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Section III – Background Papers

Lessons Learned from the U.S.-China Scientific and Technical Relationship 1970 to the Present[1]

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Preface

In writing this paper my presumptions were 1) that U.S.-China scientific and technical relations are not receiving the serious, integrated national attention that they deserve, neither in the United States nor in China, 2) that with efforts by both sides they can be given their due attention, and 3) that scientific and technical relations between the United States and China can play a leading role not only in bettering the overall U.S.-China relationship but also in convincing each side of the trust and goodwill of the other across the entire spectrum of the relationship. While I feel that presumptions 1 and 2 are realistic, regrettably I do not feel the same with regard to presumption 3. That is, I can no longer believe that scientific and technical relations can overcome the strong forces pulling both countries in the direction of increased tension. Neither the will nor the objective basis for mutual trust is evident in the overall U.S.-China relationship that would allow the S&T relationship to reach its full, positive potential. Nevertheless, we have to try to make the S&T relationship as meaningful and beneficial for both sides as possible in these circumstances.

Introduction

The United States and China have been engaged in scientific and technical relationships since the historic reestablishment of contacts in the early 1970s following a generation of political separation and animosity. News of the secret trips to China by National Security Advisor Henry Kissinger followed by the famous visit of President Nixon to China and his meetings with Chairman Mao Zedong and Premier Zhou Enlai captivated the American public; and the signing of the Shanghai Communiqué ushered in a new era of scientific and technical (S&T), trade, and cultural contacts finally leading to what was called the "normalization" of ties in 1979 – that is, the establishment of diplomatic relations. The breadth, complexity, and sheer size of current U.S.-China S&T relations could hardly have been imagined back then even to the most ardent of proponents. Yet despite the generic meaning of the term "normalization", the overall relationship between the United States and China has never been "normal" and probably never will be simply given the sheer immensity of the two nations and their impact on the rest of the world. This is an important reality to keep in mind as we seek to identify lessons learned from the S&T relationship and to contemplate how we might apply those lessons to problems of today and tomorrow.

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1. *Editor's note*: transcripts of interviews by Mr. DeAngelis with several Americans who were instrumental in U.S.-China relations during their early years are appended.

As we look back at the development of S&T relations over more than thirty-five years, our logical minds compel us to seek lessons. However, it is easier to identify "things learned" than it is to draw "lessons" from them as the very concept of "lesson" implies something that can be applied to current or future problems. Richard P. Suttmeier, a noted authority on China's science and technology, confessed this very same difficulty when he tackled the problem of divining lessons from the S&T relationship with China in a paper that he wrote in 1998.[2] Nevertheless, as he did back then, I shall also attempt to identify lessons learned, partly by using the general typology that Suttmeier applied in his paper in order to simplify the search for lessons, and partly by adding some factors of my own. His typology included the role of governments, motivations for cooperative activities, and implementation. To these I add the role of scientists and engineers, the role of students, and the role of non-governmental sectors (universities, corporations and professional organizations). It is essential that we understand all of these roles and factors before we can reasonably hope to draw lessons from what we have learned.

Let us also acknowledge here that two nations as large and diverse as China and the United States will have many goals and desires. So, when we speak of China wanting this or that or the United States wanting this or that, we are really talking in highly aggregate terms. For example, if we say that China wants advanced technology to make a strong nation, we shouldn't think that individual Chinese scientists have the same goals. In fact, one thing that we have learned through thousands of cooperative research projects is that scientists in China tend to want the same things as scientists in the United States, i.e., to do the best research possible in their particular fields without too much thought about grand, national goals. We should keep this distinction in mind as we attempt to divine lessons.

AN OVERVIEW OF MAJOR FACTORS SHAPING THE S&T RELATIONSHIP

The Role of Governments

The two governments have played a fundamental role in establishing and maintaining the conditions through which the S&T relationship can proceed. They serve a monitoring and review role through the US-China Joint Commission on Cooperation in Science and Technology; and they also serve a programmatic role through the management of agency-to-agency protocols or cooperation and exchange. Without the initial rapprochement between the two governments in the early 1970s, the relationship among scientists could not have flourished. At the time of these historic events, the two governments were eager to establish communications for a number of well-known reasons. One reason that they shared in common was to establish communications that would act as a counterbalance to pressures from the Soviet Union. The scientific, trade and cultural ties agreed to in the Shanghai Communiqué thus served the geopolitical interests of the two countries.

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[2] Suttmeier, Richard P, "Scientific Cooperation and Conflict Management in U.S.-China Relations from 1978 to the Present," Annals of the New York Academy of Sciences, Vol. 866:137-164, December 1998. I urge anyone interested in this subject to read this entire article as it captures most of the important themes and issues that we are dealing with now, eight years later.

Partnership between the U.S. government and leading U.S. academic institutions made it possible both to monitor and to steer the new S&T relationship. During the first two decades of the S&T relationship, the U.S. government strongly supported three private entities that were officially designated as "facilitating" organizations – that is, organizations outside the government that would facilitate contacts in lieu of direct diplomatic relations. These organizations were the Committee on Scholarly Communication with the People's Republic of China (CSCPRC), for science and technology; the National Council on U.S.-China Relations, for cultural relations; and the National Council on U.S.-China Trade, for trade relations. The CSCPRC was housed in the National Academy of Sciences and was sponsored by the three most prominent, private, scholarly organizations in the country, the National Academy of Sciences (NAS), the Social Science Research Council (SSRC) and the American Council of Learned Societies (ACLS). This tripartite sponsorship brought together the main branches of learning in one body: science, engineering and medicine through the NAS, the social sciences through the SSRC, and the humanities through the ACLS. During this first two decades of relations these three scholarly organizations worked closely with the government and with the scholarly communities to insure that all legitimate interests were met.

The CSCPRC met regularly both with officials in the White House, including the Office of Science and Technology (from 1976 onwards, the Office of Science and Technology Policy) and the National Security Council, and with officials in the Department of State, including at that time the Bureau of Cultural Affairs. The CSCPRC also agreed to let State Department officials participate in U.S. delegations to China in order to provide them with the kind of direct access to China that they otherwise could not have obtained. For its part, the government, through various science agencies such as the National Science Foundation, the National Institutes of Health, the Department of Energy, etc., provided financial support to the CSCPRC greatly augmenting funds that the CSCPRC received from private foundations such as Hazen, Ford, Rockefeller Brothers, etc. For its part, The Chinese government supported the China Association for Science and Technology (CAST) as counterpart to the CSCPRC. CAST acted in close cooperation with the Chinese Academy of Sciences and the "Education Circles" of China (i.e., the State Education Commission, later the Ministry of Education).

After the establishment of diplomatic relations in 1979 and the signing of the umbrella agreement in science and technology on January 31, 1979 (the Agreement between the Government of the United States of America and the Government of the People's Republic of China on Cooperation in the Fields of Science and Technology), both governments continued to support their respective implementing organizations while at the same time encouraging individual science agencies to establish direct relationships and agreements known in diplomatic parlance as "protocols." For example, the National Science Foundation (NSF)[3] established a Protocol for Cooperation in Basic Science with

[3] I apologize for the fact that throughout this paper I refer often to examples involving the National Science foundation rather than to examples involving other U.S. science and technology agencies. The reason for this is simple: I know many more details about NSF, having worked there for 24 years, than I do about other agencies.

the Chinese Academy of Sciences, the State Education Commission, and the Chinese Academy of Social Sciences. Later, the newly-founded National Science Foundation of China (NSFC) joined the protocol. Likewise, the National Institutes of Health signed a protocol on medical sciences with the Chinese Academy of Medical sciences, and so on for many other agencies. The two governments also established the U.S.-China Joint Commission on Cooperation in Science and Technology headed by the Science Advisor to the President of the United States and the State Councilor for Science and Technology of the People's Republic of China, later changed to the Minister of Science and Technology.

Both in fact, then, as well as in appearance, support from the two governments for the science and technology relationship was indeed very strong. The governments established the framework whereby the two communities of scholars were able to pursue their own rapprochement after decades of estrangement; and they gave substantial financial support through their S&T agencies. They also made it possible, after the establishment of diplomatic relations, for their agencies to initiate long-term contacts in science and technology; and they provided the political and legal framework for industries and universities to initiate ties in pursuit of their interests. However, in the United States, after "normalization", the mode of operating the relationship became quite decentralized and pluralistic, much like American society in general. The U.S. government in essence promoted this decentralization by encouraging the science agencies to develop their own relationships with their own funding as well as by constructing the legal and diplomatic framework whereby individual corporations, universities, and individual scientists could self-initiate linkages with China.

Of course, the interests of governments change over time. With the downfall of the Soviet Union, the initial unifying geopolitical rationale for the relationship – that is, to counter the power of the Soviet Union – no longer existed. People had worried about whether this rather negative rationale for the relationship was sufficient and what might happen if that rationale were to disappear. I recall discussions among the members of the CSCPRC – scientists, social scientists, and humanists – asking rhetorically what binding rationale should exist, aside from the geopolitical rationale that someday might change. Should there not be a positive rationale that pertained specifically to the relationship between the United States and China rather than to any third party? Of course, the scholarly community answered this question by asserting the importance of the advancement of science for mankind as well as for the specific interests of each country. Likewise, other communities such as industry, universities, individual agencies, etc., each answered the question according to their own interests. The only policy that existed was the formula that "a strong and stable China is in the best interests of both countries."[4]

[4] The policy-formula that "a strong and stable China is in the best interests of both countries" goes back to the early 1970s. More recently, as noted in the President's 2002 National Security Strategy, the formula has changed: "[t]he United States relationship with China is an important part of our strategy to promote a stable, peaceful, and prosperous Asia-Pacific region. **We welcome the emergence of a strong, peaceful, and prosperous China**[emphasis added]" and "Our strategy seeks to encourage China to make the right strategic choices for its people, while we hedge against other possibilities." A link to the new version of this strategy and additional China language is http://www./whitehouse.gov/nsc/2006/nss2006.pdf . I have to thank Kathleen Walsh for pointing this out to me.

Such vague guidance was not very useful as China began to become a rival in the eyes of American policy-makers and officials concerned with the commercial and security interests of the United States.

After the downfall of the Soviet Union, the differences in the two governments' approaches to scientific and technical relations with each other accelerated. For the U.S. government, scientific and technical relations with China, which had started out as a means toward countering the power of the Soviet Union, increasingly became a cause of worry. The creation of the U.S.-China Economic and Security Review Commission (USCC) grew out of the concern that China would use S&T contacts and access to U.S. research gained through participation in the U.S.-China S&T Agreement to increase its commercial and military capabilities to the detriment of the United States. For the Chinese government, however, scientific and technical relations with the United States, as well as with other countries, were and are central to its goal of becoming a strong nation with a global presence, thereby assuming what it regards as its rightful status in the world. Yet despite the political differences between the two countries, S&T relations generally have remained fairly robust even in times of tension such as in the aftermath of the Tiananmen Incident or during the frequent disputes over Taiwan. I shall return to this theme a bit later.

Motivations for Cooperative Activities

For the Chinese government, one of the principal benefits of S&T relations with the United States was and is the ability to send science and engineering students to the United States to learn from leading American scientists and engineers, to absorb the latest techniques in research, to work in innovative and creative environments, to learn English as the standard world language for S&T, and to learn how to function in American society, etc. In the earliest days China had to make up for the losses suffered to a whole generation of students due to the closure of schools and laboratories during the Cultural Revolution. Even today the need continues to train large numbers of high quality scientists to make it possible for China to achieve its policy goals of building a strong nation through science and technology. Even though China has dramatically increased its domestic capabilities to train and educate students, it still recognizes now and for the foreseeable future that it must continue to send high quality students abroad so as to keep abreast of the world. It must also grow enough teachers, as well as scientists, if it hopes to keep pace as shortages of high-quality, experienced educators have become a growing problem because many current and likely candidates are being lured to profit-making or higher-paying jobs at home and abroad. For the above-mentioned reasons, I would argue that the ability to send students to the United States is still the one of the greatest benefits and highest priorities of China's S&T relations with the United States.

The Chinese government is primarily interested in science and technology as a means to economic development in the short term. Thus it is focused much more on technology than on basic science. The fact that China spends only 5% of its S&T budget on basic research, as opposed to 15-20% spent by developed nations, supports this view. Also, if we look at the "sixteen remarkable S&T achievements" of China that are listed in

Michael Pillsbury's 2005 paper entitled "China's Progress in Technological Competitiveness: *The Need for a New Assessment*," we see that their core focus is technological.[5] While it is also true that in the recent Medium and Long-term Program for Science and Technology in China the Chinese government has announced its intention to increase spending on basic research from the current 5% level to 15% or so between 2010 and 2020,[6] when you look only slightly deeper you will find that the basic research component of the Chinese mix of science and technology is much more targeted than what you find in the United States. Thus, speaking of these basic research funds, Vice Minister of Science and Technology Cheng Jinpei said, "Considering shortage of R&D funds, we need to gather those funds [speaking of basic research funds] into key research projects [973 Program] and make wise strategy for development."[7]

The U.S. Government's goals in S&T relations with China are harder to discern because they are not quite as single-minded as is China's drive for great nation status. Let's talk about the students first. Obviously many thousands more Chinese science and engineering students come to the United States than American science and engineering students go to China. The reason is obvious on one level: generally speaking the Chinese students have more to learn in science and engineering from coming to the United States than the American students from going to China. The United States benefits from having some of the world's brightest students working in American university laboratories thereby helping to keep American university research at top levels. The U.S. government hopes that exposure to the United States for thousands of China's future science leaders will make them favorably inclined toward us and toward our values.[8] It could also have the opposite effect, but at the very least it would provide them with a more realistic picture of the United States as a whole than they would get simply from reading about it or listening to the news. One of the facts that support this hope is that during the early days of the rapprochement it was precisely the Chinese scientists who had been trained in the United States who led the way toward better scientific relations with the United States. Not only did they serve this role, but the impression is that most of them, if not all, relished the opportunity to rekindle their friendships with colleagues in the United States.

Another benefit to the United States is that by training Chinese scientists in the United States, we can develop any personal attachments that could prove to be extremely helpful

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[5] Pillsbury, Michael, "China's Progress in Technological Competitiveness: *The Need for a New Assessment*," a report prepared for the US-China Economic and Security Review Commission, April 21, 2005, pp. 11-17: 1.) a new plant doubles production capacity of robotics firm; 2.) seven astronomical projects to explore space mysteries; 3.) nuclear industry pebble-bed technology; 4.) Shanghai supercomputer, 10 trillion calculations per second; 5.) China claims property rights to Pentium equivalent computer chip; 6.) immuno-chips for staphylococcus enterotoxins; 7.) Taiwan's largest semiconductor design service center in China; 8.) cell cloning technology – world's first buffalo cloned; 9.) plan to launch 100 more satellites by 2020; 10.) packetized optical switching – 10,000 times more data; 11.) major breakthroughs in China's mini-satellite; 12.) 3 examples of nanotech progress with Japan; 13.) new high-thrust rocket design technology; 14.) China, EU sign agreement on Galileo satellite navigation project; 15.) Xinhua lists PRC's space technology development; 16.) particle accelerator joint research.

[6] Ibid, p. 26.

[7] Ibid.

[8] Both rationales are given in the Department of State's U.S.-China Science and Technology (S&T Agreement) Cooperation: Report to Congress, Bureau of Oceans and International Environment and Scientific Affairs, April 15, 2005. See pages 2,3, and54.

in future in cutting through Chinese government red tape and hierarchy. This works not only in science but also in business and other spheres as well.[9] The Department of State also believes that the training of Chinese students in the United States will help the United States "to exert influence on China and advance social change in China."[10]

U.S. interests and Chinese interests also differ in terms of specific fields of interest. When the scientific rapprochement began, the CSCPRC pursued a policy of "reciprocity" not in terms of numbers but in terms of meeting China's interests while China was to meet differing U.S. interests. China's interests were and remain primarily in science, engineering, and technology. American interests were in these fields too, albeit from a different perspective in that our scientists were eager to know the status of research and education in their areas of interest and, it may fairly be said, to help Chinese scientists "level-up" their research. Yet, in addition to American interest in China's state of science and education, American scientists were also interested in China itself, and thus the CSCPRC proposed many contacts in the social sciences and humanities as well as in natural science and engineering. But American social scientists did not have any easy time accessing China. This difficulty in gaining access to social science research opportunities in China was evident from the very beginning when Premier Zhou Enlai personally accepted nine of twelve proposals from the CSCPRC and rejected three proposals that were in the social sciences, including China studies, urban studies, and science and technology in China's development.[11] And throughout the US-China S&T relationship, the social sciences have continued to be problematic. There are many reasons for this. Science and technology were given emphasis in China whereas the social sciences were not. Therefore, there wasn't as much to share in the social sciences. By nature, the social sciences involve aspects of society that centralized systems tend to want to control. In China the social sciences are linked to the Ministry of Propaganda and thus are at one and the same time outside of the realm of the sciences and closer to the heart of the Party. The social sciences were much less "professionalized" in China than the sciences and engineering. By this I mean that the social sciences had not achieved a separate professional center of gravity as legitimate fields of study that followed their own inherent rules and procedures. Despite these differences, many American social scientists, particularly of Chinese ancestry, have been able to gain access to social science research opportunities in China, especially in recent years, not particularly because the Chinese government has changed its policy toward social science research but more likely because after Deng Xiao-ping announced his opening policy in

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[9] Suttmeier, Ibid., p. 141-142, referring to a quote from Wendy Frieman, "Asian Winds, American Chills," in Todd M. Davis (ed.)Open Doors, 1995/96(New York: Institute of International Education, 1997), pp. 110-111. in which she speaks of how personal relationships formed as classmates together can help cut through the hierarchical structures of Asian institutions.

[10] Department of State, Ibid., p. 2.

[11] Wang Zuoyue, "U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond," in Historical Studies in the Physical and Biological Sciences, University of California Press, Fall 1999 v. 30, part 1, p. 214. I would must also point out that among the nine accepted fields were archeology, anthropology and early man, early childhood education, and linguistics, all fields that covered a range of interests from science to social science. It would be interesting if someone would take up this point for what it says about the difficulties that social scientists faced in other areas.

the late 1970s, the relative decentralization of authority in such matters made it possible for local entities to pursue their own interests.

The policy adopted by the CSCPRC of defining "reciprocity" in terms of exchange of differing interests, remained problematic throughout the history of the CSCPRC. In this sense it can be said to have been a failure in the sense that success would have been the achievement of complete openness to the U.S. social science interests in much the same way that, by and large, the United States was open to Chinese science and engineering interests. This does not mean that it was not worth promoting.

