster innovation, a pool of talent that is capable of sustaining innovation, and a political and legal environment that supports innovation.

According to Chen Jin, Vice President of the College of Public Administration at Zhejiang University, the key is innovative enterprises. "A suitable independent innovation system is critical to enterprise core competition as well as sustainable development," Chen observed. Companies must develop their innovation systems, moving from the integrative and imitative to the original. And with technology changing so fast, it is not enough to simply rely on "incremental" innovation; firms must apply "disruptive", even "radical" innovation to stay ahead of the game.

For enterprises to be innovative, they need to have a strategic direction and vision; sound operations; an external network of collaborators; and a support system to sustain R&D, financing, human resources, information and the corporate culture. The latter is especially important, said Chen. Successful brand-name appliance maker Haier, for example, reconfigured itself along the GE model, setting up autonomous strategic business units in an organizational structure that is intended to promote independent innovation. In addition, the company has emphasized human resources development. "Training is very important," Chen noted. "Innovation is not theoretical work." Indeed practicality is crucial. A key success factor for Huawei Technologies, the leading Chinese telecom networks group, is its skill at quickly turning R&D into marketable applications.

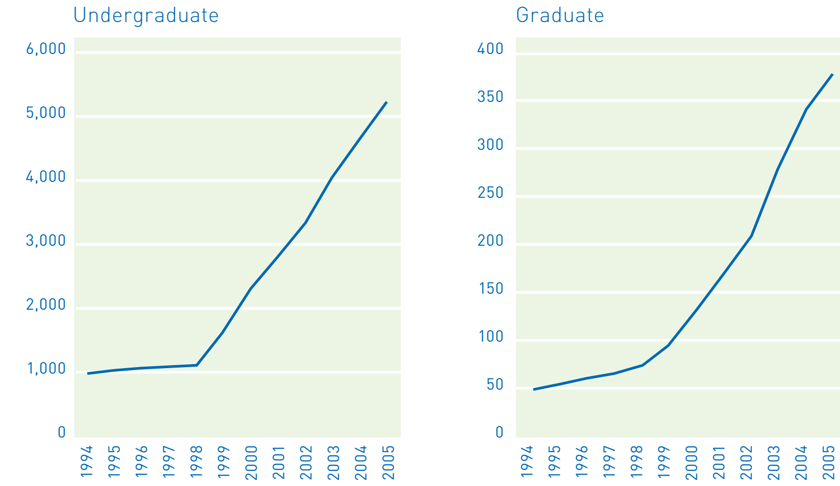
Any enterprise's main source of innovation is its talent pool. President Hu Jintao and other senior officials have acknowledged that China's international competitiveness hinges to a large extent on its human resources. For the world's most populous country, this would seem to be the least of its problems. Yet China faces major challenges, said Cao Cong, Senior Research Associate, The Levin Institute. According to a study by consulting group McKinsey & Co., only 10% of Chinese professionals with at least seven years of experience are capable of working for a multinational. A Duke University study revealed that of the 600,000 engineering "graduates" in China every year, only half have completed a four-year bachelor's degree program, while the rest have only done a short-term course.

In recent years, China has dramatically increased its higher-education enrollment, but is still likely to face a talent shortage over the next 5-10 years. According to Cao, the shortfall of scientists and engineers is expected to be around 370,000 in 2010. Supply and demand could balance by 2015. "While there are enough students being trained, they are not receiving the relevant skills and knowledge for the current and future job market," said Cao. "The real labor shortage may actually be larger as companies demand specific experience-based skills that universities cannot meet." In addition, there is a "geographic mismatch" of supply and demand. Chinese scientists and engineers have been moving to the eastern coastal areas, though the need is great in the western regions that the government is aiming to develop.

Further complicating the situation is the uneven quality of higher education, Cao noted. Curricula are outdated in many schools, while the supply of qualified faculty is limited. University students still have to spend a good portion of their time in their freshman and sophomore years studying Marxist ideology. But with China's deepening integration with the global economy as underscored by the large amount of foreign domestic investment in the country and the gradual shift of FDI from labor-intensive sectors to knowledge-intensive industries, the demand for better educated and trained personnel, particularly scientists and engineers, is rising sharply. "Unfortunately, creativity is still not nurtured in Chinese higher education," Cao remarked. "China still lacks an adequate high-quality talent pool to sustain innovation in science and technology, education and the economy." Another problem: a brain drain in which the best talent goes abroad but does not return.

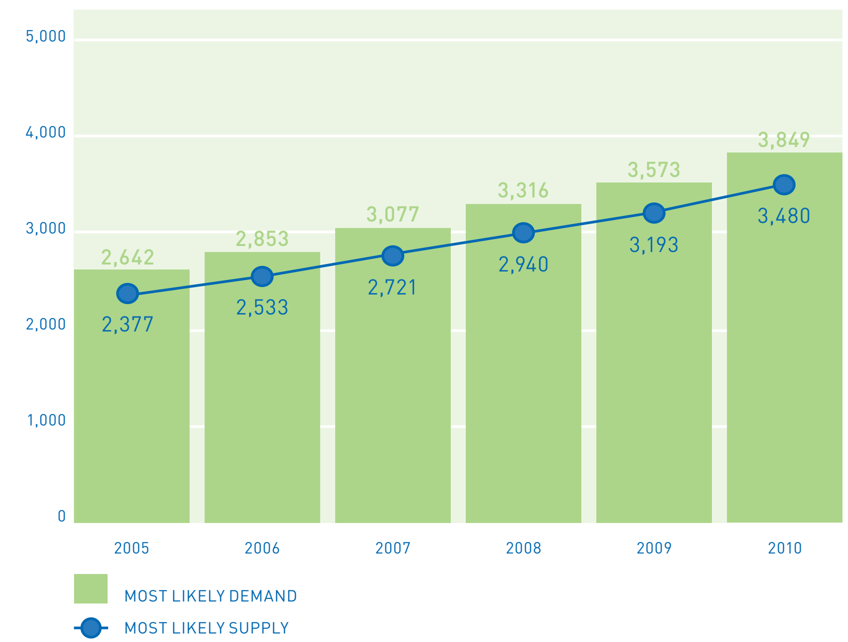
The talent shortage could have a negative impact on the pace of China's economic growth over the near-to-medium

New University Enrollment
(in Thousands)



Credit: Cao Cong and Denis Simon

Chinese Scientists and Engineers: Supply and Demand
Most Likely Scenario 2005–2010



Credit: Cao Cong and Denis Simon

Dr. Andrew Mertha
Washington University

term. And, of course, it could hinder the development of China's indigenous capacity for innovation and, as a result, undermine its ability to attract higher value-added foreign investment. Said Cao: "Over time, the ability of foreign firms to attract the best and the brightest will be affected by this projected shortage as China could experience the onset of a real talent war. China's capacity for overcoming its science and engineering talent shortage, including its ability to provide training-related quality improvement, will determine the extent to which it can reduce its current dependency on foreign technology and invention." The government needs to act swiftly, Cao concluded.

On the government's agenda too is the protection of intellectual property rights (IPR). The enforcement of IPR laws is crucial for the creation of the right climate and legal support system to foster innovation. "There is an environment of insecurity in China when it comes to IPR enforcement," said Andrew Mertha, Assistant Professor of Political Science, Washington University in St Louis, Missouri. "This is not particularly auspicious. But I don't believe this is due to a lack of interest but more with the state's capacity to enforce IPR protection."

The difficulty, Mertha explained, is with the legal and administrative infrastructure that is responsible for IPR protection. Judges and lawyers are not adequately trained; courts are under the control of local governments and not truly autonomous; and penalties are light. "There really is no deterrent effect offered by the civil courts," Mertha said. Meanwhile, criminal prosecutors are usually unwilling to take up cases, viewing IPR violations as lightweight crimes not worth prosecuting at the risk of diluting their typically high overall conviction rates. As for the patent and copyright bureaucracy and the customs service, they remain weak or overextended, saddled with too many responsibilities. Also, conflicts of interest often get in the way.

Many positive steps have been taken to improve IPR protection in China, including the revision of pertinent laws, the centralization and professionalization of relevant agencies, and better education of the public. Particularly in the enactment of IPR legislation, China has accomplished a great deal very quickly, said Hu Zhijian, Department of Reform, Regulation and Policy, Ministry of Science and Technology. He pointed out that China has signed on to dozens of international IPR conventions, treaties or protocols. Its accession to the World Trade Organization in

2001 has been a major driver of better enforcement both by the judiciary and the bureaucracy.

Yet, Hu agreed, concerns remain. Precisely because of the new state policy to encourage R&D and innovation, stronger IPR protection is needed, Hu explained. If China is to strengthen the competitiveness of its industries in the global market in line with government policy to encourage enterprises to venture abroad, then China has to learn more quickly how to play by the rules of the game.

Obstacles include the lack of administrative expertise and the limited awareness of IPR among the people. While the situation is improving, "it will take a long time to popularize the concept and culture of IPR," Hu acknowledged.
In addition, China's direct stake in IPR protection as measured by its share of world patents is still small. But that will change as China develops its own intellectual property and the number of China-held patents continues to increase. China, Hu said, is moving on several fronts to pursue a more rigorous national IPR policy, including the improvement of awareness among citizens, in cooperation with trading partners and international organizations. Mertha suggested a number of specific steps such as increasing the budgets and manpower of IPR enforcement bureaus, granting courts more autonomy, enhancing the power and status of the State Intellectual Property Office (SIPO) and local IPOs, pursuing more criminal cases, and making copyright enforcement independent of the Culture Ministry bureaucracy. China's Ministry of Science and Technology also is playing a very active role in drawing attention to the costs of an under-developed IPR regime and has taken an aggressive stand against IPR violations.

Clearly, China has come a long way in IPR protection, but has much more to do if it is to create the appropriate environment for a culture of innovation and enterprise R&D to blossom.

Session 6
Foreign Linkages and China's Industrial Innovation System

Speakers

Openness and Innovation in Chinese Manufacturing

Dr. Thomas Rawski
University of Pittsburgh

The Role of Chinese Self-Initiated Innovative Enterprises in the Global Economy

Chen Wei
CEO, Beijing Xinwei Telecom Technology Co. Ltd.

Role of Foreign R&D Centers in China's Industrial Innovation System

Dr. Sylvia Schwaag Serger
Swedish Embassy-Beijing

Imported versus Domestic Technology in China's Light Metals Industries: Case of Aluminum and Magnesium

Michael Komesaroff
Urandaline Investments-Australia

China, Innovation and Growth in the 21st Century: Challenges and Opportunities

Taffy Kingscott
Director of Worldwide Innovation, IBM

Moderator

Dr. Zhou Yuan
NRCSTD

Dr. Sylvia Schwaag Serger
Swedish Embassy-Beijing

A notable trend in the development of innovation in China is the increasing number of foreign companies setting up R&D centers in the country. According to Sylvia Schwaag Serger, Counselor for Science and Technology, Swedish Embassy Science Office (ITPS), Beijing, there are now at least 750 such facilities, while about 30 multinationals—mainly large manufacturing corporations in only a few sectors including IT, telecom, appliances and transportation—have established around 60 strategic R&D centers, or innovation hubs critical to the global operations of those companies and not just the China market.

Many companies want R&D facilities physically nearby to support local production, develop production processes, and collaborate with local suppliers. They may also find it useful to have an R&D unit in the proximity of the target customers and the markets where the new technologies or systems are to be applied. Another attraction: access to talent and a nurturing domestic environment. "Companies are locating R&D close to 'centers of excellence' to access knowledge and skilled research personnel," said Schwaag Serger. "Sometimes these centers take the form of technology clusters specializing in a particular technology or discipline. By participating in these clusters, companies can keep abreast of new technologies and take advantage of technologies developed by other companies. Some companies are looking for skilled researchers and engineers in large numbers and must locate R&D activities in centers with a considerable supply of technical students." Many such clusters have emerged in China and more hubs are emerging.

The emerging links between the international innovation network and China's will be the pipelines that supply the knowledge, technology and models essential to stimulating the growth of the Chinese innovation system at a time when China has "a clear ambition to move from 'shop-floor economy' to innovation economy," as Schwaag Serger put it. But "so far, the positive spillovers from foreign corporate R&D to China's domestic innovation capacity have been limited though they could increase and be mutually beneficial."

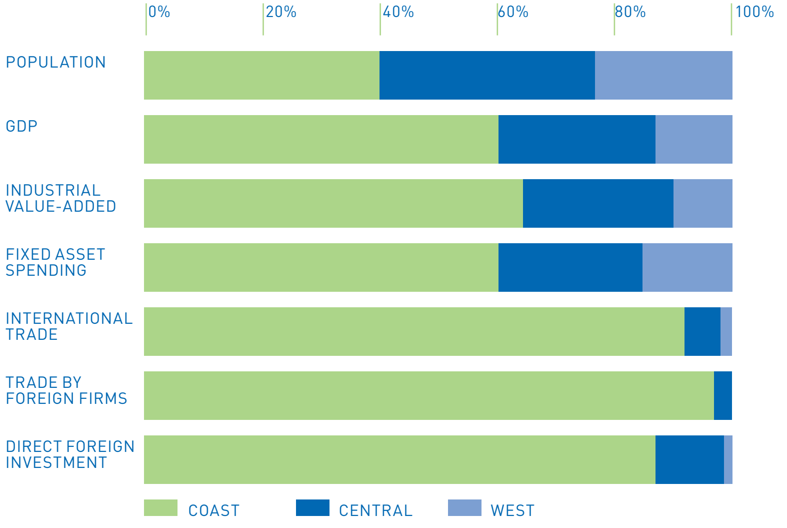
There is a bigger dynamic at work. "The global innovation and knowledge landscape is changing," Schwaag Serger noted. "Developing countries can compete for knowledge resources. China's development is both a challenge and a significant opportunity for small open economies such as Sweden. There is a need [for such economies] to formulate strategies for R&D cooperation. There is no alternative."

This is precisely what China's neighbors including South Korea, Southeast Asia, and even Japan have come to understand in recent years—that approaching China as an opportunity rather than a threat offers greater dividends. There will be competition, to be sure. But collaboration creates more advantages.

This is certainly true in the business of innovation. "Openness entails costs," Thomas Rawski, Professor of Economics and History, University of Pittsburgh, explained. "It is tempting to avoid such costs, but the foolish policies of economic nationalism usually fail." China has chosen the open door. Yet for all the foreign direct investment China has attracted over the years, not all regions of the country have been touched by globalization and foreign funds are a small and declining portion of total investment. And China's foreign trade, which only recently surpassed Canada's, remains small for a country of its geographic size and population.

For the injection of foreign investment and technology to have a meaningful impact requires money and time. The right domestic conditions are necessary—and they will come together. Take intellectual property rights (IPR) protection. "IPR piracy is part of the growing pains for any

China: Regional Patterns of Development and Global Engagement, 2004



Credit: Thomas Rawski

country that wants to have an independent economy," said Chen Wei, President of Beijing Xinwei Telecom Technology Co. Ltd. Added Rawski: "China will develop an effective IPR enforcement mechanism not because of the complaints of foreigners, not because of threats that foreign investment will not be forthcoming, which obviously is not true, but primarily because technical progress in Chinese industry cannot continue without an IPR mechanism."

