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Overview: I would like to thank the Commission for organizing this special hearing and for taking up the issue of China's technological development. China's emergence as an increasingly significant player in global economic and technology affairs raises a number of important challenges for the United States. These challenges stem from the fact that the rapid changes occurring in China's international role are part of a broader set of fundamental changes in the structure and operation of the world's S&T system--engendered, in large part, by the onset of the process of globalization. Since the last decade of the 20th century, no less than five major continental-size economies have expanded their level of participation and deepened the nature of their involvement in international economic and S&T affairs—China, India, Russia, Mexico, and Brazil. Add to this mix the growing technological capabilities of the so-called "Asian four tigers"—South Korea, Taiwan, Hong Kong, and Singapore, plus Japan, and we must recognize that the world's S&T order is already in the midst of a paradigm change of immense consequences for our country. Simply stated, there is no turning back the clock insofar as the evolving landscape of global economic and technology affairs is concerned; as new competing centers of technological excellence emerge, the US will no longer be the sole or even the leading "rule maker" or trend-setter in everything ranging from scientific breakthroughs to the setting of technical standards. Accordingly, it is incumbent upon the US—the business, academic and government communities--to take stock of the features of this new playing field, to alter many of our existing operating assumptions about key success factors, and to prepare ourselves for a world of more intense competition and perhaps greater turbulence in the coming decades.

Just as we have witnessed important changes associated with the globalization of product and capital markets, we also are experiencing critical changes associated with the globalization of technology. Generally speaking, there is a more general awareness around the globe today regarding the strategic role of technology in driving both economic progress and international competition. In fact, technological advance has been upgraded to a national priority among many countries. Facilitated by the revolution in communications and transportation, the liberalization of economic and trade policies, and a combination of both increased domestic and foreign investment, new centers of pronounced technological capability have started to appear outside of the US, Europe and Japan. As the world's leading multinational firms seek to take greater advantage of critical knowledge and skill complementarities that now exist across a range of different economies, the processes of technological exploration and exploitation have become further globalized. In many instances, globalization has led to the more rapid movement of technology and know-how overseas at an earlier point in their so-called life cycle. The new core competency for success in this demanding environment of technological globalization is the ability to identify, harness and manage the forces for transborder innovation and technological advance. This holds true for universities as well as the commercial world. As Ghoshal and Bartlett have demonstrated in their seminal book *Transnational Management (McGraw Hill)*, the hallmark of competitive advantage in a world of globalization, is knowing how to link and leverage knowledge, information and people expertise across borders and cultures.

According to a business survey published in September 2004 by the Economist among 104 senior executives from the world's leading multinational corporations (Scattering the Seeds of Invention: The Globalization of Research and Development), 52% of the firms indicated they had plans to expand their overseas R&D activities over the next three years. The most crucial imperative among multinational firms is to shorten the time it takes to commercialize new innovations. The key to success, in this regard, is fully mining the global talent pool, which involves effectively tapping into "the new centers of scientific and technical excellence that are mushrooming around the world." In fact, it might not be too far fetched to suggest that, somewhat akin to the patent wars of the 1980s and 1990s, the United States is about to find itself in the midst of a global war for talent. Interestingly, in this regard, China was named the top destination for future R&D growth among 39% of those interviewed, closely followed by the US (29%) and India (28%).

As indicated above, at the forefront of the changes associated with globalization stands China, a nation whose political leaders and technical community have placed great faith in the development of science and technology as a tool to enhance their country's modernization and international role. China's growing technological prowess has become an increasingly important catalyst in the evolving re-configuration of the world's manufacturing and knowledge networks. Cities such as Dalian, for example, are now being touted as emerging centers of excellence for providing software services for both regional and global markets. Currently, the most critical manifestations of China's technological advance lie in the steady quality improvements that already have occurred with regard to the country's human resource base and its physical infrastructure. In short order, the payoffs from on-going economic reforms and structural change in the S&T system are likely to be more consistently realized as well, thus further drawing China into the mainstream of international S&T competition and cooperation. I would argue that the key issue for the United States regarding China's technological advance has less to do with how to respond to a potential Chinese technological threat or how to deal with China as a possible competitive adversary, and more to do with how we engage China as a strategic partner in a world where scientific progress and technological advance are no longer simply within the purview of one nation. More specifically, the real questions are first, whether, as a country, we can truly grasp—in both political and technological terms--and take advantage of the unique opportunities for our country and the world that derive from the emergence of more technologically capable China; and second, whether we have the political will and commitment to prepare, educate and train ample numbers of junior and senior professionals--scientists, engineers, and managers--who can interact and work effectively across borders and cultures with their Chinese counterparts. Our strategic goal as a nation vis-à-vis China should be to capture potential technological synergies, take advantage of evolving scientific and technological complementarities, and collaborate successfully to push out the frontiers of science and the boundaries of technology for the mutual benefit of American and Chinese citizens as well as the rest of humankind.

