Issues in
Technology Innovation

Number 23 April 2013

Becoming a Techno-Industrial Power: Chinese Science and Technology Policy

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EXECUTIVE SUMMARY

China's science and technology policy has developed through four phases since the founding of the People's Republic in 1949. In the first phase, to 1959, technology supported the creation of heavy industry along Soviet lines, while the second, up through the end of the Cultural Revolution in 1976, saw economic stagnation and ideological domination of technology projects. A third phase, under reforms launched by Deng Xiaoping and carried forward by Jiang Zemin to 2001, stressed building of an independent research base and the gradual shift to market-oriented, product-driven research. Since 2002, Chinese policy has increasingly backed high technology industrialization, along with support for the nascent green technology industry.

Chinese technology policymakers also have promoted an innovation-driven economy. The Ministry of Science and Technology (MOST) is the key policymaking and policy coordination organ, and it funds the five most important technology development projects: 1) the Key Technologies Research and Development Program, focused on industrial technology, 2) the 863 Program, centered on basic and applied research on marketable technologies, 3) the Torch Program, which supports commercialization of high tech products, 4) the 973 Program, funding multi-disciplinary projects in "cutting edge" technology, and 5) the Spark Program, promoting development and use of technology in rural areas.

Science and industrial parks are key venues for high tech research and development (R&D). Currently, there are fifty-four such parks, mostly located in large cities or provincial capitals. Firms operating in the parks

must create or apply technology in high tech fields, devote at least three percent of gross revenues to R&D, and employ at least thirty percent of college degreed workers. The information technology (IT) industry is one of the leading industries in the science parks, and has received special policy recognition since 2000.

The space program has become one of China's proudest recent accomplishments. Building steadily on its experience with military and civilian missile technology, China has already launched four manned space missions, and has ambitious plans for a space station and unmanned exploration of the Moon, along with possible manned lunar missions. China has also made a major push into green (or "clean") technology, driven by twin concerns about dependence on foreign oil and serious environmental degradation within China.

China's Tech Trajectory: From Ancient Invention to World Factory

China boasts perhaps the world's oldest continuous science and technology (S&T) program. Its scientists and technicians gave humankind many of its most important pre-modern inventions, including ceramics, crossbows, gunpowder, pulp paper, compasses, sternpost ship rudders, printing presses, seed drills and iron plows, wheelbarrows, and seismographs. Joseph Needham (1900-1995) wrote extensive works cataloging the myriad traditional Chinese inventions.[1] Many of these discoveries were diffused westward, and became a basis of Western industrial progress from the seventeenth century onward. Chinese innovation slowed during the eighteenth and nineteenth centuries due to the combined economic, demographic, and political problems the country faced. As Western imperial powers encroached on the Chinese empire, it was clear that China lagged far behind in technology development, and continued political chaos throughout the republican period (1911-1949) left few resources for scientific efforts.

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With the Communist triumph in 1949, the government initiated a massive effort to catch up with the West. Party chairman Mao Zedong (1893-1976) strongly supported technological development for key military and industrial applications, and science and technology development was tied to ideological and political efforts. For instance, China's first attempt to put together a manned space program in the

1. Needham's series entitled *Science and Civilization in China* was published by Cambridge University Press between 1954 and 2000. Topics included the history of Chinese scientific thought, mathematics and astronomy, physics and physical science, biology and biological technology, civil and nautical engineering, medicine, and agriculture.

1970s was predicated on revolutionary Maoist ideas. After Mao's death in 1976, power shifted to economic reformers under paramount leader Deng Xiaoping (1904-1997). Science and technology now became one of the Four Modernizations, i.e., one of the government's most important economic goals, and the modernization that would support the other three (agriculture, industry, and the military). Since Deng's retirement in 1993, science and technology have been more strongly funded by the state, but much of the technological effort is driven by corporate, foreign-invested, or joint foreign-Chinese efforts.

Science and technological development has undergone four distinct phases since 1949. The first decade of Communist rule, 1949-1960, saw technological efforts driven by adoption of a heavy-industrial model based on experience of the Soviet Union. The Soviets developed 156 large industrial projects, mostly in electrical power generation, steel making, and heavy equipment production. Large amounts of equipment were imported from the Soviets and their Eastern European satellites. Over 3,000 Soviet and Eastern European technicians worked in China, mainly training Chinese workers. Meanwhile, 20,000 Chinese received training or college degrees in the Soviet bloc. Soviet-trained personnel were at the forefront of most Chinese scientific and technological development for the next generation. The disastrous Great Leap Forward (1958-1960) did not set back the industrial economy for long, as the economic structure underwent a substantial change; heavy industry as a share of GDP went from 7.9% to 35.7% from 1949 to 1962, and from 26.4% to 53.5% of all industrial output in the same period. As a result, the economy began to experience serious imbalances during the 1960s.[2]