The demand for a proper Chinese IPR mechanism will grow within China. Citing the case of flat-screen TV technology and China's limited abilities in this niche field, Rawski observed that to be competitive requires an array of patents on technology that no single company can control. Chinese companies, for now, are unable to play the complex game of putting together the necessary licensing agreements. "If you have a technology tie-up with a Chinese company, you are giving the whole world your IPR," Rawski remarked. "What is going to happen is that Chinese companies developing their own technology will demand that the government create a mechanism for protecting neither Microsoft nor Disney but Chinese property rights. The international companies will benefit by accident as a result."

Chinese Industry:
15 Sectors Receiving Largest FDI Inflows (%)

MANUFACTURING SECTOR	SECTOR SHARE OF INDUSTRY FDI	EXPORT SHARE OF SECTOR OUTPUT	FIE SHARE OF SECTOR EXPORTS	SECTOR SHARE OF INDUSTRIAL EXPORTS
Plastics	2.18	17.30	79.19	1.44
Metal Products	2.73	19.60	84.80	2.18
Smelting-Rolling of Ferrous	3.15	7.87	49.13	2.41
Food products	3.24	23.26	60.42	2.42
Electric equipment	3.35	16.25	81.84	2.79
Paper products	3.37	8.84	77.85	.86
Textiles	3.52	27.16	50.41	5.54
Beverages	4.30	4.76	58.93	0.48
Garments	5.07	45.93	61.40	10.63
Ordinary machinery	5.56	18.82	58.13	4.66
Non-metal mineral products	6.14	14.75	76.48	2.74
Transportation equipment	6.50	6.55	64.03	2.78
Medical and pharmaceutical	7.03	9.11	56.34	3.42
Electronics	7.88	32.16	91.12	19.01
Instruments and meters	10.64	30.45	93.83	13.11
Average	4.98	18.85	69.59	4.96
Total for top 15	74.66			74.47

Credit: Thomas Rawski

The shift by China's machine tool makers to focus on computer numeric control (CNC) products was a struggle that paid off. While revenues dropped initially and costs increased, eventually the Chinese tool companies learned new capabilities and began manufacturing globally competitive CNC products that are finding markets overseas. The key to success was the determination of Chinese companies to acquire and absorb foreign technology. Some firms went to Japan, Germany and the US to buy tool plants and bring them to China. Another option: import experts.

The motor vehicle industry is another impressive case. Studies of auto components producers show that over 15 years of development more than half of first-tier suppliers have brought down their defect rates to the highest international standards. Further down the supply chain the picture is different, with defect rates still reminiscent of what Rawski described as the "old world of Chinese manufacturing where quality is not very important." He added: "Chinese firms are beginning to move into the global markets for auto parts and automobiles. They couldn't do it without the contribution of international firms both directly and indirectly to upgrading production operations in the Chinese auto sector. The government should stand back and let this happen."

The development of China's magnesium industry also illustrates how China has benefited from the adoption of foreign technology. Magnesium is used in lightweight alloys used in metallic products such as auto components and vehicles. In the 1990s, Chinese metal producers were faced with the choice of adopting either the more modern but capital-intensive electrolytic process or the less efficient, cheaper thermal method that was no longer employed by metal works in developed economies. Because the barriers to entry were lower and the raw materials required were inexpensive and readily available across the country, Chinese metal producers adopted the thermal process.

This turned out to be the better choice – "an ideal fit with China's circumstances," said Michael Komesaroff, President of Urandaline Investments, Australia. "China did not seek to reinvent the wheel. It selected the right wheel for the job." Armed with the cheaper technology and low costs, China became the world's dominant magnesium producer, controlling 75% of the global market. The trade-off has been in the environmental impact: the thermal process is not as clean as the electrolytic method. But as China's magnesium producers have gradually improved

Michael Komesaroff
Urandaline Investments-Australia

efficiency and moved up the value chain to produce alloys and die-cast components, they have also begun to address the problem of carbon emissions and adopt cleaner processes.

The absence of an IPR mechanism meant that the thermal method technology was easily transferred from one local player to another. Producers, meanwhile, have shifted from process innovation to product innovation, going beyond applications for the auto sector to the aerospace industry. Collaboration among the central and local governments, academia and companies has driven the upgrading. For every dollar spent by government, the industry has spent nine.

The right domestic policies and the appropriate level of state support, provided fairly, are prerequisites for innovation success. The machine tool industry benefited from government recognition of the sector's importance. But often, as in the steel industry, vested interests and the government's habit of favoring incumbents, the established state-owned enterprises, can undermine market forces and impede innovation. "From the American economic experience, we know that innovation comes from unexpected places—not just big firms that have been around for 30-40 years," said Rawski.

Many essential components for a robust innovation system in China are still missing. There is no adequate financing system to support start-ups and SMEs. China did not have a venture capital law until 2006. The equities markets do not operate as freely as those in more developed economies. "In an established industrial sector, the chances for a start-up to survive are close to zero," said Xinwei's Chen.

Xinwei, a joint venture between the Datang Group of China and US-based Cwill, has succeeded thanks to its ability to keep a leading position in technology, Chen explained. It holds the rights to a China-developed solution that is the core technology of a local 3G wireless standard. The company focused initially on making products for low-income consumers and has aimed to carve a niche for itself on the global market. In addition, it has aligned its vision with the government's long-term planning goals and sought state support through specific regulatory reforms. Finally, it has also concentrated on building strong customer relationships.

"For a start-up to survive, it has to take some uncommon or innovative way to work around its own weaknesses," Chen observed. The ways to do this include developing or acquiring new technology and the rights to use it, identifying a niche market in which the new technology fits, lobbying for the opening up of new markets, scaling up viable business models, and leveraging the cost savings from new technologies to apply them to higher-margin services.

The interdependence of China's economy, particularly its manufacturing sector, and the global economy will deepen. The increasing investment overseas by Chinese enterprises and the proliferation of foreign R&D facilities in China are connecting China's innovation system with the world's network, boosting the emergence of new industries in China such as shipbuilding and biotechnology. The globalization of various sectors from banking to railways is also contributing to reforms in corporate governance.

Indeed, the growth of innovation in China will have significant impact beyond commerce. "Building an innovation system will have profound social effects and will be the starting point of political reform in China," argued one speaker. There could be global geopolitical benefits too. "International engagement has been a big driver of domestic reforms in the past and will continue to be so in the future as international engagement deepens," Rawski concluded. "China's large and expanding reliance on global markets will enhance the feasibility of China's 'peaceful rise'."

Session 6A
China, Innovation and Growth in the 21st Century: Challenges and Opportunities

Kathleen Kingscott
Director of Worldwide Innovation, IBM

In globalization discourse, "innovation" has become a catchword so frequently employed that it is regarded as something of a silver bullet against the pressures of economic competition. A dose of innovation will remedy a country's weakening performance; an injection of creativity will revitalize any industry that has lost its cost advantage.

Why the fascination with innovation? For Kathleen Kingscott, Director, IBM Worldwide Innovation Policy, it is all about opportunities and challenges. "The world has changed," she told participants at the luncheon on the second day of the conference. Globalization is bringing all corners of the world closer and speeding up communications and transactions. In just over a decade, the Internet has grown to link more than a billion devices. There are more than 100 million websites to surf. And e-commerce spending is rising sharply.

"Networking is allowing the integration of businesses and organizations in a way that is totally new, connecting customers, suppliers, users and employees," Kingscott said. "The enabler is the component business model. Because we are building business systems and infrastructure made of individual components, you can take a piece of a business anywhere in the world so long as there's a network." This flexibility is spawning innovative ways of doing business, from business process outsourcing to global or regional supply chain management. "It is revolutionizing business," reckoned Kingscott.

IBM carried out a global survey of 765 CEOs to assess how technology is changing the business landscape. Among the findings:

Business model
Innovative models for how customers and suppliers are connected and integrated are crucial to succeed. "CEOs are focusing on how to restructure their businesses to take advantage of the technology, infrastructure and skills we have," Kingscott noted.

Collaboration
Companies need to create "connective tissues," said Kingscott. "In this very connected world, connectedness is very important." A manager has to be open to collaboration "outside your zone of comfort, your company or the people you work with regularly," she added. "We need to expand our horizons and reach out to new players because in this hyper-competitive world, there is a lot of knowledge out there. CEOs understand the importance of collaboration

but have a hard time doing it. The bottom line is we have to do it."

Leadership

To implement these changes and mindset shifts requires leadership that is focused on promoting innovation.

The survey underscored the major challenge facing companies and organizations in the globalization age: how to find the best solutions for increasingly complex problems. People are not well prepared to deal with systemic challenges across geographies and disciplines. "We find that the skills and classes we are teaching aren't creating the kinds of skills we need to solve complex problems," Kingscott observed. Particularly lacking are the skills people need to thrive in the services sector, the component of the global economy that is expanding most rapidly, especially in fast-growing emerging markets such as India and China.

IBM itself is an example of the shifts playing out globally, Kingscott observed. The company's business is now 65% in software and services, with the old computer hardware segment no longer as large as it used to be. For IBM, this has meant a change in the talent it is hiring. It is no longer employing just engineers, IT experts and scientists. The company now requires people with advanced business skills, industrial management experience and other specializations beyond technology and the natural sciences.

IBM's investment decisions, said Kingscott, are based primarily on the skill sets and quality of infrastructure available, not simply on labor costs. Its employees are now fully networked to allow a level of collaboration that could not have been achieved just ten years ago. The company is also identifying innovation hotspots and finding ways to develop them further by building up skills and attracting talent. IBM has been setting up R&D centers to take advantage of an expertise available in a particular location. For example, its lab in Israel focuses on software development. More and more, its research hubs across time zones are working together to handle projects on a continuous basis.

In the future, the economies that will succeed, particularly in attracting foreign direct investment, will be those where the skills needed to support a vibrant services sector are available and where the capacity exists to adopt innovative business models. India, for example, has demonstrated its

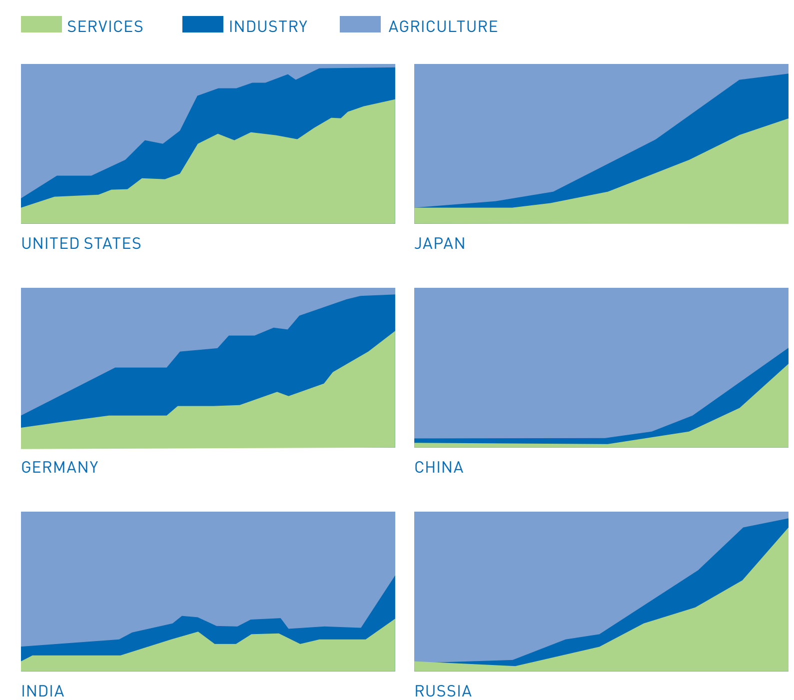
The World is Becoming One Big Service System

Top Ten Nations by Labor Force Size

NATION	% LABOR	% AGRICULTURE	% GOODS	% SERVICES	25 YEAR % DELTA S
China	21.0	50	15	35	191
India	17.0	50	17	23	28
U.S.	4.8	3	27	70	21
Indonesia	3.9	45	16	39	35
Brazil	3.0	23	24	53	20
Russia	2.5	12	23	65	38
Japan	2.4	5	25	70	40
Nigeria	2.2	70	10	20	30
Bangladesh	2.2	63	11	26	30
Germany	1.4	3	33	64	44

Credit: Kathleen Kingscott

The Rise of the Service Economy



Credit: Kathleen Kingscott

prowess at handling outsourcing assignments. In two years, the number of US tax return orders its back offices have processed has jumped from 25,000 to 400,000.

The key is education, said Kingscott. For this reason, IBM is working with a number of universities around the world to develop programs to prepare students to work in the services industry. For example, a multidisciplinary certificate course in services management science and engineering is starting at the University of California, Berkeley. Concluded Kingscott: "We have to understand the value of entrepreneurship and teach it. We need to work together to develop a culture that values growth and innovation."

Session 7
Sectoral Perspectives on Industrial Innovation in China

Speakers

Regional Industrial Innovation System: Case of the Shanghai Pharmaceuticals Industry

Miao Qihao
Deputy Director, Institute of Scientific and Technical Information of Shanghai

Innovation & New Models for Software Engineering in China

Roy Singham
ThoughtWorks

A Case Study of Industrial Innovation in China: Case of Hi-Sense

Zhao Gang
NRCSTD

No Innovation, No Future!

Wang Runying
Senior Economist, Linix Motor Company, Hengdian Group

Innovation in China's Energy Industry

Dr. Marco DiCapua
US Embassy-Beijing

Moderator

Dr. Thomas Rawski
University of Pittsburgh

Shifting China away from its manufacturing and export focus to become a consumption-driven, energy-efficient, and knowledge-based economy is the primary challenge confronting the country's leaders. It is crucial to sustaining long-term growth and promoting social stability. "This challenge is an opportunity," said Wang Runying, Senior Economist at Linix Motor Company, part of the Hangzhou-based Hengdian Group. "The only alternative is innovation."

Chinese leaders in government and business across the country generally recognize this creative imperative. Beyond the central government's national science and technology development policy, there are many initiatives of varying scale meant to promote innovation—everything from industrial parks to enterprise incubators, R&D centers to education programs at universities. While it remains unclear how all of this could coalesce into a coherent industrial innovation system in China, indications that enterprises are beginning to address the issue are encouraging.

"Innovation policy used to emphasize the role of government research institutions, but now the focus is on enterprises—how to build and strengthen their innovation capacity," explained Mu Rongping, Professor and Director-General the Institute of Policy and Management (IPM), Chinese Academy of Sciences. Said Chen Jin, Vice President of the College of Public Administration at Zhejiang University: "The independent innovation system of Chinese enterprises is the key for the whole competitiveness of industrial independent innovation in China."

For enterprises and their leaders, how they innovate is inextricably tied to their business models and strategy. Are they open to adopting new processes and fresh approaches to problems? Do they have the talent that can disrupt the

Zhao Gang
NRCSTD

old order? Are they daring enough to forge partnerships that make commercial sense with companies that they do not know? As Chen put it, "if an entrepreneur cannot take risks, then innovation can hardly happen. What we need is better innovation management."

That is clearly happening in certain showcase sectors and specific enterprises where the right environment, investment climate and business model have helped. During the conference, participants learned about many companies that have taken steps to boost their capacity for innovation and to expand their intellectual property as a way to drive and sustain new growth. Motor maker Linix in Dongyang, Zhejiang Province, for example, has focused on accumulating patents, developing national and international standards, and building its brand around the world.

