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Technology Innovation in China

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Consumer demand, interaction with U.S. industry, reverse migration of Chinese scientists and engineers, and government-sponsored S&T initiatives are accelerating China's development and use of new technology.

During my 4 years (1993-1997) as a diplomat-scientist leading the Environment, Science, and Technology section at the U.S. Embassy in Beijing, I witnessed stunning economic transformation and growth in China. I also saw the slow but steady realignment of U.S.-China relations, which were severely damaged by the tragedy at Tiananmen Square in 1989. Science and technology, which held a steady course in this turbulent period, played a subtle yet key role in this transformation, growth, and realignment. This transformation and growth, reaching most of urban and rural China, has relieved some of the pain and eased the bitterness of Tiananmen and provided the one-party central government a degree of legitimacy that perhaps it would not otherwise have.

When I began my Foreign Service assignment in Beijing, I was still humbled by the complexity of China's history and overwhelmed at first in my attempts to understand the fit and function of science and technology in the governance and the economy of China. As I traveled along the path to understanding, China's cultural continuity forced me to re-explore several centuries of history.[1] I would like to share with readers of The Bridge what I learned about how present-day China is engaging technology and innovation. And, when discussing the future, I choose to stress history and process rather than numbers and statistics.[2]

China's science and technology exchanges with the rest of the world began auspiciously. Inventions that originated in pre-15th century China, like the compass, gunpowder and pyrotechnics, moveable type, and paper making, became pivots in the unfolding of world history and culture. Others, like materials technology associated with porcelain and silk processing and weaving, resulted in products that shaped world trade patterns and enriched world culture for centuries (Needham, 1982).

China's Passage into Modernity Beginning in the 17th century, Qing Dynasty rulers started to choke this fruitful pattern of commercial interchange and the cultural contacts that accompanied it. China effectively closed its doors to outsiders while benefiting from exports of tea and silk that early-19th century Britain paid for with silver. Britain, to reverse this foreign exchange flow, attempted first to market textiles in China and, when that failed, introduced opium from colonial India. The process culminated with the Opium War (1840-1842), which forcibly opened China's doors

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[1] I am indebted to former China State Councilor Song Jian; U.S. Science Advisor John Gibbons; U.S. Ambassador to China J. Stapleton Roy; Prof. Thomas Rawski, University of Pittsburgh; Prof. Richard Suttmeier, University of Oregon; Halsey Beemer, China Officer, World Bank; and Michael Finegan, David Cowhig, and Paul Triolo, State Department, whose wise counsel - during my stay in China and since - aided me on this journey of learning.

[2] The views and opinions of the author of this paper are his own and do not necessarily state or reflect those of the U.S. government or the University of California. Reference to specific services, trade names, manufacturers, corporations or otherwise, does not constitute an endorsement. The author may be contacted by e-mail at dicapua1@llnl.gov.

through the establishment of treaty ports.

This, then, was the rather inauspicious beginning of China's passage into modernity, a path upon which the United States and China have encountered one another many times. Yung Wing, the first student to leave China to study abroad in the modern era, came to the United States in 1847 (Yung, 1909). Upon Yung's return to China in 1854, his vocation became to recruit the most promising talent in China and enroll this talent in U.S. schools and universities. Yung did this with a deep conviction that the knowledge these students would acquire in a dynamic American environment could propel tradition-bound China into a world that was being radically transformed by the Industrial Revolution. Yung and others (see, for example, Qian, 1996) poignantly chronicle the challenges these pioneers faced in the United States and China in the century and a half that followed the Opium War. Their efforts in China were severely hampered by the turmoil that accompanied the creation of the Republic of China in 1911, the warlord period, the Japanese invasion of Manchuria, the war with Japan, and the Chinese civil war that ended in 1949.