The second period, 1960-1978 centered on the chaotic Cultural Revolution (1966-1976). Despite political turmoil and economic stagnation, China became only the fifth member of the nuclear-armed club when it tested a device in 1964; it developed intercontinental ballistic missiles later in the decade, and became a space-faring nation by launching a satellite in 1970. Premier Zhou Enlai (1898-1976) realized that China needed to spur innovation and proposed the Four Modernizations in 1974. Denied access to Soviet technology due to the Sino-Soviet split from 1962 onward, Zhou turned to the West for help. Mao's successor, Hua Guofeng (1921-2008), wanted to return to the state-dominated heavy industrial model and initiated a RMB 50.1 billion program of industrial catch-up in 1978, along with roughly $10 billion in technology imports; as a result, China suffered a severe drop in foreign reserves. Upon gaining control of the Party in December, 1978, Deng cancelled this effort.[3]

2. Yang Yao. 2001. "In Search of a Balance: Technological Development in China." Beijing: China Center for Economic Development, Beijing University, January, pp. 3-5. en.ccer.edu.cn/download/482-1.doc (retrieved 11/5/12).

3. Ibid., pp. 5-6.

In the third period, 1979-2001, Deng's reform program put technology to work in the overall shift from socialist economic planning to a market-driven system.[4] Colleges and universities, largely sidelined during the Cultural Revolution, were reopened and expanded, as research centers were reestablished or set up. Both universities and research laboratories began to develop and transfer technology, at first to state-owned enterprises (SOEs). Foreign manufacturers operating in China were required to transfer essential technologies to local partners. Among the key developments by the 1990s was the growing strength of the private sector, which began to absorb increasing amounts of state-developed technology. Chinese electronic appliance manufacturers came into their own, gradually eclipsing Japanese firms in the domestic market. The nature of technology imports shifted from equipment contracts (from over ninety percent in the 1970s to only forty-four percent at the end of the century) to technology licenses (41.4% in 1999), technological consultation fees (9.3%), and joint production or design (5.3%). China became a leading producer of manufactured goods by the mid-1990s, when China's top exports were textiles and apparel, electronic appliances, telecommunications equipment, toys, and steel.[5]

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The first years of the twenty-first century, 2002-2012, have seen a great expansion of manufactured exports, in large part due to Chinese membership in the World Trade Organization (WTO); high tech exports also have markedly increased. China is now commonly called "the world's factory." The private sector (or semi-private sector) has now taken the lead in innovation from SOEs, and relies on foreign funding along with government support for technology projects. Government-supported research institutions are now spread throughout the country, but innovation leadership in key centers, especially Beijing, Shanghai, and Guangzhou, has passed to private firms. The Chinese defense industry has successfully reverse-engineered a range of Russian weapons systems, and is now a major arms producer. China became only the third nation (after Russia and the U.S.) to launch humans into space (see below).

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4. Ben Thornley, et al. 2011. "Case Study 13: National High-Tech R&D (863) Program." *Insight at Pacific Community Ventures and the Initiative for Responsible Investment*, Harvard University. January, p. 3. http://ja.scribd.com/doc/51211913/Impact-Investing-Policy-FULL-REPORT-FINAL (retrieved 2/13/13).

5. Yang Yao, op. cit., pp. 6-7.

Though lagging behind the U.S. and Japan, China does relatively well in international comparisons of S&T activity. R&D as a share of GDP rose from 0.6% to 1.5%, 1995-2008. This is well below American and Japanese levels, but indicates significant progress. Government provides over seventy percent of R&D funding, but this is a huge drop from the 1980s, when the state provided virtually all research money. Technology development is primarily concentrated in a few major urban areas, especially Beijing, Shanghai, Guangzhou, Chengdu and Chongqing, but is gradually spreading to other major cities. While China has become proficient in low-end production and R&D still concentrates on industrial projects, the country receives few inventive patents, and foreign firms (Taiwanese, Japanese, and Western) account for an increasing share of technology exports (up from seventy-three percent in 1998 to eighty-eight percent in 2005). Much of the latter is due to the heightened presence of Taiwanese high tech manufacturers on the mainland.[6]

China's Technology Policymaking/Funding: the National Innovation System

The government sees technological development as a "main engine" for sustainable development, and hopes to foster an innovation-centered economy by the 2020s.[7] S&T policy literature stresses the importance of erecting a National Innovation System (NIS) in creating a modern science and technology infrastructure. Among the most vital tasks are building key policy and research organizations to lead R&D efforts and forge ties between industrial firms and research organizations. The State Steering Committee of Science and Technology and Education is the highest level S&T macro-policy body. Operating under the State Council (similar to a Western cabinet, but including more ministries and agencies), it assists the Premier in coordinating state policy for S&T and education among ten ministries.[8]