Qingdao-based consumer electronics, computer and communications manufacturer Hisense has seen its sales grow sharply as it has invested more in R&D and focused on developing innovative products. "The cultivation of an innovation culture has always been vital for Hisense," said Zhao Gang, National Research Center for Science and Technology for Development (NRCSTD) of the Chinese Ministry of Science and Technology. "Enhancing R&D capability is the key. Technology development is positively correlated to innovation, especially indigenous innovation."

The emergence of the pharmaceutical industry in Shanghai demonstrates how the crucial interplay among government, business, and academia is essential to the growth of innovation in China. It also illustrates the critical role that regions play in the process, particularly if the key ingredients needed to foster enterprise innovation are present. "The regional pharmaceutical industry innovation system is a government-orchestrated set of efforts to mobilize local resources, improve the environment for and remove obstacles to innovation," said Miao Qihao, Deputy Director of Shanghai's Institute of Scientific and Technical Information.

Among the pharmaceutical companies that have had a major impact in the sector's growth in Shanghai: Fosun, Sunway, and Shanghai Wanxing. They have benefited from the strengths that the municipality offers enterprises in the industry. These include access to a cluster of biotechnology R&D facilities, the high level of infrastructure development, the foreign investment and technology that is attracted to the city, and the high level of government commitment.

Shanghai also has its weaknesses such as higher business costs, a regulatory environment that could discourage entry and investment, and the lack of the herbal resources to support drug development. But the essence of innovation is the transformation of creativity into commercial profit. In that respect, the banking and financial services available in Shanghai have been integral to the growth of the pharmaceutical industry, which requires heavy investment to develop and test drugs. That intellectual property rights are better enforced in Shanghai than in most places in China has been another advantage. The city's international outlook and connections have also contributed. "All these factors have favored the cultivation of a culture of innovation," Miao noted.

Creating that culture requires more than a favorable environment; it also needs a mindset shift that will allow or even encourage enterprises and their leaders to embrace new business models, to be disruptive. Software development is a good example. While the current focus of Chinese firms is on capturing outsourcing business, the more lucrative long-term opportunities are local. "China is missing the big issue in innovation," said Roy Singham, Founder and CEO of global IT consultancy ThoughtWorks. "The Chinese domestic software market has the biggest potential to change software in the next 20 years."

Miao Qihao
Deputy Director, Institute of Scientific and Technical Information of Shanghai

The era of big software such as Microsoft Windows is over, Singham contended. He argued that the software world is moving more towards lean or "agile" design methods and service-oriented architecture, or free software embedded in a service. China should embrace these techniques and adopt the open-source ethos. "The era of Microsoft is being replaced by the era of Google," Singham explained. "The idea that one company can control everything is gone." Software is produced in modular pieces through open collaboration, assembled into a system, and then distributed widely, he added.

This approach goes against the grain of conventional patenting practices. It allows better software to be developed more quickly, Singham maintained. "The best way for China to innovate is to allow open-source markets to occur. This will allow businesses to mature quickly and will undermine the Western economic models that are holding back the Chinese markets." Firms should be part of an innovation network with transparent links to other software hubs such as Brazil and India, Singham advised. "China shouldn't make the mistake of focusing only

Dr. Marco DiCapua
US Embassy-Beijing

on domestic innovation but must be part of a global innovation network."

While spillover benefits from the global innovation system will be important for China, the development of the domestic innovation system is crucial to sustaining long-term economic growth. Marco DiCapua, Executive Director, US Department of Energy China Office, US Embassy, Beijing, used the case of electric bicycles to illustrate how innovation can grow in response to local market forces. "The development of the electric bicycle is an excellent example of how demand driven innovation has taken root in the private sector in China," he said.

The success of electric bicycles in China has been built on the large manufacturing base for traditional bikes. Increased affluence reduced demand for the regular bicycle, the vehicle of choice before the blossoming of the automobile industry. At the same time, wealthier consumers are able to afford better products. In addition, existing roads no longer could support bicycle traffic. And as commuting distances lengthened as urban areas expanded, the need rose for a bicycle that could convey users longer distances without exhausting them or taking too much time. Finally, China's large manufacturing base for ceramic magnets and electromechanical devices directly contributed to the development of electric bicycles.

The spillover effects of the growth of the electric bicycle market will be significant, DiCapua reckoned. "How innovation works along the supply chain is a very interesting question," he said. "Electric bicycles are important because they will spur further innovation in batteries, control electronics and electric motors. These developments most likely will climb the value chain into the automotive sector, and they may position China to become a major supplier of hybrid cars in the future." For example, DiCapua suggested, innovation along the supply chain could lead to the development of an electric airplane. Why not? Only if such flights of fancy are possible in China will its dynamic economy be sure to soar for years to come at its customary high cruising altitude.

Session 8
Asian Perspectives on China's Innovation System

Speakers

A Comparative Perspective on Innovation in China and India

Dr. Adam Segal
Council on Foreign Relations

A Korean Perspective on China's Innovation System

Dr. Kim Yong June
Sungkunkwan University-Korea

A Japanese Perspective on Innovation in China

Dr. Atsushi Sunami
National Graduate Institute for Policy Studies-Japan

Moderator

Liang Hui
Ministry of Science and Technology

Dr. Adam Segal
Council on Foreign Relations

Whether through investment, trade or other commercial connections, many of China's Asian neighbors have had significant impact on its economic development, including the way the Chinese innovation system has evolved. While their own innovation networks are linking with China's, there is also increasing competition, particularly as Chinese enterprises break into regional and global markets. Taking the perspective of China's Asian partners and rivals is therefore highly useful in understanding the Chinese innovation system.

Of particular current interest is the relationship between China and India. Few Asia analysts can resist contrasting the two fast-growing economies. But as Adam Segal, Senior Fellow at the Council on Foreign Relations in New York, warned, it is premature to determine how the China-India dynamic will play out—whether one will win over the other or their relationship and cooperative-competitive interaction will generate some kind of synergy that will be positive for both sides.

"Both countries have clearly benefited from globalization and are no longer constrained by it," said Segal. The two have created obvious pockets of innovation excellence but are still struggling to put all the diverse components together to shape an integrated national innovation system. India and China both have dedicated R&D programs. While this is a strength, it is also a weakness, given that the majority of spending goes to government labs and military applications. India's move towards commercialization of its research facilities has been measured, while China has been slow to scale up its efforts.

The two countries share other strengths: Both have a large educational capacity and growing knowledge resources. Their domestic markets are expanding. The wave of growth and the success that each country has enjoyed—China in manufacturing, India in services—have fueled optimism, or a "we can do it" mentality, among their people. But commercial triumphs can also have a negative effect. In India, the outsourcing business has proved so lucrative that some companies are not focusing on the need to innovate. And, with poverty so acute in many areas of China and India, some wonder if it makes sense to concentrate on building high-tech, knowledge-based economies when there are such disparities of income.

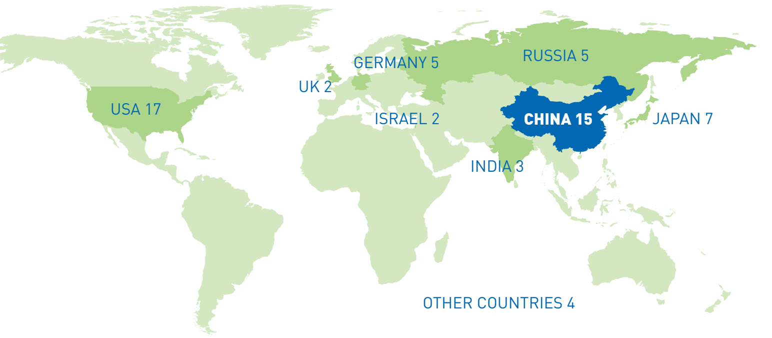
For both countries, a key issue is human resources—whether they will have the talent, particularly in engineering and sciences as well as management that they need to fuel innovation in the coming decades. Other common challenges: How to improve the access to capital of small and medium-sized enterprises, how to leverage to best advantage local and international connections such as the links between universities and industry and between foreign multinationals and domestic firms, and how to encourage entrepreneurship.

According to Segal, all these issues raise important questions about corporate governance and management style, and about political control and the integrity of institutions. For efficient innovation systems to emerge, both countries must boost transparency, adopt management practices that foster creativity, build trustworthy scientific and educational institutions, and create an environment that promotes the flow of information. China, in particular, will have to determine whether it is possible for its leaders to encourage disruptive innovation while maintaining social and political control. Can a country be innovative and yet control access to information?

It is worth remembering, Segal told participants, that China and India are not operating in a vacuum. The web of their bilateral, regional and multilateral relationships will surely affect how their societies are transformed, how their economies develop, and how innovative they become. The case of Korea may hold lessons for China, in particular, the value of investment in R&D.

The US, Japan and major European countries have recognized R&D innovation as a new growth engine. They have achieved higher growth by investing in R&D both in the public and private sectors. Korea has had to follow that approach, recognizing the need to discard some of its social rigidity to harness the knowledge and talent of its people. "Innovation starts from people's ideas and

Korean Companies with R&D Centers in China (2005)
Since 2002, 15 R&D Centers have been established in China by Korean companies



COMPANY NAME	R&D CENTER IN CHINA	YEAR
Samsung Electronics	China Beijing (BST)	2000
	China Suzhou (SSCR)	2003
	China Nanjing (SCRC)	2004
LG Electronics	Shandong R&D Center	2000
	Tianjin R&D Center	2000
	Beijing R&D Center	2002
LG Chemical	Tsinghua University Center	2004
Hankook Tire	CTC	1998
SK	China Shanghai Center	2002
Mando	Beijing Center	1996
Amore Pacific	Shanghai R&D Center	2004
TG Computer	China R&D Center	2004
NcSoft	NcSoft R&D Center	2004
Korea Omyang	Suzhou KOC Center	2004
Hyundai Automobile	Beijing R&D Center	2005

Credit: Kim Yong June

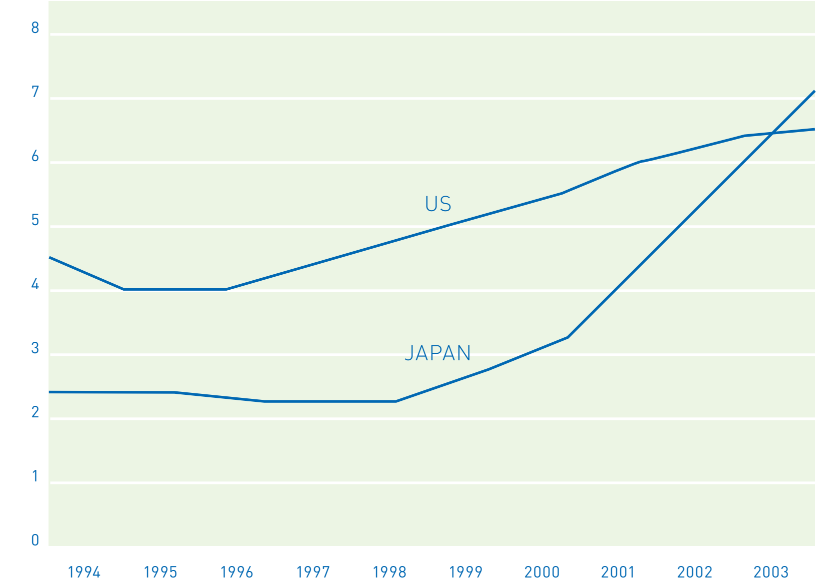
attitudes," Kim Yong June, Professor, School of Business, SKK University in Seoul, said. "It can cause a lot of social and family problems because it causes a lot of change." R&D investment is now the eighth highest in the world, the fifth among OECD countries. "But Korea's R&D performance is low compared to other major countries," Kim acknowledged.

This has prompted Korea to focus on increasing the quality and efficiency of its R&D system. Top Korean companies have come to understand the need for innovation as they have reacted to domestic economic setbacks such as the 1997-98 financial crisis. They have applied this strategic thinking overseas. For several years now, Korean companies have been setting up R&D facilities in China. Leading enterprises such as Samsung Electronics and LG Electronics have been enlarging their R&D centers to focus on developing new core technology and product models for the Chinese market. "The main purpose of Korean R&D investment in China is to develop new localized products," Kim explained. "The major issue for them in China is how to recruit, motivate and mould Chinese R&D talent."

Japanese companies too have moved to establish R&D centers in China and elsewhere in Asia. And they have recognized the value of Chinese R&D talent. The decision to set up research operations in China has been driven mainly by the quest for market access, the availability of science and technology talent at a relatively low cost, the need to keep up with industry leaders and competitors, and the desire to boost collaboration with the Chinese government and institutions. "China and Japan cooperate in the same areas of technology where both of them have relative strengths," remarked Atsushi Sunami, Associate Professor, National Graduate Institute for Policy Studies and the National Institute for Science & Technology Policy, Ministry of Education, Culture Sports, Science and Technology (MEXT), Japan. "The cooperation in the areas of energy and the environment will be Japan's high priority."

Japan, Sunami added, has been taking advantage of the surplus of Chinese university graduates, encouraging more scientists and engineers from China to work in Japan's industrial R&D sectors. While many may stay, many others will return home. All will likely contribute in some way or another to the development of innovation in China. This is yet another example of how vital international links and exchanges are to the growth of the Chinese innovation system.

Chinese Students in Japan and the US
(in tens of thousands)



Source: http://www.mext.go.jp/a_menu/koutou/ryugaku/index.htm
Open Doors, http://www.iienetwork.org, Institute of International Education
RIETI, Dr. Kwan's HP

Session 9
China's Innovation Trajectory

Speakers

China's New 15 Year Long-Term S&T Plan: Implications for Industrial Innovation

Prof. Xiao Guangling
Tsinghua University-Institute of Science, Technology and Society

Defining the New Frontiers in China's Innovation System: Beyond Technology

Dr. Zhou Yuan
Deputy Director General, NRCSTD

China's Potential as a Global Techno-Power: Myth or Likely Reality?

Dr. Denis Simon
The Levin Institute

Moderator

Edgar Hotard
ArchVentures USA

Zhou Yuan
NRCSTD, Ministry of Science and Technology

Two thirds of China's new science and technology development plan is devoted to the issue of industrial innovation. The strategy provides guidelines for improving the country's indigenous innovation capability. The goal: an innovation-oriented nation. To achieve this, China has so far focused on importing foreign technology or imitating it. Now, it must create the environment necessary to foster homegrown innovation.

Despite its importance, not enough research has been done on Chinese innovation. According to Zhou Yuan, Professor at the National Research Center for Science and Technology for Development at China's Ministry of Science and Technology, the state of the Chinese innovation system and the experiences of other countries need to be studied in greater depth. It is critical to understand how regional innovation systems relate to the national innovation network and how the regional innovation systems compare to each other. In addition, it is crucial to appreciate the differences between innovation systems in the manufacturing sector and those in services.

Many major questions about innovation in China have to be addressed:

— What are the main drivers of technological innovation in China?
— Are multinational corporations involved and, if so, through which mechanisms?
— What are the key features of China's national innovation system?
— What are the chief mechanisms promoting innovation?
— What does China's emphasis on "independent innovation" mean domestically and internationally?
— Does it make sense for China to build a "national system of innovation" in a world of globalization? Or has China moved beyond the "national innovation system" (NIS) model to embrace the concept of a "global system of innovation"?
— How will China's participation in the global R&D network change the dynamics of china's innovation strategy and its role in international knowledge creation?
— What is China's innovation trajectory?