Implementation

In Suttmeier's typology, "implementation" refers to asymmetries in the institutions which the two sides brought to the relationship. He points out many of the asymmetries in motivations, levels of scientific development and wealth, and in the institutions that both sides brought to the relationship, but then he concludes:

> "…one might have predicted that programs of S&T cooperation would not have done as well as they have. Perhaps this puzzle points to one of the more important lessons of the case. Any attempt to manage these asymmetries and disparities centrally would almost certainly have slowed the progress of the relationship, if not led to its stagnation."[12]

The most obvious asymmetry was the organization of Chinese science according to the Russian model of centralized government institutions and academies governed by top-down decision-making vs. the much more diverse U.S. system of university-based research and bottom-up research programs and decision-making. Suttmeier also accurately points out that even in the case of government-to-government accords (agreements, protocols, memorandums of understanding, etc.) implementation on the U.S. side "was allowed to devolve to the technical agencies," with the result that "implementation tended to be driven by pragmatic agency concerns over program costs and benefits in relation to agency missions."[13] Specifically his refers to the fact that the U.S. government did not set aside or ask for from Congress any line item funds for the U.S.-China S&T relationship. (The same is true for bilateral relations with other countries as well, except for a few special bilateral commissions such as the US-Israel Bilateral Commission and the US-Mexico Bilateral Commission.) Thus, each agency despite being encouraged by the White House and the State Department to establish S&T programs with China was left to squeeze the monies for these programs out of their regular budgets. One may claim that this caused each agency to make sure that its programs with China were both fully competitive with its other programs and in compliance with their missions; but this would really be stretching the truth. Indeed, each agency did try to make the special programs as close to its regular way of doing business as possible, but in fact the political pressures from the White House and State

[12] Suttmeier, Ibid., p. 156.
[13] Ibid, p. 155.

Department often trumped any scientific justifications. In contrast, the Chinese government has always provided provides funding for the relationship to its agencies.

In fact, it is one of the most frustrating and abiding characteristics of America's international S&T relations that whereas they are usually started with political aims in mind, such as we are discussing here – that is, the reestablishment of US-China relations through initial S&T contacts – no separate funds are ever allocated for these purposes. Thus, each agency must dig into its own basic budget to carry out the political mandate initiated through the Department of State and the White House Office of S&T Policy. For this reason the funds allocated to international projects are always fairly small and even then begrudgingly given by those within each agency who otherwise would use them for their own agendas. The small amounts of funds and the lack of a clear government policy consensus as to the degree of cooperation with China that is desirable add up to a situation in which no agency wants to appear too forward-stepping in the relationship. This of course is not conducive to either innovation or creativity.

The U.S. – China Joint Commission on Cooperation in Science and Technology was established to monitor the overall relationship. It is chaired on the U.S. side by the Science Advisor to the President and on the Chinese side by the Minister of Science and Technology. It meets approximately every two years. The next meeting that will occur in China in October 2006 will be the 12th meeting of the Joint Commission. In the years up to 2002 the JCM was attended by numerous agency representatives of both sides who would hold separate meetings to discuss agency-to-agency activities under their various agency-to-agency protocols. In 2002, in preparations for the 10th meeting of the JCM, Science Advisor John Marburger and Minister of S&T Xu Guanhua agreed to restrict the JCM to selected heads of science agencies, particularly those with independent science credentials. The reason for this was to make it possible for the smaller group of government agency leaders to discuss issues of broad importance to the overall S&T relationship.[14] The details of agency-to-agency cooperation were thus to be handled by the various agency counterparts. In between meetings of the Joint Commission, the Executive Secretaries meet to discuss implementation details. The agency-to-agency counterparts have tended since then to cluster at the time of the Executive Secretaries Meetings.

As mentioned above, the first JCM meeting that took this smaller group approach occurred in 2002 in Beijing. At that time the members of the JCM on both sides agreed to identify seven fields for priority cooperation between the United States and China under the government-to-government S&T umbrella. These fields were 1) agricultural science and technology, clean energy, 3) nanotechnology, 4) global change, 5) genomics, 6) science education, and 7) information technology.

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[14] They may or may not have been aware that this recommendation had been made over ten years prior by Ralph Clough, then Research Fellow, Institute of Sino-Soviet Studies, The George Washington University, and also former Foreign Service Officer in 1981 in a 116 page report prepared for the White House Office of Science and Technology Policy and the Office of Research of the U.S. International Communication Agency, entitled A Review of the U.S.-China Exchange Program, February 23, 1981.

Various agencies were given leading roles in pursuing these areas of cooperation. However, while some of these so-called priority areas were pursued and promoted within the agencies, others were not. Nanotechnology was pursued and resulted in a series of joint workshops, the second of which was held in the United States earlier this year. On the other hand, IT was simply considered as too sensitive and as of little benefit to the United States for active promotion, and science education was essentially ignored by pointing to other things that had already been done in this area. The point is that each agency was left to decide what to do, or whether to do anything at all; and the Joint Commission did not insist on following up in these "priority areas." Another point is that there was no adequate preparation before the JCM in terms of consultations within the agencies as to what areas would be appropriate for designation as "priority areas."

Another important factor that needs to be recognized is that shared institutional values and structures can greatly augment the working relationship between institutions of the two countries. The relationship between the National Natural Science Foundation of China (NSFC) the U.S. National Science Foundation (NSF) has demonstrated this point. Shared values include peer review and avoidance of conflict of interest that find expression in methods of operation. Most recently the two institutions have also shared experiences in dealing with waste, fraud and abuse, the effect of which can be seen in increasing punishment in China for transgressions of these principles.[15] Adherence to shared values and steadfastness in upholding these values through actions have increased the trust between the two institutions.

To this should be added the important role that building long-term relationships between people who manage the U.S-China S&T relationship has played in creating mutual respect and trust. It is axiomatic that respect will grow between individuals on both sides when each knows what they are talking about both in terms of the particular relationship in S&T and in terms of understanding each others cultures and languages. Suttmeier has commented on this point in noting "that the Chinese side has often been frustrated and annoyed at what it regards as a certain amateurism among U.S. officials."[16] He was speaking here about the effects of the frequent rotations of officials in OSTP and OES verses the longer times that Chinese S&T officials tend to remain on the job. He also pointed out that "time spent in OES is not regarded as career enhancing."[17] This was eight years ago, but I believe that the situation has not changed much since then.

Scientific Accomplishment

What has been achieved scientifically through the US-China S&T cooperation writ large; where do these accomplishments stand in relation to accomplishments in S&T generally; and how do these achievements measure up against what might have been accomplished? Many good scientific activities and accomplishments have occurred as a

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[15] "NSFC Punishes Three Chinese Scientists," China CSR: News and Views on Corporate Social Responsibility in China, September 21, 2005 (http://www.chinacsr.com/2005/09/21/nsfc-punishes-three-chinese-scientists/)
[16] Suttmeier, Ibid., p. 146.
[17] Ibid.

result of the cooperation. The State Department's report on the state of U.S.-China scientific and technical cooperation under the U.S.-China S&T agreement lists many scientific accomplishments culled from the separate reports provided by all of the S&T agencies in the U.S. Government.[18]

In the areas of basic research, whether in basic sciences or medicine, many important projects have added to our scientific knowledge. The National Science Foundation in cooperation with the National Natural Science Foundation of China and the Chinese Academy of Sciences has funded thousands of projects in nearly all fields under its mandate including science, engineering, and the social sciences. It is easy to point out the achievements that have been made in the areas of science in which access to geological and biological resources have contributed to scientific knowledge. For example, the Flora of China project conducted under the guidance of Dr. Peter Raven, President of the Missouri Botanical Garden, in cooperation with the Institute of Botany in Beijing, the Kunming Institute of Botany, the Jiangsu Institute of Botany, and the South China Botanical Garden, as well as indeed with many botanical institutions around the world, now comprising 25 volumes, is a major contribution to the field of botany. Likewise many contributions to science have accrued through cooperation in such fields as earthquake hazard reduction, the physiology of the panda, plate tectonics, epidemiology, etc. Accomplishments in other areas of science that are not based in access to particular natural phenomena have also occurred, but less often than in the nature-based disciplines.

However, a look at the "Highly Cited" database of the Institute for Scientific Information (ISI) reveals some interesting points. There one finds a list of twenty scientists under the People's Republic of China. However, of these twenty, fifteen are associated with universities in Hong Kong and two with the Academia Sinica in Taiwan. The remaining three are as follows:

- Chen Hesheng — Institute of High Energy Physics — physics
- Gao Lian — Chinese Academy of Sciences (CAS) — physics
- Zhang Tao — Beijing Institute of Aeronautics and Astronautics — materials sci.

This list is interesting from a number of viewpoints. The few occasions in which these scientists published with foreign counterpart were primarily with Japanese scientists and to a smaller extent with European scientists.[19] I could not find a single American counterpart. Another interesting fact is that all three of the Chinese researchers listed are in fields of physics, computer science, and materials sciences – in other words they are

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[18] U.S.-China Science and Technology (S&T Agreement) Cooperation: Report to Congress, Bureau of Oceans and International Environment and Scientific Affairs, April 15, 2005. See pages 3 and 79-87.

[19] See ISI (Institute for Scientific Information) Highly Cited.com of Thomson Scientific. Being acknowledged as a Highly Cited researcher means that and individual is among the 250 most cited researchers for his/her published articles within a specific time period in refereed journals of worldwide recognition. This database lists 3568 U.S. researchers, 350 British researchers, 221 German researchers, 215 Japanese researchers, 135 French researchers, 55 Swedish researchers, 20 PRC researchers including 16 primarily from Hong Kong but several from Taiwan, 7 Taiwanese researchers, and 3 Korean researchers.

not in fields which are nature-based as discussed above. A search of the NSF database reveals that none of these scientists appears too have been part of an NSF award for cooperative research with China. The inaccuracy of the Highly Cited database makes it impossible to draw hard conclusions from the information. Nevertheless, in the negative it is interesting and worthy of further investigation in that very few authors from the PRC show up in this attempt to find highly cited authors.

If we were to ask ourselves how progress in science is measured, we would come up with a list similar to that below:

- By solving serious problems that confront mankind, e.g. the discovery of antibiotics and antiviruses that have obliterated many diseases such as small pox, rubella, polio, chicken pox, etc.
- By discoveries and inventions that transform our lives, e.g., transistor, computers, radio, television, radar, synthetic rubber, x-rays, etc.
- By publishing of seminal papers that mark major breakthroughs in understanding nature.
- By discovering or developing hitherto unknown things, e.g., new galaxies, mapping of the human genome, new species, etc.
- By achieving the means to measure large events such as global change, global warming, el Niño, plate tectonics, etc.
- By the discovery/invention of new food and energy sources, e.g., yellow rice, dwarf rice, atomic energy, fusion, etc.

Which of these things have occurred as a result of the US-China S&T relationship?

- A new galaxy was discovered by an American astrophysicist and her Chinese counterpart
- Acupuncture anesthesia and traditional Chinese medicines have entered the US medical armory for treating illnesses and have been and are being subjected to scientific analysis.
- Others?

Even if we were to compile an exhaustive list of accomplishments, we would soon realize that not many scientific breakthroughs, if any at all, have occurred as a result of the relationship. This fact potentially in and of itself could be a “lesson” learned.

How else should we measure the achievements of US-China scientific cooperation? The search for an answer to this question leads us to look at the process of cooperation itself and to inquire whether there have been valuable accomplishments of a scientific nature that, while not breakthroughs in knowledge, nevertheless constitute important work that could not have occurred otherwise. The afore-mentioned Flora of China project is one such example. Another example is the establishment of the Global Grid Network called GLORIAD, a linkage of broadband computing and communications through cooperation among the United States, China and Russia. This Network has provided scientists with a powerful tool for data-sharing and research. But this is not as much a scientific accomplishment as it is the fruit of successful planning and evidence of political will to use technologies for the betterment of science. Nevertheless, it is an important development that someday could lead to scientific discoveries. CERN is another such example of how computing and instrumentation may be joined together for common scientific purposes among nations. The International Long Term Ecological Research (LTER) Network, System-On-a-Chip[20], and the Antarctic exploration treaty, etc. are all examples, but they are not limited to US-China cooperation alone. Many more examples of benefits of U.S.-China scientific cooperation may be found in the testimony of Anthony Rock, Principal Assistant Secretary of State to the United States-China Economic and Security Review Commission, April 2005.[21]

While it appears that U.S.-China cooperation has not yet produced any breakthrough research, al least as determined by numbers of citations, it should be noted that only a few percentage points of published articles of scientific research of any kind - single investigator, multiple investigator, international, etc. - ever reach the highly cited category. Thus it is most likely true that U.S.-China scientific collaboration is no different than 98% of all scientific research in achieving important results if not major breakthroughs.

The Role of Scientists and Engineers

One reason why asymmetries in motivations, levels of scientific development and wealth, and in the institutions that both sides brought to the relationship did not prevent the S&T relationship from blossoming is the eagerness with which both communities of scientists and engineers approached each other. Even before the U.S. and Chinese governments got into the act, American scientists had begun to plan for and work toward the day when scientist-to-scientist, engineer-to-engineer relationships would start. Well before the Nixon visit to China that ushered in the new era of cooperation – we see that the private community of scientists were in the lead with respect to planning for renewed contacts with China. The National Academy of Sciences, the National Academy of Engineering (both of which are non-governmental bodies), the American Council of Learned Societies, and the Social Science Research Council took the lead in March 1966 under the leadership of Harold Brown, NAS Foreign Secretary, John Lindbeck, Director of the East Asian Institute at Columbia University, and Alan T. Waterman, former Director of the National Science Foundation, by establishing the Committee on Scholarly Communication with Mainland China funded by the Hazen Foundation and the Carnegie Corporation. The goals of this committee were to explore possibilities for contacts between American and Chinese scholars and to promote studies and analysis of China's

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[20] System On a Chip (SOC) technology is the ability to place multiple function "systems" on a single silicon chip, cutting development cycle while increasing product functionality, performance and quality. In February 2001, the National Science Foundation awarded $1,367,967 to the University of California-Los Angeles to establish an international center for research on System-on-a-chip designs. The project involves scientists from UCLA as well as scientists supported by the National Science Council in Taiwan and the National Natural Science Foundation in Beijing.

[21] See "Written Statement of Anthony Rock, Principal Deputy Assistant Secretary of State, Bureau of Oceans and International Environmental and Scientific Affairs, Hearing on China's High Technology Development, Before the U.S.-China Economic and Security Review Commission, April 21-22, pp. 3-4.

scientific and scholarly attainments and organizations, among others.[22] Unfortunately, the establishment of this committee was nearly simultaneous with the start of the Great Proletarian Cultural Revolution in China. The Committee's attempts to communicate with scientists in China were unsuccessful. Nevertheless, when the political situation changed for the better in the early 1970s, this committee, renamed the Committee on Scholarly Communication with the People's Republic of China, was ready to assume a major role in the developing relationship. Likewise, the Federation of American Scientists took a leading role in initiating some of the first contacts. The very first US scientists to visit China in 20 years (May 1971) were sent through the auspices of the FAS, they being Yale botanist Arthur Galston and MIT biochemist Ethan Signer.

Once the two governments had lit the match that ignited scientific ties in the early 1970s, the eagerness of the two scholarly communities to rediscover each other and to forge new relationships was the fuel that carried the relationship forward at an ever-accelerating pace. Those of us who worked on the staff of the CSCPRC all have memories of taking Chinese delegations around the United States and of being astounded by the eagerness of American scientists and engineers to give them a warm welcome. From our office in Washington we would call individual scientists and engineers to come to Washington to help plan for the visit of the each delegation, and they would be more than willing to come. Without prior notice we would telephone presidents of universities, heads of agencies, presidents of corporations, and scientists of all levels including many Nobel Prize winners, and all we had to say was that we were calling from the National Academy of Sciences and that we wanted to discuss the possibility of bringing a Chinese delegation to their institution. Without exception we were immediately put through to these people who immediately agreed to host the delegations and to appoint a coordinator within the institution to work with us on the planning. And it was not just the scientists that felt this eagerness to meet the Chinese, but average citizens throughout the United States. I personally recall an incident that occurred in rural Arkansas in 1973 when I was escorting the Chinese Hydro-technical Delegation to various dams and water control facilities around the country. It was a very unusual experience because in those days there were fears on the part of both the US and Chinese governments that due to so many years of hostility and negative propaganda some harm might befall the delegations. For this reason, each delegation was assigned a team of armed, State Department Security Officers who maintained 24 hour surveillance around the delegations. Sections or floors of hotels were blocked off and set with alarms in case anyone without permission might try to get to the delegations. We were in Arkansas touring a rural water facility when suddenly a local man walked up to one of the delegation members and said in a distinct southern accent, "You boys from Red China?" He noticed that one of the delegation members closest to him had on a pin or button – I don't remember exactly what it was, but I think it was a pin with the US and Chinese flags together. He reached out to touch the pin. By this time the chief of the security detail was hovering just at his shoulder ready to pounce should the man exhibit any hostile intentions. The Chinese, for their part,

[22] Lindbeck, John M.H., "The Committee on Scholarly Communication with Mainland China," a paper delivered at the Twenty-Second Annual Meeting, Association of Asian Studies, San Francisco, California, April 3-5, 1970, from the Archives of the Committee on Scholarly Communication with the People's Republic of China, Box ?, Gelman Library, The George Washington University.

did not know what to say or how to react. Firstly, “Red China” was not a term that they especially liked. Secondly, they too were keenly aware of the hostility with which the two countries had faced each other for so many years. But, as they were pondering how to react, the man said, “I just wanna welcome you to the United States. We’re glad ta see ya, and we hope that you’all have a great time in our country.” Thus the ice was broken. Similarly, Anne Keatley Solomon, then-Director of the Office of the CSCPRC, recalls walking the Freedom Trail in Boston and Cambridge in 1972 with a Chinese delegation escorted by Mayor Kevin White. As they proceeded down the street, shopkeepers came out of their stores and people of all walks of life went up to the Mayor and to the delegation to welcome them to the United States.[23] Incidents like this happened many, many times.

Also, the process of reestablishing ties and forging new ones in S&T was greatly helped by the presence of senior scientists and engineers of both sides who had studied with, worked with or learned from each other before the 1950s. Many of China’s leading scholars, who studied in the United States in the 30s and 40s, were instrumental in forging the new relationship. Examples include physicist Zhou Peiyuan, a Vice President of the Chinese Academy of Sciences and former President of Peking University who headed up the Chinese side’s counterpart to the CSCPRC, earned a master's degree in physics from the University of Chicago in 1927 and a doctorate from the California Institute of Technology in 1928, worked at the Institute for Advanced Studies at Princeton University from 1935 to 1936; mathematician Hua Luogeng, who studied at Cambridge and did research at Princeton; CAS Member and seismological engineer Hu Yuxian who received his masters and doctorates in engineering from the University of Michigan in 1949 ands 1952 respectively; former CAS President and photosynthesis expert Lu Jiaxi who studied at Cambridge and Caltech; Shi Changxu (Chester), materials scientist and Member of the CAS who obtained a master's degree from Missouri Mineral Metallurgy College in 1948. An exhaustive list would encompass many of the senior members of the Chinese Academies of Science and Engineering.

After the Tiananmen Incident in June 1989, American scientists and engineers along with their counterparts in China played a major role in keeping the relationship going despite the tremendous sense of disappointment and, one could accurately say, “loss of heart” that many felt. The scientists and engineers, by and large, were convinced that continuing scientific and engineering relationships were important for the future of the two countries and the world.