6. "OECD Reviews of Innovation Policy: China." 2009. Paris: OECD, p. 1. http://www.oecd.org/science/innovationinsciencetechnologyandindustry/39177453.pdf (OECD) (retrieved 2/11/13); Thornley, et al., op. cit., p. 4; "IT in Taiwan and China: Hybrid vigour." 2010. *The Economist,* May 27, pp. 1-2. www.economist.com/node/16220584 (retrieved 2/20/13).

7. "OECD Reviews..." op. cit., p. 1. Micah Springut, et al. 2011. "China's Program for Science and Technology Modernization: Implications for American Competitiveness." U.S.-China Economic and Security Commission, Centra Technology, Inc., January, p. 6. http://origin.www.uscc.gov/sites/default/files/Research/USCC_REPORT_China%27s_Program_forScience_and_Technology_Modernization.pdf (retrieved 11/12/12).

8. Xinghua Zhu. 2009. "Science policy advisory in China," in Miltos Ladikas, ed., "Embedding society in science and technology policy: European and Chinese perspectives." Brussels: EU Commission, Directorate-General for Research, p. 69. http://ec.europa.eu/research/science-society/document_library/pdf_06/european-and-chinese-perspectives_en.pdf (retrieved 2/13/13). Can Huang, et al. 2003. "Organization, Programs and Structure: an Analysis of the Chinese Innovation Policy Framework." p.

Of these, the leading technology policymaking, decision making, and coordination organ is the Ministry of Science and Technology (MOST), formed in 1998 from the earlier State Science and Technology Commission. MOST drafts basic policy, funds and administers national R&D programs, manages the national system of science parks and technology incubators, and assists entrepreneurs and small businesses to upgrade technology.[9] Research support is MOST's most important task, and R&D funding grew about twenty percent per year during MOST's first decade to 2008.[10] MOST administers five key R&D programs. The Key Technologies R&D Program, the largest, was the first to be set up in 1982. It focuses on projects designed to aid industrial development and restructuring in vital economic sectors, such as agriculture, electronics, energy, and materials.[11]

Second oldest is the National High Technology Development Program (863 Program), which funds both basic and applied research, and has received the most international attention in recent years. It originated in a proposal from four leading scientists in 1986 to focus on development of basic science and high technology.[12] Deng responded immediately by appointing a committee of 200 scientists to set strategy for basic science and applied technology. The swiftly drafted first plan called for concentration on fifteen topics within six areas (biotechnology, astro-biology, information technology, lasers, automation systems, and energy), later expanded to twenty research themes. The 863 approach adapts methods pioneered by America's National Institutes of Health and Department of Defense: most projects are in basic or applied science; planners select researchers for each topic, and firms are encouraged to participate in specific projects. Funding was relatively modest for the program's first fifteen years, and then greatly

3-4. University of Santiago (Portugal). http://xcsc.xoc.uam.mx/apymes/webftp/documentos/biblioteca/analysis%20of%20the%20Chinese%20innovation%20policy.pdf (retrieved 11/12/12).

9. Ministry of Science and Technology. Undated. "Organization," p. 1. http://www.most.gov.cn/eng/organization/Mission/ (retrieved 2/24/13); Peilei Fan. 2004. "Comparative Analysis of Japan and China's Technology Policies and Industrial Development: Lessons for Developing Countries." Tokyo: U.N. University Working Paper No. 125, December, p. 3-4. http://www.ias.unu.edu/binaries2/IASWorkingPaper125.pdf (retrieved 11/5/12);

10. Evan Osnos. 2009. "Green Giant: Beijing's crash program for clean energy." *The New Yorker,* December 21, pp. 3-4. http://www.newyorker.com/reporting/2009/12/21/091221fa_fact_osnos (retrieved 2/13/13).

11. Ministry of Commerce (China). "National Programs for Science and Technology." 2009. p. 1. http://english.mofcom.gov.cn/aarticle/zm/201205/20120508139141.html (retrieved 2/13/13).; Swissnex. 2009. "A Quick Overview of the Science and Technology System in China." p. 6. http://www.swissnexchina.org/background/090821-a-quick-overview-of-the-st-system-xiaoyin-2-.pdf (retrieved 2/13/13).