Stocktaking of Science and Technology in China: To understand China's growing role in global science and technology affairs, it is essential to appreciate a number of the critical changes that have taken place across the Chinese S&T system over the last 5-10 years. The decision of many foreign companies to establish substantial R&D centers in China is closely linked to the recent evidence of progress in a number of key areas.

China's leadership sees ongoing progress in science and technology 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. As someone who has been working professionally on the study of S&T advance in the People's Republic of China (PRC) for about 25 years, it is clear to me that China has entered an important watershed period in terms of the operation and performance of its science and technology system. After undergoing two decades of structural reform that began under the leadership of Deng Xiaoping, the Chinese science and technology system is positioned for an important take-off—the question is no longer if this will happen, but rather when. 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 long run, a scientific and technological superpower.

The evidence for suggesting that China has reached such an important milestone comes from a broad array of data points across the PRC's S&T system. Let me discuss several of the most recent positive developments, all the time recognizing that China's S&T system is not some sort of unstoppable juggernaut that knows no limits; nor is it an example of a failed experiment in structural reform. China's recent progress cannot be ignored as the following two examples indicate: a)the development of the Dawning-4000A computer, running at a speed of over 10 trillion operations per second (10 Tflops) and ranked tenth in the world in 2004 on the list of the world's top high performance computers and b)the launch of Phase II of the Qinshan Nuclear Power Plant (Zhejiang) in May 2004, which marks the operation of the first large-capacity nuclear power station independently developed by Chinese engineers. There are others involving space as well as biotechnology and the human genome. At the same time, it should be realized that there still are numerous structural hurdles and resource constraints that China must overcome before it can begin to approach the comprehensive scientific and technological strength of countries such as the US and Japan.

First and foremost, it is apparent that the inputs contributing to the formulation and implementation of science and technology policy in the PRC have become more sophisticated and globally oriented. China is now focused a creating and perfecting a fully integrated "national system of innovation," with the goal of bridging together those critical components needed to enhance the overall yield from growing investments by government and industry in research and development. Overall expenditures on R&D have now reached 1.3%, reflecting a rapid acceleration in spending on R&D over the last five years. Based on country data from the AAAS for 2003, China is now the third largest R&D spender in the world, trailing only the US and Japan. And, while there are still considerable differences in the magnitude of spending on R&D between China and the US, it should be realized that increases in Chinese S&T spending have grown faster than the growth of the overall PRC economy according to statistics provided by China's Ministry of Science and Technology. Of course, we should be careful not to mistake quantitative growth with qualitative improvements as large components of the Chinese S&T system remain inefficient and ineffective users of available funds. Nonetheless, it also is safe to say that current Chinese policymakers and experts recognize that as they devote more resources into the S&T system, they also must attack, with great vigilance and steadfastness, the problems of bureaucratic red tape and organizational inertia that remain in numerous parts of the system.

Second, driven by a combination of economic reform and globalization, China is engineering the formation of a new technological architecture, one that is helping to re-define the rules, structures, and standards that have been in place over the last several decades. This does not mean that government has disappeared from the S&T landscape; through continuing state-sponsored high technology promotion and commercialization programs such as 863, 973, Climbing, Torch and Spark, the central government remains a major force behind China's effort to catch up with the West. The most compelling example of continued government leadership is embodied in State Council Document #18 issued in mid-2000, which continues to provide direction for growth of the software and semiconductor industries. That document was followed by a MOST initiative published in November 2003 called the China Offshore Software Engineering Project (COSEP), which has provided much of the impetus behind the further expansion of outsourcing activities, especially those targeted at the United States and Europe.

Nonetheless, like a gradual but steady volcanic eruption, the old elements of the planned, Soviet-style system are now progressively being pushed aside as the core features of a new science and technology system emerge. A good example of the Chinese willingness to be bold and even provocative is reflected in the Knowledge Innovation Project (KIP), a major reform initiative that has been introduced by the Chinese Academy of Sciences. The KIP project involves a significant restructuring effort inside the CAS organizational framework, leading to the closing down of a number of non-productive research institutes, the merging of others, and the introduction of new commercial incentives to ensure that CAS research activity is more closely linked to the needs of the economy. While we have not yet seen the full impact of the KIP project on R&D activity inside the CAS and there still are an assortment of obstacles to overcome, it is clear that there has been a major shake-up and the changes are anything but modest in terms of moving away from the often rigid modus operandi of the past and establishing new financially-oriented metrics and performance drivers for promoting a more innovative culture.