Innovation is now a central aspect of any approach to achieve sustainable growth, both for economies and companies. As management guru Gary Hamel told Fortune magazine in 2004, "there are no strategies for creating wealth in the long term that are not driven by innovation." Today, with the forces of globalization putting pressure on all countries and the emergence of the BRIC economies—Brazil, Russia, India and China—driving global competition even higher, business and government leaders and managers regard innovation as something of a silver-bullet solution to their competitiveness shortcomings.

But innovation is not just a buzzword with little meaning. It is imperative to keep in mind exactly what is meant by "innovation", said Denis Simon, Provost of the Levin Graduate Institute at the State University of New York. The word "refers to the process that transforms ideas into commercial value." He drew a distinction between "invention," or the simple creation of a new idea or concept, and "innovation," which is the turning of a new concept into a commercial success or a product or service that goes into widespread use. "An 'innovation system' refers to the set of distinct institutions which contribute to the development and diffusion of new technologies in an organization, region or country," Simon explained. The end result must have commercial value.

The key issue for any country or company is where to get the resources—human and financial—to drive innovation. Where is the talent and who has it? Globalization has changed the nature of innovation. As indicated, innovation is now a global process. The key priority is to construct the right environment to promote innovation, or ecosystems of innovation that involve not just domestic players and institutions but foreign ones as well. Partnerships and other collaborative links, local and cross-border, are the building blocks of these networks. "We are at a phase of major changes in the international innovation system," Simon observed. "The question is whether China is building an innovation system that will allow it to be successful in the 21st Century."

China's success depends on its ability to fit smoothly into the fast-changing global innovation system. These days, business models come and go rapidly. Successful companies have to adapt quickly and be innovative at all times. Knowledge creation relies more and more on the collective intelligence of employees, customers and engaged outsiders all over the world. "With China coming on the playing field, we will see some fundamental changes in the system," Simon reckoned. Nonetheless, China itself must make some major adjustments internally if it is to be a key player.

Where is China heading as an innovation hub? "China has taken a new strategic step in focusing on 'independent innovation' as the driving force underlying its economic strategy and focus," said Simon. "During the course of the next five to ten years, it can be expected that China will take multiple actions to strengthen its domestic institutions, especially at the enterprise level to promote their enhanced commitment to technological innovation."

China is already embedded in the game of global competition as reflected in the fact that it is the top destination for foreign direct investment (FDI). Foreign firms have been and will continue to bring advanced know-how and related higher value-added operations to China as part of their strategic positioning. "While the Chinese system lags behind the West in most areas of innovative capability, the fact that it is now a preferred site for R&D FDI suggests it is already enmeshed in the global knowledge system," Simon remarked.

The issue of the ownership of innovation may be a short-term "political" concern, he argued. "Eventual labor circulation means that local scientific and engineering talent, currently employed by multinationals, will eventually become part of a projected upsurge in local technological entrepreneurship." Added Simon: "As China becomes more integrated into the fabric of global R&D activities, it will gradually and steadily command and demand a greater share of the associated revenue streams." There will be obstacles to this integration. These include sensitivities over technology sharing and transfer, as well as IPR protection. The Chinese government is likely to behave in ways to maintain and strengthen the competitiveness of domestic players, Simon suggested. This could produce some conflicts with the West from a WTO perspective.

The biggest questions over China's innovation trajectory have to do with the "software", not the hardware or technology side. Of particular concern are skill and management issues such as the capacity to adjust to the fast-changing environment and to manage the exchange of technology across borders and cultures, the ability to work outside established networks and within politically charged environments, the capability to train and develop managers with the cross-cutting analytical and problem-solving abilities, and the need to train leaders with the necessary global outlook to compete in an increasingly open, more collaborative economy.

Simon proposed the following five hypotheses to help better understand the impact of globalization and China's emerging innovation trajectory:

1 More and newer technologies are flowing into China at an earlier point in their life cycle than has occurred in any other developing country since the end of the Second World War.

2 The proliferation of China's formal and informal commercial and cooperative science and technology relations over the last two-plus decades has contributed to a more rapid and sustained pace of technological advancement than originally projected by most experts.

3 The real strategic value of China for many multinational corporations lies in two areas: its critical role in global production networks and supply chains, and access to its critical knowledge assets, the cadre of under-utilized scientists and engineers who are now part of the global R&D system and talent pool.

4 More multinational corporations will not only be setting up R&D and engineering activities in China, but they will be looking at China as a critical partner within their overall global innovation system, leading to more technology sharing.

5 China's increasing worries about being able to leverage globalization to gain access to technology is one key factor driving the new emphasis on "independent innovation" and intellectual property rights (IPR) creation.

As these trends and developments play out, the biggest challenge for China will be to change its mindset. To succeed in the complex business of global innovation today, it is essential for the Chinese to discard their own technological nationalism and replace it with a truly global outlook. That will mean that China will be more and more an integral part of the global economy. And this can only promote the peaceful rise of China and enhance global stability and security in the final analysis.

Appendix
Excerpt from China's "Guidelines for the Medium- and Long-Term National Science and Technology Development Program (2006-2020)"

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1 Preface

The 16th National Party Congress, proceeding from the overall interests of building a well-off society [xiao kang she hui] in an all-around way and of accelerating socialist modernization, called for formulating a long-term national S&T development Program. The State Council has drawn up these guidelines in view of this.

Since the founding of New China, especially since the Program of reform and opening up was launched, China has scored great, internationally acclaimed achievements in socialist modernization. At the same time, we must clearly realize that China is in the initial stage of socialism and will remain there for a long time to come. Building a well-off society in an all-around way poses rare historic opportunities as well as a series of acute challenges. We rely too much on the consumption of energy and resources for our economic growth, and we experience serious environmental pollution. Our economic structure is unreasonable, our agricultural foundation is weak, and the development of our high-tech industries and modern service industries is lagging. Our independent innovative capabilities are quite weak, the core competitiveness of our enterprises is not strong, and we have yet to improve our economic returns. We need to urgently resolve numerous difficulties and problems in increasing employment, rationalizing distribution relationships, providing health safeguards, and ensuring national security. On the international front, China will face tremendous pressure for a long time to come due to the economic, scientific and technological, and other advantages enjoyed by developed nations. To seize the opportunities and meet challenges, we need to work on various fronts, including planning our overall development, deepening structural reform, expanding democracy and the legal system, and strengthening social management. In the meantime, we need to rely more on S&T progress and innovation than at any time in the past to bring about a qualitative leap in our productive forces and promote comprehensive, coordinated, and sustainable economic and social development.

S&T is the primary productive force; it is also an embodiment and a key hallmark of advanced productive forces. In the 21st century, a new S&T revolution is unfolding quickly, carrying with it the potential for new major breakthroughs, and it is expected to wreak profound economic and social changes. Information S&T is still in the early stages of development and remains a dominant force in sustained economic growth. Life science and biotechnology are developing swiftly and are expected to play a key role in improving and raising the quality of life for mankind. There is renewed interest in energy-related S&T, which is opening up new avenues for solving global energy and environmental problems. New breakthroughs in nano-science and nano-technology have emerged in a steady stream and are expected to bring about a profound technological revolution. Major breakthroughs in basic research have created new prospects for technological and economic development. The pace of applying and commercializing S&T achievements has kept accelerating, giving rise to new opportunities for catching up and overtaking by leaps and bounds. Therefore, we must stand at the forefront of the times and meet the opportunities and challenges of the new S&T revolution with a global vision. Globally, many countries seek to enhance S&T innovation as a matter of national strategy, view S&T investments in strategic terms, and are vastly increasing their S&T investments. They also make advance plans for and develop cutting-edge technologies and strategic industries, execute major S&T plans, and work hard to enhance their innovative capabilities and international competitiveness. Faced with the new international situation, we must heighten our sense of responsibility and urgency; act more consciously and steadfastly to make S&T progress a primary driving force in economic and social development; regard the improvement of independent innovative capabilities as the centerpiece f our efforts to adjust our economic structure, change our growth mode, and improve the country's competitiveness; and view the construction of an innovative country as a future-oriented major strategic choice.

Thanks to the extraordinarily arduous and sustained struggle of several generations of people, China has scored heartening tremendous achievements in S&T endeavors during the 50-odd years since the founding of New China. A large number of major S&T achievements, signified by "two bombs and one satellite" [atom bomb, hydrogen bomb, and man-made satellite], manned spaceflight, hybrid rice, the theory of the continental origin of oil and its application, and high-performance computers, have greatly enhanced China's overall strength, improved China's international standing, and inspired our national spirit. At the same time, we must realize that China's overall S&T standard still falls quite far short of those of developed nations. This is mainly manifested as follows: Our self-sufficiency in key technologies is low, and we have few patents for inventions. Technological standards are still quite low in some areas, especially rural areas in the central and western regions. The quality of science research is not high enough, and outstanding and top-notch personnel are in relatively short supply. At the same time, our S&T investments are insufficient, and our structures and mechanisms are still significantly flawed. Although China is now an economic power, it is still not an economic powerhouse, and a fundamental cause of this is its weak innovative capabilities.

Heading into the 21st century, China, as a large developing country, still needs to work hard over a fairly long period of time if it is to accelerate its S&T development and narrow the gap with developed nations. At the same time, it has many conditions working in its favor:

1 China's sustained and rapid economic growth and social progress have fuelled strong demand and laid a solid foundation for S&T development.

2 China has established a fairly complete system of disciplines, manned by a vast pool of human resources, and has the basis and capacity for great S&T development, with research and development [R&D] capabilities in some important fields among the world's advanced ranks.

3 Our commitment to opening up to the outside world and our increasingly brisk S&T exchanges and cooperation with other countries have allowed us to share in the fruits of the new S&T revolution.

4 By upholding the socialist system, we can combine our political superiority in concentrating our resources on undertaking major endeavors with the basic role of market mechanisms in effectively allocating resources, thereby providing important institutional guarantees for the booming development of S&T endeavos.

5 The Chinese nation has a 5,000-year history of civilization, and Chinese culture is extensive, profound, and all-encompassing and is conducive to the formation of a unique culture of innovation. We can definitely score splendid S&T achievements that are worthy of the times as long as we enhance our self-confidence as a nation, implement the scientific development concept, thoroughly implement the strategy of rejuvenating the country through science and education and the strategy of building a strong country through the development of talent, do all we can to catch up, and work hard with an indomitable spirit over the next 15 years or even for a longer period of time to come.

2 Guiding Principles, Development Goals, and Overall Plans

2.1 Guiding Principles

The first 20 years of this century are a period of important strategic opportunities for China's economic and social development as well as for S&T development. We must take Deng Xiaoping Theory and the important thinking of the "Three representations" as our guidance, implement the scientific development concept, comprehensively implement the strategy of rejuvenating the country through science and education and the strategy of building a strong country through the development of talent, proceed from our national conditions, take a people-centered approach, deepen reform, open up wider to the outside world, promote the vigorous development of China's S&T endeavors, and provide strong S&T support for achieving the goal of building a well-off society in an all-around way and for building a harmonious socialist society.

The guiding principles for S&T work over the next 15 years are: Innovate independently, achieve development in selected areas by leaps and bounds, support development, and guide the future. Innovating independently means proceeding from strengthening the country's innovative capabilities and stepping up efforts at original innovation, integrated innovation, importation, absorption, assimilation, and re- innovation. Achieving development in selected areas by leaps and bounds means doing things selectively and concentrating our resources on key fields with certain foundations and strengths that have a bearing on the national economy, the people's livelihood, and national security in order to achieve key breakthroughs and bring about development by leaps and bounds. Supporting development means proceeding from actual pressing needs and focusing on achieving breakthroughs in major key and generic technologies to support sustained and coordinated economic and social development. Guiding the future means taking the long view, making advance plans for cutting-edge technology research and basic research, creating new market demand, cultivating newly emerging industries, and guiding future economic and social development. These guiding principles, which were drawn up on the basis of summing up China's practical experience with S&T development in more than half a century, represent a future-oriented important choice for bringing about a great revival of the Chinese nation.

We must give prominence to improving our independent innovative capabilities in our overall S&T work. The party and government have always put a premium on and advocated independent innovation. We must earnestly learn from and fully draw on all outstanding achievements in human civilization in promoting socialist modernization under the conditions of opening up to the outside world. China has brought in technology and equipment on a large scale in the 20-plus years of reform and opening up, and these have played an important role in improving industry technological standards and promoting economic development. However, we must clearly realize that bringing in technology without paying attention to absorption, assimilation, and re-innovation will surely weaken our independent R&D capabilities and widen the gap with advanced international standards. Facts tell us that we cannot buy true core technologies in key fields that affect the lifeblood of the national economy and national security. To gain leverage in fierce international competition, China must improve its independent innovative capabilities and master a number of core technologies, own a number of proprietary intellectual property rights, and groom a number of internationally competitive enterprises in certain important fields. In a nutshell, we must improve our independent innovative capabilities as a matter of national strategy, which we must implement in all facets of modernization and in various industries, sectors, and regions, and vastly improve the country's competitiveness.

S&T personnel are the key to improving independent innovative capabilities. In our S&T work, we must give priority to creating a good environment and good conditions; to training and bringing together S&T personnel of all stripes, especially outstanding and top-notch personnel; and to fully inspiring the initiative and creativity of the broad ranks of S&T personnel; create a good situation in which talented people emerge in an endless stream, people can make full use of their talents, and talented people are put to good use; and build a large, rationally structured corps of high-caliber S&T personnel that is compatible with economic and social development and national Defense construction so as to provide ample personnel support and intellectual guarantees for China's S&T development.

2.2 Development Goals

China's overall goals for S&T development through 2020 are: Markedly enhance our independent innovative capabilities and our ability to promote economic and social development and guarantee national security through S&T in order to provide strong support for building a well-off society in an all-around way; and markedly enhance our overall ability to conduct basic science research and cutting-edge technology research, score a number of S&T achievements with great influence in the world, and join the ranks of innovative countries in order to lay a solid foundation for becoming a world S&T powerhouse by the middle of this century.

After 15 years of hard work, China has achieved the following goals in a number of important areas of S&T:

1. Mastering a number of core technologies in the equipment manufacturing and information industries that have a bearing on China's competitiveness, and joining the world's advanced ranks in terms of technological standards in the manufacturing and information industries.
2. Joining the top ranks of the world in terms of overall agriculture-related S&T capabilities, bringing about an improvement in overall agricultural production capacity, and effectively guaranteeing the country's food security.
3. Achieving breakthroughs in energy development, energy conservation technology, and clean energy technology; promoting the optimization of the energy structure; and reaching or approaching advanced international standards in terms of the indicators of unit energy consumption for major industrial products.
4. Establishing technological development models for a recycling-based economy in key industries and cities in order to provide S&T support for building a resource-efficient and environment-friendly society.
5. Markedly improving the prevention and control of major diseases; curbing AIDS, hepatitis, and other major diseases; achieving breakthroughs in manufacturing new medicines and in researching and developing key medical apparatus; and owning industrial development technological capabilities.
6. Our Defense-related S&T basically meets the needs of independently researching and developing modern

weaponry and pursuing informatization, thereby providing guarantees for safeguarding national security.