The Special Role of Chinese-American Scientists and Engineers

When considering the role of scientists and engineers, we must acknowledge that Chinese-American scientists and engineers played a unique and important role both in joint research and in bringing Chinese students to the United States. From the very

[23] Anne Keatley, from a taped interview, March 12, 2006, on her role in the development of US-China S&T relations. Presently the tape is in the personal possession of Alexander DeAngelis, but at some point in the near future he intends to give it and other taped interviews on this subject to an archive that will make them available to students and scholars of the US-China S&T relationship.

beginning, Chinese-American scientists were very active in promoting the relationship despite the fears that a considerable number of them with ties to Taiwan might oppose the relationship.[24] Nobel Prize winners C.N. Yang (Yang Zhenning), one of the Boxer Scholars who came to study in the United States on funds returned to China from the Boxer Indemnity, and T.D. Lee (Li Zhengdao) were prominent among the first Chinese-Americans to visit China: Yang met with Zhou Enlai in July 1971 and Lee met with Zhou Enlai in October 1972. Yang recommended more research in basic research and Lee recommended that China develop its own high energy particle physics program; and in addition he launched the China – U.S. Physics Examination and Application Program (CUSPEA) that brought 915 of China's top physics students to American universities in the decade before it ended in 1989. Yang Zhenning is credited with directly influencing both Zhou Enlai and Mao Zedong to encourage the CAS to foster basic research and Lee with convincing Zhou Enlai to develop a high energy particle physics program as well as to invite foreign researchers to China and to send Chinese students abroad. He also is credited with explaining to Premier Zhou the importance of peer review and relative autonomy for the scientific community. Chinese-American scientists also brought to China "not only the state of the art in science, but also social, cultural, and institutional approaches to the modernization of Chinese science and technology."[25]

An early delegation (June 1972) of twelve Chinese-American scientists and their spouses was among the first to be allowed to make an extensive visit to China (forty-seven days). It included Professors C.K. Jen (Jen Chih-kung) of the Applied Physics Laboratory, Johns Hopkins University, C.C. Chang, a meteorologist at Catholic University, and Ron Shen (Shen Yuan-rang), a physicist at Berkeley. The group was hosted in Beijing by Kuo Mo-jo, President of the CAS and it met for four and a half hours with Zhou Enlai "until the wee hours of the morning."[26]

Chinese-American scientists continue to have special access into and influence on China's S&T development. A good number of them have been invited to offer opinions as to the directions that science should take and/or to hold important scientific positions in China while simultaneously maintaining their positions in the United States. Two of the most prominent examples are Muming Poo and Yi Rao. Prof. Poo is Paul Licht Distinguished Professor in Biology and Head of Division of Neurobiology in the Department of Molecular and Cell Biology at the University of California, Berkeley, while at the same time he also serves as a director of the Institute of Neuroscience of the CAS in Shanghai. Dr. Rao is Associate Director of the Institute of Neuroscience at Northwestern University, while at the same time he also serves as co-director of the Shanghai Institute of Advanced Studies. Both have been openly critical of problems that they perceive in China's scientific research system with a degree of forthrightness and

[24] Wang, Zuoyue, "U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism During the Cold War and Beyond," in Historical Studies of Physical and Biological Sciences, Fall 1999, v. 30, part 1, pp. 249-277.
[25] Ibid.
[26] Jen, C.K., "Mao's "Serve the People Ethic'," Science and Public Affairs, p. 16, in Box 2, CSCPRC Archives, Gelman Library, The George Washington University.

candor that would be difficult for non-Chinese to muster without being dismissed as arrogant foreigners.[27]

Finally we note that in recent times a number of U.S. scientists of Chinese ancestry have taken on leadership roles in industrial research programs in China. Two of the most frequently noted are Steve Chen, former Vice President of Cray, who is founder and deputy chairman of Galactic Computing Shenzhen Company Ltd., China's effort to develop the world's fastest computer, and Kai-fu Lee, who had a long history of corporate research and managerial positions in the United States after receiving a bachelors degree from Columbia University and a doctorate in computer science from Carnegie Mellon University who founded Microsoft Research Asia and who sparked a legal battle between Microsoft and Google when he switched to Google in 2005 to head up its research in China.

The Role of the Non-governmental Sectors

For reasons discussed earlier, innovation and creativity in the S&T relationship come primarily, if at all, from the private sector including institutions of higher learning and private corporations. I have already discussed the role of individual scientists and of institutions such as the NAS, SSRC and ACLS. In this section I will concentrate on other private, non-governmental actors. Four of the best examples of recent efforts of an innovative nature that focus on helping us to understand China's scientific and technical development and the directions of U.S.-China S&T relations are 1) The U.S.-China Cooperation Program in Science Policy, Research, and Education launched in 1989 by Prof. J. Thomas Ratchford of George Mason University, 2) an ambitious program for US-China S&T cooperation at Texas A&M University launched in November 2003, and 3) the creation in September 2005 of the Center for Science, Technology & Innovation in China (CSTIC) at the State University of New York's Levin Institute in New York City, and Stanford University's Asia Technology Initiative (ATI).

The U.S.-China Cooperation Program in Science Policy, Research, and Education at George Mason University, with funding from the National Science Foundation for the participation of American participants and from the National Natural Science Foundation of China for Chinese participants, utilizes a variety of science and policy events as a basis for expanded bilateral and multilateral science policy cooperation. These serve as a foundation for strengthened partnerships in specific areas of science and engineering. Activities include a decade of science policy seminars, forums, and related events conducted since 1998 that have explored issues with significant implications for the vitality of science and engineering in the emerging, global, borderless, knowledge-based economy. Seven major policy events have been held so far in areas such as

[27] See Poo, Mu-ming, "Commentary: Cultural reflections: China's economy is booming and yet its scientific output isn't. Mu-ming Poo explains why," Nature, Vol. 428, 11 March 2004, pp. 204-205; and Rao, Yi, Bai Lu and Chen-Lu Tsou, "A Fundamental Transition from Rule-by-Man to Rule-by-Merit – What will be the Legacy of the Mid-to-Long Term Plan of Science and Technology?" Science and Culture, IHNS, CAS, Beijing, China (Zhongguo Kexueyuan, Ziran Kexueshi Yanjiusuo, Kexue Wenhua Xiaozu/ Chinese Academy of Sciences, Natural Science History Research Institute, Science and Culture Group), Kexue Wenhua Pinglun (Science and Culture Critiques), 2 December, 2002, 17:46:49.

infectious diseases, engineering education, science, society and the internet, and biotechnology and biomedicine. Indeed, the Comparative U.S.-China Science Policy forum for which this paper was written was organized under the (For more information see http://techcenter.gmu.edu/programs/science_trade_policy/us_china.html

Texas A&M's program to stimulate greater cooperation and research between the United States and China, including significant scientific research emphasis, began in November 2003 in cooperation with the Chinese People's Association for Friendship with Foreign Countries with the holding of a large-scale international conference entitled "China-U.S. Relations: Past, Present, and Future." Its purpose was to build long-term, collaborative research partnerships that address topics of mutual interest and provide models for future cooperation between the United States and China. The conference was sponsored by a number of large companies including FedEx, Motorola, Visa, IBM and CNPC (China National Petroleum Corporation). Many of the over 400 attendees from both sides were scientists and engineers, and a major focus was on subjects involving science, technology, and education (3 of 8 plenary sessions). In addition to the scientists, other participants included U.S. specialists on China, Chinese specialists on the United States, representatives of government agencies of both countries, businessmen, and statesmen and politicians including former President Bush, then Secretary of State Colin Powell, former United States National Security Advisors Henry Kissinger and Brent Scowcroft, former Vice Premier of the State Council of China Mr. Qian Qichen, former United States Under Secretary of State for Political Affairs Arnold Kanter, former United States Secretary of State James Baker, Ambassador of China Mr. Yang Jiechi, and several former United States Ambassadors to China. The striking things about this conference to promote greater U.S.-China ties, aside from the high level speakers and guests that either spoke to or participated in the conference, were the facts that it was conceived and implemented while at the same time in Washington and in the national press most of the attention focused on China was negative, that it was held at a university far away from Washington, D.C., and that it took place in a rather conservative area of the country. A second conference was held in Beijing in 2005, and plans are begin made for a third conference in 2007. (For more information on the series of conferences see http://china-us.tamu.edu/index)

In September 2005, the Center for Science, Technology and Innovation (CSTIC) was established in the Levin Institute of the State University of New York located in New York City. It is headed by the noted scholar of China's science and technology Denis Fred Simon. It was created in response to the need to better understand China's increased prominence in the fields of science and technology as well as to study the impact and implications of S&T developments in the PRC in terms of such key issues as global competition, sustainable growth, international security, and worldwide S&T progress. The Center serves as a platform for bringing together experts and scholars from around the world including from China. Equally important, it will train a new generation of scholars that presently is sorely lacking who will focus on China's S&T developments and what they mean for the United States and the world. (For more information see http://www.levin.suny.edu/cstic.cfm)

The Asian Technology Initiative of Stanford University seeks to cultivate the next generation of global hi-tech entrepreneurs by providing students with cross-cultural and entrepreneurial experience and to build long term ties between Stanford and entrepreneurial communities in Asia. In its six years of operation, ATI has launched global entrepreneurship programs in China (Shanghai & Hong Kong), India (Bangalore & Mumbai), Japan, and Singapore. Stanford students participate in overseas hi-tech summer internships, engage in preparatory entrepreneurship seminars at Stanford and coordinate culminating summer global entrepreneurship conferences. Ultimately, these entrepreneurial programs have the goal of building long-term ties between Stanford University and Asian academia and industry.

The Role of U.S. Corporations in US-China S&T Relations

The role of U.S. Corporations in the U.S.-China S&T relationship will be discussed in greater detail in a companion paper by Kathleen Walsh.[28] I wish to mention only a few key points here because the corporate role in U.S.-China S&T relations is such an important part of the overall S&T relationship, and because it, along with a) access to American research and education by Chinese students studying in the United States and b) some aspects of the role of Chinese-American scientists and engineers, is one of the key areas that will continue to draw concerns about technology transfer, dual-use technology, security, and intellectual property rights.

A National Science Foundation InfoBrief of February 2004 pointed out the growing R&D presence of U.S. corporations in China in the form of R&D laboratories and R&D alliances:

> "Foreign direct investment (FDI) and research and development (R&D)-related activity by U.S-owned companies in mainland China (henceforth China) expanded substantially during the 1990s, especially in the information technology sector. U.S. affiliates in China were among the most R&D intensive overseas affiliates in 2000, making China the eleventh largest host of U.S. R&D expenditures overseas, up from the number 30 spot in 1994. Investment by U.S. companies through majority-owned affiliates grew, while the frequency of new industrial R&D alliances dropped. However, U.S. companies and other organizations still participate in more industrial R&D alliances with Chinese partners than do entities from other investing countries."[29]

Kathleen Walsh's study entitled Foreign High-Tech R&D in China: Risks, Rewards, and Implications for U.S.-China Relations, shows that U.S. multinationals established over half (128) of the 200 information and communications technology (ICT) related R&D centers in China established over the 1990-2002 period and that of the 82 different companies invested in more than 200 R&D centers in China, 41 were from the United

[28] See Walsh, Kathleen, "Industrial R&D: A Comparison of U.S. and China," prepared for the U.S.-China Forum on Science and Technology Policy, Beijing, October 16-17, 2006.
[29] Moris, Francisco, "U.S.-China R&D Linkages: Direct Investment and Industrial Alliances in the 1990s," InfoBrief, NSF publication number 04-306, February 2004, p. 1.

States.[30] She also points out that intangible elements of management, in addition to any specific technologies that may be transferred, are part of the know-how that is being transferred to the China-based R&D centers in hopes of inspiring greater innovation among the locally-hired staffs.[31] More and more, the managerial element is thought to be one of the keys to increasing China's competitiveness in research, development and innovation. As occurred in Silicon Valley and other high-tech centers in the United States, the ripple effect of vibrant centers of multinational corporate R&D in China, linked closely to universities, small high-tech spin-offs and government labs potentially could not only pose a competitive challenge strictly in economic terms but could also, some fear, eventually shift the nexus of innovation away from the United States.[32]

LESSONS LEARNED

As we turn to divining Lessons Learned from the past 35 years of U.S.-China scientific and technical relations, we should keep in mind that there are various kinds of lessons. There are lessons that pertain primarily to the United States. There are lessons that focus on what both countries might do together. There are lessons as to the limitations of the S&T relationship with respect to certain vexing problems that face the relationship today. And there are lessons as to what cannot be done as well as to what can.

LESSON: If we want to receive maximum benefit from the U.S-China S&T relationship, we must devote more attention to it – the attention that it deserves – concerted, integrated, high-level attention.

The current mode of managing the overall S&T relationship may be described as "modified laissez faire," whereas we should be able to describe it as "active partnership."

The US-China Joint S&T Commission is nominally in charge of monitoring the relationship, but its focus is solely on the government-to-government agreement that is but a small part of the highly diverse relationship. The vast majority of S&T contacts that occur are outside of the government agreement, primarily through industries and universities. Even within the government relationship, the Joint Commission cannot hope to monitor adequately what is being done. The staffs of OSTP and State's OES are too small to do it; so a great deal is left to the agencies. This stems from the

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[30] Walsh, Kathleen, Foreign High-Tech R&D in China: Risks, Rewards, and Implications for U.S.-China Relations, 2003, The Henry L. Stimson Center, 2003, p. 94.
[31] Ibid., p. 96.
[31] See Business Week Online, August 22, 2005, that points out the growing managerial innovations of Chinese and Indian entrepreneurs. See also Shirley N. Jackson, President of Rensselaer Polytechnic Institute, "Security, Innovation, and Human Capital ion the Global Interest," a talk delivered at the Center for Strategic and International Studies, June 17, 2004, *If present research and development manpower trends continue, with fewer American, Japanese and Western European students opting for careers in the physical and mathematical sciences, the research and development center of gravity will move to China and India, or to places like Singapore where targeted investments are being made in specific areas…*
http://www.rpi.edu/president/speeches/ps061704-csis.html

decentralized structure of government research and funding and from the decision from the beginning to let the system take care of itself. This is of course highly American, but inappropriate

Treating the U.S.-China S&T relationship as if it were a "normal" relationship is misguided. The U.S.-China S&T relationship is one part of a much larger relationship that is anything but normal.

As the world's largest economy and the world's fastest growing economy, the United States and China are already vying for limited energy resources and materials, even to such mundane materials as cement. The United States is currently the most powerful nation in the world; or, as it is often stated, the United States is the sole remaining superpower. Yet China surely sees itself as eventually equal to if not greater than the United States. There are bound to be struggles between the United States and China over control and influence in the Pacific and quite possibly elsewhere as well.

In the context of the U.S.-China relationship, science and technology are not just abstract, intellectual fields of endeavor but rather vital, motive forces in the development of national strength and security. Surely many scientists on both sides would prefer to let the forces of pluralism and of the market of ideas be the engines that power the S&T relationship, but this is a luxury that is not supported by reality. We need at the very least to able to say where the relationship is heading and whether it is heading in the right direction.

In recent years, just about the only group that has taken a "serious look" at the U.S-China S&T relationship is the U.S.-China Economic and Security Review Committee (USCC) set up by Congress to monitor how the U.S.-China relationship may be detrimental to the United States's economy and security. By saying a "serious look" I mean a concerted, integrated, high-level, and sustained look guided by principles and goals. The USCC has all of these virtues, but in addition it also has an appointed group of Commissioners and a permanent staff. It holds hearings to which it invites experts from around the country to testify. It commissions papers. On the other hand, its commissioners are primarily from one side of the political spectrum, the conservative side.

The S&T relationship with China is broader than economics and security, as important as they are; yet no one in government is giving the overall S&T relationship as serious and sustained oversight as the USCC is giving to the economic and security aspects of the relationship.

No one is actively calling on the thousands of scientists and engineers engaged in cooperation with China to "testify" as to how their cooperation may be helping to advance knowledge or promote better lives for people. There ought to be a focus on the overall S&T relationship rather than on just the economic and security aspects. Like anything else, especially in a society such as America's where there are any number of groups pressing their agendas on any given topic: if you only hear one side of the story you are likely to think that it is all that can be said about the issue; and if you don't speak out you are as much as admitting that the other side is right.

In the first two decades of the relationship from 1970-1980, the CSCPRC played an important role in providing not only a mechanism for exchange but also in giving some intellectual guidance to the relationship. It was never intended as an overseer of the relationship, but its broad sponsorship by the leading academic associations in the country – that is, the National Academy of Sciences, the Social Science Research Council, and the American Council of Learned Societies - gave it a special place both within academia and also in relationship to the government. With the arrival of "normalization" of relations, the role of the CSCPRC both as a vehicle of exchange and potential source of insight receded as the government started its own programs and established the Joint Commission. But the Joint Commission, which meets only every two years and does not otherwise actively monitor the relationship in between, was and is incapable of truly monitoring the relationship. Similarly, the National Academy of Sciences, the Social Science Research Council and the American Council of Learned Societies have all gone their separate ways vis a vi China and are certainly not focusing on the overall national interest in U.S.-China S&T relations.

Today the relationship is far greater and more complex than it was back then; and the issues differ greatly from what they were then. In the early days of S&T relations reciprocity was a primary concern. In recent times the attention is focused on technology transfer and its implications for national security and trade; and therefore the scientific and technical relationship is seen in this context. So it is fair to ask whether the early history teaches us any lessons at all about what we could be doing better today.

The essence of the early U.S. approach toward the US-China S&T relationship was that the government and academia and industry worked in **partnership** with one another.

For due attention to be paid toward today's U.S.-China S&T relationship, we need to create a national partnership of stakeholders that would include the voices of industry, academia (including universities, academic societies and national level academic institutions) and government. This entity would provide the knowledgeable overview of the S&T relationship that the government needs in order to develop its strategies and approaches to S&T relations with China.

The United States government should approach the National Research Council (representing the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine – often more widely referred to as "the Academy") - to initiate a new national dialogue and a process of creating a partnership of all of the relevant stakeholders in U.S.-China scientific and technical relations. The Academy has both the national stature and the distance from government per se that give it legitimacy and recognition within the American system. It is the one national body that can provide an objective overview of the S&T relationship as a whole yet work closely with both government and private sectors. In order to assure all parties of its objectivity, it must take great care to involve voices from the main branches of the political spectrum. As it did once before in creating the CSCPRC, it should also bring in representatives from the other major academic communities including the social sciences and humanities.

The dialogue would begin with a discussion of the relationships that exist in S&T between the United States and China today and how the needs of the main sectors relate to one another. It is vital that the dialogue include voices from the commercial and security sectors as well as from academia. Following this discussion, the NRC should forge a statement of goals and objectives for a new national roundtable on U.S.-China S&T relations. For this effort to be effective and long-lasting, it must be supported by a staff that works on preparing background papers as well as organizing the meetings of the roundtable. The U.S. government should support this effort financially.

The image of this roundtable should not be a "happy-face" effort to counter to the USCC, but rather an objective effort to assess the total scope of the U.S.-China S&T relationship.

LESSON: The main problems that vex us today in the S&T relationship between China and the United States involve the intersection of S&T with commerce - including intellectual property rights - and with security - including dual-use technology. Neither of these is essentially S&T in nature nor are they susceptible to S&T answers. Attention only to commercial and security will undermine the good that can be done in other parts of the S&T relationship.