Related to the changes occurring in the CAS is the growing role of the enterprise as the major source of R&D spending in China. Chinese enterprises accounted for over 60% of the money spent in 2004 on R&D in China, a major change from the situation that existed when the S&T reforms were introduced in 1985. Chinese firms such as Huawei, Legend, Haier, Founder, etc. are now joining foreign-invested firms in helping to define the cutting edge for technological advance in China. Foreign investment has served as an important ingredient in helping to stimulate rather than constrain local technological gains, though the short-term focus of many Chinese companies does inhibit the creation of a real "culture of creativity" inside many PRC enterprises. George Gilboy, Edward Steinfeld and others have argued that we have yet to see firm evidence of true innovative performance coming out of Chinese industry. This is no doubt reflected in a close scrutiny of Chinese data regarding increases in high technology exports. The overall level of these exports indeed may be growing, especially in the IT and telecom fields, but still largely (though not exclusively) on the basis of products generated by foreign invested firms or through the assembly of parts, components and sub-assemblies imported from abroad. Nonetheless, I would argue that there also is discernible evidence of real progress taking place--as a result of new competitive pressures associated with WTO commitments, the continued opening up of the Chinese economy to competitive forces, and the expanded return of larger numbers of PRC nationals from abroad. The bottom line is that we are beginning to see an important convergence of critical success factors that will only enhance innovative performance inside Chinese industry. The path for China's technological future has been spelled out quite well in the following quote in Murtha's discussion of LCD technology in South Korea:

> "Stepping forward into on-going, knowledge-driven competition begins by taking a step back, recognizing that the point of entry is not a teacher's position, but that of a student. Follower companies can often take advantage of equipment, materials, licenses, process recipes, & consulting services that encompass important elements of the knowledge created by predecessors who have started from nothing. Creating the vital resources needed to succeed in a knowledge driven industry, however, does not begin with purchasing state-of-the-art technology, but rather with creating a basis in people for learning how to use it. Often this means entering the industry with current generation technology, achieving commercial yields, and running at efficient scale to build up the knowledge foundations necessary to seize a leadership position as the next generation emerges. Substandard returns or losses that come with late entry in current technology amount to tuition, reimbursable through timely entry to the next [technology]." From: Thomas Murtha, et.al, Managing New Industry Creation: Global Knowledge Formation and Entrepreneurship in High Technology (Stanford, 2001)

Third, there has been an appreciable improvement in the university sector in China. Not only has the system grown in terms of its capacity to produce larger numbers of university graduates—only a few years ago, only 3-4% of high school graduates could enter university in China—today that number has jumped to approximately 17%. China is now graduating more IT engineers than India; the Chinese churned out about 350,000

IT graduates in 2004 compared to 300,000 in India and 50,000 in the US. In addition, there is appreciable evidence from discussions with a broad range of foreign-invested firms in China that the quality and skill levels of graduates in the fields of science and engineering also have risen, though not necessarily evenly across the education system. Major investments have been made in providing new equipment and related resources to upgrade university laboratories and associated facilities. This enhancement of the physical infrastructure has been complemented by the steady improvement in the quality of the faculty. Problems of nepotism and faculty "inbreeding" are being attacked as the Chinese take on the challenge of creating a number of truly world class universities. Here again, these improvements admittedly have not been homogenous throughout the system, with university campuses in the West generally lagging behind those situated along the coast. There also are a large number of graduates that remain unemployed after graduation; estimates are that between 750,000-900,000 will have difficulties finding work this year. Nonetheless, China's universities have shown some remarkable progress that cannot be ignored when looking at the country's human resource endowment, particularly as the demand for higher skilled individuals increases in the years ahead.

Based on data from MOST, China now claims to have the second largest stock of scientists and engineers in the world, with the US still holding the number one position. That number reached approximately 1.3 million in 2004. Of course, on a per capita basis, the Chinese situation still reflects a comparatively weak position, with China being significantly behind Japan, Germany, France and Russia as well as the US. The highest quality professionals remain concentrated in Beijing, Shanghai, and Shenzhen, a situation that must be changed if scientific and technological progress is to diffuse to the country's Western regions and lesser developed areas. Experienced research managers and project leaders also remain in short supply, a fact that continues to be one of the key drivers behind recent PRC efforts to court more Chinese who hold positions in industry and academia in the US, Europe and Japan to return home to take on leadership roles. There is solid demographic evidence in various scientific and technical fields that China still continues to experience a "talent fault," that is, the after-effects of the damage to the country's talent pool wrought by the Cultural Revolution, with shortages in the numbers of senior, experienced technical and managerial talent still quite apparent.