12. 863 refers to the origin of the program with the scientists' letter of March, 1986. The 973 program takes its nickname from the third meeting of the National Science and Technology Commission in March, 1997. Xiaomei Tan and Zhao Gang. 2012. "An Emerging Revolution: Clean Technology Research, Development and Innovation in China." *WRI Working Paper*, pp. 3-4. World Resources Institute. http://pdf.wri.org/working_papers/an_emerging_revolution.pdf (retrieved 2/12/13).

expanded from 2004 onward.[13]

Third, the Torch Program focuses on developing and commercializing products in new high technology fields. Established in 1988, it funds projects in seven high technology industries (including new materials, biotech, IT, and energy-saving processes), helps local governments set up high tech zones for businesses and technology start-ups, supports training of high tech personnel, and promotes cooperation between Chinese and international firms.[14]

Fourth is the Basic Research Program (973 Program), which began in 1993. It supports multi-disciplinary basic research in "cutting-edge" technology, and promotes promising scientists. Most of its projects involve some form of international cooperative research.[15] Fifth, the Spark Program concentrates on development and use of technology in rural areas, and now covers over ninety percent of Chinese counties; it has funded roughly 150,000 technology demonstration or development projects in the countryside.[16] MOST accounts for roughly seventy-two percent of funding for these leading programs. It also operates the periodic China High Technology Fairs (CHTF) that bring together technology developers and users.[17]

Also vital to Chinese S&T is the Ministry of Education, which sets policy for research universities and human resource development programs. These include various training, award, and professorial support efforts. Most prominent are the 211 Project, started in 1983 to build 100 new universities, the 985 Program providing focused support to a small number of universities to become world class schoo ls, and the China Scholarship Council that aids student and scholarly exchanges. Universities now perform about forty percent of basic research and thirty percent of applied research.[18] The State Intellectual Property Office (SIPO) handles issues relating to patents and copyrights. The National Natural Science Foundation (NNSF), which reports to the State Council, provides grants for basic and applied science under a rigorous blind review process. The Ministry of Information Industry (MII) has taken a leading role in the creation of the Chinese information

13. Peilei Fan, op. cit., p. 29; Osnos, op. cit., pp. 4-5; Ministry of Commerce, op. cit., p.1;Swissnex, op. cit., p. 6.

14. Peilei Fan, op. cit., p. 30; Ministry of Commerce, op. cit., p. 2. In 2009, approximate funding for the major R&D programs were: NNSF RMB 5.1 billion, 863 Program RMB 5.0 billion, Key Tech RMB 5.0 billion, 973 Program RMB 2.8 billion, and Torch RMB 0.2 billion. Springut, op. cit., p.25.

15. Swissnex, op. cit., p. 6

16. Ministry of Commerce, op. cit., p. 2; "Rural Technology 'Spark Program' covers over 90% counties." 2006. Gov.cn (official government website), October 15, p. 1. http://english.gov.cn/2006-10/15/content_413723.htm (retrieved 2/23/13); "Spark Program." 2012. *Erawatch*. Brussels: EU Commission, June 8, pp. 1-3. http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/cn/supportmeasure/support_0015?tab=template&country=cn (retrieved 2/23/13).

17. Ministry of Commerce, op. cit., pp. 2-3. Can Huang, et al., op. cit., p. 12.

18. As with MOST's programs, the numerical names refer to the programs' origins. Ministry of Commerce, op. cit., pp. 5-8; Springut, op. cit., pp. 19-20; .Zhu, op. cit., p. 73.

technology industry since the early 1990s (see below), and the Ministry of Finance helps technological firms' efforts through the Innovation Fund for Small Technology-Based Firms.[19]

The Chinese Academy of Sciences (CAS) is the leading state-run research organization. Originally set up in 1949 on the Soviet research model, it underwent a major restructuring in the 1990s. It now encompasses 125 institutions, including eighty-four research units, a university and a graduate school, and related facilities. Its units are located across China, employing a staff of nearly 50,000, 67.2% of whom are science and technology researchers. It receives about twenty percent of its funds from the NNSF. The Chinese Academy of Engineering (CAE) is an advisory body bringing together academic and industrial engineers, and promotes international cooperation on engineering projects.[20]

Huang, et al. note that policy has undergone at least four major shifts during the reform era. In the early Deng period, 1978-1984, China put together a simple S&T system that could be included in planning. Before 1985, nearly all R&D was performed in government-run public research institutions (PRIs). As reforms accelerated, 1985-1991, the R&D system established links with indigenous firms, while beginning to attract foreign partners with tax incentives and joint venture projects, and began to tie its activities to the market (i.e., basing research work on contracts with SOEs or private firms). A third shift under Jiang Zemin (1926-) tied R&D activities closely to the "Socialist Market Economy," i.e., operating applied (or non-basic) research organs as enterprises. A final change took place from 1999-2004, as nearly all state-run (i.e., non-CAS) research institutes were either merged or, in a few instances, sold off to firms. Merged units remained under the Land and Resources, Agriculture, and Health Ministries, while units formerly under economic ministries or agencies shifted to SOEs or private firms.[21]

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19. Zhu, op. cit., 67-70, 73; Can Huang, et al., op. cit.., pp. 4, 6.