The most recent National Trade Estimate report on U.S.-China trade relations indicates that the authorities in China have done much to meet the requirements of belonging to the World Trade Organization (WTO) but that problems persist in Intellectual Property Rights (IPR) protection and in general transparency of the Chinese enforcement system. Some of the specifics are 1) that penalties imposed on IPR transgressors in China are meted out according to the Chinese street value rather than according to international standards, e.g., pirates of movies are fined a few yuan rather than the $30-40 dollars that the same movie would sell for internationally, and 2) that the enforcement system in China is not sufficiently transparent.[33]

One might be tempted to argue that all developing countries, including the United States when it was developing, stole intellectual property until it was no longer in their interests to do so - that is, until they developed their own intellectual property needing protection. According to this argument, the problem will go away in time. However, we do not live in the future but right now, and therefore industries need to protect their intellectual property now, not a hundred years from now. Certainly this is an area in which China needs to improve its follow-through and not just its rhetoric. But this is primarily a matter of law and not of S&T. One would have hoped that U.S. corporations

[33] National Trade Estimate Report (NTE) on Foreign Trade Barriers, U.S Trade Representative, 2004, pp. 57-95, http://www.ustr.gov/Document_Library/Reports_Publications/2004/2004_National_Trade_Estimate/2004_NTE_Report/Section_Index.html

had learned a lesson from the sad experience of technology transfer with Japan; yet this apparently is not so.[34]

In the purely scientific realm, setting aside the fact that there is a huge gap between what is being done and what could be done in U.S.-China S&T relations, things are going fairly well. Chinese scientists and students gain access to U.S. research and education; in return American scientists get access to China, the opportunity to work with Chinese colleagues, and the benefit of having highly intelligent Chinese students in their laboratories. American scientists also gain friends that can help them and businessmen allied with them to cut through bureaucracy and red tape when trying to forge partnerships and do business in China. We also gain greater insight into China's potential technological future and development strategy.

The problems that exist are not so much in science as in technology - that is, fear of the loss of technology that may be used against American industrial or security interests. In his 1998 study, Dr. Richard Suttmeier noted that there was "no carefully coordinated effort to wed S&T and commerce, and that "the United States is left with the unanswered question of whether individual programs of government agencies, universities, foundations, corporations, etc. – which by themselves are rational and justifiable – are collectively in the national interest."[35] Of course, that was before the USCC was created.

Before I retired from the government over a year and a half ago (February 2005), there was a movement afoot in the Department of State's OES to develop greater coordination among the agencies of government, including the military. The first encounters were a bit rocky as the world-views of the science agencies and the military differ substantially, the former being largely open and optimistic about cooperation and the latter being circumspect and skeptical. I do not know how far this "dialogue" has developed, but I would guess that it is still highly problematic. Whatever the differences are between the military and the science agencies, they are dwarfed by the differences between the academic science community and the military. The science community tends to be very liberal in orientation and, frankly, anti-military. In the scientific community, the standard approach to science and technology matters is to avoid the military aspect even though many individual scientists and engineers receive support from the military.

There are good reasons for this separation as the scientific community has flourished on the principle of academic freedom and openness whereas relations with the military tend to be closed. But times have changed a lot since 9/11, and the realignment of interests has not yet settled into a comfortable accommodation. Also, the issue of security will not go away as many might hope. Certainly the accommodation between the scientific community and the security community must be pursued. Any attempt to address U.S.-China S&T relations without acknowledging this reality would be both

[34] Kathleen Walsh (ref. footnote 27) who has focused on China's industrial technology and on US-China industrial technology relations, believes that much technology has already been transferred form U.S. corporations to China allowing greater Chinese competition to arise faster. From a personal communication.
[35] Suttmeier, Ibid, p. 146.

fruitless and self-defeating. The same logic propels the academic community, government and the industrial sector to seek a new accommodation.

As for dual-use technology, we need to be practical. A main reason why the United States S&T system is the most productive in the world is because it truly functions on the principle of "letting a hundred flowers blossom and a thousand schools of thought contend," to borrow a well-know phrase from the Chinese. Better to deal pragmatically with the needed exceptions than to abandon the rule all together. We stay strong primarily by keeping ahead.

LESSON: Creativity and innovation in the S&T relationship is most likely to come from outside the government.

The two governments will always be constrained by budgets and by politics in making any bold moves toward greater and deeper S&T relationships. It is neither likely, nor is it necessarily desirable, that the government would get more money to develop greater agency-to-agency programs. In the United States it isn't even possible for the agencies to get any additional money specifically for the relationships that they are already maintaining, although getting such monies perhaps would be efficacious.

On the other hand, as various non-governmental initiatives have shown, innovation and initiative can be found primarily outside of the government. The examples cited previously of Texas A&M University and the Levin Institute's China S&T Program show that even as the government is focused primarily on the security and trade aspects of the relationship, private institutions have taken up the challenge of moving the S&T relationship forward. Would that there were more such initiatives outside of government.

This is where the government can and should play a catalyzing role in helping the academic and industrial sectors spawn more centers of US-China S&T cooperation, study, and teaching about China's scientific and technical development and inquiry into the potential for greater US-China S&T cooperation. The government has the means and the mandate to bring the various sectors together to discuss how best to improve the relationship. The government needs to be active in seeking input from the major stakeholders in the S&T relationship – scientists, universities, industry, and private foundations. For sure the OSTP and the OES would greatly benefit from the existence of greater pools of expertise on China's S&T development and that of other countries as well. As it stands now, when the biennial Joint Commission Meetings occurs every one-and-a-half to two years, OSTP must rely on advice and guidance from the few people who know something about US-China S&T relations. Not only are such people few in number, but they are also aging. This is why the creation of the China S&T Program within the Levin Institute of the State University of New York is so important for the future – because it will create a new generation of scholars focused on the development of China's S&T, on what that means for the United States, and on how to achieve maximum potential and benefit from the relationship.

LESSON: The current mode of S&T interaction has not approached the potential for scientific and technical advancement that should be expected from the S&T relationship. New international partnerships in S&T for mutual benefit between the United States and China are needed in order to achieve the potential for good, both scientifically and politically, that exists between the two countries. Instead of only looking at problems in the relationship we ought to be focusing also on maximizing the potential.

We need to set our sights on what could be achieved together. The obvious areas in which to initiate common efforts and programs are energy and disease prevention and treatment (especially infectious diseases). Current programs in these areas do not have sufficient political attention. We need to consider forming **binational partnerships** for the solution of problems amenable to S&T solutions.

We can begin by accepting the idea suggested by the USCC that the United States and China develop a long-term research partnership in energy development. This effort at collaborative research and cooperation to solve a major world problem of diminishing energy resources should be initiated at the highest level in each government, and it should be funded. It should be monitored for progress and it should have the ability to change research directions when necessary. Also, it should be well-published so that the people of both countries can appreciate what their two nations are doing together for the common good.

LESSON: The benefits from S&T cooperation are different for each side. The Chinese side benefits from access to higher education and research in United States while the American side benefits from the bright Chinese students and scholars who populate U.S. laboratories. Instead of thinking of closing our doors, we ought to be thinking of opening them even wider to Chinese students.

Over ninety percent of the Chinese scholars who obtain their doctorates from American institutions of higher learning remain in the United States for some time, either to take advantage of postdoctoral fellowships of because they are hired by American institutions. Many choose to remain permanently. Those who return to China tend to keep up their ties with colleagues in the United States and thus are not lost completely to the United States as whey once were.

Two of the main benefits to the United States stemming from S&T cooperation with China are access to China's natural resources and talented pool of scientists and engineers. The ability to conduct certain kinds of experiments in China that could not be so easily done in the US is another. For example, the civil engineering community has benefited greatly from the ability to set up instruments in Chinese buildings that monitor the effects of earthquakes at a cost much less than would be possible in the Unites States, to say nothing of the insurance hazards involved in doing such research in the United States. On the other hand, the number of American students and scholars in science and engineering who may be found in China at any given time is far less, by orders of magnitude, than the numbers of Chinese students studying in the US. This is to be expected and is natural given the disparity and perceived disparity in levels of research. But it is nevertheless short-sighted because American students also need to know what is happening in the rest of the world, especially in a country like China where things change so rapidly. The United States may wake up one day to find that it has been surpassed by the hard-working, intelligent students of other nations that recognize the importance of scientific and technical research. The Chinese also benefit from exposure to an American atmosphere of inquiry that is highly conducive to and rewarding of creativity, innovation and initiative. Access to funding for scientific research is also relatively abundant and forms a major part of the "atmosphere" for S&T in the United States. Many Chinese graduate students and post-docs in the United States receive substantial support through grants from US agencies either to their mentors in graduate school or to them directly as researchers at American colleges and universities. Businesses too offer many opportunities to them for employment and research.

For its part, the United States receives the benefits of tapping into many of the brightest young minds of China, as well as, of course, those of many other countries, at stages in their careers when they are at their most active and creative. Many have acknowledged this factor by rhetorically questioning what would happen to America's great research institutes and universities if the foreign scientists and engineers were absent? Who would people our labs?

Greater understanding of each other should not be overlooked in tallying the pros and cons. Greater understanding of each other's systems and cultures should logically be one of the results of cooperation in science, especially if it is prolonged cooperation. Here it is quantitatively more beneficial, theoretically, to the Chinese students and scholars than it is to the Americans based simply on the disparity in numbers in each other's country. One may delve further by asking whether the Chinese students and scholars gain as much understanding as they could when, for various reasons, they tend to stick together and to concentrate solely on their work in the laboratories. But that leads to other areas of inquiry that are not really germane to this discussion.

Then there are certain fields of scientific inquiry that by their very nature have been greatly enhanced and even made possible only by scientific cooperation, e.g., geophysical studies in situ, study of the Panda, fisheries research, and so on, in other words enhancements to science through access to each others flora, fauna, and geophysical environments.

Exposure to China or to America will not necessarily make those so exposed into great friends of each other's countries or societies. Many will become friends with individuals or grow to admire certain aspects of the other's cultures and societies. Others will become disenchanted or disappointed with the other's cultures, societies, and politics. But, whatever the case, understanding will be enhanced by exposure to one another. We can hope that such understanding will help both to avoid misjudgments.

LESSON: Wherever possible, we should strive to engender long-term relationships between U.S. and Chinese agencies and staffs and to share management procedures and skills. Concurrently, we need better mechanisms for insuring that the leaders of our science agencies know each other and share concerns.

As has been stated, the long-term relationships that developed between staffs of certain agencies, such as NSF and the National Natural Science Foundation of China and the Chinese Academy of Sciences, created a bond of trust that helped each of these agencies work together. These agencies also shared ways of doing things from everyday issues of financial management to issues such as peer review and conflict-of-interest. Other agencies have also benefited from long-term staff relationships and sharing of procedures. Perhaps a step further in this direction would be for science agencies to second their staffs to one another for various periods of time in order to learn even better how each one functions. For this to be feasible, money would have to be set aside to support such exchanges and to temporarily replace busy staffs that would be involved in these exchanges.

CONCLUSIONS

If we continue down to pathway on which we are currently going, in fifteen years time we can only expect greater tensions in the U.S.-China S&T relationship. China will be stronger scientifically and militarily then than now, but its need for high quality scientific education and training will still be acute; and it will want to continue to solve that need by doing what it is doing now – that is, by sending great numbers of Chinese students to the United States while simultaneously trying to increase the quality of its indigenous scientific training. The problem will be that the trade deficit, not only in regular commodities but also in high tech know-how, will be even more unbalanced in favor of China, and American jobs will be even more threatened. This is a recipe for great acrimony and mistrust.

In the meanwhile, the status of India in the world will have risen tremendously in terms of S&T, commerce, industry, trade, and so on. By then, India may also be the most populous country in the world. Furthermore, we are already seeing more and more public references to India as "the world's biggest democracy" and to why it will be the world's "next great economic superpower." [36] Additionally, commentators are already juxtaposing India as "the world's biggest democracy" with China as a one-party dictatorship and asking rhetorically whether it wouldn't be better and easier in the long run for the United States to work more closely with India, as difficult and cantankerous as that may prove to be, than to place too much hope in a relationship with a country like China that has such a different political philosophy. Fifteen years from now it is likely that this sentiment will be even deeper and more widely-accepted within the American political landscape.

[36] See the cover story of Time, June 26, 2006.

At the same time, the relationship between India and China, if it continues down the pathway that it is now on, will become closer and closer, despite previous antagonisms. Their partnership in East and South Asia will rival and often oppose the interests of the United States both in the region and globally. In addition, fifteen years from now we will still be dealing with fundamental Islamic terrorism, but we may find that our relationships with Europe and China have worsened and thus that our allies are very few.

Both India and China have a high regard for the value of science and technology for society. Many developing nations share this same regard for S&T. In the early days of U.S.-China rapprochement, S&T served as a bridge of increasing interaction and friendship between the United States and China. Today the situation is more complex than it was then, but the fact remains that scientific and technical relations can be used as means for mutual friendship. The United States still has resources in S&T that these countries do not have and from which they seek to benefit. Our research universities and institutes are still the best training grounds in the world, and our innovation system continues to be the most prolific in the world. We should be thinking about how we can use our relative S&T strengths now to partner with them and thereby to build up a reservoir of trust and understanding. We should also be thinking about how their S&T systems and strengths in future could benefit us. If we allow the S&T relationship to continue to drift as it is now, our relationship in science and technology 15 years from now will be much worse than it is today. However, if we devote due attention to the S&T relationship with China with the principle of mutual benefit in mind, I am sure that we will think of ways to increase friendship and trust and also to benefit our own indigenous needs.

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Appendices

Transcripts of Interviews with Americans who were instrumental in the early years of the U.S.-China Scientific and Technical Relationship.

Interview with Mary Brown Bullock on the Development of U.S.-China Scientific and Technical Relations, 4 May 2006

(The persons involved in the following interview are Dr. Mary Brown Bullock, President of Agnes Scott College and former Director of the Committee on Scholarly Communication with the People's Republic of China, and Alexander De Angelis, former director of the East Asia Program at the National Science Foundation and former member of the staff of the Committee on Scholarly Communication with the People's Republic of China.)

Alexander De Angelis (AD)
This is Alexander De Angelis, Today I am interviewing Dr. Mary Brown Bullock, President of Agnes Scott College and former Director of the Committee on Scholarly Communications with the People's Republic of China, on the history of U.S.-China scientific relations and her role in those relations.

Mary, would you tell us what your position is and what your role has been and is in U.S.-China S&T relations, and particularly if you had a specific issues that really stand out that you had to deal with.

Mary Brown Bullock (MBB)
I am Mary Brown Bullock and I currently am President of Agnes Scott College, but from 1974 to 1988 I was first on the staff and then Director of the Committee on Scholarly Communication with the Peoples Republic of China [CSCPRC]. Since 1988, I have been less involved in the U.S.-China science relationship, although while I was at the Woodrow Wilson Center in Washington, periodically we did get involved in related programs. As a college president, I have seen this issue from an educational viewpoint and from some of the national settings with which I am involved – particularly the role of younger Chinese scientists on American college and university campuses. So, that's my basic background.

My involvement with the CSCPRC of course was fabulous. It was in the very early days of American scientific cooperation with China. I suspect that those issues are quite different than today. When we started trying to create a scientific relationship with China in the early l970s, China was considered such a developing, backward country. In a very short period of time that has changed so much. So one of my major observations is that it's a very different today, and there may not be so many lessons from the earliest period of exchanges.

During the years that I was at the CSCPRC we were initially just trying to create some relationships with Chinese scientists on a personal and professional level. The fields that were chosen before I came but were very well defined to try to create collaboration or at least information in areas that American scientists and social scientists had an interest in China, and they included areas such as cancer, research, seismology, paleontology… fields like that. The challenge was to try to create ties with a Chinese scientific community that had really been repressed for a long time, and with Chinese institutions that had almost no infusion of funding, or major funding, as well. So, at that time, it was rally the Chinese who were looking to see what they could gain from Americans science. We were looking for a role there, but we were also looking for American benefits as well. I remember that one of the key themes, I suppose, during much of my time at the CSCPRC, was the issue of reciprocity. It really was how do you define reciprocity between a highly advanced scientific country and a developing country. We often defined that by saying that the United States had much to learn about Chinese history and society to try to gain more access for our social scientists, even as the Chinese were pushing for access to the scientists in this country. So, issues such as reciprocity and access were two of the main themes that I remember from that era.

In retrospect I guess it is quite amazing that even during that time relationships began to flourish as quickly as they did. It helped that there still existed in China a senior cadre of scientists and engineers who had been trained in the United States. So they knew quite a bit about American higher education and science. Many of them had been trained in this country, and so they were accustomed to the kinds of professional collaboration that we would expect. Those individuals made a huge difference in reconnecting the educational and institutional infrastructure between the two countries.

Alex, I think maybe I would pause there.

AD
OK. Yes, you've hit already some of the themes that I thought about: reciprocity, access, social sciences learning from China, and so on, and also the role of the senior scholars.

Look at it in terms of benefits from the relationship for a minute: benefits to the United States verses benefits to China in terms of science and technology, and then more broadly in other terms.

MBB
You mean in that era?

AD
Well, yes. Well I'm thinking actually now coming up from that era and into the present.

MBB
Well, I think the benefits today are really the interlocking – that may be too strong a word - the interweaving of the scientific communities in both countries. If you believe that science needs to be global and that it needs to be collaborative, we certainly have created that far beyond our wildest dreams when we were at the CSCPRC. I think there is no question there is a bilateral infrastructure both between institutions but also in the disciplines that is pretty thick; and I see that as a benefit and I think that most scientists see that as a benefit. Another benefit, of course, is that both American scientists and social scientists have gained extraordinary access to China for their own research. That doesn't mean – and I'm not up to date on the challenges – I'm sure there are probably still challenges in terms of access to China.

AD
You're thinking primarily of the social scientists now?

MBB
I'm thinking primarily of the social scientists. But I certainly know that the American academic literature on contemporary China is rich; its deep; its varied; and its based on people who've spent extended time in China and have access, whether its at the county, village or national level. Again, there are limits to that, but look at any book published in the last ten years in China, and this would include history as well as contemporary China, and you would see it's based on significant scholarship in China. So, the American knowledge of China, the American knowledge-base, has certainly been one of the biggest benefits for this country.

I guess a third benefit – and you would have to go discipline by discipline as I'm not totally conversant with this – would be to take all the different scientific areas where there have been collaborations, whether in cancer, epidemiology, pharmacology, or molecular biology – and say, "Well what have been the scientific gains to the world as a result of that?" Or, "What do we now know that we didn't know prior to that?" That would create more of a common good. Understanding these advances in knowledge that are common to all would be very important.

AD
Thank you. That's very clear. Going back just a bit to the knowledge of China, you second point, that we've gained, do you feel that the Chinese American scientist and social scientist community has played a special role in that or do you think that it's across the board that the things that are being written about China are written by both Chinese and non-Chinese scholar here?

MBB
If you look at the social sciences first, there's no question that a significant number now are Chinese born scholars with careers in the United States and China. They are beginning to – dominate is not the right word I want to use – beginning to be very prolific and very important. There was an interesting paper given at a conference I went to in Fudan - and, Alex, I assume you may have that book Briefing the Pacific - …

AD
Yes. Yes I have.

MBB
-…a really interesting article on the field of international relations and the role of Chinese scholars, that is people born in the mainland, studies in the United States, some of who are active in publishing and in American universities, some of them in China, and the topics that they have pursued, how their work is really transforming the literature on the international relations of China. That's just an extraordinary change since twenty years ago. They are also very theoretically oriented. Many of these scholars have been very well trained in American universities. Their first interest may be models or a certain kind

of theory, but than they apply that to China in their own context. That's one analysis of a particular field that I'm aware of. Certainly in my own field, Chinese history, I'm amazed that when I look at the books that are available, how many of them are authored today by younger people with Chinese surnames. That doesn't mean that you still don't have people of different nationalities and more traditional American writers, but this has been a big change in the field of social science. I have less of a sense of the hard sciences , but I guess my impression still is that Chinese scientists in American universities have probably been the largest group that have been involved in collaborative science projects with China, and Alex, I'm sure you know that number.