Finally, and most relevant for purposes of this hearing, China has stepped up its interest in further internationalization of its science and technology system. From the perspective of bilateral science and technology relations, while the Sino-US S&T relationship continues to grow in several areas, it continues to under-achieve in many others. One reason is that the S&T component of our relations with China frequently has been treated as the icing on the cake in the face of other larger US foreign policy concerns; from the Chinese perspective, however, access to US science and technology resources has been the cake itself! The unfortunate demise of the US-China cooperative program in management because of inadequate funding is just one example of a failure on the part of the US to fully appreciate keys ways to reap benefit from as well as shape the evolution of the Chinese system. On the other hand, China's S&T relations with the European Union have become especially strategic; the European Union sees the net addition of

Chinese scientists and engineers to their own S&T programs as a key asset in its competition with the United States. China sees Europe as an alternative partner to the US, with the Europeans seemingly being more willing to place political considerations on the backburner while they focus on the mutual benefits of enhanced S&T collaboration with the PRC. More broadly speaking, Chinese scientists and engineers are becoming important participants in international science and technology affairs and are contributing an increasing share of papers to the world's technical literature, with there being growing evidence that the work of Chinese researchers is being cited in Western journals with increased frequency in fields such as nanotechnology, biotechnology, etc.

Even more profound, however, are developments that have occurred on the commercial side of the equation. China continues to have a voracious appetite for acquiring foreign technology, and as noted by *Business Week*, unlike Japan, there is no "not invented here" syndrome in the PRC. While financial constraints made it necessary for the Chinese to rely heavily on foreign investment during the first twenty years of the open policy, there clearly is now a stronger emphasis on securing access to know-how rather than equipment and process technologies to support manufacturing. The PRC government has introduced legislation over the last several years to make it attractive for foreign firms to bring not only manufacturing and distribution to China, but also to fill out the value chain and engage in R&D activities as well. Estimates are now that there are over 700 foreign R&D centers in China, with the number increasing steadily every six months or so.

We must remember it was not too far in the past when many foreign firms remained skittish about doing business in China and were skeptical about the staying power of China's reform program. Since the early 1980s, Chinese leaders have been quite forthcoming in declaring their intentions regarding the import of foreign technology and equipment to support China's modernization efforts. At that time, China lacked a growing market as well as a normalized business environment to attract many foreign firms, especially when it came to the transfer of high technology. And, to the great frustration and chagrin of Chinese leaders during this period in Sino-US relations, COCOM and US export controls further diminished Chinese access to state-of-the-art know-how, especially in the telecom, computer and microelectronics sectors. Today, however, that situation has changed in a fundamental way. China is now deeply embedded in the framework of global business and commerce. In the 1980s, management gurus such as Peter Drucker argued that American companies had to have an appreciable presence in Japan to be a true global player; today, those companies striving to position themselves globally will not be successful unless they have a significant presence in China, and not simply manufacturing and marketing, but increasingly, as suggested, research and development. Similarly, in the 1980s, Japan specialists such as James Abegglen and others suggested that the Japanese would continue to be the principal economic and technological force in the Pacific Rim for the foreseeable future. Today, however, we can say that a fundamental shift has occurred in the Pacific Rim technological order; Japan's once untouchable position as the premier technological power in the region is steadily, albeit gradually, being challenged by the continued rise of China.

There appears to be an increasing level of coherence as well as serendipity between the imperatives driving Chinese science and technology strategy, international competitive trends, and globalization. The need for new, expanding markets among multinational firms seems to fit nicely with the timing of China's increased market openness along with the growing prosperity and sophistication of Chinese consumers. More specifically, the Chinese value proposition--market access for technology transfer--has become a meaningful attraction for many of the Global Fortune 500. In addition, the ability of multinational firms to tap into China's labor pool and take advantage of the rapidly upward learning curve among many Chinese enterprises fits well with the Chinese desire to sustain high levels of employment and to expand technology-intensive exports. Gaining higher and higher levels of technological mastery has allowed China to assume a more central role in the global supply chain across key industrial sectors, including telecommunications, electronics (consumer and industrial), and information technology. Moreover, the growing desire among multinational companies to capture China's knowledge assets to enhance their local and global competitive position dovetails nicely with the PRC's objective of gaining expanded access to foreign know-how in design, product development, engineering, etc. Many multinationals now see it in their strategic interest to have a substantive R&D presence in the PRC. In essence, China has become the new battleground for the playing out of US-Japan-EU-Korea competition. Winning or losing in China now has global implications in terms of international competition in everything from pharmaceuticals to telecommunications. This means that newer, more advanced technologies are steadily being brought into China as various multinational companies seek to leverage their core technological strengths for competitive advantage in the PRC and abroad.