In an ambitious decade following the establishment of the People's Republic in 1949, locally educated talent, returnees from abroad, and technical advisors from Russia and other socialist countries began to rebuild China. Under strict party guidance, they eagerly collaborated to develop an economy based on heavy industry and overseen by central-government ministries. In war-devastated areas, the building took place from the ground up. In the northeast, some Japanese-built steel-making and industrial infrastructure remained in place, and China used what the Russians did not take away. The textile industry in Shanghai remained intact, providing a foundation that served China well over the years.

The educational enterprise, with the Ministry of Education at the helm, engaged some of the same talent pool in restaffing universities in major urban centers such as Beijing, Shanghai, and Guangzhou. The Chinese Academy of Sciences (CAS), patterned after the Soviet science academy, became the scientific research base of China. Mission-oriented institutes, which sprouted within the industrial and military ministries, took the lead in narrow areas of training and applied research.

Perhaps the most innovative products of this "strongly regimented pattern of science and technology (S&T) management" (Baark, 1992) are China's nuclear weapons (Lewis and Xue, 1988), intercontinental ballistic missiles, and nuclear submarines (Lewis and Xue, 1994). Development of these technologies relied heavily on scientists who trained and worked abroad,[3] the know-how they brought back (Chang, 1995; Ryan and Summerlin, 1968), and Soviet technology and know-how (Velikhov, 1997). Young and enthusiastic indigenous talent also contributed to these efforts.

In other industrial endeavors, research and production had only sporadic interactions in the sluggish and often clogged channels of the government bureaucracy. Therefore, except for the strategic weapons programs, R&D had little relevance to the needs of industry. Technologies arrived in turnkey factories that China imported from socialist countries, thus establishing the technology core of the state-owned sector. Mastering

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[3] Some, like Song Jian and Zhou Guangzhao, became the leaders of the State Science and Technology Commission and the China Academy of Sciences, respectively, during the second wave of reform in the late 1980s.

these technologies and attaining production levels became a top priority. Innovation, with its attendant disruption of production, was not seen as important to this goal. Therefore, managers ducked innovation unless the leadership expressed a special interest in innovation rather than the attainment of production quotas. An extreme example is the Anshan steel mill, where equipment installed by Japan in the 1930s is still in operation.

China squandered some of the momentum it had developed in the first decade of the People's Republic with the Great Leap Forward, the "three years of difficulties" (during which many researchers went hungry), the break with the Soviet Union, the move of scores of key industries to the hinterland, and the decade of chaos that accompanied the Cultural Revolution (1966-1976). Except for national defense programs, evolution of Chinese technology lagged behind technological progress that was accelerating economic growth elsewhere in Asia.

Recognizing that the Cultural Revolution was a catastrophic mistake, Deng Xiaoping launched market-oriented reforms at the Third Party Plenum in December 1978. Beginning with the agricultural sector, these reforms started to percolate throughout the economy. Science and technology started to make some inroads in self-direction (Suttmeier, 1997), especially in the military and the aerospace sectors. At the same time, scores of western-educated scientists, shamed during the Cultural Revolution, were brought back from forced retirement. And, in an extraordinary move, after a 30-year hiatus, China resumed sending science and engineering students to the United States on government scholarships (Orleans, 1992; Qian, 1996).

The Chinese National Natural Science Foundation (NNSF), established in 1984, was modeled after the U.S. National Science Foundation. It provided those returning from abroad the opportunity to engage in scientific research on a broader scale and compete with researchers working in CAS institutes. To level the playing field, the best facilities of the CAS were opened to these and other researchers outside the CAS. This provided important resources for facilities-poor junior university faculty and created avenues for collaboration.[4]

The "Decision of the Central Committee of the Chinese Communist Party on the Reform of the Science and Technology Management System," issued in 1985, set the stage for the "863" strategic research program established in 1986. This program targeted biotechnology, space technology, information technology, laser technology, automation technology, energy, and advanced materials as key technology "tickets" that China had to punch to move into the 21st century. (See article by Hui Yongzheng, this issue.) Through a program of technological renovation (jishu gaizhao) that began in the early 1980s, the State Economic Commission provided money to state-owned enterprises (SOEs) so they could purchase know-how and machinery from abroad to upgrade their production capabilities. In a break with the past, SOE suppliers became Japan, Europe, and the United States (Simon, 1992).