7 The emergence of a number of scientists and research teams of international standards, resulting in a number of innovative achievements with major influence in mainstream science development, and achieving advanced international standards in cutting-edge technologies in such fields as information, biology, materials, and aerospace.

8 Building several world-class science research institutes and universities as well as internationally competitive enterprise-based R&D offices, resulting in a fairly complete national innovation system with Chinese characteristics.

By 2020, we aim to increase the proportion of R&D investment in society relative to the gross domestic product to 2.5 per cent or more, strive for a contribution rate of 60 per cent or more [to the gross domestic product] by S&T progress, reduce our degree of dependence on technology from other countries to 30 per cent or less, and join the world's top five countries in terms of the number of patents granted annually for home-grown inventions and the frequency of citations in international science papers.

2.3 Overall Plans

China's overall plans for S&T development over the next 15 years are: One, identify several key fields, achieve breakthroughs in a number of major key technologies, and comprehensively improve the supporting capability of S&T in light of China's national conditions and needs. These guidelines identify 11 key areas of national economic and social development and select for arranging on a priority basis 68 preferential subjects for which there are clearly defined tasks and in which technological breakthroughs can be achieved in the near term. Two, implement several major special items with the country's goals in mind in order to achieve development by leaps and bounds and fill the gaps. These guidelines identify a total of 16 major special items. Three, make advance plans for cutting-edge technology research and basic research in order to meet future challenges, improve sustained innovative capabilities, and guide economic and social development. These guidelines identify 27 cutting-edge technology issues and 18 basic science issues in eight technological fields for planning on a priority basis and propose four major science research plans. Four, deepen structural reform,

perfect policies and measures, increase S&T investments, step up efforts to train personnel, and promote the construction of a national innovation system in order to provide reliable guarantees for bringing China into the ranks of innovative countries.

In keeping with the urgent requirement for building a well-off society in an all-around way, the trend of S&T development in the world, and China's national strength, we must set strategic priorities in S&T development:

1 Giving priority to developing energy, water resources, and environmental protection technologies and showing determination to resolve the major bottlenecks that are impeding economic and social development.

2 Seizing the rare opportunity stemming from the upgrading of information technology and the swift development of new materials technologies over the next several years to make the acquisition of proprietary intellectual property rights over core technologies for the equipment manufacturing and information industries a breakthrough point in improving the competitiveness of China's industries.

3 Stressing biotechnology in trying to catch up with other countries in high-tech industries and making greater use of biotechnology in such fields as agriculture, industry, the population, and health.

4 Accelerating the development of aerospace and marine technologies.

5 Strengthening basic science research and cutting-edge technology research, in particular, interdisciplinary research.

China must develop S&T on the basis of making overall plans and advancing on all fronts, and make plans and arrangements for key fields and priority subjects in order to provide comprehensive, strong support for resolving pressing problems in economic and social development.

Key fields refer to industries and sectors that need to be developed on a priority basis and that urgently require support from S&T in national economic and social development and national Defense security. Priority subjects refer to technology groups that urgently need to be developed, have clearly defined tasks and a fairly sound technological basis, and can yield breakthroughs in the near term in key fields. The principles for identifying priority subjects are: one, they can help break free of bottlenecks and improve the ability to sustain economic development; two, they can help master key technologies and generic technologies and improve core industrial competitiveness; three, they can help resolve major S&T issues that affect the public interest and improve the ability to serve the public; and four, they can help develop technologies for both military and civilian uses and improve the ability to ensure national security.

3 Key Fields and Priority Subjects

3.1 Energy

Energy occupies a strategic place of special importance in the national economy. Currently, there is an acute imbalance in China's energy supply and demand, which is unreasonably structured, with poor efficiency in energy utilization. Coal figures predominantly in primary energy consumption, and the massive consumption of fossil energy has caused serious environmental pollution. Meeting the energy demand for sustained, rapid growth and making clean and highly efficient use of energy over the next 15 years present major challenges in the development of energy-related S&T.

Development ideas:

1 Give priority to energy conservation and reduce energy consumption. Gain mastery over key energy conservation technologies in major energy-consuming fields, actively develop energy conservation technologies for buildings, and vigorously improve efficiency in primary and ultimate energy utilization.

2 Promote the diversification of the energy structure and increase the energy supply. Vigorously develop nuclear energy technologies and acquire the capability to independently develop technologies in the nuclear power sector while at the same time improving oil and gas development and utilization and hydropower technological standards. Achieve breakthroughs in and apply on a mass scale technologies related to wind energy, solar energy, biomass, and other renewable energy.

3 Promote clean and highly efficient coal utilization and reduce environmental pollution. Vigorously develop clean, highly efficient, and safe coal development and utilization technologies and strive to reach advanced international standards.

4 Do more to absorb, assimilate, and re-innovate on imported technologies relating to energy equipment manufacturing and gain mastery over advanced coal power, nuclear power, and other major core technologies relating to equipment manufacturing.

5 Improve the technological ability to facilitate the optimum geographical distribution of energy. Give priority to developing safe and reliable advanced power transmission and distribution technologies and achieve large-capacity, long-distance, and highly efficient power transmission and distribution.

Priority Subjects:

3.1.1 Industrial Energy Conservation

We will give priority to researching and developing energy conservation technologies and equipment in major fields that entail high energy consumption such as process industries like metallurgy and the chemical industry as well as the transportation sector; energy conservation technologies for electromechanical products; highly efficient, energy-saving, and long-lasting semiconductor products; and comprehensive energy cascading utilization technologies.

3.1.2 Clean and Highly Efficient Coal Development and Utilization, Liquefaction, and Polygeneration

We will give priority to researching and developing highly efficient power generation technologies and equipment such as highly efficient coal mining technologies and supplementary equipment, heavy-duty gas turbines, integrated gasification combined cycles (IGCC), high-parameter and ultra-supercritical power plants, and large-scale supercritical circulating fluidized beds.
We will vigorously develop conversion technologies such as coal liquidation, gasification, and chemical processing; polygeneration system technologies based on coal gasification; and technologies and equipment for the comprehensive control and utilization of fuel coal pollutants.

3.1.3 Exploration, Development, and Utilization of Oil and Gas Resources Under Complex Geological Conditions

We will give priority to developing technologies to explore for oil and gas resources in complex environments and lithostrata, highly efficient technologies to develop low-grade oil and gas resources on a large scale, technologies to vastly improve recovery rates in mature oil fields, and technologies to explore for and mine deep-lying oil and gas resources.

3.1.4 Low-Cost, Mass Development and Utilization of Renewable Energy

We will give priority to researching and developing large-scale wind power generation equipment, technologies and equipment for building coastal and land-based wind farms and areas with high concentrations of wind energy resources in the western regions, high-performance and low-cost solar photovoltaic cells and technologies to use them, solar thermal power generation technologies, integrated technologies for solar energy buildings, and technologies for developing and utilizing biomass and geothermal energy.

3.1.5 Ultra-Large-Scale Electricity Transmission and Distribution and Power Grid Safety Assurances

We will give priority to researching and developing large-capacity, long-distance, direct-current power transmission technologies; ultra-high-voltage, alternating-current power transmission technologies and equipment; intermittent power grid merging, transmission, and distribution technologies; technologies for monitoring and controlling the quality of electrical energy; technologies for ensuring the safety of large-scale interconnected power grids; major key technologies for the west-to-east power transmission project; technologies for automating power dispatch operations; and information technology and systems for highly efficient power distribution and supply management

[Passages omitted on the development and utilization of water and mineral resources; the development of environmental protection technologies; the rehabilitation of ecosystems; and the improvement of farming operations]

3.4 Agriculture

3.4.2 Healthy Livestock, Poultry, and Aquatic Products Breeding and Epidemic Disease Prevention and Control

We will give priority to researching and developing safe, high-quality, and highly efficacious feed and large-scale, healthy breeding technologies and facilities; create highly efficacious specific vaccines and highly efficacious safe veterinary medicines and apparatus; develop epidemiological technologies for advance warnings, monitoring, quarantine, diagnosis, immunization, prevention and control, sanitization, and eradication in the event of outbreaks of animal epidemics and zoonoses;

achieve breakthroughs in technologies related to aquaculture on mudflats in coastal waters, aquaculture in shallow waters, and freshwater aquaculture; and develop technologies and facilities for deep-sea fishing and storage and processing at sea.

[Passages omitted on sophisticated and downstream processing of farm products, modern storage and shipping, agricultural and forestry biomass development and utilization, the development of environment-friendly fertilizers and pesticides, and the development of modern forestry and dairy farming.

3.5 Manufacturing Industry

The manufacturing industry is the main pillar of the national economy. While China is a world manufacturing power, it is not a manufacturing powerhouse. It has a weak technological basis and poor innovative capabilities and primarily produces low-end products using manufacturing processes that entail heavy consumption of resources and energy and cause serious pollution.

Development ideas:

1 Improve equipment design, manufacturing, and integration capabilities. Take the promotion of enterprise technology innovation as a breakthrough point and basically achieve independent design and manufacturing of high-end numerically-controlled machine tools, lathes, major turnkey technologies and equipment, and key materials, components, and parts through tackling key technological problems.

2 Actively develop green manufacturing. Accelerate the application of relevant technologies throughout a product life cycle, from developing, designing, processing, and manufacturing materials and products to providing sales services to recycling, and develop highly efficient, energy-saving, environment-protecting, and recycling new manufacturing techniques. Join the ranks of advanced international manufacturing industries for resource consumption and environmental impacts.

3 Use new and high technologies to transform and upgrade the manufacturing industry. Vigorously apply information technology in the manufacturing industry; actively develop basic raw and semi-finished materials; vastly improve the grades, technological content, and added value of products; and comprehensively raise the manufacturing industry's overall technological standard.

Priority Subjects:

3.5.1 Basic Spare Parts and Standard Components

We will give priority to researching and developing key technologies for designing, manufacturing, and mass-producing key basic spare parts and standard components needed for major equipment, and develop technologies for shaping and processing large-scale and special parts and components, technologies for designing and manufacturing standard components, and high-precision testing instruments.

3.5.2 Digitized and Intelligent Design and Manufacturing

We will give priority to researching and developing digitized design, manufacturing, and integration technologies and build digitized and intelligent design and manufacturing platforms for products in certain industries. We will develop digitized and intelligent innovation and design methods and technologies geared towards whole product life cycles in a networked environment, computer-aided engineering analysis and process planning technologies, and integrated technologies for design, manufacturing, and management.

3.5.3 Process Industry Greening, Automation, and Outfitting

We will give priority to researching and developing green process manufacturing technologies; highly efficient and clean techniques, processes, and equipment that make full use of resources and associated process amplification technologies; systems integration and automation technologies based on ecological industry concepts; and sensors, intelligent testing and control technologies, equipment, and adjustment systems needed by process industries. We will develop large-scale cracking furnace technologies, large-scale turnkey technologies and equipment for steam ethylene cracking production, and large-scale energy-saving processes and equipment for producing chemical fertilizers.

3.5.4 Recycling Iron and Steel Process Techniques and Equipment

As a typical example of a recycling-based economy, we will give priority to researching and developing new-generation recycling iron and steel processes that combine the three major functions of product manufacturing, energy conversion, and waste recycling on the basis of smelting reduction and the optimization and utilization of resources. We will develop secondary resource recycling and utilization technologies, technologies for coal-gas power generation during metallurgy processes and low-heat-value steam cascading utilization, highly efficient and low-cost clean steel production technologies, noncoking coal technologies, and large-scale integrated design, manufacturing, and systems coupling technologies for sheet-metal continuous casting and rolling machines

[Passages omitted on the development of marine technologies and equipment and R&D related to basic raw and semi-finished materials.]

3.5.7 New-Generation Informatic Functional Materials and Devices

[No further details as received.]

3.5.8 Key Materials and Engineering To Supplement Military Industrial Production

[No further details as received.]

[Passages omitted on the development of technologies and equipment for building and maintaining transportation infrastructure, the development of high-speed rail systems, the production of automobiles that feature low energy consumption and are powered by new energy, the development of intelligent transportation management systems, and the development of technologies to ensure transportation safety.]

3.7 Information Industry and Modern Service Industries

Developing the information industry and modern service industries is the key to advancing a new type of industrialization. The application of information technology in the national economy and society and the rapid development of modern service industries have imposed higher demands on the development of information technology.

Development ideas:

1 Break free of core technology impediments to information industry development; master core technologies related to integrated circuits, key elements and parts, large-scale software, high-performance computers, broadband wireless mobile communications, and next-generation networks; and improve independent development capabilities and overall technological standards.

2 Devote greater efforts to the integrated innovation of information technology products; raise design and manufacturing standards; give priority to resolving the issues of expandability, ease of use, and low costs for information technology products; nurture new technologies

and services; and improve the information industry's competitiveness.

3 Attach importance and devote greater efforts to integrated innovation geared towards application demand, develop technologies and key products that support and spur the development of modern service industries, and promote the transformation and technological upgrading of traditional industries.

4 Develop network information security technologies and related products, with the emphasis on the development of highly trustworthy networks; establish a system of information security technological safeguards; and own technological capabilities for guarding against all kinds of unexpected information security incidents.

Priority Subjects:

3.7.1 Information Technology for Supporting Modern Service Industries and Large-Scale Application Software

We will give priority to researching and developing key technologies needed for the development of such modern service industries as finance, logistical operations, online education, the mass media, medical care, tourism, e-government, and e-commerce, including highly trustworthy network software platforms, large-scale application supporting software, middleware, embedded software, network computing platforms and infrastructure, and software systems integration.

3.7.2 Next-Generation Key Internet Technologies and Services

We will give priority to developing high-performance core network equipment, transmission equipment, and access equipment as well as core technologies in expandability, security, mobility, service quality, and operations management; build trustworthy network management systems; develop equipment and systems such as intelligent terminals and home networks; and support various broadband, secure, and ubiquitous new multimedia and network computing services and applications.

3.7.3 High-Performance, Trustworthy Computers

We will give priority to developing computing methods and theories of advanced concepts, develop a high-performance and trustworthy petaflop supercomputer system and a new server system based on new concepts, and develop key technologies related to new architectures, mass storage, and system fault tolerance.

3.7.4 Sensor Network and Intelligent Information Processing

We will give priority to developing various new sensors, advanced bar code automatic identification technologies, radio frequency identification tags, and intelligent information processing technologies based on multi-sensor information, and develop a low-cost sensor network and a real-time information processing system in order to create information service platforms and environments that are more convenient and have more powerful functions.

3.7.5 Digital Media Content Platforms

We will give priority to developing key digital media content processing technologies that mainly feature video and audio information services and are oriented towards the cultural, entertainment, and consumption markets as well as radio and television services, and develop modern comprehensive media information content platforms that are easily interoperable and interchangeable, have copyright protection functions, and are easy to manage.

3.7.6 High-Definition, Large-Screen, Flat-Panel Displays

We will give priority to developing high-definition, large-scale display products; develop various flat-panel and projection display technologies such as organic light-emitting display, field emission display, and laser display technologies; and establish an industrial chain of flat-panel display materials and devices.