The rapidly expanding flow of foreign R&D into China has been complemented by a steadily growing, albeit much smaller, flow of Chinese R&D investment abroad. These investments are largely focused on establishing technological listening posts overseas to further facilitate the upgrading of China's technological base. Huawei, the leading Chinese telecommunications equipment manufacturer, has over ten such listening posts across Asia, the US and Europe. Along with helping to support Huawei's global aspirations, these operations also serve as a magnet for recruiting Chinese talent abroad, especially among those who are not yet ready or willing to return to China after living and working in the US for several years. The vibrancy of the Chinese technology networks around the world is one of the most dynamic elements in helping to explain the progress that has been made since the mid-1990s. In fact, Chinese information networks, which increasingly are linked to vibrant capital networks, already have become a steadily potent mechanism for helping to steer China onto a more innovative path. In this regard, the strategic role that Taiwan has played cannot be ignored, especially with respect to the IT sector and recent progress regarding development of the Chinese semiconductor industry.

To more fully encapsulate the impact of globalization on China's technological trajectory, I would like to offer four key hypotheses that we ought to consider as we contemplate how far and how fast the Chinese S&T system may progress in the coming years.

1. Unlike a number of other developing countries that have felt threatened or under attack by the forces of globalization, China seems to have embraced the onset of globalization. Globalization is now viewed as a strategic process for obtaining increasingly unencumbered access to state of the art technologies and know-how.
2. More and newer technologies are flowing into China at an earlier point of time in their life cycle than has occurred in any other developing economy since the end of WWII. The product life cycle, and associated technology life cycles, have been turned on their head in the Chinese case, even as complaints have proliferated and continue to abound regarding the leakiness of the PRC system for protecting and enforcing IPR.
3. The real strategic value of China for the majority of multinational firms lies not in simply gaining access to cheap labor, but rather in accessing China's higher end brainpower, that is, the cadre of heretofore under-utilized or inefficiently utilized scientists and engineers who are now part of a "global" talent pool.
4. More and more multinational firms will not only be setting up R,D&E activities in China, but they will be looking at the PRC as a strategic partner within their overall global innovation system, leading to even greater technological sharing, e.g. Alcatel Shanghai Bell

I want to stress once again that the picture I am painting is not either of an infallible China or of a Machiavellian China surging forward at the expense of the rest of the world. Rather, what we are seeing in the Chinese case are the results of 25 years of knowledge absorption and learning starting to kick in. Traveling to China 4-5 times a year for the last 20+ years, I continue to be impressed by the inherently more open and sophisticated nature of the discourse that is taking place across Chinese policymaking, business and academic circles. And, I also have been impressed by the growing transparency of the debates regarding science and technology issues. Foreigners, once largely isolated from policy discussions in China, are now asked to render opinions and conduct investigations about the degree to which progress has been made. The recent invitations provided to a broad range of foreign experts to offer their ideas regarding China's 15 Year Comprehensive Long-term Science and Technology Plan is just one such example.

"Grabbing the China market by harnessing the Chinese wisdom"

Foreign R&D in China: In the last part of my presentation, I would like to discuss some of the features of foreign R&D in China as a way for us to better understand where the future might take us in terms of the interrelationship between the US and Chinese S&T systems. In the late 1970s, as part of the so-called "new international economic order, many multinational firms set up R&D centers in developing countries as a way to exhibit their commitment to technology transfer and Third World economic development. In the majority of cases, however, these R&D centers were largely "hollow" operations, with little of substance—research or training--taking place inside except for some local product adaptation. Today, we see somewhat of an opposite picture emerging in the case of China. While clearly not all of the 700+ foreign R&D centers are engaged in state-of-the-art research—basic or applied--and most have eschewed a focus on basic research, there are a growing percentage of foreign companies who are filling out their complete value chain in China by deepening their R&D activities as part of a strategic global re-positioning of their business.

Like many other critical transitions in China's economic modernization drive and its relationship with the outside world, the growing role of foreign R&D in the PRC is being driven by a confluence of government and market forces. First, as indicated earlier, the Chinese government has emphasized the importance of strengthening the country's technology base and upgrading the innovative potential of PRC enterprises. Accordingly, in April 2000, MOFTEC (now MOFCOM), issued Circular Waijingmaozifa #218, which basically formalized the status of foreign R&D centers in China by providing guidance and details on the rules for their establishment. In April 2002, MOFTEC's foreign investment legislation was modified to change R&D activity from a permitted" to an "encouraged" form of foreign investment. These new policies complement a series of related changes that have taken place with regard to the importation of foreign technology. Moving away from the restrictive regulatory regime of the 1980s and 1990s, in 2002, Beijing radically revised the existing legislation regarding foreign technology imports. In essence, the spirit and intent of these revisions has been to promote smoother and faster movement of technology and know-how into China by shifting the PRC government emphasis toward approval rather than tight control.