AD
Yes. They certainly have been, let's say, there beyond their percentage in the scholarly population.

MBB
Right. In the medical fields, that I know more about, they of course have brought with them many of their colleagues and so it is not just Chinese Americans that are in that field; many American medical scientists on their own terms have been involved in China. I suspect if you looked particularly at the published articles, the Chinese would dominate.

AD
You made a very interesting point in that you pointed out the Chinese-named scholars who are doing work. The thing I thought about, in the social sciences that is, the thing I thought about then is that how sometimes its difficult to distinguish who is a Chinese scholar and who is an American scholar when it comes to a lot of these young folks because many of them are trained in the United States and in fact seem to hold positions teaching and whatnot here as well as having some sort of roles in China as well.

MBB
You know, that's a very important point, and of course, many of them are American citizens as well. So, you really have to be very careful about this, and I suspect if you look at issues of potential controversy in the future would be as we become more economically competitive with China that there could be a backlash against those scholars, particularly more in the scientific fields who had Chinese surnames perceiving that they were not working on behalf of the American national interest. We've certainly seen that in earlier eras of history and I'm sure that's something that needs to be guarded against.

AD
Right. Well we've already seen some of that occur in the fact that you have the former vice president of Cray, a man of Chinese descent, who quit Cray and then went over to head up China's supercomputer project. So there's that kind of thing, you know, how do you judge the right thing to do and how do you judge how much to cooperate, and so on.

MBB
Well, I think in my mind that's why we're in a new era in U.S.-China science relationships because China is becoming a competitor and innovator and so the old kind of mission that maybe we're going to help Chinese science advance or show them the light – this doesn't ring true anymore. So, it seems to me some kind of new kinds of norms and new kinds of language may need to be used, looking at China as a partner in solving world problems or China's problems rather than – the concept of partnership – rather than American tutelage. That will take a lot of hard work, you know, to get that concept fully accepted in the broader American public. Within the scientific community I suspect its not an issue. The danger of this becoming very politicized I see very much on the horizon. In fact, in your little list of questions, there's something about what things to avoid, I'd put avoid use of both sides of politicizing the relationship, but its going to be very hard not to do. American universities, Alex, as you know are outsourcing lots of their labs in China; so you're getting a replication of what's happened in some areas of industry. So, the concept of an international university today, like a Yale university, is going to be that it has a significant partnership with China's scientific infrastructure. I don't think the broader public of America, or even people that look at U.S.-China relations, say in the Senate or the House, the normal pundits, have any concept of how close knit this infrastructure has become and how many people like the person from Cray, Chinese, will go back and are playing a role in the ongoing development of their own society.

AD
Well, two examples of that of a different kind are two scientists, Pu Muming at UC Santa Barbara ad Rao Yi at Northwestern, both of them in the biological sciences. They went back to China and they have the title of heads of laboratories over there in the Chinese Academy of Sciences; as well they are also working here. The reason I mention them is that they have actually come out in public criticizing the Chinese system rather strongly for not being creative enough, and so on. Maybe you have even seen some of their articles?

MBB
I've seen one of them.

AD
But it strikes me that scholars like that maybe have a unique capability, or special capability, of criticizing very strongly without being rejected by the Chinese themselves, as maybe being arrogant foreigners.

MBB
That's a fascinating concept, and actually it may go back in part…you know I used to, and still do work on the Rockefeller Foundation in China…and their concept is that in at the turn of the century or around 1910 that modern science brought democracy. It is a very simplistic, we would think of today, concept but that scientific thinking would really be transformative in a political sense in a country. I think if you study the role of what happened with American science moving into China, you do see some very interesting

cultural and social influence, for example the concept of professional societies that are trans-Pacific in their communication, you know, goes back to the twenties and thirties. So, the Chinese have a concept that they need to be participating in a global scientific exchange. Then, also, the way that American laboratories are organized is so different from the European and the Russian model and these small groups that compete for funding sources is again a kind of democratizing structure that may be having much more of an impact in China. So, you would see from the scientific community, a critique of what is still a very top-down, paternalistic, authoritarian educational structure. So, I'm glad you made that point.

AD
Yes. Thank you. You are undoubtedly familiar with the U.S.-China Security and Economic Review Commission that was established here under Congress a number of years ago and has written several – I think, two – annual reports on the relationship. Now they're specifically looking at the impact of the Chinese not only on our economy but also on our military - that is, the question from the S&T relationship is: are the Chinese gaining anything will help them out militarily. The reason I bring this up is that you touched on one of the concepts of changing from teaching to partnership and even in that context the USCC made a recommendation that the United States and China ought to engage in a program of joint research in energy, and energy sources. So there is, I think, even among real skeptics and critics of the relationship that maybe we need to partner with China.

MBB
I'm delighted to hear that that is in there. I actually jotted down any number of areas that you could consider joint collaboration that could be very important: the whole issue of an aging society, the geriatric society, social welfare, and all of that is something both societies are facing. It's a way to look at the common problems that we need to address and then looking at them from both their scientific aspects and from a broader viewpoint of public policy. I also wondered whether …I don't know, Alex, how many regional partnerships have been established that, for example, might involve Japan or India or Southeast Asia. The whole structure of United States relationships with Asia has been so bilateral in all these different countries, and yet we see China playing a huge role now becoming the regional leader. There could be a danger that the United States would be the odd-man-out over time. So, whether there is a way to develop some very strong regional programs, and maybe with Taiwan as well, that use science as their base. I know there are some. I just don't know whether that's a concept that has any legs from a policy viewpoint.

AD
Right. I know that there are some too, but there are far fewer than one might hope or imagine would exist these days. The GLORIAD – I don't know if you're familiar with that? – is a communications network between the United States, Russia and China, a tripartite thing which allows broadband access among scholars and scientists in those three countries and others. That's a kind of a regional approach, NSF funded, but there

aren't that many examples of that other than China's participation in various global-warming or other weather-related activities and things like that

One of the experiences that you and I share in common is having worked on the CSCPRC. What I think was unique about that was that it represented the three major branches of learning in the institutions of the National Academy of Sciences, the Social Sciences Research Council, and the American Council of Learned Societies. It did, I think, a great job of running exchanges and as well giving some guidance to the relationship. Looking at the situation today that is, broadly looking at how we are engaging China and how we are analyzing our engagement, thinking about it, promoting it and so on what is you feeling about the current modes of operation? Are they sufficient or is there more that we should be doing? That's a loaded question, I realize.

MBB
I'm not aware of any central effort to pull information together or to develop policies either within the private sphere - that is, within the educational community, or within the government community. There must be something within the government. But in the educational sphere, universities and disciplines are going at it alone and are often shocked to hear what other universities are doing and surprised. You have today very interesting beginning of proliferation of joint degree programs in which an American university confers its name on a group of Chinese at some sister institution. Sometimes those individuals spend a little bit of time at the home institution; sometimes they don't. Sometimes it's a money-making proposition for American universities, or other international [ones]. I've been in meetings where college presidents are just shocked to realize that somebody else is doing this and that they hadn't learned any examples of what to avoid or what would be some of the pitfalls in that kind of program. I may be wrong, but I'm not aware of a kind of a pulling together of all of that and I thought the project that I took part in, the Fudan conference, was interesting, but [while] it had some essays that dealt with some of the social science, there weren't any articles that dealt with the scientific exchange. I don't know of any. I think it's great what you are doing. I don't know of any comprehensive pulling together.

AD
Yeah. I don't think there is actually.

MBB
You can say "Well, do we need it or not?" Well, certainly if our competitive relationship continues – well, we can see where we're going – people are going to want to know what is the character of this relationship; and it will be answered anecdotally with a negative example here or a positive example there if there isn't a better analysis. So, we were able to keep track in those days. The <u>China Exchange Newsletter</u> did a nice job; but you can't do it that way anymore because the relationship is so broad and so deep. So I don't know how you go about doing it. I don't know that…Remember when we used to have meetings and university presidents would sit and discuss the relationship with China, or American foundations, I don't know if people would be interested in that kind of sharing or not.

As you know, I'm chairing the China Medical Board, which is a foundation that supports medical education in China. We have a new president, who incidentally is Chinese American, our first Chinese American president, and this will be very interesting; but we're going to have a strategic planning session in the fall in which we are going to try to bring other people who have worked on medical relations with China. We are looking at commissioning some sort of study that looks not just at what has happened with American medical schools but also at the big international donors which are so important in medicine to see if we could do a map which we could then look at and say "OK. Within this map, what does this little foundation thinks it can contribute?"

AD
Right. Well, yes. The days of the CSC were different days –that's for sure – than they are now. It's much more complicated these days. But again, I thought it was that partnership, not only in the intellectual community. But between the intellectual community and the government as well …

MBB
Yes…and in fact that's one of the things that I wrote down about the history, the public-private partnership in the United States that existed in the seventies and the eighties was very important; and there was a two-way flow of ideas and information at that time. One of the key things that you and I will remember that there were people like us and there were other new China specialists that thought the study of the relationship intellectually was important. People got involved and they had no problem representing their American scholarly needs and interests to the American government and sometimes to the Chinese government. Certainly in the academic sphere today, people are caught up in pursuing their own research agenda but not really looking at a public policy agenda related to science and education with China.

AD
That's an excellent point. It does call to mind that Denis Simon, who is now Provost of the Levin Center of the State University of New York located in New York City just last November inaugurated a China S&T studies program.

MBB
Oh, they did? I didn't know that. That's great.

AD
I think that's great because, as you know, there are very few scholars of Chinese science and technology in the United States, and mostly they're aging and they're not really being replaced, except in some instances, as I noted you were talking about earlier, by some younger Chinese Americans or Chinese trained in America who are doing that. But I think it's important that we have more of those kinds of effort out in the universities.

That gets me to another thing and that is the role of government verses the role of the private sector, and by private I mean everything not involving the government. I would think that, given the politics of the situation, the governments are going to be fairly hampered budgetarily unless things change and that its in the private sector that we can look for creativity and innovation. You're out in that sector. Do you feel that it's the case for the private sector here?

MBB
You know, here in Atlanta it's just a boom city, and China is a boom industry. There are various China study groups pretty high up in corporations. Some of these are high-tech corporations, and some are quite different, like architectural firms. But there is really a feeling – and I see it here all the time – of companies that are making major investments in the people that they're hiring and training in their offices in China. The State of Georgia is about to open an office in Beijing; and they are going to work with their own companies. It's a big cost for any state as well. I think all of that is just going to continue. I think the challenge is how do you pull together? How do you understand what that looks like? From an American government policy point of view, it seems to me that the public sector at least has a responsibility for understanding what is happening under its own umbrella. That is all the S&T – I know you're doing this for the S&T bilateral meeting – that they ought to have a good evaluation and understanding of what is happening under their own sector. I don't know if that exists or not.

[pause in tape]

AD
To some extent there is some pulling together of some of those kinds of things for the U.S.-China Economic and Security Review Commission. The State Department is tasked with that. I know from my own role at NSF that I would have to basically pull together all the stuff at NSF; and others would do that for other agencies. Then again, when there's the Joint Commission Meetings there is some attempt to pull together information, but it is really sort of sporadic and it's not sustained and there's no common methodology, no real agreement between the White House or the Congress and the people in the government as to how these things are going to be done. So, it's something that is not being done to the extent that it really should.

MBB
I remember when you and I were talking about NSF funding related to China you said while it was easy to get the funds that has gone through the China program, but it was very hard to get examples of grants where China was a component of a totally separate kind of research project.

AD
Well, I can tell you that when I did this last report before I retired, I found out that the footprint of China was anywhere between $5 and $8 million dollars a year.

MBB
Now, I consider that very little considering the potential for cooperation given the hugeness of China and the United States. That included both the U.S.-China Program

and the things that were not specifically China-oriented. We sort of did a little calculation: was it a half, or was it a third, or whatever of other things that we found.

MBB
Alex, how did that compare with any other country?

AD
It is … Frankly, I don't know. We did not do that for any other country [in Asia], not even for Japan. I would suspect that it's far less than say we're doing with England and Germany…France, etc. That's my guess.

Would you care to venture into trying to enumerate three things that would improve the relationship in S&T, or three lessons that can be drawn, or any number of lessons?

MBB
I tried to think about that. I think I said …Well, this is also sort of related to the history. We have to recognize that **national interests are important to both countries**, and that they don't always coincide, and to be frank about that. I think we certainly learned that in the old CSC days. You know our national interests did diverge, but you would try to create a program from within that. There may be a need for – and I don't know how you create an American national interest profile as there are so many subcategories of that – but if there was a way to move toward a conceptual understanding of why is it in the American national interest to have a fixed scientific relationship with China, it seems that would help when the policy-going gets tough and people are saying "Oh, my God! Why are we doing this? Why is NSF spending $5-6 million dollars on China?" So some articulation of that… Another thing I wrote down was **transparency.** I guess that has to do with data, but it also has to do with …are there things within the S&T relationship that neither side would want divulged? Would that be bad? I don't know what I'm asking there, but you would kind of want to anticipate if we have some sensitive science project with them what would happen if that became public in either country?

AD
It interesting you mentioned in the last 30 minutes or so **partnerships** and you mentioned **transparency**. You mentioned reciprocity, but reciprocity is sort of an old term now. But both partnership and transparency are two words that seem to keep coming up in whatever sphere we're dealing with in China. I know in the trade relationship that's one of the key complaints – lack of transparency.

MBB
Well, I think that partnership, if it could be defined in such a way which the Chinese and Americans work on some problem that is not related to either of them – you know, some issues in Africa, or something like that – would, might be a fascinating endeavor and might make a contribution to mankind. You've got these huge countries, and how do you get them to work together? I think one of the challenges is how to see China in a new role.

AD
It certainly would be a confidence-builder too if that were to work out.

MBB
You know, how do you treat China with the kind of respect… You remember, Alex, when they did their first five or ten-year plan, the plan to 2000 and they had those eight goals for the millennium, they were going to be world-class in things like lasers and materials and space science, etc., and they actually went out and made huge headway toward that. It sounded crazy and impossible at the time. Well, today they've set out to create international class universities and the attendant research facilities. That's happening so quickly. So, how do you recognize them as an international scientific player? I think that's one of our big challenges in multiple ways.

AD
Let me ask one final question. You mentioned education and that you primarily have been in the past years engaged in the education side of things. I think that education is , has to be considered one of the key factors even when you're talking about the S&T relationship since so many of their students are in science and technology who come over here. Do you have any comments on how the educational exchanges – I'll not necessarily call them exchanges – but how the flow of scientists is going and what are the roles that they are playing on our campuses and are they positive, negative…how would you judge them?

MBB
Well, if you look at the role of those that have gone back to China - and I think that Cheng Li's article is so good on this in which he looked at the presidents and the party secretaries of China's top 25 universities – you found that almost all of them had studied in the United States. These are not people that for the most part got Ph.D.s in the United States, but they actually had studies here for some significant time. That is an amazing reality. You don't know what that means, but it means that some of them are in leadership positions and some of them are really pushing for reforms of their educational system. In this country, it's still a young generation that is coming through… Many of them have not gone back and are getting good jobs in our colleges and universities as scholars and as academics. I think its hard to say what their role will be, those that settle here, in the long term. No question however that they are making a significant contribution to American science, and I think when you talk about it we're going to have some new policy statement on this relationship. It shouldn't be bad to say that these Chinese people of Chinese origin are some of our key young scientists in labs in different fields across the country. But, as we see with debate on the immigration bill today, this is a very sensitive topic. So, we have to keep trying to define it in terms of American national interest. You know, I don't know at what point you say some aspect of this really isn't in American national interest and be firm enough so that most of it can continue.

AD
Well, thank you very much for answering these questions and for this interview. As soon as I get the transcript done, I will send it to you for you to take a look

MBB
Okay. I've never seen …with the ooos and the aaahs all evened out?

AD
Hopefully.

MBB
The comas and the periods?

AD
Yes, hopefully.

MBB
Alex, are you going to make your paper available?

AD
Yes. Let me turn this off now. Hold on.

On the Development of U.S.-China S&T Relations
Interview with Anne Keatley Solomon, March 12, 2006

(This is a transcript of an interview with Anne Keatley Solomon, formerly Director of the Committee on Scholarly Communications with the People's Republic of China. The voices transcribed herein are those of Anne K Solomon, Richard Solomon, formerly a member of the National Security Council staff under President Nixon, and Alexander De Angelis, formerly a member of the staff of the Committee on Scholarly Communications with the People's Republic of China.)

Alex De Angelis (AD):
We're interviewing today Anne Solomon. Anne, if you would, would you tell us what you're doing and talk a bit about your role in the development of U.S.-China scientific relations.

Anne Keatley Solomon (AKS):
I'm Anne Solomon, formerly Anne Keatley - Anne Keatley Solomon. Currently I am a Senior Advisor on Technology Policy at the Center for Strategic and International Studies (CSIS). CSIS is a Washington think-tank that works on geopolitical, economic, trade, technology relationships, and global relationships. My work deals with global technology and the implications of the globalization of knowledge, skills and capabilities. It does touch on China, and China today is a tremendous concern in every field, not only China's capabilities in scientific research but also China as a major player in the globalization of technology relationships. Multinational firms, for example, are establishing key corporate functions in China including research and development laboratories. There also is a great interest now in China's technological capabilities as they relate to China's military strength and what that portends for U.S. security interests.

My work on U.S. - China relations started in 1970. Actually earlier than that, in the late 60s I lived in Hong Kong, and in 68-69 I studied Chinese at the Yale-in-China Center which was part of Hong Kong University at the time. My intention was to work on U.S.-China relations; although there were no U.S. – China ties at the time. I moved to Washington in '69 and started working at the National Academy of Sciences in May of 1970. My first job there was with the Environmental Studies Board because at the time there were no job opportunities in Washington having to do with China. So really, to pay the rent I took this job at the Academy, and I was really enormously fortunate. In the spring of 1971 when Kissinger went to China – that was in 71 wasn't it? – it provided an opportunity for the National Academy of Sciences to reinvigorate what was called the Committee on Scholarly Communication with Mainland China which had been started in 1966 by three individuals, Harrison Brown who was Foreign Secretary of the Academy, John Lindbeck who was a China specialist at Columbia, and Alan Waterman who was head of the National Science Foundation. The National Academy of Sciences had made early attempts to get in touch with the Chinese with a letter to the Swedes; and I believe it made some other attempt to get in touch with the Chinese Academy of Sciences but without any success, no response.

After I started working at the Academy – I believe it was in 1970 – Harrison Brown, who was then, as I said, Foreign Secretary of the Academy, and I went up to Ottawa to deliver yet another letter from the Academy to the Chinese Embassy in Ottawa, and once again we heard nothing back.

AD
That was in 1970?

AKS
I believe it was 1970. Maybe you could check on that and see if you can find a copy on that.

AD
I'm not actually sure about the 71 date for Kissinger, whether it was 71 or 72.

AKS
Right. In fact, in fact, I had been to China in the spring of 1971 with my then husband Robert Keatley who was a journalist for the Wall Street Journal. He and Sy Toppings of the New York Times, and Bill Atwood at Newsday, these three journalists were invited by Zhou Enlai to come to China. So they, with their wives, went to China in the spring of 1971, in May-June of 1971, and shortly thereafter Kissinger traveled to China to initiate government-to-government ties. So at that time things really began popping in U.S.-China relations, and the National Academy of Sciences decided to reestablish, reinvigorate the Committee on Scholarly Communication with Mainland China that had been in mothballs since '66, since the Chinese did not respond to the Academy's forays and letters. At that time, the Academy asked me to be the first Staff Director – I should say the first in this era. At that time we changed the name to the Committee on Scholarly Communication with the People's Republic of China.