20. Springut, op. cit., pp. 18-19; Thornley, et al., p. 4; Can Huang, et al., op. cit., p. 5.

21. Can Huang, et al., op. cit., p. 9; Thornley, et al., op. cit., p. 3.

Chinese Silicon Valleys: The Role of Science and Technology Parks

Science and technology industrial parks (STIPs) have been promoted as the venues most likely to foster corporate research: companies and state labs working in close proximity create research synergies, incubate new technology firms, and stimulate high technology production. One of the most successful Asian efforts has been Taiwan's Hsinchu Science-based Industrial Park (HSIP), located southwest of Taipei. HSIP became the center of Taiwan's electronics and computer industries from the 1980s, and has spawned many of Taiwan's leading high tech firms. From the late 1980s, China's government constructed a national chain of science and industrial parks. The first was Beijing's Zhongcuancun Park, which formed semi-spontaneously in the 1980s, but was given official status as China's first STIP in 1988. Often called "China's Silicon Valley," Zhongcuancun has concentrated on development of the computer hardware, software, and biotechnology industries.[22]

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The government approved most of the current fifty-four STIPs in the early 1990s (twenty-six in 1991 and twenty-five the next year), and two have been created since then. Many are located in the most advanced economic areas, especially the eastern coastal provinces. Four of the most important parks are in key municipalities controlled by the central government: Beijing, Shanghai, Tianjin, and Chongqing. Twenty-three are in provincial capitals, while twenty-seven cluster in fast developing cities, e.g., Shenzhen and Qingdao, or specialized settings such as Yangling (agricultural products).[23] Parks vary by quality of facilities and area of research concentration. Shanghai's parks are among the most developed, while Hainan's park suffers from a relatively undeveloped infrastructure. Wuhan's park focuses on international projects and those involving Overseas Chinese.[24]

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22. Haiyang Zhang and Tetsushi Sonobe. 2011. "Development of Science and Technology Parks in China, 1988-2008." Economics (e-journal), April 12, pp. 1, 3, 8. http://d/dx.xd.odi.oorig.o/1r0g.5/10018.5/e0c1on8o/mecicosn-eojomurincasl-.jea.j2o0u1r1n-6a (retrieved 11/12/12).

23. Zhang and Sonobe, op. cit., p. 3.

24. Xinhua News Service. 2013. "Shanghai Zizhu Science Park Announces Opening." January 8, p. 1. http://www.prnewswire.com/news-releases/shanghai-zizhu-science-based-industrial-park-announces-opening-73718902.html (retrieved 2/21/13); "Hainan International Science and Technology Industrial Park." 2012. *China Knowledge Press*, December 20, p. 1. http://www.marketresearch.com/China-Knowledge-Press-v2682/Hainan-International-Science-Technology-Industrial-7282623/ (retrieved 2/21/13) ; Hubei Provincial Government. 2012. "China Science and Technology Industrial Park Launches in

To operate inside a STIP, firms must meet four qualifications: 1) they must create or employ technology in new or high technology products, as specified in MOST's "new and high tech products" catalog, 2) they should devote at least three percent of annual gross revenue to R&D for products or services, 3) at least thirty percent of employees must possess college degrees, and at least ten percent must do R&D activities, and 4) companies have to be recertified annually by provincial science and technology offices. Qualified firms receive a range of tax and regulation benefits, including deferral of corporate taxes for three years, along with reduced rates thereafter, an exemption from taxes for the first RMB 300,000 (approximately $45,000) produced from technology acquired abroad, and exemptions from import licenses for technology materials or parts used in export production.[25]

The Urumqi state high-tech industrial zone in Xinjiang, though far from China's economic heartland, is typical of many of the parks. The municipal government, supported by the provincial district government, constructed the site, which houses three functional parks: technological (general technology), "pioneering" (high tech), and export-oriented processing. Major R&D projects are administered by the Torch Center, under the Torch program outlined above. A management committee, which consults with the municipal government and local CCP branch, works out of one office to provide all government functions and a variety of services for organizations and firms in the zone (under the concept of "small institutions, big services"). The zone has reached a number of international agreements with Central Asian organizations and businesses.[26]

Not all high technology firms choose to locate inside the parks. According to the Torch Center, China possessed over 43,000 high tech firms in 2006, including over 27, 000 inside parks (on-park) and nearly 16,000 outside parks (off-park). On-park firms tend to enjoy smaller revenues, value-added production, and export earnings than their off-park counterparts, perhaps because off-park companies are less technology-intensive, and employ a less educated workforce. Zhang and Sonobe suggest that, though park output and overall productivity levels greatly increased in the last decade, the parks did not bring about the dynamic effects of raised productivity growth predicted by STIP promoters.[27]

Wuhan," pp. 1-2. http://en.hubei.gov.cn/news/newslist/201210/t20121016_415649.shtml (retrieved 2/21/13).