A BUREAUCRATIC OBSTACLE COURSE

The introduction of new technology in SOEs has been and still is a bureaucratic

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[4] See the special issue of Science, Volume 270, Number 5239 (1995), for a broad overview of academic research in China.

obstacle course. The first and foremost difficulty is political and stems from the unique structure of China's government. This has more to do to do with Mao's concept of the flow of political power and China's historical governance than with Communist or Marxist doctrine. In China, the provincial governments replicate the ministerial structure of the central government. At the provincial level, however, the bureaus that carry out the functions of the ministries are led by provincial governors who hold ministerial rank (Lieberthal, 1995, 1997). Thus, provincial bureaus serve two masters: the minister in Beijing and the provincial governor, both of whom have the same government rank.

There is tension among SOE enterprises, collective enterprises, and privately owned enterprises, all of which fall under provincial control. The SOEs have the additional burden of responding to central-government ministries. The provincial government would prefer to channel resources, raw materials, technology, and know-how to collective- or privately owned enterprises, because these firms' taxes go to provincial coffers (Stepanek, 1992). The central government, however, has a different view. Its present interest is in steering investment to less-developed areas of China, which it does through the State Planning Commission (SPC). The SPC has the right of final approval for investments above $30 million. Thus, on occasion, the SPC will redirect projects, thwarting the efforts of provincial governments and foreign investors.

THE TORCH PROGRAM

The Torch Program, introduced in 1986 under the leadership of the State Science and Technology Commission (SSTC), aims to commercialize discoveries made by government research institutes and universities. Its approach is to nurture the process leading from these discoveries to new technology enterprises (NTEs), so these enterprises can mature and withstand the rigors of the market. The program provides facilities that can serve as technology incubators, encourages funding by banks or state-owned enterprises, and develops management skills among technical personnel.

The Torch Program co-locates technology-rich enterprises in the hope of creating new technologies through synergy. SSTC has established 52 high-technology zones (which resemble research parks in the United States) that are anchored by NTEs, the commercially viable offspring of the program. Examples of successful NTEs are Legend Computer, a PC manufacturer; Stone Company, which produces a popular word processing program; and Founder Company, which produces typesetting software that is in worldwide use (Mufson, 1998a).

I gained real insight on China's perception of these high-technology zones from a call I once received at the U.S. Embassy. The caller asked me for help in making an appointment for an SSTC official who wanted to meet with U.S. government officials "in charge of" high-tech-rich areas such as Silicon Valley in California, Research Triangle in North Carolina, or Route 128 in Massachusetts. I had a hard time convincing the caller that these were not government creations and that such officials did not really exist at the federal, state, or local level.

It is difficult to make a quantitative judgment on how successful the Torch Program has been (Baark, 1992). From a qualitative standpoint, the advantage of the program is that in the risky process of commercializing technologies, failures can be more effective teachers than successes. Thus, even failures can have a positive impact on downstream technology developments.

Following the 1985 decision, SSTC established the Spark Program to facilitate the acquisition of S&T inputs by so-called township and village enterprises (TVEs). TVEs, rooted in rural areas, started to develop in the early 1980s and were fueled by the vast labor pool unleashed by the increased efficiency of China's agricultural sector (Zweig, 1992). The program targeted inland TVEs that were less successful than coastal TVEs in accessing technologies from foreign partners. China conceived the Spark Program as a way to encourage local-level decisions about technology choices. This concept carried a demand that funding also take place at the local level.