Under the new rules for foreign R&D centers, ownership structures can vary from equity joint ventures to wholly-owned enterprises. To qualify for formal R&D status, however, 80% of the staff must hold a college degree and be involved in actual R&D activities. Two types of R&D activities are permitted under the legislation: 1) an R&D center whose main purpose is to engage in the general transfer of know-how to any entity; and 2)an R&D center that is controlled by a parent firm and is involved in research for which it will be reimbursed expenses plus a reasonable profit. In the latter case, the expectation is that the IPR belongs to the parent sponsor. R&D centers, however, cannot engage in so-called "technology trade" that is not the product of their own research and development efforts. These foreign R&D centers are eligible for a range of tax incentives as well as tax relief for equipment imported to support the R&D activities. In addition, the Chinese government has committed itself to easing visa requirements to enable entry and exit to/from China for both locals and foreign nationals employed at the center. Moving beyond the preferences offered by the central government, both Beijing and Shanghai have issued their own regulations to further encourage foreign companies to set up R&D operations in their respective cities; some of these regulations are aimed at attracting expertise from outside China's coastal areas by awarding residency permits, etc.

A second driver behind the growth of foreign R&D centers in China revolves around the issue of technical standards. Since the mid-1990s, Chinese government policy has placed a greater emphasis on acquiring technical know-how to enable local industry to gain a greater percentage of the revenues associated with licensing and technical standards. In January 2005, XU Jianguo, Vice-Director of MOST's Development and Planning

Department, announced that the Ministry will provide a new injection of funds into R&D for the purpose of establishing 29 international technical standards. The original program, which began in 2002, now involves more than 2,100 scientists and experts working in such fields as environmental protection indicators, trace element examination, textile safety, broadband local area networks, and RFID. Given the steadily expanding size of the Chinese domestic market and the potential weight of Chinese market power on an international level, foreign firms have been anxious to shape or influence China's decisions regarding which standards are being adopted in telecommunications, software, computers, pharmaceuticals, etc. Perhaps no area better illustrates how the competition for standards setting has drawn in foreign R&D investment than mobile telephony. Siemens, Nokia, Ericsson and Motorola have all made substantial investments in building out R&D operations in China in this highly competitive sector. Nokia, for example, used its R&D capabilities as leverage to secure a position in the CDMA handset market in China, while at the same time hoping to secure an advantaged position by working with its Chinese counterparts on further development of CDMA technology. As the requirements and sophistication of Chinese consumers continue to rise in the highly dynamic mobile phone market, local R&D is needed to get new products into the market quickly and reliably, thus helping to set trends and win market share.

Cost-cutting considerations are clearly a third driver for attracting foreign R&D to China. The data seems to vary from city to city and from province and province, but the fact remains that the loaded costs of employing and supporting an engineer in China run about 20-25% of a US counterpart. The issue, however, is not always one of cost-based substitution. In many instances, the movement of R&D to China by foreign firms also reflects a desire to create a critical mass of talent, at affordable rates, that can be utilized to focus on an auxiliary problem or alternative technical solution that otherwise might ignored and bypassed due to lack of available staff and funds in the US. Moreover, the presence of an advanced technical team in China, especially with local language skills and cultural familiarity, gives the foreign firm a better chance to work with local suppliers and vendors to ensure that domestically manufactured parts and components meet required levels of quality and performance. Once local Chinese R&D teams can be integrated culturally and operationally within the global R&D infrastructure of a large multinational firm, they are ready to service global markets as well as the local Chinese marketplace. This is clearly the intention of firms such as Microsoft, IBM and GE—all of whom have steadily grown their research presence in China.

Professional services companies in the human resources field, more commonly known as "headhunters," have found that the demand for their services has substantially increased over the last 2-3 years. In the 1980s and 1990s, the major headhunters, mostly based out of HK and Singapore, spent the bulk of their time finding appropriate expatriates to take top managerial assignments in China. Today, they have expanded their operations to Beijing and Shanghai, and their principal focus is largely on identifying experienced PRC nationals in China and abroad who wish to return home to assume a leadership role in these types of foreign-invested R&D centers and technical organizations. Chinese scientists and engineers, at home and abroad, are drawn to working in foreign R&D organizations because of the nature of the projects, the opportunities for training and travel overseas, better salaries (though not always), and more varied career opportunities. As the staffing needs for these foreign R&D operations have grown, the result has been the creation of an emerging internal brain drain problem, with some of the best and brightest Chinese talent forsaking opportunities with domestic companies and government labs for the seemingly more exciting career path in foreign-invested organizations.