25. Zhang and Sonobe, op. cit., pp. 3-4.

26. "Profile of Urumqi state high-tech industrial zone." 2012. China Daily, May 10, pp. 1-2. http://www.chinadaily.com.cn/m/xinjiang/urumqi_hightech/2012-05/10/content_15257735.htm (retrieved 2/21/13).

27. Zhang and Sonobe, op. cit., pp. 4-5.

The IT Industry: Industrial Policy for Emerging Technology

Among high tech industries, information technology (IT) has received particular government attention. Deng era industrial policy focused on light export-oriented industrialization, as it revitalized heavy industry, while the Jiang government undertook a wholesale restructuring of SOEs designed to maintain only national champion companies. State bureaucrats shifted support to high tech industries toward the end of Jiang's tenure. For instance, the State Council in 2000 issued its "Policies on Encouraging the Development of Software Industry and Integrated Circuit Industry," which set forth a package of incentives for software companies. This was followed up by further measures in 2002.[28]

Harwit contends that the Chinese government played a central role in creating a competitive modern telecommunications industry. In the early 1980s, few Chinese had telephones, China Telecom maintained a services monopoly, and the Ministry of Posts and Telecommunications (MPT) resisted liberalization. By the early 1990s, the newly created Ministry of Electronic Industry (MEI) and several allied ministries thought that competition would stimulate the industry, and convinced the State Council to allow formation of Unicom, a second mobile phone carrier. Despite continuous MPT obstruction, poor top management and a badly handled strategy to attract foreign capital, Unicom gradually gained market share. When MPT and MEI merged to form the Ministry of Information Industry (MII) in 1998, most bureaucratic roadblocks fell away; a divested China Telecom and strengthened Unicom (as a result of mergers) grew to share a huge market with newer, smaller entrants.[29]

High tech industries were given special recognition at the Communist Party Congress in 2007. Officials noted that industry was shifting toward higher value-added production, heady economic growth was already slowing, and Chinese businesses needed to exploit opportunities for greater international development, as more foreign multi-national corporations set up research facilities in China. By then, the IT industries were primarily concentrated in three major areas:

By [2007], the IT industries were primarily concentrated in three major areas: the Yangtze River delta (Shanghai area), the Pearl River delta (Guangzhou area), and Bohai Bay (Beijing and Tianjin).

28. Hiromi Hinata. 2009. "Offshore Outsourcing of Knowledge Based Industry: Software and ITES Sector," in Ohara Moriki and Koichiro Kimura, eds. *Comparative Study on Industrial Development Process in China and India*, Interim Report. Chiba (Japan): Institute of Developing Economies, pp. 85-86. http://www.ide.go.jp/Japanese/Publish/Download/Report/pdf/2008_104_03.pdf (retrieved 2/20/13).

29. Eric Harwit. 2008. *China's Telecommunications Revolution*. New York: Oxford University Press, pp. 43-78.

the Yangtze River delta (Shanghai area), the Pearl River delta (Guangzhou area), and Bohai Bay (Beijing and Tianjin). From 2000 onward, the government devoted forty-one national research projects and 2,400 high tech development projects to high tech. This helped create greater industrial infrastructure and R&D capability, including twenty national engineering research centers, nine national engineering laboratories, and 499 government-recognized corporate research centers.[30]

Ernst and Naughton suggest that development of high tech industry has greatly altered the nature of China's political economy. While government continues to play a significant role in shaping industrial policy, it has softened the developmental state approach and now concentrates primarily on building infrastructure, providing incentives for R&D, and creating a supportive legal structure (through intellectual property rules and industrial standards). Lenovo and Huawei, two of China's leading firms, are now players in global markets; both boast mixed ownership and vigorously pursue international research and marketing alliances. High tech companies are increasingly setting up new facilities away from Beijing and Shanghai, and thus ownership and workforces are becoming diversified.[31]

China's Space Program: Leadership, Prestige, and Dual Use

China's space program was intended as the pinnacle of high tech activity. It traces its origins to the successful ballistic missile program in the 1960s and 1970s. Qian Xuesan, a Chinese scientist working in the U.S. who came under suspicion during the early Cold War, left for his homeland and became the team leader for China's first missile tests in 1966.32 China launched its first satellite in 1970 (which did little more than play the revolutionary song, "The East is Red"), and hoisted its first recoverable satellite in 1978. An

Depending on the U.S. for virtually all communications satellites or critical components, China needed American licenses through the 1990s, but bilateral cooperation was subject to periodic suspension due to political tensions.