To attract additional funding, the Spark Program initiated "high technology fairs," events to which TVEs sent representatives to exhibit technologies developed or improved through Spark sponsorship. The fairs I attended were highly eclectic in nature, with an atmosphere reminiscent of what county fairs must have been like in rural America perhaps 75 years ago. Exhibits included colorful minerals and chemicals in tear-drop-shaped vials; machines to fill and seal snack food packages; country-living conveniences like portable showers and solar water heaters; coal-burning stoves and composting toilets; patent virility enhancers and pseudo-science medical devices; and even fetal sonogram franchises.

Fair organizers spent much effort publishing large volumes listing hundreds if not thousands of Spark-related projects seeking investment partners. In most cases, the local TVE would contribute land, buildings, and a large labor force, while investors were expected to supply additional technology, manufacturing equipment, and working capital to bring a Spark-related product to market.

Government officials 5 and policy pronouncements now appear to publicly acknowledge that state-directed infusions of capital and technology have failed to yield the hoped-for rise in product quality and profitability of SOEs, so another call was issued in 1995 to increase investment in R&D (Foreign Broadcast Information Service, 1995). This was accompanied by a thorough soul-searching on why these attempts had failed (Zhu, 1995).

The climate created by the 1985 decision also allowed some industries to distance themselves from the planning bureaucracy by becoming offshoots of the SOE sector (Suttmeier, 1997) as joint venture enterprises. The most successful at innovation are enterprises that participate in market sectors where technologies are undergoing rapid global evolution. One example is the Haier refrigerator company, a Chinese-German joint venture enterprise in Qingdao, Shandong province. Haier took technology supplied by its German partner and pushed it several steps farther. Taking advantage of the worldwide push to eliminate chlorofluorocarbons (CFCs) as foaming agents and refrigerants, and using U.S. EPA Montreal Protocol-related funding, Haier has become a pioneer in developing high-efficiency, CFC-free refrigerators that now are sold throughout China and exported to Southeast Asia.

TVEs, especially in coastal areas, are very successful innovators and may account for up to 50 percent of China's industrial output (Suttmeier, 1997). TVEs supply internal and export markets with labor-intensive, low-tech, low-end consumer products. At the same time, fueled by the growth of the Asian economies (up to the recent crisis) and a galloping U.S. economy, TVEs in "special economic zones" supply "Made in China" brand-name products for global markets.

TVEs rely upon a network of overseas Chinese links (mainly in Hong Kong, Taiwan, and Singapore) for capital, technology, product design, quality control, manufacturing equipment, and raw materials or components. They have benefited immensely from instant access to global marketing know-how and infrastructures, which their partners painstakingly built in the 1970s and early 1980s.

The development of TVEs is a happy accident of history and the result of economics. In 1987, when China decided to grant TVEs the economic and administrative space to grow and participate in export markets (Suttmeier, 1997), rising wages had already started to squeeze the profit margins of producers in Hong Kong and Taiwan. Producers fortuitously found a unique opportunity to transfer production facilities to a low-labor-cost area with common language and culture. China, for its part, found an established distribution channel for products made with Chinese labor, thus bypassing the time-consuming process of having to develop these markets ab initio. Thus, China became linked to Taiwanese and Hong Kong industry in the same way that Japan had a decade before.

DECLINE OF THE FLYING PIGEON

Due to foreign exchange restrictions, TVE products are not intended to reach Chinese consumers. However, because of the sheer volume of production, some of the product stream does reach China. These TVE products have whetted the Chinese appetite for world-class, competitive consumer items, thus effectively raising the expectations for consumer products from nonexport-oriented Chinese producers.

An excellent example is the wide availability (at a premium price) of 10-speed road bikes, which are identical to those that TVEs produce for U.S. consumers. The Taiwanese-made ancestors of these bikes displaced more expensive, and less-exciting, U.S.-made one-speed bikes, with names like Typhoon and Radar Flite. The competitive presence of TVE bikes in China's markets now is forcing the SOEs that produce staid, British-style, black one-speed bikes, like the ubiquitous Flying Pigeon, to update their product lines with sporty, colorful 10-speed road bikes. But, unlike in the United States where labor costs are high, SOE-made bikes now compete head to head with the TVE bikes in price and value. It is likely that the Flying Pigeon may succumb to the same competitive pressures as the Typhoon and Radar Flite did in their path to extinction.