Fortunately or unfortunately, depending on one's perspective, this problem may be short-circuited by the further growth of technological entrepreneurship in China. There is a saying in Chinese, "it is better to be the head of a chicken than the tail of an ox" [ning wei ji tou, bu wei niu wei]. The high turnover rate for junior and mid-level talent in both foreign-invested and domestic R&D operations reflects their apparent willingness to further "jump into the sea" and embark down an entrepreneurial path that increasingly involves starting their own firms. This is not much different than what happened on Taiwan in the late 1970s and 1980s in Hsinchu Park, when many local engineers left employment with foreign companies such as Motorola and General Instruments to open their own firms—sometimes with indirect government support and even encouragement. One particular difficulty that has already arisen in China from the rapid circulation of such technical talent, however, deals with the security of IPR and adherence to confidentiality agreements contained in employment contracts with their foreign employers. With many foreign firms utilizing trade secrets and not always patents to protect their IPR, it is sometimes hard to prevent critical know-how from being used inappropriately in some of these start-up firms. This also is the case with some returnees from abroad, who have left positions with US-based firms to begin an entrepreneurial journey in China.

There are a range of other drivers that account for the step up in the number of foreign R&D centers being established in China. Some of these factors exist on the "push" side rather than the pull dimension. They include tax and visa policies at home in the US, the growing pressures on compensation and benefits packages, and overall problems regarding the availability of well-trained technically-oriented individuals. Most critical, however, remains the imperative of global competition, which continues to be creating more pressures for more sustained innovation, greater customer responsiveness, and more rapid commercialization of new products and services. China's role in this regard promises to be anything but passive. PRC government policies are distinctly based on the notion that the expanding number of foreign R&D centers will serve as a catalyst for sparking new innovative behavior throughout the economy.

Heretofore, it is safe to say that the contributions from foreign R&D activities in China still remain limited, though this has much to do with the fact that the phenomenon is still in its early stages of development. A number of important questions remain, nonetheless. For example, will foreign R&D in China become an integral part of the PRC's national innovation system? Is there a formal capture strategy in place or being conceived by the Chinese government to ensure that the contributions from R&D can be absorbed? And, is China's national innovation system structured and developed to the point that it can maximize the benefits from being steadily embedded in a comprehensive web of global knowledge networks in world science and international engineering? At the present time, the response to these three key questions would seem to be, “stand by, the answer is yet to be fully determined.” That said, from both a policy and organizational perspective, there has been growing evidence that the Chinese S&T system is indeed pointed in the right direction as it seeks to optimize the growing presence of foreign R&D activity. While the direction of China’s technological progress may not be always linear, aided and abetted by the development of continuously more cohesive relationships with the world’s leading technology-based corporations, the pace of progress will likely be more rapid than we might anticipate.

To get more specific, so far, the identifiable contributions from foreign R&D in China seem to lie more in the world of intangible benefits rather than concrete ones. Nonetheless, they still are critically important as a precursor to more rapid Chinese technological advance. They fall into the following areas, many of which in the past have been areas of major weakness for the PRC:

- Training: technical training, cross-functional/cross-cultural teaming, and product and process design methodology, esp. electronic design automation for shortened design cycles;
- Technology transfer: the diffusion of “uncodified” trade secrets rather than specific patented information;
- Standards: best practices, industry standards, performance metrics, and quality requirements;
- Software: programming methodologies, software design architectures, systems integration techniques, and overall testing procedures and quality assurance;
- Management: project management, business management, and management of knowledge workers;
- Networks and information resources: participation in global knowledge networks;
- Spin-offs: new business ventures and entrepreneurial activity; and
- Spillovers: technical assistance to vendors and suppliers.

In the final analysis, however, as Chinese policymakers fully recognize, the R&D activities of foreign firms in China are driven by the strategic agendas of these companies. To gain a deeper, longer term commitment from foreign firms in the R&D area, China will have to improve its overall enforcement of IPR protection. This also is true with respect to China’s efforts to develop its software industry, especially if the country hopes to move beyond basic, low-end outsourcing activities. The need for better IPR enforcement is often affirmed by many academic, business and legal observers of the Chinese scene, though with little expectation that much will be done in the short term. Strong IPR enforcement also is necessary for MNCs to be willing to engage in more extensive basic research in China. Securing this type of scientific-oriented research is very much coveted by China’s S&T leadership. Venture capital will be hesitant about supporting technological entrepreneurship if there continues to be pervasive apprehension that IP rights cannot be made secure. Based on the experience of other Pacific Rim economies, the key to solving the IPR problem in China actually lies in the degree to which the roots of local technological entrepreneurship take hold. With locally created

IP at risk, the appropriate conditions will exist for local government and enterprise stakeholders to make progress in cracking down on those who violate foreign and domestic IP rights.