30. "China's High Tech industry development since the 16th CPC Congress." 2007. Gov.cn (Chinese Government official web page), October 9, pp. 1-3. http://english.gov.cn/2007-10/09/content_771221.htm (retrieved 2/6/13).

31. Dieter Ernst and Barry Naughton. 2009. "China's emerging industrial economy: insights from the IT industry," in Christopher A. McNally, ed., *China's Emergent Political Economy–Capitalism in the Dragon's Lair.* London: Routledge, pp. 39-59; IT Industry Drives China's Unique Industrial Capitalism." 2009. Honolulu: East West Center, July 26, pp. 1-2. http://www.eastwestcenter.org/news-center/east-west-wire/it-industry-drives-chinas-unique-industrial-capitalism (retrieved 2/20/13).

32. Rosita Delios. 2005. "China's Space Program: A Strategic and Political Analysis." *Culture Mandala.* Vol. 7, No. 1, pp. 1-2. www.internationalrelations.com/CM7-1WB/ChinaSpaceWB.htm (retrieved 1/1/13).

initial attempt at a manned space program in the early 1970s got as far as astronaut selection and training before it was cancelled. China entered the commercial satellite business in 1986 with its Long March (*Chang Zheng*) rocket series, its first successful launch four years later. Depending on the U.S. for virtually all communications satellites or critical components, China needed American licenses through the 1990s, but bilateral cooperation was subject to periodic suspension due to political tensions.[33]

Unlike the American or European space programs, the Chinese effort is run by the People's Liberation Army (PLA). China started its second human spaceflight program (Project 921) in 1992, and sent two *taikonauts* (astronauts) to train in Russia by 1997. The *Shenzhou* (Sacred Vessel) space vehicle consisting of descent, service, and orbital modules, was based on old Russian Soyuz models. China claims that it is an original design, but acknowledged Russian help for docking, flight control, and life support systems. Four unmanned test flights between 1999 and 2003 led to the successful twenty-one hour, fourteen orbit flight of *taikonaut* Yang Liwei in October, 2003. Several space firsts followed: a five-day, two-man mission in 2005, a space walk in 2008, and rendezvous with a space module by a crew that included the first Chinese female space traveler (Liu Yang) in 2012. China's next launch (*Shenzhou* 10) will include another female *taikonaut*, and is scheduled for June, 2013. [34]

China uses three launch sites: 1) Jiuquan in the Gobi desert, used especially for human space flight, and dating to the 1960s, 2) Xichang near Chengdu in southwest China, opened in 1984, and employed generally for launches of geostationary orbit satellites (mostly communications), and 3) Taiyuan, near Beijing, set up in 1988 for polar orbit satellites (mainly weather satellites).[35] The space program continues its "steady, unrushed" effort to develop new technologies and gradually expand abilities and has consistently met targets set in Five-Year Plans since the 1990s. And it is relatively inexpensive, estimated at $2.5 billion per year, with roughly $2.0 billion spent for the

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33. James A. Lewis. 2005. "Surmounting the Peak: China's Space Program." CSIS Report on American Astronomical Society National Conference, p. 1. http://csis.org/files/media/csis/pubs/051116_china_space_program.pdf (retrieved 2/13/13); Marcia Smith. 2005. "China's Space Program: An Overview." Congressional Research Service, October 18, pp. 1, 4. http://www.fas.org/sgp/crs/space/RS21641.pdf (retrieved 2/5/13).

34. The word *taikonaut* derives from the Cantonese word for cosmos (*taikon*) and the Greek stem meaning navigation (naut). Brian Spegele. 2012. "Chinese Hit New Space Heights." *The Wall Street Journal* online, June 18, p. 1. http://online.wsj.com/article/SB10001424052702303703004577473850707372174.html (retrieved 2/13/13). William Browning. 2012. "China's Outer Space Achievement Timeline." Yahoo news, p. 1. news.yahoo.com/china-outer-space-achievement-timeline-1557003.html (retrieved 2/13/13); Mark Brown. 2011. "China's space programme flourishes while the United States flounders." Wired.co.uk, July 12, p. 1. www.wired.co.uk/news/archive/2011-07/12/china-looks-to-the-moon (retrieved 2/13/13); Smith, op. cit., p. 2; Lewis, op. cit., p. 1; "China to Launch Manned Space Mission in 2013." 2012. *Discovery,* December 13, p. 1. http://news.discovery.com/space/private-spaceflight/china-space-mission-2013-121112.htm (retrieved 2/13/13).