Ummh, should I continue to talk?

AD
Sure.

AKS
OK. We reestablished the Committee and the members. The real intellectual energy came from two individuals, Doak Barnett and Alex Eckstein. Both by that time were also the primary intellectual and emotional leaders of another committee, The National Committee on U.S.-China Relations. The Committee was sponsored not only by the National Academy of Sciences, but also by the Social Science Research Council and the American Council of Learned Societies. So the President of the American Council of Learned Societies, Fred Burkehardt, and the President of the Social Science Research Council, Eleanor Sheldon, and Harrison Brown who was Foreign Secretary of the Academy, got together and reconstituted the Committee with a tripartite membership. The membership included members of the Academy and outstanding China specialists

and individuals from other disciplines in the humanities. I assume you'll attach, Alex, a list of all the members.

AD
Attach the list as an appendix to the report?

AKS
Right. The first Chairman of the Committee was Emil Smith.

AD
Of the reconstituted Committee?

AKS
Right. We began to do a number of things at the same time. One was to try to establish ties directly with our Chinese counterparts. Another was to talk with the people in the U.S. government who were working on U.S.-China ties. Our primary contact was Richard Solomon on the NSC staff. We also had important contacts in the Department of State. Remember to put those names in. Of course [we also had contacts] with everyone involved with U.S.-China relations at that time – all the private sector entities, the National Committee on U.S.-China Relations, the Trade Council.

We all talked among ourselves, trying to figure out what kind of policy basis to establish both for relationships with China and for relationships with the U.S. government. It was interesting to me because there was tremendous excitement, as you say, intellectual energy and also emotional energy in terms of U.S.-China ties among the scientific community. Another primary organization interested in these relationships, other than the National Academy of Sciences, was the Federation of American Scientists (FAS). There was some dispute about what organizations the Chinese would prefer… with whom the Chinese would prefer to deal between the Academy and the Federation of American Scientists. Because the FAS was of a liberal political persuasion, they thought that the Chinese would prefer to deal with them.

It is interesting because, in one of my conversations with a Chinese government representative– I'll have to look back at my notes to see who this was –the question this individual posed to me was basically in the hierarchy of the U.S. scientific establishment, who was highest and most prestigious? I said it was the National Academy of Sciences. I thought that was really important to the Chinese. They wanted to deal with the establishment. They wanted to deal with the highest levels in the scientific establishment. Nevertheless, the first Chinese groups that we received in the United States were co-hosted by the National Academy of Sciences, or actually the Committee which is the tripartite committee, jointly with the Federation of American Scientists.

AD
I didn't know that. That's interesting.

AKS
Right.

AD
I knew there was a separation of the groups agreed to when you went to China. There were groups that they [the Chinese] had agreed to prior to [your visit], or something like that? These [groups] were folded in [to the list agreed to by the Chinese].

AKS
I'm going to have to look that up in my notes.

AD
I'm really not sure.

AKS
I'm going to have to look that up. The very first groups that came both came after the Kissinger trip and after the Nixon trip in 72

AD
February 72.

AKS
Seventy-two?

AD
There was a toast to Chairman Mao and to Zhou Enlai. I assume it was in China.

AKS
The first two groups that came were a Chinese medical delegation and a Chinese scientific delegation. I traveled around with both those delegations along with Denise Emery and Guy Alito. They were received everywhere at the major universities. You can append their itinerary. It was interesting. Everybody was so excited about this relationship. I was just a little bureaucrat at the National Academy of Sciences as Director of this Committee, but I could call university presidents, Nobel Prize winners. I could call anybody and say that I was Anne Keatley calling from the Committee on Scholarly Communications with the National Academy of Sciences, and I would be put right through to presidents and potentates. Anybody would take my call because they were so excited about the relationship. It had its upside and its downside, this kind of emotional enthusiasm.

These first two delegations we took around to all the major universities. We had a full complement of State Department Security. In Boston we walked the Freedom Trail with Mayor Kevin White, the Mayor of Boston, with grocery store owners coming out of the grocery stores and saying, "Oh, hi Mayor White." It was really very touching and exciting. Of course everyone was so interested in the Chinese. With the Medical Delegation we were hosted by Paul Dudley White, who had been President Eisenhower's doctor, and his wife. What we were trying to do from the outset of the Committee's work, from these first trips and throughout the 1970s, the real focus and purpose of the Committee's work was to establish direct ties between scientific institutions, between individual scientists, and between government entities - government scientific entities - and to do so on a basis of mutual interest and reciprocity.

We defined reciprocity not as direct reciprocity but as reciprocity of interests – that is, we strived to have the Chinese formulating their interests…to express their interests, and we would be responsive to the extent that we could to their interests which were primarily in the physical sciences. We wanted them in turn to respond to our interests in exchanges, our substantive interests which while certainly they were in areas of the physical sciences, were perhaps more so in the areas of the social sciences and humanities. So we defined and perceived reciprocity in that way. Each side would respond to the other side's interests. This was a constant matter for negotiation and area of disagreement. Accordingly, we had to devise various ways to pursue U.S. interests in this respect.

AD
May I ask you, did that difference in interests continue throughout the time that you were the head of the staff of the Committee- that is, our interest more in the social sciences?

AKS
Yes. Yes. Certainly the members of the scientific community were enormously interested in meeting with their Chinese counterparts and learning about the work that was going on in China in their fields. In every field, I would say in every field basically China had lost a whole generation of training and research because of the Cultural Revolution. So, other than access to China as a land mass, the Chinese capabilities were uneven.

There were some areas, pharmacology for example, where access to Chinese traditional medicine or Chinese botany, or Chinese history in seismology [for example] which had an extraordinary record of earthquakes going back three-thousand years… there were some areas where the scientific community was enormously interested and could benefit from access to Chinese, to China as a land mass, and to Chinese records. However, for the most part clearly in the sciences they were far behind.

What we did try to do throughout the 1970s was to compile a record, an understanding of Chinese scientific institutions, the Chinese scientific community, and the nature of the work at that time.

So all of our delegations… Let me say at the outset that the form of U.S.-China exchanges under the Committee's work in the 1970s was exchange of delegations. That is, we would send to China and receive in the United States delegations in broad fields, in broad sectors…I mean, really broad - chemistry, physics, seismology – with ten people on the delegation. For the Chinese delegations coming to the United States, the delegations were almost always headed by very senior scientists, many of whom had trained in the United States in the 40s or before ‘49, before relationships were cut off. The delegations going both ways, they were the very senior people in the field.

With the Chinese scientists coming to the United States there was always a political representative. I suppose they assumed that there were political representatives on our delegations going to China since we always had someone from the State Department and we always put on a China specialist. We added some of the most senior China specialists in the United States to our delegations whether they were the entomology delegation or the seismology delegation; and we did so because there was no other way that our China specialists had access to China. While we were attempting to push this concept of reciprocity, in fact we had great difficulty getting social scientists, particularly China specialists to China. So we just started adding a senior China specialist to every delegation we sent and a State Department person as well.

AD
In reading up on some of this history, I recall the first CSCPRC visit in 1973 when you met with Zhou Enlai. You had brought twelve proposals, and I believe that he had accepted nine, but the three that he didn’t accept were basically in the social sciences and not in the hard sciences. Urban studies was one of them.

AKS
I’m going to have to look up my notes on that Alex. You know, I should say that when I went to China on my first visit with Robert Keatley, the three journalists, I carried with me a letter from the Academy. That was, as I said, in the spring of 71. When the first Chinese delegations – that is, the scientific delegation and the medical delegation – came in 1972, the first formal Academy delegation to China – or I should say from the Committee on Scholarly Communication, which was a tripartite committee – that delegation went in 1973, if I’m not mistaken. I know it very well. It went in 73 because I was pregnant with my son Eric in the spring of 73.

AD
Spring of 73. Yes, that’s right because that’s when I came on board too and you were away at that time.

AKS
Eric was born in November and I was four months pregnant when that delegation went to China, and we did meet with Zhou Enlai. I had met with Zhou Enlai in the spring of 71 with the journalists’ delegation. Then of course the CSCPRC delegation met with Zhou Enlai in the spring of 73. You probably have better…Of course we had a list of..

AD
I’ve read up on it so I know that list of the people who went.

AKS
And the list of the fields that we suggested?

AD
And the fields that we suggested. There were twelve fields as I remember, nine of which Zhou Enlai accepted. Interesting…Zhou Enlai was the one who did this.

AKS
Yes. Right.

AD
And three [fields were] rejected. I remember one was something to do with city studies.

AKS
I'm going to have to look. Social sciences, undoubtedly.

AD
Right

AKS
I'm going to have to refresh my memory on that.

So, would you like to ask me a question, or shall I just…

AD
Yes. I'd like to ask…

AKS
Can I just say one thing?

AD
Yes.

AKS
About motivations?

AD
Yes.

AKS
And background? This CSCPRC was formed in 1966, and from the point of view of the scientific community, the scientific community had this… I'd call it "an ideology," although they wouldn't like that, that science was universal, and that there was a universal camaraderie within the scientific community that could transcend political…a lot of geopolitical problems. The view was that all scientists should be able to communicate with each other and could talk about their work without being inhibited by political or ideological problems that beset government-to-government relations or even relationships between societies and countries. They also felt that scientific exchanges could lead to better relationships between and among countries.

The scientific community had been very active in relations between the United States and the Soviet Union, particularly concerned with Jewish scientists in the Soviet Union that were persecuted in the Soviet Union and could not pursue their work. So this view of the "universality" of science and the ability of scientific ties to transcend the political differences was a fundamental basis for the Academy of Sciences to be so interested in establishing ties with China. From the point of view of the White House, I believe, non-government programs such as ours were important primarily for their symbolic value. They were symbols of the evolving government-to-government ties. For the scientific community, however, I would say the primary early interest was the belief in the universality of science and of the nature of science to transcend political differences.

AD
May I ask about that, just to follow up? At one point early in its history, the Committee became, along with two other groups, a "facilitating organization" meaning that the U.S. government viewed it as helping to facilitate the evolving relationship with China in accordance with government policy. What I want to ask you is whether that government involvement was of any concern to the members of the Committee that you may recall?

AKS
Right. I wouldn't say concern; but I also wouldn't say we were completely in harmony with the government desires. Our exchanges and those of the National Committee [on U.S.-China Relations], in the Trade Council [National Council on U.S.-China Trade] were referred to, primarily by the U.S. government, as "facilitated exchanges". That was their word, "facilitated". I'm not sure who was facilitating, but certainly when Henry Kissinger went to China and had discussions with Zhou Enlai he would come back and there were a lot of things he couldn't talk about. One thing he could say, however, to the press and publicly about his discussions was that both agreed to these exchanges, - our exchanges and those of the other two committees.

Certainly the fact that we had the blessing of the US government was important; and the blessing of the Chinese government was essential to what we did during the 70's. On the other hand, we had some differences with the government. The only major difference that I had, that I can recall, had to do with the number of groups going back and forth each way. The government viewed the three organizations that were operating these so- called facilitated exchanges, as being all in one basket of non-governmental relationships. The Committee wanted to pursue reciprocity within its programs. We wanted reciprocity to be in connection with the work of the CSCPRC and its sponsoring organizations - the Social Science Research Council, the American Council Learned Societies and the National Academy of Sciences.

I remember having an exchange with Henry Kissinger. I was quite a young woman, but I can remember in a very serious manner explaining to Henry Kissinger -- he was kind of staring at me but I could still see his face with this kind of bemused look like 'you silly girl' -- how important our view of reciprocity was within our own program, rather than reciprocity that included our receiving Chinese scientists and some other organization like the National Committee on U.S.-China Relations] sending congressional groups. That was the only real difference of opinion that I can remember with the government.

AD
Let me ask what the key factors had been in determining the evolution of US-China scientific and technical relations since the 70's? And…

AKS
I'm sorry. What was the question?

AD
What key factors have determined the evolution of US-China scientific and technical relations from the early 1970's to the present? And what do you think of the current state of the S&T relationship?

AKS
Well, it's changed over time. In the early 1970's the scientific community is what I just described- that is the view that the U.S. scientific community and international scientific community could have contacts and ties, substantive ties, that weren't inhibited by political strains or differences, and secondly that they could also contribute to better ties between countries and governments. That was the main view of the scientific community.

Throughout the 70's, the mitigating factors were political, however. That is, the exchanges provided the first opportunity for peoples of both countries to see each other, know each other, get a first-hand sense of each other. For us, the scientific community, we got a sense of what the Chinese were doing, and where and what the priority of their work was. However, what the American groups in China saw was highly structured and highly choreographed. That is, there was always an ideological message, and we accepted this. I think we were fairly clear about the ideological message and the fact that we were seeing, I wouldn't say a false picture, but the Chinese were putting forward their best face. It's interesting because for the Chinese groups coming to the United States I assume that they thought we were putting forward our best face as well, but the response that they got in the United States was enormously positive. It was like a love affair actually, certainly on the part of the Americans. It was amazing, I mean….

AD
Not just the scientists.

AKS
Everyone, not just the scientists. The people were writing poems, singing songs, presenting Bibles, practically fighting for access to the delegations.

AD
Haha. Just what they needed.

AKS
Haha, right. People were just emotionally engaged in this relationship. It was odd that people always felt that they were the first to have some sort of ties, some sort of new breakthrough in terms of US-China relations. We heard repeatedly that this was the first time the Chinese had done something like this-I don't know-not only the first time they had visited a place-I don't know-but the first time they had gone out to a Chinese restaurant and opened a fortune cookie. Some people managed to find things and exalt in establishing a tie with China that was the first. I think this was part of their very successful choreographing that China managed to design in terms of the relationship. The bottom line is there was a tremendous emotional element to these ties.

Throughout out the 70's the CSCPRC continually tried to make the relationships ties more sustentative. I mean we wanted to move the format of delegations of ten persons traveling around the country for a month, to a more substantive relationship, for example of individuals going and spending a lot of time -- longer stays and individual stays. We were constantly trying to make the relationship more substantive intellectually, and on a professional basis. But actually we were actually not able to do that until the official diplomatic ties were established in 1979.

AD
You had mentioned…you had said something about being in China and how they put their best foot forward. Could you say a little more about your impression of China as you went around at that time, and of the people that you met – the scientists - how you and they intereacted…. not just you but the other Americans, and also, whether or not the Chinese had the same view of things that we did – that is, American scientists felt that this was to be scientist-to-scientist and free of politics and so on. Was that reflected in the Chinese?

AKS
Not during the 70s …not to me. The Chinese delegations and the individual Chinese were quite disciplined. They never deviated from the political message that was being put forth by the individuals on these delegations who were the political representatives. First of all, the delegations that I traveled around with were very, very high level. When the Committee delegation went in 73, it was a very senior, multidisciplinary delegation. We traveled around to…I can't remember the number of cities, but we were always received by the most senior political people and leaders of many universities and the research establishment. We had major banquets with the best Chinese food everywhere we went. So, in the 1970s my experiences were unusual because they were with very senior delegations. We interacted at a very senior level of institutions.

I will say that my impression of the Chinese scientists was very, very positive. Maybe here I get emotional too, but I found these people not only brilliant and having been really deprived of an opportunity to do their work, but also I found them personally very attuned to people's feelings - very warm, responsive. They were lovely people. I'll give you an example. The very first scientific delegation that came to the United States we took to the White House to visit the President's Science Advisor. I have to look back at who that was. It may have been Ed David in 1973. It must have been Ed David. We took the first scientific delegation in and there were formal presentations on both sides that involved a lot of references to scientific institutions – the Office of Science and Technology Policy, the National Science Foundation, the National Academy of Sciences, etc., etc. We had an interpreter, Guy Alito, who was a superb interpreter, but this was really difficult. It would have been difficult for anyone. He wasn't scientifically trained, but even more so he just didn't have any idea how to very quickly do the translation and interpreting of these scientific names. So as we got back onto the bus, it was dark and everybody was very quiet, and I could hear the Chinese talking among themselves saying "Hsiao Ai hen xinku," [which was basically saying in Chinese "Little Alito was very sad." I heard them back there: "Little Alito is very, very sad."] In fact, Guy was embarrassed that he hadn't done as well as he wanted to do. So the Chairman of the delegation cleared his throat and said: "Mrs. Keatley, we think Mr. Alito did an excellent job under difficult circumstances."

This is just one anecdote and there are so many. They were so attuned to the feelings and the relationships. I will say also – Alex, you can speak to this – that sometimes these delegations, because they were required to play these political roles…sometimes they were really difficult. It was usually when somebody had done something they considered to be politically unacceptable, like instead of saying People's Republic of China, somebody got confused and said the Republic of China. Then there would be an official complaint. There were official complaints all the time.

AD
Can I tell my little anecdote? We were flying over Boston with a Chinese delegation at the time, and the pilot was very enthusiastic about having a group from the People's Republic of China on board. So he came onto the microphone and said to all of the passengers, "Ladies and gentlemen, we are very honored to have a group of distinguished scientists from the Republic of China today, and I'm going to do a few little curves and dips of the airplane and show them a little of Boston, if you won't mind. So he proceeded to go left and right, and so on. Hard to imagine these days.

AKS
Never.

AD
So, that all was very nice, but suddenly I felt a tapping on my shoulder after this was over, and the representative from the, at that time, the Liaison Office because there was no Embassy at the time of the Liaison Office…I remember it was Yu Renquan…he tapped me on the shoulder and he said: "He said Republic of China." "Yes," I said. "Well yeah, but he meant, you know, the Peoples Republic." I said, "Believe it or not, most Americans don't know the difference between Mainland China and Taiwan China." I didn't say it that way, as of course there only is one China. But then he said, "Yes. He seemed like he was friendly, but if he is truly a friend, he will correct his mistake. Would you please inform the captain?" So I called the stewardess over and I said "yada yada yada," and she went up and she told the captain, the pilot, and in a minute or two he

comes back on and he says, “Oh, I’m so sorry. I meant to say the People’s Republic of China.” They could be very difficult that way.

AKS
But that was all about that issue, very seldom about any other issue.

Richard Solomon (RS)
Not to interrupt, but David Bruce was invited by the Chinese Liaison Office for a going-away party at the Yenching Palace Restaurant. David Bruce was at that point, I would guess, in his early seventies. He had been an ambassador most distinguished to Britain and several other countries. He was our leading ambassador, and when he got up to tell about the growing friendship between China and the United States, he said the Republic of China. There was a stunned silence for a nanosecond. Then everybody departed. Everybody realized this was a (unintelligible)

AKS
Everybody realized he was the first head of our Liaison Office [in Beijing]. Well the Chinese could be enormously diplomatic and gracious when the circumstances required.

RS
They could ignore it [protocol offenses] depending on the circumstances.

AKS
They were enormously sympathetic to anything. I remember poor Jerry Ford. I took a scientific delegation to see Jerry Ford after Fromm…what was her name?

RS
Squeaky Fromm.

AKS
After Squeaky Fromm shot at him, and we went in to see him and I had never seen someone who looked so awful. His eyes were red. He was pale. He looked exhausted, the President. So, he looks up and he starts giving his welcoming remarks and he said, “We’re so happy to have this delegation here with scientists in physics and chemistry and astrology.”

AKS
The interpreter of course just ignored it and translated [it as] astronomy. Nobody said anything.