Very much to the chagrin of the affected Chinese companies, some intellectual property, like trademarks and designs, is diffusing as well. This is most evident in the apparel sector. Many Chinese now wear "American" (but made-in-China) clothes. While some of the franchised logos appear authentic, others, through diffusion, have acquired Chinese characteristics.

TVEs, by exposing personnel to new technologies and management methods, are now an important training ground for China's labor force. Through labor mobility, which itself is a new phenomenon in China resulting from relaxation of political controls, this labor force is raising the overall standards of Chinese industry (Jefferson, 1994).

U.S. CORPORATE INITIATIVES

Technology-based U.S. corporations eye the evolution and expansion of China's economy as an opportunity to enter the world's most populous market and integrate China markets and technology into their global structures. Therefore, many have established training, research, and technology-development bridgeheads. These activities are intended to facilitate the delivery of locally made products and services compatible with China's fastest-growing market sectors.

To accomplish this goal, U.S. firms

- need technologically up-to-date, locally trained talent to staff their China plants and marketing forces;
- want their Chinese employees to be technically competitive and interchangeable with personnel in operations elsewhere in the world, adding symmetry to intracompany transfers out of and into China;
- strive to incorporate locally developed intellectual property in their products for global and local markets (and work to get the Chinese government's help in protecting this and other intellectual property rights); and,
- must work to develop goodwill within the scientific community, general public, and government of China.

It is helpful to look at some concrete examples. By establishing joint ventures with provincial enterprises far from Beijing, Ford quietly started auto production in Nanchang, Jiangxi Province, well before its rival General Motors (GM). As a first step, in late 1993, Ford worked with the NNSF to establish a Ford-funded program of peer-reviewed applied research at Chinese universities and research institutes. This research addressed Ford's global as well as China-specific corporate goals.

GM chose a different route. Starting in 1995, the car maker supported research directly at six Chinese universities. GM's research is aimed at solving some China-specific problems as well as problems in GM's global development portfolio, where Chinese researchers have unique capabilities (Chan, 1997). GM has a joint venture with Shanghai Auto Works to produce the Buick Regal in a new plant in the Pudong District of Shanghai. Due to the magnitude of this operation, the central government and the Shanghai municipal government have kept this joint venture on a very tight leash, reminiscent of the days when such collaborations were first established in China.

IBM, a wholly owned foreign enterprise (WOFE), is the first global corporation to establish a corporate research laboratory in China. IBM China Laboratory opened in September 1995 in the Haidian District, the Silicon Valley of China. In addition to its corporate laboratory, IBM has agreements with Fudan University, Shanghai Jiaotong University, Peking University, and Tsinghua University to carry out original research. A major goal of IBM is to establish the same research presence in China as it has in the United States (Almaden, Calif., and Yorktown, N.Y.), Israel (Haifa), and Switzerland (Zurich).

In a parallel effort designed to contribute to the training of university students in computer science, IBM and the State Education Commission (SEC) have jointly established IBM Technology Centers at 23 China universities. The purpose of these centers, which opened in June 1996, is to gradually integrate state-of-the-art computer technologies into the college curriculum.

In 1995, another WOFE, Motorola, which wants to maintain a dominant position in China's cellular-phone, pager, and radio communications markets, opened its Asia Manufacturing Research Center through a joint agreement with Qinghua University. In 1996, Motorola joined forces with the National Research Center for Intelligent Computing of the Chinese Academy of Sciences to open the Joint Development Laboratory for Advanced Computer and Communications Technologies (Motorola, 1996). The lab's research is expected to exploit the latest scientific achievements in advanced computing systems of China's 863 Program and Motorola's strengths in microprocessor architecture. According to Science Minister Zhu Lilan, this collaboration is an attempt at new forms of international collaboration (Newsbytes, 1996). It raises the interesting possibility that a U.S.-owned company could split the benefits with China from China's investment in the 863 Program. Another Motorola initiative is the Beijing branch of Motorola University, established in 1993, whose goal is to train Motorola employees, customers, and Chinese public servants in a range of technical, management and other disciplines (Motorola, 1996).