35. Smith, op. cit., p. 1.

first decade of the Shenzhou program (e.g., the Shenzhou 6 in 2005 only cost about $10 million).[36]

Future plans are ambitious. A 2011 State Council White Paper stated that the program will launch a space laboratory and send robotic craft to collect Moon samples by 2016. China will fully develop its Beidou Navigation satellite system by 2020, so that it will no longer depend on America's GPS, and will build more powerful Long March rockets (the Long March 5 rocket will be able to lift twenty-five tons, roughly the same as America's Delta IV rocket, thus allowing China to assemble deep-space manned missions in orbit). It also plans a series of lunar orbiters and rovers. There has been much discussion about a possible manned Moon mission, and the White Paper mentioned it as a distant goal, but avoided official commitment to such a project.[37]

The Way of the Future: China's Green Industry

> *In 2006, the government set targets for renewable energies that exceeded American goals. ... China had almost no solar cell industry in 2003, but led world production five years later.*

Energy and the environment have also become vital technology concerns, as policymakers are worried about energy independence and sustainable industrial growth. China is already heavily dependent on energy imports from the Middle East, its cities choke on some of the world's heaviest air pollution, eighty percent of its electricity comes from coal, and its cities add millions of new cars every year. The government decided to direct a large chunk of 863 funding to energy technology projects (especially renewable energy and energy storage technology) in 2001. Funding increased roughly fifty times from 1991 to 2005, far more than for any other major area of research. Favored technologies include wind turbines and "clean coal." In 2006, the government set targets for renewable energies that exceeded American goals. Chinese wind generation capacity doubled each year for the next three years. China had almost no solar cell industry in 2003, but led world production five years later.[38]

The government of Wen Jiabao (1942-) made a strong financial commitment to

36. Lewis, op. cit., p. 2; Edward Wong and Kenneth Chang. 2011. "Space Plan from China Broadens Challenge to U.S." *The New York Times*, December 29, pp. 1-2. www.nytimes.com/2011/12/30/world/asia/china-unveils-ambitious-plan-to-explore-space.html?pagewanted=all&_r=0 (retrieved 2/5/13).

37. Smith, op. cit., p. 3; Wong and Chang, op. cit., pp. 1-2; "China to Launch...," op. cit., p. 1.

38. Osnos, op. cit., pp. 1-5; Thornley, et al., op. cit., p. 4.

"clean" energy projects from 2006. The Medium to Long-term Science and Technology National Plan listed energy and environmental protection among its top priority research items, and MOST's National Five-Year Development Plan, 2006-2010, included three clean energy projects: energy-saving systems, 2-3 megawatt wind turbine commercialization, and high quality electrical transmission technology. The 863 and 973 programs provided the largest amounts of funds. The Twelfth Five-Year Technology Plan (2012-2016) set a goal of $300 billion in renewable energy investments within five years. Meanwhile, MOST and the National Development and Reform Commission started an international science and technology cooperation project for "new" or renewable energy; it signed103 cooperation agreements with ninety-seven countries (the largest numbers of projects were with U.S., EU and Japanese firms or organizations).[39]

Since it began economic reforms in 1978, China's greatest technological strength has been its ability to quickly adapt foreign technology to export-oriented industrial production. Its recent effort to develop renewable energy technology, fueled by government funding, helped create a booming yet protected, uncompetitive domestic market for new technologies. This has both limited capacities of domestic firms and constricted opportunities for foreign firms. Foreign firms have outsourced production for cheap exports to China but, due to joint venture and technology transfer requirements, have only marginal penetration of Chinese markets. Lack of intellectual property rights (IPR) protection has further discouraged multinational companies from expanding Chinese operations.[40] China's credibility as a green technology leader will likely depend on its ability to shift to a less energy-intensive development model, get its new middle class to buy electric vehicles, clamp down on polluters, and more vigorously clean up its air and water.

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39. Tan and Zhao, op. cit., pp. 2-6; Luke Schoen. 2012. "Clean Technology's Rise, Part 1: Will U.S. and China Reap the Mutual Benefits?" *China FAQs Issue Brief*. World Resources Institute, April, pp. 2-4. http://www.chinafaqs.org/files/chinainfo/ChinaFAQs_IssueBrief1_MutualBenefits.pdf (retrieved 2/16/13).

40. Thornley, et al., op. cit., p. 5.