AD
Sure.

AKS
It would be interesting to talk to American scientists about their observations. I remember in 1980 I was walking through the Great Hall of the National Academy of

Sciences and met an Academy Member, Arthur Kelman, a plant biologist. Art grabbed me by the arm and said, "Do you remember me? You sent me to China. It changed my life." I said "What do you mean it changed your life?" He said "Well I was doing very theoretical research, and I went to China and everybody was talking about serving the people. So I came back and talked to the farmers in my state. "I talked to them about what their problems were and what they needed, and I started doing applied research that would meet the needs of the farmers in my state.

AD
So that changed him a lot.

Do you have any thoughts about the current relationship in S&T.? I mean, you've obviously had a long history with US-China relations and at a very crucial stage in that relationship. Have things developed in the way that you… Do you think that they have developed well or do you have some concerns. What do you think of the current relationship?

AKS
One thing I didn't mention. We talked about the CSCPRC. During the Carter Administration I took a leave-of-absence from the National Academy of Sciences, and I went to work at the White House Office of Science and Technology Policy [OSTP] which was then headed by Frank Press, who was President Carter's Science Advisor. Frank Press had been Chairman of the Committee on Scholarly Communications with the People's Republic of China. He asked me to join the staff of OSTP when he became Carter's Science Advisor. I got to work on U.S.-China science relations and other U.S. international science and technology relationships. So I spent three years at OSTP working on the first US – and we can talk about this later – how we put together the first US-China science and technology agreement.

You asked about U.S. policy motivation – the issue of policy motivations is something that Richard [Solomon] can talk about. It has also been written about by Mike Oksenberg who was then on the NSC [National Security Council] staff under [Zbigniew] Brzezinski. Mike [Oksenberg] has written about US-China relations in the political context and in the context of U.S. relations with the Soviet Union at that time. From the point of view of the motivating forces, they were bigger than the scientific community; basically U.S.-China scientific relations were one part of the political development and political ties which were of course the dominant and motivating force in the relationship. The first U.S.-China science and technology agreement was negotiated in 1979.

It did allow for the first time government-agency-to-government-agency ties. The National Science Foundation, the National Institutes of Health, NASA, and Department of Energy – all of these government agencies and their laboratories were at last able to have official ties with their Chinese counterparts. It also established an opportunity for the first time for students to go back and forth. This was enormously important because it provided a chance for individuals to come and stay for longer periods of time, including young people, which was dramatic and is enormously important in the relationship to this day. We can talk about the pros and cons of that, but in my own view it was important and positive for both countries as well as for the individuals involved.

RS
Anne, you should talk about the meeting with Deng Xiaoping in May of 78 when you were there and we talked about sending students to the United States.

AKS
That was Frank Press who led that delegation.

RS
The point is the political climate was changing dramatically as Deng instituted his de-Maoisization and opened the "kai-fang" [opening] policies and the notion of sending … You see, you were dealing at a senior level and can you talk about it. There was a big gap emerging [in science and technology] because there was no junior level – the Cultural Revolution was destroying the educational system that was generating that power. So, comes along Deng who totally changes the situation. The ability to send very young people over here and motivate them focused very heavily in the sciences. It was an enormous breakthrough, and you were in the middle of that transformation.

AKS
Well, Brzezinski went to China in the early spring, March, of 78. Frank Press led a delegation later in the spring of that year. I think it was 78. That delegation included all the senior presidential appointees in science: the head of the National Science Foundation, the Director of the National Institutes of Health, the Undersecretary for Technology, Energy, etc., etc. That time we presented a menu of the areas for the substance of the science and technology agreement. The substance was very simply government-to-government ties. So we had – I'll have to look back at the records – we even had for NASA the sale and the delivery of a U.S. "turnkey-in-orbit" communications satellite. There was a lot of discussion, even dissention, in the U.S. government prior to presenting these areas, specific areas for exchange.

During the Press delegation the Chinese – and this comes from Deng Xiaoping – the Chinese shocked us by saying they wanted to send 700 students to the United States. One member of the U.S. delegation, Roger Sullivan, from the Department of State, said "This is nothing new. This is nothing new." And I kept saying, "This is dramatic. This is major. This is new." And it was major, dramatic and new. The Chinese – Deng Xiaoping was ready to have young Chinese students come to the United States for the very reason you mentioned – that is, he realized that it was essential to have these young people trained, and he wanted them trained at American universities. The Chinese educational system had been decimated by the Cultural Revolution.

AD
Now these were by and large graduate students or older.

AKS
Graduate students.

AD
Because I remember that there was some concern at the time that people would be rewarded for their …

AKS
They'd be political…

AD
…longevity and their political stuff, but I guess by and large they were bona fide scientists.

AKS
Right. That really, at the Office of Science and Technology Policy, marked the end of my direct work on US China relations until in the mid-90s. I was Deputy Assistant Secretary of State for science, technology and health, and once again I had responsibility for the U.S-China Science and Technology Agreement. That was in the mid 90s.

AD
So you were involved in the Joint Commission Meetings?

AKS
Yes. What I wanted to say about the government-to-government agreements was that those ties, just as predicted, by the science communities in the 60s… the science relationship survived the worst of times: Tiananmen, when everything was stopped. The science ties quietly continued despite the severe political problems between the two countries, at least in that Tiananmen Incident in June of 89.

AD
Tiananmen and the fall of the Soviet Union were certainly major breakpoints in the tenor of the relationship. But I do remember that the S&T relationship seemed to continue. In fact it thrived even after that.

AKS
You asked me a question and I didn't address it.

AD
I had asked you what you think of the current state of the S&T relationship. When you look back at what you had hoped for and what we thought was going to happen, do you think that we have reached the point…have we fulfilled the promise? What do you think of the current S&T relationship?

AKS
The objectives of the Committee on Scholarly Communications as they were set up in the early 70s were really fulfilled by the 80s, I mean, the objectives to aid the establishment of direct ties between individuals and major institutions – universities, research institutions, between government agencies. That was the objective of the Committee on Scholarly Communications, and that objective was really fulfilled. Now perhaps the Committee could have acted to take on other roles. We can talk about that. But in terms of the initial objectives those were the right objectives in my view; and those were fulfilled, unlike the scientific exchanges with the Soviet Union, that were often structured through one organization

Now, in terms of ties today, they are very exciting, dynamic, and complex. You've got people going back and forth and no longer a single organization, not even the federal government, although I'm sure to its disappointment, knows everything that's going on. You've got universities establishing research labs. Yale University is just establishing a major research lab in Shanghai in biomedical research. You have high-tech companies placing not only their key corporate offices and not only manufacturing facilities but also establishing research and development facilities in China. We have superb Chinese young people in our universities and in our research labs. The universities rely on these young people for research and for teaching; and the companies rely on them as well. They are smart; they're capable; and they're doing important work. So, the relationships today are dynamic; and what everybody is asking now is China going to be a scientific and technological powerhouse, and what does this mean for U.S. interests – not only our economic and competitive interests and high-tech industry, but also our security interests. The future will tell, but there's no doubt about the fact that the Chinese stated intention these days is to have an integrated research, technology and education system that serves both commercial and military security interests. Many of the areas such as information and communication technology are dual-use as are many other sectors. Biotechnology is dual-use. It can be used for cures or for bio-weapons. The fifteen year plan that just came out this January (2006) indicates that the research and training investments are intended to support both commercial and military objectives -- to build technological strength for both commercial and military purposes.

AD
How should we react to that? Obviously they didn't even have to say it. We knew that it was going to be done. But now that they've said it as well…?

AKS
Sure. Well, the big issue is that the United States is no longer the "fat boy" in the boat – that is, the only source of S&T strength. The Chinese have intellectual, educational research ties with countries in Europe, with the Israelis, with countries throughout the world. They have access to advanced technology all over the world. They have access to intellectual ties globally. So, the extent to which the United States can control Chinese access to the best scientific and technological assets that it doesn't have within the country is really questionable. There may be a short list of technologies that we can control or could control for the most part, but we have a global system and an important

component is the multinational companies. Multinational companies are globalized. I was trying to say that we are living in a globalized world and companies are pursuing markets globally; and China is the most important market for companies these days. The China market is considered by multinational firms to be essential in their growth. This means establishing corporate facilities, including research and development, and these research and development facilities are intended to develop products not only designed for the Chinese market but also for regional markets, and now even global markets. They're looking for human resources – that is, smart, trained people – at a low cost and they also have to have close ties to the market. They have to have not only their manufacturing but also their product development close to the market so that whatever they're selling or want to sell is designed specifically for the Chinese market and the regional market.

AD
I would like to go back for a moment to something that you alluded to a few minutes ago. When you were talking about the Committee on Scholarly Communication with the People's Republic of China, you sort of implied that there could have been some role for that committee, or that that committee might have served some other purpose after it finished the initial purpose of bringing the two communities together. Do you want to expand on that a little and tell us what you had in mind? Or did I misread what you said?

AKS
I have to think about this. I think that the Committee was correct that it shouldn't be a gate, an almost exclusive means or mechanism for operating exchanges. On the other hand, a whole range of issues that come up – policy issues in U.S.-China relations, including in academic and scientific relations (unclear) warrant consideration and analysis by the United States. I think the Committee had the capability because of its sponsorship by the National Academy of Sciences, the Social Science Research Council, and the American Council of Learned Societies, to draw on people from a wide range of disciplines to consider thoughtfully some of the policy issues that the institutions were confronting in developing ties with the Chinese. Even today the issue of intellectual property rights, for example…

There are two things that a committee or entity could do. One is they could look at the policy questions confronting institutions dealing with the Chinese and describe them, discuss what the issue are, and maybe come up with some recommendations. Secondly, they could explore these policy issues with the Chinese directly. Intellectual property rights (unclear) is an easy one. Perhaps on our side one that could be considered here is the recent confrontation involving Microsoft, Yahoo, and Google and how high-tech companies, Internet companies, are dealing with issues of responding to Chinese requests for censorship and repression of materials and people.[37] Those kinds of issues are really

[37] Early in 2006 Amnesty International accused the three Internet giants of throwing aside their stated corporate values and policies for a slice of the Chinese market by implementing censorship on Chinese territory and breaching the Universal Declaration on Human Rights while partaking in Beijing's repressive measures. AI's report is entitled Undermining Freedom of Expression in China.

ones that require a lot of thought and concern by our smartest people. That's the kind of role I would like to see a successor to the committee taking on.

AD
By saying that, you are saying that it is not being done – that kind of overlooking of the situation including what is happening and other things that are going on.

AKS
It's being done here and there. Obviously there are organizations, like the 'Council on Foreign Relations-like think tanks that look at US-China relations and that look at that aspect of it, but not in the way the committee could, focused specifically on China. I don't think we have a critical mass that has all the capabilities, that is the convening power, the multidisciplinary convening power that was back of those institutions, the bipartisan, balanced nature of those institutions. Those three institutions brought a lot to the table to discuss policy issues. We need respected institutions and a multidisciplinary group of people together in a balanced bipartisan way to deal with these tough issues, and that can bring in people from the private sector without being seen as a mouthpiece for the private sector.

AD
Do you see such a group having a special relationship with the government?

AKS
I think it would probably be like the seventies. It would have good ties with the government, although it would be outside the government and independent and not constrained to go along with government policy. At the same time it would have to operate in such a way that it would be influential in terms of the government policy. It's a fine line. It would not be seen as in opposition to the government but supporting and providing the basis for wise government policy, like independent commissions that we have today.

AKS
You touched upon some of the questions that remain when you talked about a role for a multidisciplinary body like the committee was but to reflect the current situation in S&T between the two countries. However, specifically, if you have any other thoughts about how to improve the situation in addition to starting a committee of that sort, do you have any thoughts about other things that might be done and what not to do also?

AKS
Sure. I don't want to say that the committee should include the Europeans, but it certainly should be global in its focus. This kind of body should have periodic discussions with others who are dealing with similar issues.

AD
Interesting point. Could you see this kind of group having a counterpart in China with which it deals, like the CSCPRC did in some respects?

AKS
Well, it would certainly have to have bilateral discussions on China. But it might not just be one committee. It might be different groups.

AD
When you look back to the early seventies, all of the seventies, and all of those delegations that went to China and that wrote up their reports, do you feel that they withheld their impressions or do you feel that they adequately explained what they saw and heard in China?

AKS
I think so. I mean, I have no way of knowing, but the people we sent were senior people from the US scientific establishment with all of the self-confidence and egos, and I don't think they held back on anything they wanted to say. I mean, they probably couched it in diplomatic language, but the kind of people we sent I don't think they held back. They may have. But I have no way of knowing.

AD
In addition to what you've said already, are there any other lessons that you can think of that we should focus on for the future that we've learned from this past thirty-six years of relations? Or, is what we learned so tied to a time that is gone that some of those lessons can't be applied?

AKS
Well, the question of reciprocity and of pursuing your own interests is a general principle that can be pursued in different contexts today. Also, [we should be] collaborating within the United States in such a way that you are strong in negotiations with the Chinese. I mean the recent Microsoft situation is a perfect example. Those companies have made real mistakes. Their rationale is understandable but what they almost begged for in their hearing on the Hill was for the U.S. government to mandate a code of conduct. If the U.S. government and other governments mandated codes of conduct on censorship, it would allow these companies – just as we do on graft and corruption of paying bribes around the world. It would give them more of a backbone and a rationale for refusing to kow-tow, to act in such a way that is against what many feel are our western principles. So, I would say yes. It puts a lot of strength and this is once again an addition to the question as to what the committee could do. It could bring American institutions together to formulate responses and positions, such as policy positions and ethical positions to different issues that arise in the relationship and give them more backbone and strength in negotiations.

AD
Before we end this interview, are there any other points that you would like to mention at this time

AKS
Not right now. I may add it to the transcript. I'm sure I'll think of a whole range of things.

AD
Well, that was tremendous; and I appreciate very much your willingness to talk about all those things. There are a lot of questions and issues that you brought up, but I tried to keep my mouth closed as much as possible because I felt that this you being interviewed and not necessarily what I might think. There are a lot of things that you said that are of tremendous interest.

AKS
Well, any questions that you may have when you read over or listen over the transcript…

AD
What I meant was, we could sit here until the cock crows talking about, for example, your suggestion about bringing the Europeans in and what the implications of that are, and many other things that you said.

I just want to say thank you for permitting me to take this record.

AKS
Thank you. It's been a real privilege actually.

Interview with Peter Raven, Director of the Missouri Botanical Garden, on His Role in the Development of U.S.-China Scientific and Technical (S&T) Relations 1970 to the Present, recorded 14 April, 2006

(The voices transcribed on this cassette are those of Dr. Peter Raven, Director of the Missouri Botanical Garden, and Alexander De Angelis, former Director of the East Asia Program of the National Science Foundation.)

Alexander De Angelis (AD)
This is Alexander De Angelis. Today's interviewee is Dr. Peter Raven, President of the Missouri Botanical Garden. The date is 14 April 2006; and the subject is his role in the development of U.S.-China Scientific and Technical Relations.

Here we are. Would you please state your name and your current position and then tell us about what your role was and some of the issues that you confronted in your role in U.S.-China relations.

Peter Raven (PR)
My name is Peter Raven, and I'm President of the Missouri Botanical Garden in Saint Louis and also George Engelmann Professor of Botany at Washington University in St. Louis. I was born in China in Shanghai in 1936. My parents left bringing me in 1937. Like most people [I] was in the dark about what was going on in China from 1949 until the late 1970s.

Now, the first set of relationships that I dealt with in China had to do with the reestablishment of interchanges in the field of botany. In, I suppose it was 1977, the Committee on Scholarly Relations with the People's Republic of China (Committee on Scholarly Communications with the People's Republic of China or CSCPRC)) wrote me as at that time President of the Botanical Society of America – this was following Mao's death at the end of the Cultural Revolution – wrote me and said that it was time, if we were interested, if the Botanical Society of America was interested, it was time that we began looking into relationships with China and seeing what could be established. That was the main thread in my relationships. I served sporadically as a member of the Committee for the CSCPRC both before and after that. The Botanical Society matter led to a long series of relationships that I'll describe. However, I would also mention that when I became Home Secretary of the National Academy of Sciences, which I was for twelve years, that I began dealing with U.S.-China relationships in detail. In that role, with the officers of the Chinese Academy of Sciences – something that also opened up in the 1980s – as a result of the botanical activities and their unfolding that I'm about to describe, I was named in the first group of foreign members to the Chinese Academy of Sciences. I've been made an Honorary Director of many institutions in China including the Institute of Botany in Beijing [and the] the Institute of Botany in Kunming. I'm Honorary Director of the Botanical Institute in Nanjing, Honorary Professor at Peking University, and so forth. So, I've been very involved.

In recent years, I should say, before circling back to the beginning, I've done a number of reviews for China, for the Chinese Academy of Sciences, of botanical gardens and other institutions under its care such as those in Guangzhou and Kunming and Beijing, and also I've been Honorary Director of the Open Laboratory in Plant Systematics and Evolution in Beijing since it was established in about 1977. So, I've been very involved with the operation of botany in China; and also I was, I think, the only foreign member of the 1993 review of the activities of the Chinese National Science Foundation which met for three days in Beijing; and then finally we reported to Jiang Zemin about our findings in an effort to help to strengthen science funding in China on the basis of their science foundation which of course was established very much in imitation of and in complete cooperation with the National Science Foundation in the United States.

Now let me go back to the beginnings of the botanical interchange and explain how that developed. In 1977 and 1978, acting on behalf of the Botanical Society of America, I wrote Tang Peisong, who at that time was the Director of the Institute of Botany in Beijing and President of the Botanical Association of China, and proposed that we start a kind of relationship following the guidelines presented by the CSCPRC. I suggested an exchange of delegations; and in 1979 the first American delegation went to China. I selected the members of that delegation to represent diverse fields of botany. It was headed by Lawrence Bogorad, a Member of the National Academy of Sciences, a plant physiologist at Harvard University. It was about a ten person delegation. They went too China in the summer of 1979, toured all of the major botanical institutes in China, stayed there something like six weeks and in general had a very illuminating time. Sporadic trips had been made by botanists and agriculturalists since the establishment of a…since President Nixon had visited China in 1971 [sic., 1972], but they were pretty uneven and time-to-time and so forth so didn't really establish a picture of what was going on in China in botany overall. We found the report from that trip … I did not go on that delegation, although I did raise the money and select the people…we filed a report on that trip and in it we found that the picture of scientific research in botany in 1979 was pretty gray. There were a lot of people in all the laboratories who were doing identical research programs as it had been prescribed nationally. For example, many laboratories were working simultaneously on tissue cultures in rice. The possibility for foreign connections had been off the menu for so long, thirty years by that time, that the people were fairly oppressed and, of course, fairly guarded in all the early exchanges with China including many that I took part in the early 1980s, which I will get to in a minute. Of course, every one who went there was closely observed; detailed files were prepared on everything that was said and done; and interchange was pretty tightly controlled. In 1989, the Chinese sent a delegation to the United States, which I also raised money for, in the field of botany. Consisting entirely of senior scientists who had been trained before the Great Leap Forward, before 1949, who had in many cases been trained in institutions in the United States or Britain, and who were, in most cases, heads of laboratories, and so forth. By 1979 they had possibly been subjected to imprisonment, punishment and ridicule during the Cultural Revolution, but by the late 70s, of course, were rehabilitated and had taken over labs and positions of authority in China. So it was a good group. We met at the end of their trip at the University of California – Berkeley when they were ready to fly back across the Pacific and we had a conference, a day-long meeting, about what would be the most desirable next steps in Chinese-American botanical relationships. The one point which proved to be a bit of a dead-end because the timing wasn't quite right was joint field trips to parts of China – and I'll talk about that separately in a minute. Another recommendation was that the Flora of the People's Republic of China, Flora Popularis Republicae Sinicae, that [be translated] into English and then an international revision of it – and I'll talk about that separately also. Of course, a lot of movement of scientists back and forth was advocated and mutual strengthening of laboratories, and the rest. Now of course, in retrospect, that was almost simultaneous with Deng Xiaoping taking over the government and with the great liberalization, not only the well-known economic liberalization, but also a liberalization and freeing of based on Deng's consideration of all, I think, the harm that Mao had done to the country in concentrating too much power centrally and with great ambitions. Things began to open up then; but they opened very slowly, and people were naturally wary. There had been so many reprisals and problems during the past thirty-one years based on actions that people had taken which later came back to haunt them. There were so many central files and all that looking back on it one could well understand why people were as wary as they were.