3.7.7 Information Security for Core Applications

We will give priority to researching and developing security technologies for the national basic information network and important information systems, and develop network survivability technology, active real-time protection technology, secure storage technology, Internet virus prevention technology, malicious attack prevention technology, network trust systems, and new password technology under large complex systems

[Passages omitted on safe birth control, the prevention and treatment of non-communicable diseases such as cardiovascular and cerebrovascular diseases, the prevention and treatment of common and frequently occurring diseases in urban and rural communities, the inheritance and innovation of traditional Chinese medicine, the development of advanced medical equipment and biomedical materials, urban planning, the upgrading of urban functions and the economical use of space, the development of technologies and equipment for designing green buildings and promoting energy conservation in buildings, the development of

technology to monitor the quality of urban ecological and living environments, and the development of urban information platforms.]

3.10 Public Safety

Public safety is the cornerstone of national security and social stability. China faces acute public safety challenges, which have given rise to major strategic requirements for S&T.

Development ideas:

1 Strengthen technological support for rapidly responding to and dealing with unexpected public accidents. Develop multifunctional and integrated national emergency response and safeguard technologies for public safety guided by the application of information and intelligent technologies, and form a public safety technological system featuring scientific forecasting, effective prevention and control, and highly efficient emergency response.

2 Improve early detection and prevention capabilities. Give priority to researching and developing monitoring, early-warning, and prevention technologies for production accidents in coal mines, unexpected social safety incidents, natural disasters, nuclear safety, and bio-safety.

3 Enhance overall emergency response and rescue capabilities. Give priority to researching and developing emergency response and rescue technologies for coal mine disasters, major fire disasters, unexpected major natural disasters, hazardous chemical spills, and mass poisoning.

4 Accelerate the modernization of public safety equipment. Develop major public safety equipment and protective product lines to safeguard production safety, food safety, biosafety, and social safety, and promote the rapid development of related industries.

Priority Subjects:

3.10 National Information Platforms for Dealing With Public Safety Emergencies

We will give priority to researching multidimensional and obstacle-free technologies for detecting, monitoring, precisely locating, and gaining information on sources of danger; multi-scale dynamic information analysis and processing and optimum decision-making technologies; and integrated technologies related to national decision-making and command platforms for dealing with public safety emergencies. We will build national decision-making and command platforms for dealing with emergencies that integrate early monitoring, rapid advance warnings, and highly efficient handling.

3.10.2 Early Warnings and Rescue Operations for Major Production-Related Accidents

We will give priority to researching and developing early-warning, prevention, and control technologies for mine gas, mine flooding, and dynamic disasters, and develop prevention, control, and rescue technologies and related equipment for major industrial accidents involving fuel, explosions, and toxin leaks.

3.10.3 Food Safety and Entry-Exit Inspections and Quarantine

We will give priority to researching key technologies for assessing risks, tracing the sources of contamination, drawing up safety standards, and conducting effective monitoring and testing with regard to food safety and entry-exit inspections and quarantine. We will develop intelligent technologies for preventing and controlling food contamination and safety monitoring and control technologies for high-throughput inspections and quarantine.

3.10.4 Prevention and Swift Handling of Unexpected Public Incidents

We will give priority to researching and developing biometric identification, physical evidence tracing, rapid screening and verification, and simulated forecasting technologies as well as technologies and equipment for long-distance positioning and tracking, real-time monitoring and control, and baffle-penetrating identification and rapid disposal; for fire control in high-rise buildings and underground buildings; for detecting over long distances explosives, narcotics, other contraband, and sources of nuclear, biological, and chemical terror; and for on-site disposal and protection.

3.10.5 Bio-safety Safeguards

We will give priority to researching rapid, sensitive, and specific monitoring and detection technologies; testing technologies for products of metabolism by chemical agents in the body; new types of highly effective disinfectants and rapid disinfection technologies; toxin filtration and protection technologies; technologies for distinguishing, preventing, and treating dangerous vectors of transmission and for preventing and controlling biological invasions; and vaccines, immunoadjuvants, antitoxins, and drugs for dealing with unexpected biological incidents.

3.10.6 Major Natural Disaster Monitoring and Defense

We will give priority to researching and developing key technologies for monitoring, warning of, dealing with, and handling earthquakes, typhoons, rainstorms, floods, and geological disasters; technologies for monitoring and warning of forest fires, dam and dike breaches, and other major disasters; and comprehensive risk analysis and assessment technologies for major natural disasters.

3.11 National Defense

4 Major Special Items

Historically, China's implementation of a number of major projects, epitomized by "two bombs and one satellite," manned spaceflight, and hybrid rice, has played a vital role in improving overall national strength. The United States, Europe, Japan, and the Republic of Korea have regarded the organization and implementation of major special Programs tailored to national goals as an important measure for enhancing national competitiveness.

While identifying a number of priority subjects in key fields, these guidelines also further highlight key areas; select a number of major strategic products, key generic technologies, and major projects as major special items in which to achieve breakthroughs through giving full rein to the superiority of the socialist system in concentrating resources on undertaking major endeavors and to the role of market mechanisms; and aim to bring about the development of productive forces by leaps and bounds and to fill national strategic gaps through the realization of partial exponential growth in S&T.

The basic principles for determining major special items are:

1 Keep firmly in mind the major needs of economic and social development and nurture strategic industries with core proprietary intellectual property rights that can give a significant impetus to improving enterprises' independent innovative capabilities.

2 Accentuate key generic technologies that have an overall impact on and can provide a strong impetus to raising overall industrial competitiveness.

3 Resolve major bottlenecks that impede economic and social development.

4 Give expression to the principle of combining military and civilian production and embedding military capabilities in civilian capabilities, which has great strategic significance for ensuring national security and enhancing overall national strength.

5 Act in line with China's national conditions and to the extent that our national strength can support.

A number of major special items have been determined in accordance with the aforementioned principles with a view to developing new-and high-tech industries, promoting the upgrading of traditional industries, resolving bottlenecks in national economic development, improving the people's health, and ensuring national security. Major special items will be carried out one by one in keeping with the country's development needs and the extent to which the conditions are ripe for implementation. At the same time, major special items will be adjusted dynamically and carried out step by step in light of the country's strategic needs and changes in the country's development situation. Regarding major special items aimed at strategic products, we will give full rein to the principal role of enterprises in R&D and investment, make R&D on major equipment a breakthrough point in technological innovation by enterprises, make more effective use of market mechanisms in allocating S&T resources, and channel state-guided investments primarily towards tackling key and core technological problems.

Major special items refer to major strategic products, key generic technologies, and major projects that are to be completed within certain time frames through core technology breakthroughs and resource integration in order to achieve national goals; they are the priority of priorities in China's S&T development. The Program Guidelines identify 16 major special items covering core electronic components, high-end universal chips, and basic software; very-large-scale integrated circuit manufacturing technologies and turnkey techniques; new-generation broadband wireless mobile communications; high-grade numerically-controlled machine tools and basic manufacturing technologies; the development of large oil and gas fields and coal-bed gas; nuclear power stations with large-scale advanced pressurized water reactors and high-temperature and gas-cooled reactors; water pollution control and treatment; the cultivation of new strains of genetically modified organisms; the manufacturing of new major drugs; the prevention and treatment of AIDS, viral hepatitis, and other major infectious diseases; large aircraft; high-resolution earth observation systems; and manned spaceflight and moon exploration projects. They encompass the fields of information, biology, and other strategic industries and involve major pressing issues of energy resources, the environment, and the people's health; dual-use military and civilian technologies; and national Defense technologies.

5 Cutting-Edge Technologies

Cutting-edge technologies refer to forward-looking, pioneering, and exploratory major technologies in the field of high technology; they serve as an important basis for upgrading high technology and developing newly emerging industries in the future, and represent an overall embodiment of a country's high-tech innovative capabilities.

The main principles governing the selection of cutting-edge technologies are:

1 They represent the direction of the leading-edge development of high technology in the world;

2 They play a role in guiding the formation and development of the country's future newly emerging industries;

3 They facilitate the upgrading of industrial technologies and the realization of development by leaps and bounds; and

4 They possess a fairly strong corps of personnel and a fairly sound R&D basis.

We must make advance plans for a number of cutting-edge technologies in accordance with the aforementioned principles, give play to the role of S&T in guiding future development, and improve China's high-tech R&D capabilities and the international competitiveness of China's industries.

[Passages omitted on genetic target identification technologies, animal and plant species and drug molecular design technologies, gene manipulation, protein engineering, stem cell-based human tissue engineering technologies, and new-generation industrial biotechnology.]

5.2 Information Technology

Information technology will continue to develop in the main direction of high-performance, low-cost, and ubiquitous and intelligent computing. Seeking new computing and processing methods and physical implementation are future major challenges in the field of information technology. The intersection and fusion of multiple disciplines such as nano-science and nano-technology, biotechnology, and cognitive science will promote the development of "human-centric" information technology based on biometrics, images, and natural language, and propel innovations in various fields. We will give priority to researching low-cost ad hoc networks, personalized intelligent robots, human-computer interaction systems, high-flexibility data networks that are immune from attack, and advanced information security systems.

Cutting-Edge Technologies:

5.2.1 Intelligent Perception Technologies

We will give priority to researching "human-centric" intelligent information processing and control technologies based on biometrics and the understanding of natural language and dynamic images, as well as Chinese-language information processing. We will research systems technologies in relevant fields such as biometric identification and intelligent transportation.

5.2.2 Ad Hoc Network Technologies

We will give priority to researching technologies related to mobile ad hoc networks, ad hoc computing networks, ad hoc storage networks, and ad hoc sensor networks; low-cost real-time information processing systems; multi-sensor information fusion technologies; personalized human-computer interface technologies; high-flexibility data networks that are immune from attack; and information security systems. We will research ad hoc intelligent systems and personal intelligent systems.

5.2.3 Virtual Reality Technologies

We will give priority to researching technologies that synthesize multiple disciplines such as electronics, psychology, control technology, computer graphics, database design, real-time distributed systems, and multimedia technology. We will research virtual reality technologies and systems in various relevant fields such as medicine, entertainment, art, education, military affairs, and industrial manufacturing management.

5.3 New Materials Technologies

New materials technologies will develop towards composite structural functions for materials, intelligent functional materials, integrated materials and devices, and green preparation and utilization processes. We will achieve breakthroughs in modern materials design, evaluation, characterization, and advanced preparation and processing technologies. We will develop nano-materials and nano-devices on the basis of nano-science research; develop materials with special functions such as superconducting materials, intelligent materials, and energy materials; and develop new materials such as super-structural materials and new-generation photoelectric information materials.

Cutting-Edge Technologies:

5.3.1 Technologies for Smart Materials and Structures

Smart materials and structures are quick or intelligent structural systems that combine sensing, control, and drive (execution) functions. We will give priority to researching smart materials preparation and processing technologies, smart structure design and preparation technologies, and monitoring, control, and fail-safe technologies for key equipment and installations.

5.3.2 High-Temperature Superconducting Technologies

We will give priority to researching new high-temperature superconducting materials and preparation technologies, superconducting cables, superconducting electrical machinery, and highly efficient superconducting electrical devices. We will research sensitive detection devices such as superconducting biomedical devices, high-temperature superconducting filters, high-temperature superconducting non-destructive testing devices, and scanning magnetic microscopes.

5.3.3 Highly Efficient Energy Materials Technologies

We will give priority to researching materials related to solar cells and relevant key technologies, key materials and technologies for fuel cells, high-capacity hydrogen storage materials and technologies, highly efficient secondary battery materials and key technologies, and super-capacitor key materials and preparation technologies. We will develop highly efficient energy conservation and storage materials systems.

5.4 Advanced Manufacturing Technologies

Advanced manufacturing technologies will develop in the direction of informatization, maximization, and greening; form the basis for the survival of manufacturing industries; and hold the key to the sustainable development of these industries in the future. We will give priority to achieving breakthroughs in extreme manufacturing, systems integration, and collaborative technologies; intelligent manufacturing and applied technologies; turnkey equipment and systems design and authentication technologies; and systems design technologies based on high-reliability large complex systems and equipment.

Cutting-Edge Technologies:

5.4.1 Extreme Manufacturing Technologies

Extreme manufacturing refers to manufacturing devices and functional systems on extreme scales (ultra-large or ultra-small scales) or with extremely high functions in extreme conditions or environments. We will give priority to researching design and manufacturing techniques and testing technologies related to micro-electromechanical and nano-electromechanical systems, micro-and nano-manufacturing, ultra-precise manufacturing, giant systems manufacturing, and strong-field manufacturing.

5.4.2 Intelligent Service Robots

Intelligent service robots refer to intelligent equipment integrating multiple high technologies that provides mankind with essential services in unstructured environments. We will research basic generic technologies such as design methods, manufacturing techniques, intelligent control, and application systems integration, focusing on the demand for applying service robots and hazardous operations robots

[Passage omitted on the development of technologies for predicting the service lives of major products and facilities].

5.5 Advanced Energy Technologies

Economical, highly efficient, and clean utilization and the development of new types of energy represent the main direction of future energy technology development. The development of such technologies as fourth-generation nuclear energy systems, advanced fuel cycles, and fusion energy are receiving increasing attention. Hydrogen, as the ideal energy vehicle that can be obtained through various means, will bring new changes to clean energy utilization. Fuel cell power and distributed energy supply systems with clean and flexible features will offer a new important form of ultimate energy utilization. We will give priority to researching mass hydrogen energy utilization and distributed energy supply systems and advanced nuclear energy and nuclear fuel cycle technologies, and develop highly efficient and clean fossil energy development and utilization technologies with near-zero carbon dioxide emissions as well as low-cost, highly efficient new technologies related to renewable energy.

Cutting-Edge Technologies:

5.5.1 Hydrogen Energy and Fuel Cell Technologies

We will give priority to researching highly efficient, low-cost hydrogen production technologies using fossil energy and renewable energy; economical and highly efficient hydrogen storage, transmission, and distribution technologies; technologies for basic and key components preparation and stack integration for fuel cells; and fuel cell power generation and automobile power systems integration technologies, and develop norms and standards for hydrogen energy and fuel cell technologies.

5.5.2 Distributed Energy Supply Technologies

Distributed energy supply systems are an important means for providing flexible, energy-efficient comprehensive energy services for end-users. We will give priority to achieving breakthroughs in end-use energy conversion and storage technologies such as mini-gas turbines based on fossil energy and new types of thermodynamic cycles and comprehensive heat, power, and cooling systems technologies, and develop distributed end-use energy supply systems based on mutual complementation between renewable energy and fossil energy and a mixture of mini-gas turbines and fuel cells.

5.5.3 Fast Neutron Reactor Technologies

Fast neutron reactors are nuclear reactors in which nuclear fission chain reactions are set off by fast neutrons and which can achieve nuclear fuel breeding; they can make full use of uranium resources and process long-lived radioactive waste produced by thermal reactor nuclear power stations. We will research and master fast reactor design and core technologies and related nuclear fuel and structural materials technologies, achieve breakthroughs in sodium cycle and other key technologies, build 65MW experimental fast reactors, and realize critical and grid power generation.

5.5.4 Magnetic Confinement Fusion

We will take the opportunity of participating in the construction and research of the International Thermonuclear Experimental Reactor to focus on researching large superconducting magnetic technologies, microwave heating and drive technologies, neutral beam injection heating technologies, blanket technologies, large-scale real-time tritium separation and purification technologies, diverter technologies, numerical simulation, plasma control and diagnostic technologies, and key materials technologies needed for demonstration reactors. We will deepen high-temperature plasma physics research and some non-tokamak exploration and research with energy as the target.