Implications for the United States: At the beginning of this presentation I raised two critical questions: 1)whether we fully grasp the ramifications of the new globalized technological environment of the 21st century—in which China is becoming a key player; and 2)whether as a nation, we have the will and capabilities to prosper as new rules kick in and new success factors are defined. Coming to a better understanding of the prospects for future Chinese scientific and technological development is of considerable importance for evaluating and managing the consequences of China's political, economic, and social evolution in the coming decades. There are those that would discount the importance of China's emergence in the realm of science and technology simply because they do not see ample evidence of substantial Chinese progress at this time. In this group, are those whose analysis of China's S&T system tends to emphasize the shortcomings of Chinese R&D performance and the continued lags in innovative capability. At the other end of the spectrum are a range of analysts who tend to be alarmists about China's emerging technological capabilities, raising, at times, exaggerated concerns about China's ability to acquire—through legal or illicit means—as well as absorb and assimilate all types of know-how and equipment from abroad. In reality, both perspectives suffer from the same weakness—they fail to capture the complexity and dynamism of the rapid pace of change both inside and outside of China.

Globalization, complemented by economic reforms and structural changes in the S&T system, has changed the playing field for the PRC. The Chinese leadership, once seemingly daunted by the forces of interdependence and globalization, now sees enhanced opportunities for China to gain access to advanced technology and know-how. Thinking about Chinese behavior in terms of a tension between the forces of techno-nationalism and techno-globalism actually creates a false and somewhat inaccurate dichotomy for understanding China's current international orientation; these two seemingly contradictory constructs are really part of the same behavior, with techno-globalism and techno-nationalism intertwined in a single, synergistic relationship with one another. Technonationalist imperatives drive Chinese technoglobalist behavior, fostering expanded economic reforms and greater openness—both of which, in turn, facilitate more foreign involvement in the PRC economy through FDI, technology transfer, and the establishment of foreign R&D centers. Technoglobalist actions support Chinese techno- nationalist goals and objectives as broader and deeper engagement with the international science and technology system serves as an enabler for strengthening domestic technological capabilities. While not completely devoid of their old penchant of seeking technological self-reliance, China's current leadership seems to grasp the tremendous utility that comes from embracing (rather than attempting to thwart) the opportunities for cross-border cooperation and collaboration generated by increased globalization.

The United States must take a new look at the tremendous opportunities to be derived from China's scientific progress and technological advance. An enhanced ability by the

United States to tap into the steadily growing and improving human resource and technological assets inside of China—from universities to government think tanks to high tech enterprises—will only help to enhance our own country's innovative potential. In spite of some noise in the US media, the good news is that American firms are at the forefront of understanding the meaning of the China's new global economic and technological posture, though in concert with the recent NII report by the Council on Competitiveness, they also seem to grasp the dangers ahead if the United States does not expend the resources needed to upgrade our own education system and support critical research activities in both academic and commercial settings. A growing number of American universities as well are re-positioning themselves to take advantage of the opportunities for cross-border research collaboration created by recent S&T progress in the PRC and several other countries. It will not be long before a large percentage of American universities enter the borderless world, with the walls surrounding traditional academic departments coming down and departmental faculty being dispersed around the world instead of being physically co-located in one geographic venue.

As things currently stand, however, there simply does not seem to be enough appreciation in Washington, DC for how we "win" in the changing globalized world of the 21st century. The United States government needs to invest more in the training of a whole new generation of future leaders who are, at the same time, more cross culturally aware, more managerially adept, and more technologically savvy than their predecessors. To be sure, we must be more expert in our ability to monitor and analyze developments in the Chinese S&T system; we currently lack sufficient numbers of faculty and graduate students who are preparing for careers that would have them delving deeply into the emerging pockets of scientific and technological excellence in places such as China. Moreover, we also must have a cadre of individuals who are adept at seeking out opportunities and working on team-based, collaborative projects with relevant counterparts from around the world whose names may be even more difficult to spell than pronounce. America's technological future is not simply tied to protecting and advancing our own national system of innovation, but rather in creating and developing a global system of innovation, with the US in a leadership role by virtue of our enhanced global awareness and cognition. The rise of China gives us a unique chance to test the efficacy of our global commitment. If we simply envisage China as a foreboding technological threat—potential and real—we are more likely to adopt behaviors towards the PRC that will increase the chances of that becoming a reality. Or, we can view China as an increasingly capable strategic partner that affords us critical opportunities for seizing upon real and potential technology synergies and complementarities. As the Chinese look on, our actions will clearly set the tone. The final choice remains ours to make.