In May 1998, Intel announced it will open the Intel China Research Center, an information technology R&D facility that will explore Internet-related issues and information-technology disciplines such as speech recognition that have particular relevance to Chinese applications. Intel said it expects to invest $50 million during the next 5 years to fund the new organization (Intel, 1998). As with the IBM and Motorola centers, the Intel center will conduct its own research and will also fund projects at China's leading universities and research institutes.

Innovation will continue to accelerate in China, if China can become an attractive destination for Chinese scientists, engineers, and entrepreneurs who now are settled abroad and who would return to China if they could strike out on their own. Can the reverse migration that took place in the Republic of Korea and Taiwan take place in China? The answer is probably yes, if the returnees can come back and work in a milieu that respects them as individuals and allows them to exercise their freedoms, think differently, create freely, and run their lives without outside interference. These factors, more than economic opportunities, reversed the tide in Taiwan and Korea. The substantial political changes that are beginning to occur in China suggest that this homecoming, which is now a trickle (Mufson, 1998b), could easily become a torrent.

A ROLE FOR PROFESSIONAL SOCIETIES

Independent professional societies nurture creativity and innovation through the free exchange of ideas. The American Association for the Advancement of Science, the American Chemical Society, the American Physical Society, the Institute of Electrical and Electronics Engineers, to name a few, have been essential to the growth and excellence of U.S. science and engineering. In addition, their combined advocacy has contributed to the overall advance of American science and technology.

For historical reasons, China's government still views organizations outside itself as possible breeding grounds for subversion (Miller, 1996). For example, China's counterparts to U.S. scientific and engineering professional organizations are tucked too deeply under the wings of the government to harbor debate and carry out independent advocacy of science. A good omen, however, is the emergence of so-called social organizations (shehui tuanti), which are beginning to find some public space to address societal concerns, for example those related to environmental protection and ecology (Knup, 1997). Another welcome development is the vigorous debate that is taking place among economists as China endeavors to sustain economic growth. However, because of fear of retribution, reluctance still exists, even in academic circles, to have an individual name attached to a particular opinion. It is quite possible that as China's government starts to balance the societal benefits and risks of social organizations, professional societies with Chinese characteristics may emerge.

For reasons that may seem obvious now but were unforeseen as recently as a decade ago, the personal computer has become a liberating force in China. And, ironically, the government bureaucracy was the first to embrace the PC and encourage its development and diffusion. The reason is simple: Typewriters were never a viable option for China, since the character-based Chinese language, unlike other Asian languages, has defeated every attempt at phonetic writing for widespread use. Therefore, Chinese have until relatively recently had to either hand write their documents or print them in a press. PCs, which can accept, display, and print Chinese characters just as easily as they do the Roman alphabet, are liberating Chinese communication. With the "five-stroke" keyboard input method, it actually takes fewer touches of the keys to express a thought in Chinese than in English. Thus, computers now facilitate not only the functioning of the bureaucracy but also the diffusion of ideas through desktop publishing, and now, Internet connectivity.