[Passages omitted on three-dimensional maritime environmental monitoring technologies, fast and multi-parameter ocean floor survey technologies, natural gas hydrate development technologies, and deep-sea operations technologies.]

5.7 Laser Technologies

[No further details as received.]

5.8 Aerospace Technologies

[No further details as received.]

[Passages omitted on the development of basic research disciplines; life process quantitative research; condensed matter; the deep structure of matter; the laws of physics governing the large-scale structure of the universe; pure mathematics; earth system research; brain science and cognitive science; and the innovation of science experiment and observation methods, technologies, and equipment.]

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6 Basic Research

6.3 Basic Research Geared To the Country's Major Strategic Needs

A knowledge-based society has strong demand for scientific development, and the competition in overall national strength has been moved forward towards basic research and is becoming more intense. As a fast-developing nation, China must all the more emphasize the need for basic research to serve national goals and resolve key and bottleneck issues in future development through the conduct of basic research. The principles for setting the direction of research are: Having strategic, overall, and long-term significance for national economic and social development and national security; playing a key role in development despite weakness at the moment; and being capable of giving a strong impetus to the combination of basic science and technological science and guiding the future development of new and high technologies.

6.3.1 Biological Basis of Human Health and Diseases

We will focus on researching the process of occurrence and development of major diseases and the molecular and cellular bases with which it interferes; the roles of the nervous, immune, and endocrine systems in health and the occurrence and development of major diseases; the transmission of pathogens; the laws of mutation; pathogenic mechanisms; the roles and mechanisms of drugs on the molecular, cellular, and overall regulatory levels; environmental interference with the physiological process; and the system of traditional Chinese medicine theories.

[Passages omitted on biogenetic improvement in agriculture; the impact of human activity on Earth; global climate changes; and research into relationships among complex natural, social, and economic systems.]

6.3.6 Key Scientific Issues Relating To Sustainable Energy Development

We will focus on researching the physical and chemical bases of highly efficient and clean fossil energy utilization and conversion; key scientific issues relating to high-performance heat-work conversion and highly efficient energy conservation and storage; the principles of mass utilization of renewable energy and new avenues; the theory of safe, stable, and economical power grid operations; and the scientific basis of large-scale basic nuclear energy and hydrogen energy technologies.

[Passages omitted on new principles and methods for designing and preparing materials, the laws of interaction between matter and energy, the micro-scale transportation of high-density energy and matter, and the precise expression and measurement of microstructures.]

6.3.9 Major Issues in Aeronautic and Astronautic Mechanics

We will focus on researching hypersonic propulsion systems, issues in ultra-high-speed mechanics, multidimensional power systems, complex motion control theories, compressible turbulence theories, high-temperature aerothermodynamics, magnetic fluids, plasma dynamics, microfluid and microsystem dynamics, and new materials structural mechanics.

6.3.10 Scientific Basis Underpinning Information Technology Development

We will focus on researching new computing methods and basic software theories, the mechanisms of virtual computing environments, massive information processing and knowledge mining theories and methods, human-computer interaction theories, network security, and trustworthy and controllable information security theories.

6.4 Major Science Research Plans

[Passages omitted on protein research and quantum modulation research.]

6.4.3 Nano Research

The strange phenomena and laws demonstrated by nano-scale matter will alter the existing framework of relevant theories and take people to an all-new level of understanding of the world of matter; they carry the potential for a new technological revolution and provide tremendous development scope in the fields of materials, information, green manufacturing, biology, and medicine. Nano-science and nano-technology have become the strategic choice of many countries for improving their core competitiveness and are also one of the fields in which China can hope to achieve development by leaps and bounds.

We will research the controllable preparation, self-assembly, and functionalization of nano-materials; the structure and outstanding and specific properties of nano-materials and their regulatory mechanisms; the principles of nano-processing and integration; notional and principle-oriented nano-devices; nano-electronics; nano-biology; nano-medicine; the optical, electrical, and magnetic properties of molecular collections and biomolecules and information transmission; the behaviour and manipulation of single molecules; the design, assembly, and regulation of molecular machines; nano-scale characterization and metrology; and the application of nano-materials and nano-technology in the fields of energy, the environment, information, and medicine.

[Passage omitted on reproductive care and growth research.]

7 S&T Structural Reform and the Construction of a National Innovation System

Since the Program of reform and opening up was implemented, China has adopted a series of major reform measures, achieved important breakthroughs, and made substantive progress in reforming the S&T structure, while focusing heavily on promoting the integration of S&T with the economy, setting its sights on enhancing S&T innovation and promoting the commercialization and industrialization of S&T achievements, and giving priority to adjusting structures and changing mechanisms.

At the same time, we must clearly recognize that China's existing S&T structure is still incompatible in many respects with the socialist market economic structure and the requirements for great economic, scientific, and technological development:

1 Enterprises have not yet truly become technology innovators, and their independent innovative capabilities are not strong.

2 S&T forces in various fields exist as separate systems in a scattered and overlapping manner, with poor overall operational efficiency. S&T innovative capabilities in the arena of public interests are particularly weak.

3 There is a lack of coordination in overall S&T management, and the methods for allocating S&T resources and evaluation mechanisms are not suited to the new situation in S&T development and the requirement for changing government functions.

4 The mechanisms for providing incentives to outstanding personnel and encouraging innovation and pioneering work are not perfect. These problems have seriously held back the improvement of the country's overall innovative capabilities.

The guiding principles for deepening S&T structural reform are:

1 Proceed from serving national goals and inspiring the initiative and creativity of the broad ranks of S&T personnel.

2 Focus on promoting the highly efficient allocation and overall integration of S&T resources in the whole society.

3 Take as a breakthrough point the establishment of a technological innovation system featuring enterprises as dominant players and combining industry, academia, and research institutes.

4 Comprehensively push forward the construction of a national innovation system with Chinese characteristics vastly improve the country's independent innovative capabilities.

The priority tasks in S&T structural reform at present and for some time to come are:

7.1 Support and Encourage Enterprises in Their Efforts To Become Technology Innovators

Competition in the marketplace is an important motivating force in technological innovation, and technological innovation is a fundamental way for enterprises to improve their competitiveness. As the Program of reform and opening up deepens, Chinese enterprises play an increasingly important role in technological innovation. We must further create conditions, optimize the environment, deepen reform, and conscientiously enhance the motivation and vitality of enterprises in technological innovation.

1 We must give rein to the guiding role of economic, scientific, and technological policies and turn enterprises into primary R&D investors. We must accelerate the pace of perfecting the unified, open, competitive, and orderly market economic environment, and, through fiscal, taxation, and financial policies, guide enterprises towards increasing R&D investments and encourage enterprises, especially large enterprises, to set up R&D offices. We must establish national engineering laboratories and industry engineering centers with the support of restructured science research institutes or large enterprises with fairly strong R&D and technological diffusion capabilities and through the integration of colleges and universities, science research institutes, and relevant resources. We must encourage enterprises to establish all kinds of joint organizations for technological innovation with colleges and universities and science research institutes in order to enhance their technology innovative capabilities.

2 We must reform the methods of support under S&T plans and support enterprises in undertaking national R&D tasks. In drawing up national S&T plans, we must give

more expression to the major S&T needs of enterprises and encourage more enterprises to participate. We must establish effective mechanisms by which enterprises take the lead in organizing and colleges and universities and science research institutes jointly participate in implementation.

3 We must perfect technology transfer mechanisms and promote technology integration and application in enterprises. We must establish sound incentive mechanisms and sound trading systems for intellectual property rights. We must vigorously develop all kinds of S&T intermediary service organizations that serve enterprises, and promote knowledge flows and technology transfers among enterprises and between enterprises on the one hand and colleges and universities and science research institutes on the other hand. We must give enterprises greater access to key national laboratories and engineering (technology research) centers.

4 We must accelerate the establishment of a modern enterprise system and increase the inner motivation of enterprises to engage in technological innovation. We must make technology innovative capabilities an important benchmark for evaluating state-owned enterprises and make the participation of essential factors of technology in distribution an important aspect of reform of the property rights system in new-and high-tech enterprises. We must adhere to the direction of corporatizing science research institutes that are oriented towards application and development, deepen reform of the property rights system in corporatized science research institutes, and develop sound management structures and rational and effective incentive mechanisms so that these institutes will play a key role in new and high technology industrialization and industry technological innovation.

5 We must foster a good environment for innovation and support small and medium-sized enterprises in technology innovative activities. Small and medium-sized enterprises, especially those that are S&T-oriented, are enterprise groups that are full of innovative energy but have a weak ability to withstand the risks of innovation. We must create a more favorable policy environment for small and medium-sized enterprises and draft and formulate relevant laws and policies that are favorable to their development such as granting market access and combating unfair competition. We must actively develop S&T investment and financing systems and venture capital mechanisms to support small and medium-sized enterprises, and

accelerate the pace of building S&T intermediary service organizations in order to provide services for small and medium-sized enterprises in technological innovation.

7.2 Deepen Reform of Science Research Institutes and Establish a Modern System of Science Research Institutes

Science research institutes engaged in basic research, cutting-edge technology research, and research that serves the public interest are important forces for S&T innovation in China. The hope for developing S&T endeavors in China lies in building a stable and high-caliber research corps that serves national goals and is dedicated to the cause of S&T. Thanks to many years of reform involving structural adjustments and personnel reassignments, China has formed a number of highly competent science research institutes, for which the state must provide stable support. To give full rein to the important role of these science research institutes, we must set our sights on improving innovative capabilities, focus on introducing sound mechanisms, further deepen management structural reform, and accelerate the establishment of a modern system of science research institutes featuring "clearly defined duties, scientific evaluations, openness, orderliness, and standardized management."

1 We must step up efforts to build science research institutes according to the duties defined by the state. We must conscientiously change the current situation in which the duties of some science research institutes are not clearly defined, their resources are scattered, and their innovative capabilities are not strong; optimize the allocation of resources; and concentrate our resources on forming disciplines and research bases that afford us advantages. Science research institutes that serve the public interest must give rein to their technological superiority in relevant industries, improve their S&T innovative and service capabilities, and solve major S&T problems in social development. Basic science and cutting-edge technology research institutes must give rein to their superiority in relevant disciplines, improve research standards, achieve theoretical innovations and technological breakthroughs, and solve major S&T problems.

2 We must establish S&T investment mechanisms that provide stable support for innovative activities in science research institutes. The formation of disciplines, the development of manpower, and the realization of major

innovative achievements require long-term, sustained efforts. The state will provide relatively stable financial support to science research institutes engaged in basic research, cutting-edge technology research, and research that serves the public interest. In light of the different conditions in science research institutes, we must raise per capita funding rates to support long-term efforts to develop disciplines, carry out basic work, and train personnel.

3 We must institute operating mechanisms that are favorable to original innovation by science research institutes. Independent selection of topics for research is extremely important for improving the original innovative capabilities of science research institutes and for training their personnel. We must perfect the responsibility system for presidents of science research institutes, further expand the power of science research institutes to make their own decisions on their S&T spending and their personnel system, and improve the ability of science research institutes to coordinate and integrate their internal innovative activities.

4 We must establish a system for evaluating the overall innovative capabilities of science research institutes. We must establish a scientific and rational comprehensive evaluation system; comprehensively evaluate the overall innovative capabilities of science research institutes in terms of the quality of their science research achievements, their personnel training, and their management and operating mechanisms; and encourage science research institutes to improve their management standards and innovative capabilities.

5 We must establish effective mechanisms for fostering openness and cooperation in science research institutes. We must implement a personnel system that combines permanent employees with temporary employees. We must comprehensively practice a recruitment system and position-specific management and openly recruit science research and managerial personnel from society. Through the establishment of effective mechanisms, we must encourage science research institutes to forge various forms of collaboration with enterprises and universities and promote knowledge flows, personnel training, and the sharing of S&T resources.

Universities are important bases for training high-caliber innovative personnel in China, one of the main forces for basic research and original innovation in the high-tech arena in China, and a fresh force for solving major S&T problems in the national economy and for achieving technology transfers and the commercialization of S&T achievements. It is necessary to accelerate the pace of building a number of high-standard universities, especially a number of world-renowned, high-standard, and research-oriented universities, if China is to expedite S&T innovation and build a national innovation system. China has already established a number of high-standard, fairly large universities with comprehensive fields of study where talented people are brought together. We must give full rein to their important role in S&T innovation. We must actively support universities in making original innovations in the fields of basic research, cutting-edge technology research, and research that serves the public interest. We must encourage and promote all-around cooperation among universities, enterprises, and science research institutes, and step up efforts to serve national, regional, and industrial development. We must accelerate the pace of building key disciplines in universities and platforms for S&T innovation. We must train and bring together a number of leaders in specific disciplines with world-leading standards and build a corps of faculty members for colleges and universities that boasts a fine academic style and an innovative spirit and is internationally competitive. We must further accelerate the pace of reforming the internal management structures of universities. We must optimize the internal educational structures, S&T organizational structures, innovative operating mechanisms, and management systems of universities; establish a scientific and rational comprehensive evaluation system; and institute operating mechanisms that will help improve the training quality and innovative capabilities of innovative personnel, allow people to put their talents to good use, and bring forth a steady stream of talented people. We must actively explore ways to establish a modern university system with Chinese characteristics.

7.3 Push Forward S&T Management Structural Reform

In light of China's current conspicuous problems in overall S&T management, we must push forward S&T management structural reform, focusing on introducing sound national S&T decision-making mechanisms; on eliminating structural and mechanistic impediments; on strengthening overall coordination among departments and localities, between departments and localities, and between the military and civilian sectors; and on conscientiously improving the ability to consolidate S&T resources and organize major S&T activities.

1 We must establish sound national S&T decision-making mechanisms. We must perfect the procedures for discussing the country's major S&T policy decisions and develop standard consultative and decision-making mechanisms. We must strengthen the state's overall planning and management of S&T development and strengthen overall planning for the formulation of major S&T policies, the implementation of major S&T plans, and the construction of S&T infrastructure.

2 We must establish sound national mechanisms for overall S&T coordination. We must establish the status of S&T policy as the foundation of the country's public policy and form a policy system featuring coordination and interaction between national S&T policies and economic policies in keeping with the goal of promoting S&T innovation and enhancing independent innovative capabilities. We must establish interdepartmental coordinating mechanisms for allocating S&T resources under overall planning. We must accelerate the pace of changing the functions of national S&T administrative departments, promote administration according to law, and improve the overall standard of management and service. We must improve the methods for managing plans and give full rein to the role of departments and localities in managing plans and implementing projects.

3 We must reform the S&T appraisal and assessment system. In appraising S&T projects, we must reflect the principles of fostering fairness, impartiality, and openness and encouraging innovation, and create conditions for the emergence of various types of personnel, especially young professionals. We must give expression to national goals in appraising major projects. We must perfect mechanisms for appraising specialists in the same fields, establish a system for appraising the credibility of specialists, institute mechanisms for allowing international specialists in the same fields to participate in appraisals, tighten supervision over the appraisal process, increase the openness of appraisal activities, and expand the scope of information to which those subject to appraisal have access. We must show special concern and support for highly innovative small projects, non-consensual projects, and interdisciplinary projects; pay attention to evaluating the quality, capabilities, and research standards of S&T personnel and teams; and encourage original innovation. We must establish an independent system for assessing

the implementation of major national S&T plans, knowledge innovation projects, and plans for subsidizing natural science funds.