Poised for Internet Connectivity In a purely coincidental development, China started to invest heavily in its telecommunications infrastructure at the time when worldwide systems had already migrated from analog to digital formats for data transmission (Economist, 1998; Hao, 1997). Therefore, China's telecommunications infrastructure ab initio was poised for Internet connectivity. It did not take long for Chinese entrepreneurs (Mufson, 1998b) to seize this opportunity and for China's government to become sensitized to the potential of the Internet to contribute to economic development. Despite official pronouncements about government controls of access and content, the government is quietly supporting Internet implementation in China.[5]

Access to the World Wide Web has been a reality in China for some time already.[6]

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[5] An excellent example of the vertiginous speed of Internet development in China and the rush of the government to embrace it, not withstanding misgivings about content (Einhorn, 1998), is the launching of China Market (http://www.chinamarket.com.cn), a website catalog of products for export. China Market, sponsored by the China Ministry of Foreign Trade and Economic Cooperation, allows would-be buyers anywhere in the world to search or browse a range of Chinese products and reach suppliers through e-mail or by logging onto their websites. Bulletin boards that post items to buy and items for sale, and password-protected chat rooms where bulletin-board-style negotiations can take place, supposedly away from prying eyes, are available at the site. The bulletin board I looked at offered tons of Russian mercury, thousands of 486 computers, and quite a few other items in between The Haier company CFC-free refrigerators are featured prominently on the site.

[6] According to a survey carried out by the Computer Network Information Center of the Chinese Academy of Sciences, Internet users in China topped 1.18 million in June 1998. This represents a

The opening of the Yahoo China site a few weeks before this issue of The Bridge went to press adds a full China dimension to the web. On-line translation facilities offer a promise of language-independent exchange of ideas. Yet, the adoption of the Internet poses some interesting questions that have not been completely explored in the United States, much less in China. These include:

- What should be the nature of scientific and technology discourse in a Web environment?
- Can this discourse take place easily across cultures?
- What is the role of such discourse in creating new knowledge?
- How can discussion forums be made accessible to all, and what is their impact on knowledge creation?
- What is the potential for these forums to become "virtual" professional societies, and, relatedly, how should leadership and direction be established?
- Can the Web become a surrogate for professional societies in China by keeping the participants anonymous, thus protecting contrarians from retribution?
- Will the Web lead to the formation of global professional societies that can promote supranational agendas?

The answers to these questions, and globalization that is already taking place, may have a deep impact on the whole of China's science and technology enterprise. A vivid example of the breadth and depth of debate that is already possible on the Web in China and about China is the real-time chat that took place on the ABCNews.com website as President Clinton's address at Beijing University on June 29 streamed live off the site's chat page. Peter Jennings had announced the chat on ABC Nightly News, while word spread around China by e-mail. Cybercafes, like Edward Zeng's Sparkice Cafe at China World in Beijing, provided access to those without Web connections. The number, candor, and diversity of participants and opinions on both sides of the Pacific, on such hot button issues as Taiwan, Tibet, the Dalai Lama, the environment, human rights, religion, and censorship, was extraordinary (Benkoil, 1998).

My hope is that this paper provides a useful framework within which to discuss technological innovation in areas such as energy (fossil fuel and clean coal, nuclear, hydropower); the environment (global warming, water pollution, acid rain, biodiversity); aerospace; telecommunications (land and space based); air traffic control; supercomputing; and advanced manufacturing. Interactions in these areas are often the source or victims of strains in the U.S.-China relationship. Therefore, to address any one of them in a serious way requires the discussion to be framed within the context of this ever-shifting bilateral relationship, which is beyond the scope of this paper. Suttmeier (1998), however, has already made an excellent initial attempt to do this. China's engagement of science and technology to help its transition into the 21st century has thus far been successful. However, the pace of change has been less rapid than China would have liked. The crisis of confidence in Southeast Asia and Japan could easily spread to China, damping some of the enthusiasm for change and perhaps even reversing some of China's accomplishments over the past decade. But, if China can sustain its equilibrium during this transition, and the United States and

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doubling since October 1997. The survey indicates that a full 75 percent of users expect to use the Internet for business transactions. At the same time, 45 percent believe that there is no effective fund-transfer system for electronic commerce and 90 percent complain that system loads are too high and access is too slow (Wang, 1998).

China can manage the tensions that are natural in a relationship between giants, both China and the United States will benefit from China's rapid development.

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