5 We must reform the system for evaluating and rewarding S&T achievements. In light of the different traits of S&T innovative activities, we must perfect the system for evaluating science research and the system of benchmarks in accordance with the principles of openness, fairness, scientific soundness, standardization, simplification, and high efficiency; change the phenomenon of too many evaluations; and avoid seeking quick results and instant benefits. For innovative activities such as market-oriented applied research and experimentation, the main criteria for evaluation should be whether they result in the acquisition of proprietary intellectual property rights and how much they contribute to industrial competitiveness. For science research activities that serve the public interest, the main criteria for evaluation should be whether they satisfy the public's needs and how they benefit society. For basic research and cutting-edge technology exploration, the main criteria for evaluation should be its scientific significance and academic value. We must establish a system for evaluating personnel that is suited to S&T work of different natures. We must reform the national S&T award system, reduce the number and grades of awards, and emphasize key areas for government S&T rewards. In addition to rewarding projects, we must also pay attention to rewarding people. We must encourage and regularize the introduction of awards by society.

7.4 Comprehensively Push Forward the Construction of a National Innovation System With Chinese Characteristics

Our goal in deepening S&T structural reform is to push forward the construction of a sound national innovation system. A national innovation system is a government-directed social system for giving full rein to the basic role of the marketplace in allocating resources and for fostering close links and effective interaction among various types of S&T innovators.

In building a national innovation system with Chinese characteristics at the current stage, we must focus on the following:

1 We must build a technological innovation system featuring enterprises as dominant players and combining industry, academia, and research institutes, and make this a breakthrough point in comprehensively pushing forward

the construction of a national innovation system. Only if enterprises play a dominant role can we uphold the market orientation of technological innovation; effectively consolidate the resources of industry, academia, and research institutes; and truly enhance the country's competitiveness. Only through the integration of industry, academia, and research institutes can we allocate S&T resources more effectively, inspire the innovative energy of science research institutes, and give enterprises the ability to keep innovating. While seeking to vastly improve enterprises' technology innovative capabilities, we must establish new mechanisms for various forms of integration for industry, academia, and research institutes, with science research institutes and colleges and universities actively serving enterprises' needs for technological innovation.

2 We must institute a knowledge innovation system that combines science research with higher education. We must promote links and resource integration among science research institutes and between science research institutes and colleges and universities, centering on the establishment of open, mobile, competitive, and coordinated operating mechanisms. We must step up efforts to build a science research system that serves the public interest. We must develop research-oriented universities and form a number of high-standard basic science and cutting-edge technology research bases that share resources.

3 We must establish a defense-related S&T innovative system that combines military and civilian production and embeds military capabilities in civilian capabilities. We must promote the close integration of military and civilian S&T in terms of overall management, development strategy and planning, R&D activities, and S&T industrialization; step up efforts to develop technologies for both military and civilian uses; and foster a good pattern in which outstanding S&T forces across the nation serve defense-related S&T innovation, and defense-related S&T achievements are swiftly converted for civilian purposes.

4 We must build a regional innovation system with respective characteristics and strengths. We must take into full consideration the characteristics and strengths of regional economic and social development and make overall plans for building a regional innovation system and regional innovative capabilities. We must deepen local S&T structural reform and promote the integration of S&T resources at the central and local levels. We must give rein to the important role of colleges and universities, science research institutes, and national new-and high-tech industrial development zones in the regional innovation system, and increase support for regional economic and social development through S&T innovation. We must strengthen capacity-building for S&T development in the central and western regions. We must conscientiously step up efforts to build county (city) and other grassroots S&T systems.

5 We must build a socialized and networked S&T intermediary service system. To address the conspicuous problems of S&T intermediary service industries such as small scale, single-type functions, and weak service capabilities, we must vigorously cultivate and develop various types of S&T intermediary service organizations. We must give full rein to the important role of colleges and universities, science research institutes, and various social organizations in providing intermediary S&T services. We must guide the development of S&T intermediary service organizations towards professional, mass, and standardized operations.

8 Some Important Policies and Measures

To ensure the implementation of the various tasks laid out in these guidelines, not only should we solve structural and mechanistic problems but we must also draw up more effective policies and measures and perfect them. All policies and measures must help enhance independent innovative capabilities, inspire the initiative and creativity of S&T personnel, make full use of S&T resources at home and abroad, and support and guide economic and social development through S&T. The S&T policies and measures established in these guidelines were formulated in light of current major contradictions and conspicuous problems, and they will be constantly enriched and perfected in line with the development of the situation and the progress in implementing these guidelines.

8.1 Implement Fiscal and Tax Policies To Encourage Technological Innovation by Enterprises

We must encourage enterprises to increase their R&D investments and enhance their technology innovative capabilities. We must accelerate the implementation of consumption value-added taxes and include taxes levied on equipment purchased by enterprises within the scope of deductibles for value-added taxes. We must actively encourage and support enterprises in developing new products, new techniques, and new technologies on the basis of further implementing national preferential tax policies on promoting technological innovation, accelerating the commercialization of S&T achievements, and upgrading equipment; beef up incentive policies such as those allowing enterprises to make pre-tax deductions for R&D investment; and implement preferential tax policies aimed at promoting the development of new-and high-tech enterprises. In conjunction with reform of the enterprise income tax and the enterprise financial system, we must encourage enterprises to establish a system of special funds for technology-related R&D. We must allow enterprises to accelerate the depreciation of their R&D apparatus and facilities. We must provide necessary support in the way of tax policy for enterprises that purchase advanced science research apparatus and facilities. We must increase support in terms of foreign exchange and financing for enterprises that set up overseas R&D offices, and provide convenient and excellent services for their investments abroad.

We must comprehensively implement the PRC Law on Promoting Small and Medium-Sized Enterprises, support the establishment of small and medium-sized enterprises of different natures, and give full rein to the vitality of small and medium-sized enterprises in technological innovation. We must encourage and support cooperation in R&D by small and medium-sized enterprises through joint funding and commissioning and other means, and provide policy support for accelerating the commercialization of the results of innovation. We must draw up preferential tax policies to support technological innovation by small and medium-sized enterprises.

8.2 Enhance the Absorption, Assimilation, and Re-Innovation of Imported Technologies

We must perfect and adjust the country's industrial technology policies and enhance the absorption, assimilation, and re-innovation of imported technologies. We must draw up policies to encourage independent innovation and restrict the indiscriminate importation of duplicate technologies.

Through adjusting the government's investment structure and focus, we must set up special funds to support the absorption, assimilation, and re-innovation of imported technologies as well as R&D related to key technologies

and equipment and R&D related to key generic technologies for major industries. We must actively adopt policies and measures to increase investments through various channels to support the absorption, assimilation, and re-innovation of imported technologies with enterprises playing a dominant role and industry, academia, and research institutes making joint efforts.

We must make major national development projects an important vehicle for enhancing independent innovative capabilities. We must absorb and assimilate a number of advanced technologies, gain mastery over a number of key technologies that have a bearing on national strategic interests, and research and develop a number of major equipment and key products with proprietary intellectual property rights through the implementation of major national development projects.

8.3 Carry Out Government Procurement To Promote Independent Innovation

We must draw up detailed rules and regulations to implement the People's Republic of China Law on Government Procurement to encourage and protect independent innovation. We must set up mechanisms for coordinating government purchases of products of independent innovation. The government will implement a procurement policy to give priority to important new and high technologies and equipment with proprietary intellectual property rights developed by domestic enterprises. We must provide policy support to enterprises that purchase domestically produced new and high technologies and equipment. Through government procurement, we must support the formation of technological standards.

8.4 Implement Intellectual Property Rights Strategy and Technological Standards Strategy

China needs to protect intellectual property rights and safeguard the interests of rights holders not only to perfect the market economic structure and promote independent innovation but also to establish its international credibility and carry out cooperation with other countries. We must further perfect the national system of intellectual property rights, foster a legal environment of respecting and protecting intellectual property rights, promote greater awareness of intellectual property rights in the whole society and higher standards of management for intellectual property rights in the country, increase the protection of intellectual property rights, and severely crack down on various infringements of intellectual property rights in accordance with the law.

At the same time, we must establish special screening mechanisms for intellectual property rights involved in enterprise mergers, technology transactions, and other major economic activities to prevent the loss of proprietary intellectual property rights. We must prevent abuse of intellectual property rights from imposing improper restrictions on normal market competition mechanisms and from hindering S&T innovation and the popularization and application of S&T achievements. We must incorporate intellectual property rights management into the entire process of S&T management and make full use of the intellectual property rights system to improve China's S&T innovation standards. We must promote greater awareness of intellectual property rights among S&T personnel and S&T management personnel, and encourage enterprises, science research institutes, and colleges and universities to attach importance to and strengthen intellectual property rights management. We must give full rein to the important role of industry associations in protecting intellectual property rights. We must set up a sound system of professional qualifications and social credibility that is favorable to intellectual property rights protection.

In light of national strategic needs and industrial development needs, we must produce a number of inventions and creations with great significance for economic, social, and S&T development with the aim of forming proprietary intellectual property rights. We must organize joint efforts by industry, academia, and research institutes to tackle key problems with enterprises playing a dominant role, and offer them support in terms of patent applications, the formulation of standards, and international trade and cooperation.

We must make the formulation of technological standards an important goal of national S&T plans. Government departments in charge of relevant affairs and industry associations must strengthen guidance and coordination for the formulation of important technological standards and adopt these standards on a priority basis. We must push forward efforts to establish a system of technology-related laws and regulations and a system of technological standards; promote the combination of standards formulation with science research, development, design, and manufacturing; and ensure the sophistication and effectiveness of standards. We must guide industry,

academia, and research institutes in pressing ahead with joint efforts to study, draw up, and adopt on a priority basis important national technological standards. We must actively participate in the formulation of international standards and push for China's technological standards to become international standards. We must step up efforts to build a system of technical measures on trade

[Passages omitted on instituting mechanisms, laws, regulations, and policies to promote the development of venture capital investment in high technology; building new and high technology industrial development zones; and supporting the popularization of agricultural and industrial technologies.]

8.7 Perfect Mechanisms for Combining Military and Civilian Production and Embedding Military Capabilities in Civilian Capabilities

We must strengthen overall planning and coordination for combining military and civilian production. We must reform the S&T management system that separates military and civilian production and institute a new S&T management system that combines military and civilian production. We must encourage military science research institutes to undertake civilian S&T assignments, open defense-related S&T work to civilian science research institutes and enterprises, and expand the procurement scope for military products to civilian science research institutes and enterprises. We must reform relevant management structures and systems and ensure that science research enterprises and institutes that are not engaged in military industrial production will equally participate in competition to undertake science research and production related to military equipment. We must create basic S&T conditions and platforms that combine military and civilian production and are shared by the military and civilian sectors.

We must set up new mechanisms that are suited to the characteristics of defense-related science research and dual-use military and civilian science research activities. We must make overall plans and coordinate basic military-civilian research, enhance the integration of high-tech R&D forces for military and civilian applications, establish coordinating mechanisms to promote effective interaction between the military and civilian sectors, achieve the coordinated development and production of military products and civilian products, and promote the integration of various links of S&T for military and civilian purposes

[Passages omitted on encouraging science research institutes and colleges and universities to set up joint laboratories or R&D centers with overseas R&D institutes; supporting Chinese enterprises in increasing exports of new and high technologies and related products and in setting up overseas R&D offices; taking an active part in major international science projects and international academic organizations; spreading scientific knowledge among the general populace; increasing S&T investments by government and enterprises; improving the returns on funds used on S&T projects; building national laboratories, science research experimental bases, large science projects and facilities, scientific data and information platforms, a system of national standards, measures, and testing technologies, and a system of policies, laws, and regulations for sharing S&T resources; accelerating the training of world-class senior specialists; bringing the role of education into full play in training science research personnel; encouraging enterprises to recruit and train S&T personnel; formulating and implementing policies to encourage students pursuing studies abroad to return home to work; and fostering an innovative cultural environment.]

Efforts in a wide range of areas over long periods of time and very stringent demands are required for the implementation of the Guidelines for the Medium-and Long-Term National Science and Technology Development Program. We must step up efforts to organize, lead, make overall plans for, and coordinate relevant work, and adopt actual and effective measures to ensure the fulfillment of various tasks:

1 Promoting a greater convergence between these guidelines and the 11th Five-Year Program [gui hua] for National Economic and Social Development. To make the guidelines more practicable, at present we must closely integrate the relevant contents of the guidelines with the 11th Five-Year Program for National Economic and Social Development in order of importance and priority, including priority subjects, major special items, cutting-edge technologies, basic research, the construction of basic conditions and platforms, and S&T structural reform. From these, we must select key tasks that need to be launched immediately or that urgently need to be resolved during the "11-5" period, and move expeditiously to make specific arrangements and plans under the 11th Five-Year Program for National Economic and Social Development.

2 Drawing up a number of supporting policies. The development goals, key tasks, policies, and measures specified in the guidelines have a directive and guiding

nature. We need to draw up a number of feasible and practicable supporting policies, including policies to support enterprises in becoming technology innovators; policies to promote the absorption, assimilation, and re-innovation of imported technologies; government procurement policies to inspire independent innovation; policies to increase S&T investments and improve the returns on funds; policies to deepen S&T structural reform and push forward the construction of a national innovation system; policies to speed up the industrialization of new and high technologies; policies to train more S&T personnel; and polices to promote combined military and civilian production and embed military capabilities in civilian capabilities. We must task relevant departments to take the lead in formulating these policies with the participation of other departments concerned. We must promote mutual coordination and close integration between S&T policies and such economic policies as industrial, financial, fiscal, and tax policies on the basis of full investigations and study, and move expeditiously to introduce and implement relevant policies.

3 Setting up mechanisms for making dynamic adjustments to implementation of the guidelines. In light of the swift S&T development in the world and constant changes in domestic economic and social development, we must set up mechanisms for making dynamic adjustments to implementation of the guidelines on the basis of economic and social analyses, technological forecasts, and periodic evaluations. We must make timely and necessary adjustments to the development goals and key tasks specified in the guidelines in light of new trends and breakthroughs in S&T development at home and abroad and of new requirements for China's economic and social development, since some of them will need to be enriched and shored up and others will need to be adjusted appropriately.

4 Stepping up efforts to organize and lead the implementation of the guidelines. Under the unified leadership of the party Central Committee and State Council, we must give full rein to the enthusiasm and initiative of all localities, departments, and social organizations in jointly pushing forward the organization of efforts to implement the guidelines through energetic teamwork. In particular, overall management departments at the national level such as those in charge of S&T management, development and reform, and finance must cooperate closely, conscientiously assume responsibility, and strengthen specific guidance. Provinces, autonomous

regions, and municipalities directly under the central government must implement the guidelines in light of their actual local conditions.

Implementation of these guidelines has a bearing on the realization of the goal of building a well-off society in an all-around way, on the success of socialist modernization, and on the great revival of the Chinese nation. Let us take Deng Xiaoping Theory and the important thinking of the "Three representations" as our guidance, enhance our confidence, go all out to make the country strong, and work hard to build an innovate country and implement the grand blueprint for China's S&T development under the leadership of the party Central Committee with Comrade Hu Jintao as general secretary.

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Industrial Innovation in China

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