I first went to China personally –that is after leaving there in 1937 – in the summer of 1981 and engaged in some preliminary conversations and visited Beijing, Nanjing, which was our sister city and sister botanical garden here for St. Louis, Kunming, Chengdu, Mount Omei near Chengdu, and made some fair number of field observations and plans in the genus Epilobium which was the genus I was interested in. Traveling around China at that time was fairly regulated, and there were only so many places that one could go; but I was given unusual privileges including being shown the places where my parents lived in Shanghai and the place where I was born, the hospital that I was born in, which has since been torn down to make way for a freeway, and so forth. It was an extremely hospitable and generous trip very early, they basically doing everything that I possibly could have wanted. Nevertheless, the lid was very much on, as I came to understand as the years went by.

During the 1980s we went forward basically on two fronts. One was trying to lay the groundwork for more joint field expeditions. Let me talk about that part first. We had a joint expedition in 1981 to Shennongjia in Hubei, which was a very interesting place for plants. The Chinese at that time – of course most of China was closed to foreigners still in 1981 – were very interested in taking people to places where they felt they had already completed botanical surveys so that nothing new would be discovered but they could kind of look at what was already known together. In 1981 the Chinese would not on field trips eat in the same place as foreigners. Foreigners had to have everything better. There was very great circumspection about speaking. They didn't know how to deal with us any better than we knew how to deal with them, although the kinds of American who were going on field trips wanted to go to very remote places where very little was known and find new things. They would have been happy to sleep on the ground, but it just wasn't possible. The Chinese were very anxious that they go to places that were well-known, because, I guess, in a sense; finding of new things would have been an admission of guilt on their part, so to speak. Unfortunately that first field trip was badly managed in the sense that the authorities of Hubei Province basically got away with a lot of the

Chinese Academy of Sciences money and spent something like $200,000 on developing new roads and new camping facilities and all the rest in the Shennongjia area. It was all so expensive and difficult for the Chinese that they became very shy about promoting any further field trips. Eventually I found during the 1980s that I was beating my head against the wall because they, our Chinese counterparts, expected anything like that – field exploration – to be so expensive and difficult for them that they didn't really want to have anything to do with it and were very reticent to take it up. After fighting that battle, I was going to China three or four times a year through the 1980s, and after fighting that battle a lot with officials at the Chinese Academy of Sciences, their foreign office managers and the like, I just said after a while, you know the Botanical Society of America is giving up on this; I'm giving up. If people want to do field trips, they should arrange them personally with their own institution and make their own arrangements. And actually I didn't know it would be that good, but the minute I did it suddenly all became very easy and the situation rapidly opened up; areas were declassified, and people began to (unclear) to put back on limits for foreigners and so forth. A great variety of joint field trips were conducted and have been conducted ever since. So, in a sense, I think it was a situation where we were trying too hard and too impatiently and that was too worrisome at the time.

With respect to the Flora of China, which is what it was ultimately named, I first took the Chinese literally at their word and tried how to produce a direct translation of the Chinese language Flora of China. Now that language describing thirty-one-thousand species of plants in China, which is about a tenth of the world total, that flora is 120 books, considered to be about 80 volumes with about 8,000 illustrations. I could not – if it would be translated literally, of course translating Chinese to English gets you about 50 percent more pages, and I couldn't find anyone willing to deal with it, even if people had been willing to translate it and revise it, which was the original idea that they proposed, as even not even University Microfilms was not willing to do it on demand, it was just too monumental to undertake, at about that point. In trying to figure out how to achieve the desired goal, that of a revised account of the plants of China, I developed the idea of doing a very condensed version that would have the same synonymy (equivalency of names) , bibliographic references, ranges, medicinal uses, and other important information, but very short descriptions and no illustrations, and calculated that if that followed the format of some of the other world floras that were being produced at the time that it could be completed in 25 volumes. That seemed to be feasible, so I proposed to the Chinese that this format be adopted and that it be considered to produced in this more concise version. Now, I proposed that in 1985; and the editorial committee of FRPS, the longer Chinese language Flora, considered that; and I was ultimately told at the International Botanical Congress in Berlin in 1987 that the project had been approved. So we went ahead and signed an agreement in St. Louis; set up a new editorial board, and developed a number of conventions for proceeding with the Flora, and it has proceeded very well. About a half of it is published now, and we have received the manuscripts from the Chinese coauthors for most of the rest. So, the work will be completed in about four or five more years, which is startlingly fast progress for such a large work. I've been co-chairman for that Flora effort ever since the beginning. I had intended in the beginning that it be handed over to Harvard University when I finally got permission to proceed, because Harvard had historically been the major center for the study of Asian plants; but they at that time, 1987, proved unwilling to take this new effort on. So I was frustrated with having worked so hard to get permission [that] I took it on myself and the Missouri Botanical Garden has been heavily, and I might say happily, engaged in it ever since. As I said, it's about half published now, and most of the manuscripts from the Chinese coauthors are on hand and in the course of revision. We developed early on a convention that every part would be coauthored and that the names of the Chinese authors would go before a semicolon in the list of authorship and the names of all non-Chinese authors would go after the semicolon. The Chinese produced the first draft and then it's revised by the others and mutually agreed and so forth. That procedure has avoided a great many difficulties along the way. Progress has been difficult at times, mainly for a wide variety of cultural reason, and not particularly scientific ones. To some extent took Chinese authors, particularly early in the process, seemed to take it as some kind of admission of guilt when whatever they had written was revised at all. Furthermore, it seemed at times that we were being presented with the view that the knowledge of Chinese plants was genetic and almost presumed in their negotiations with us that they would know right answer about Chinese plants because they were Chinese and they were always right. We got around that one along the way by adopting a convention that if there was a permanent difference of opinion that it would be published in the way that the Chinese author viewed it, but then notes would be put in explaining the alternative point of view. Obviously cultural differences have in some cases both greater with scientists from Japan; almost always great and very difficult when we brought Chinese and Russian authors together, which we have in a number of the individual treatments. I learned a lot about the way different people think about plant systematics. In my experience, and I've dealt a lot with Russian botanists also on different matters, Chinese botanists don't on the average tend to be quite as insecure about their work, but they are still quite insecure. If we can get the Chinese coauthors together with their foreign counterparts very early in the process, then they can look at the same data together just like any reasonable people, and it comes out alright. What has been remarkable has been the extraordinary unfolding of the ease with which the partnerships, the joint treatments and all, have developed over the years, over the 19 years since 1987, so that nowadays we talk much the way that co-authors would in the Western world in the best situations and strive for scientific excellence and are much less bothered by the kinds of differences in personality, style, and opinion that I've just outlined. That's very good. In other words, the Chinese coauthors have become much more confident about their works, and the whole effort is better funded than it was at the beginning. And from a low point around Tiananmen in 1989-1990 the effort has rebounded in a very healthy way, one in which collaboration is pretty equal and things are good, very good I'd say, not perfect – nothing's ever perfect – but the relationships are now fine.

A couple of secondary points…I happen to be the one when I was on the National Science Board of the United States who asked why public Internet access was not possible for China, when the Internet was perfectly accessible commercially. It still hadn't opened up at that time. That turned to be an "emperor had no clothes" phenomenon, because access opened up very quickly after that. But the Chinese regarded it as very important for their development to have official access to the Internet as opposed to commercial and other kinds of access. So that was special.

As I've gone around China obviously like everyone else I've been deeply impressed by the development of institutions, buildings, infrastructure and universities. Following the decision of the Ministry of Education in something like 1995 to begin funding research in universities a lot more – and that was one of the key recommendation of that NSFC report slightly earlier than that and a very good thing, following more the American system – of course the universities have really flourished and anybody who goes there now and studies them will see a very large amount of private philanthropy spread through the universities, just like here, not only from places like Hong Kong and other places overseas a lot of internal private philanthropy developing too. As the universities get more into research there and get in stronger and stronger position, collaboration with the labs of the Chinese Academy of Sciences and ministries and the situation will get better. The environmental field, which is something we got into through inter-Academy officer consultations, is something in which I've taken a special interest. There's been huge progress in China, but one of the things that's stopped the progress in the environmental field has been a preoccupation with economic development, a lot of the theory for which has originated not inside China but with the United States and other industrial countries. For example, once Zhou Guangzhao who was President of the Academy, said "Every time we try to do anything environmental, you send us economists from Harvard who say that's the wrong thing to do." I said at that point "Well at least we don't send you economists from the University of Chicago; so that's a blessing." There is a lot of pressure inside China to put environmental stability aside for the sake of economic progress, but those same pressures exist in all nations. The recent passage by the Chinese government of taxes on gasoline and on timber is a sign that they're increasing their sensitivity and openness to environmental improvement, realizing what a drag on the economy the opposite policy can be. They're making giant strides in that area now.

So that's about my general comment. I'm ready to draw a deep breath.

AD
Thank you so much. I've been trying to write down some notes while you've been talking to remind myself of exactly where we are. Well, you've covered this to some extent, but if you would look at your area of concern could you say something about what some of the benefits of the relationship have been both for the United States or scholars in the United States and those in China? And have there been benefits outside of the science and technology sphere that you might point out?

PR
Well, botany is of course like geology and zoology and a number of other fields, something that's very place sensitive or place oriented. Obviously access to plants and other kinds of organisms, or geology, or the weather, or anything else that varies around the world is fundamental to the development of those kinds of sciences. I think there the benefits are clear, and the benefits have included access by American, and in the case of our project, lot's of foreign scientists from many different nations to China, to visit

institutions in their field there, and to make direct observations in the areas that interest them. For the study of botany, for example, the ability to make observations of Chinese plants in China is extremely important. I might just say parenthetically, China is the richest repository of the ancient floras and faunas of the northern hemisphere that were around prior to about 15 million years ago when the global climate started to deteriorate. In China, for instance, you have thirty-one-thousand species and in the U.S. and Canada abut eighteen-thousand, and in Europe about eleven-thousand. The U.S., China and Europe are all about the same size; so that gives you some idea of the biological richness that exists in China, which contributes to the importance of what has survived and evolved there. And obviously, particularly for plants, huge numbers of cultivated plants, both ornamentals and economic plants like citrus and rhododendrons and forsythia and so forth comes from China; so there's a very important thing to be done there in terms of scientific study. It is also extremely important, as in all fields of science, to be brought into contact with different points of view, different insights, and the like, for the development of the most complete scientific theory.

Secondly, of course, the Chinese have benefited greatly from the interchange over the past 29 years, as they expressed in that first meeting in Berkeley in 1979. They had been so closed off from the rest of the world during the period 1949…the thirty years preceding 1979 really. But their opportunity to consult either colleagues or scholarly material outside of China was extremely limited. So both Chinese and Americans have benefited from the interchange. And since much of the early exploration of China for biology, geology and fields like that had been carried out by foreigners that lack of ability to access was very important for them and it's now largely been overcome. You know we're working hard overcoming it in both points of view. That's very important, and its importance goes far beyond science.

Them there's science as a way of communicating throughout the world. I mean, not only can the science of botany, and here I'm talking not only about evolutionary, ecological, systematic botany, but all other parts of the field, the cell, molecular, and organismal levels, flourish best when colleagues from all over the world form a kind of a network collaborating and cooperating, but also they form a kind of a way of communicating between scientists and ultimately between people all over the world that's very important to world harmony. Science is a means of getting beyond barriers and limitations. It's real human connections, and it's those human connections that will play an important role building a stable world.

In addition, in a world in which the population has grown from two and a half billion in 1950 to 6.5 billion today the population of China has grown at about that same speed, as has the population of the United States. It's putting so much pressure on the capacity of the world to support people. Many of the decisions that have to be made are scientific and technical. These fields are of such great importance that it is now important for all countries, and certainly for countries as large as China and the United States, to be extremely well-developed in science and technology. There are really two reasons: one is so they can build their own sustainability soundly, defining sustainability not only as ecological and environmental, but also as economic, sustainability that takes care of the needs of the people, sustainability that will help China define ways to absorb the 250 million people expected to move from the country into the cities over the next 20 years to find education, health and reasonable ways of living and all the rest. Not only is that true, but it's also true that no country can really take advantage of scientific and technical advances made in other parts of the world for its own benefit unless it has a sufficiently developed scientific and technical infrastructure. The United States, obviously, with four and a half percent of the people in the world, depends on 25 percent of the world's productivity to maintain our standard of living; and regardless of whether that's a good or a bad thing, it indicates very certainly that we are linked to people all over the world and hence very interested in how sustainably their industries, and their industries and their institutions function. China, of course, is one of the really key places where that should be and is of great importance to us, as the whole world is and must be for them.

But I think really in a very general way, and everybody will note this, the tens of thousands, hundreds of thousands, millions of Chinese who come her to the United States to study and for other reasons, and the lesser number of Americans who have gone to China to study, have produced great benefits outside of the S&T sphere in terms of human understanding. In 1989, about two months after Tiananmen, I was in Guangzhou at a meeting, and I went outside up to the top of a park and saw the Statue of Liberty carved in marble; and I said "What is that? Is that that a demonstration?" They said no, that's the monument to the American martyrs. And I asked "Who are the American martyrs?" "They were people who came over and fought with Sun Yatsen against the soldiers of the Qing Dynasty and were killed. So the Chinese put up that monument in their memory. That reminds us that the connections between China and the United States for over a hundred and fifty years have been very close and really quite friendly compared to relationships between China and Europe and they do provide understanding upon which lots of development can be built. Not only were we heavily involved there through the 1940s, but we're heavily involved again and in general we're very welcome. You know I was once flying along in China and some official of the Chinese Academy of Sciences said, "Do you feel about us the same way you feel about Russia?" And I said, "No!", I said, "Good Lord! Americans feel very friendly towards China. They know China and they know Chinese people personally. There are large numbers of Chinese in America." As Barbara Tuchman brings out, all those generations of Protestants praying in cold churches in New England for conversion of the "heathen" Chinese and sending missionaries over there and Pearl Buck's romantic stories, and everything else have given us a good feeling about China, and whether we truly understand China or not, we kind of feel that we do; whereas our feelings about Russia is almost non-existent. It's almost as if it's not there. The doctor who delivered me in Shanghai in 1936 was in the first Boxer Indemnification class who came to the United States, where he got his M.D. in Johns Hopkins University." My life individually of course has made me feel extremely friendly and connected with Chinese because of my parents' background there were always large numbers of Chinese and Chinese objects and things around. So I can, as I said, feel extremely comfortable and connected with whenever I'm with a group of Chinese. And I think the history gives us a basis that – Tang Peisong, the Director of the Botanical Research Institute in Beijing that I mentioned – you know, when the people were going to Shennongjia? Do you know what the meaning of the word Shennongjia means? It means “Shennong’s ladder.” Shennong is the legendary Chinese Emperor who taught China the use of plants for medicine. When they were going to Shennongjia and I was there in the summer of 1981, Tang Peisong said “We welcome back our American friends;” in a toast, “We appreciate their care and concern for China and their friendship over the years.” He said, “We’ve been out of touch with you for 32 years now, but as measured in the time of Shennong, 32 years in like the blinking of an eye. Our friendship is permanent and deeply rooted.” And you know, I think it is true. It’s not that Chinese like any country was not trying to get their own objectives, and it’s certainly not that they don’t consider themselves the best people on earth, you know, and all the other many things that are well known, but I think we’ve really got a good thing going there in terms of developing and maintaining friendly relations in the future and I think that what we’ve done in science and technology has really helped out a lot. It’s been natural from the standpoint of both sides, and it’s really helped out a lot. I mean after all the twelve universities that the Americans were operating in China before 1949 were closed, the academic connections were badly injured, but now they are clearly revived and stronger than ever.

AD
Yes. Do you think that the younger Chinese today share the same feelings as their older predecessors?

PR
Better! I think it’s even better from the standpoint of those I deal with. Because they’re much more… you know, there less…it’s amazing how fast people forget, but I mean they weren’t burdened by the Great Leap Forward and increasingly not even by the Cultural Revolution, and they , and I think they feel like they’re scientists who live in the world and are eager to find connections and deal with them in an even-handed way. That’s why I say the performance in the Flora of China has improved steadily; and it’s the younger people getting in that have really, you know, cut the garbage and let’s talk about this and what do we do next. And I think they feel completely friendly. Obviously the Chinese like almost all other foreigners are incredibly thwarted by the current visa situation in the U.S. That has been a terrific negative disincentive on a relationship that otherwise has developed well. I think it’s worse for us than it is for the Chinese. I’ve talked to several upper level Chinese officials who just say “I’m not willing to subject myself to the indignity, having been to the United States fifteen times already, of going in and being interviewed by a twenty-two year old in the American Embassy to tell me whether I can go this time, or have become a serious security risk.”

AD
Yeah. Or to get finger printed.

PR
No. I mean it’s awful. It’s very, very bad. I mean, just from the standpoint of the American scientific community, I think it’s very, very bad.

AD
Does it continue to be bad? I mean, I've hear different things. I've heard from some that it's gotten better recently.

PR
Yeah. It's gotten better

AD
Good. Well, that's good.

PR
You know, I've only realized recently what you must know well, and that is that a lot of it stems, crazily enough, that we don't have an effective way of tracing foreigners once they get into the United States. You know, getting into England, for instance, is relatively easy, but they keep good track of you when you're there. We apparently don't keep any track of people once they're here.

AD
No... once they're here…

AD
No, I remember …

PR
They can overstay their visas and do whatever they want to.

AD
No, I remember…

PR
…fantastically nervous about admitting people.

AD
Well that's a good point. I remember when I was at NSF before I retired, and many years before, any attempt that we might have made from NSF to know what was happening with Chinese graduate students, and so on, we thought was a natural thing. You know, to know where they're going, for scientific reasons, was thwarted because the feeling was that if we were to ask too many questions then the private sector, the universities and so on, would feel that the government was Big Brother trying to weigh in on these things. So ..

PR
Not only that. If you're an Indian family or something and you want to come to the United States as tourists, you get inside the United States and nobody knows where you are. You might commit a crime or you might not. As I said, the really unfortunate side of that, you know, demanding all that freedom once they're here, and not registering with

the police, and not doing all the things that are so common in other countries, is that we're very tight about letting them in, which is really what causes a lot of trouble.

AD
Sure. Sure. I guess it's this fear of, you know, we really don't know what's going on so we expect the worse, you know?

PR
The Counselor Officer who lets them in has become personally responsible too. So that twenty-year-old who is so offensive is quaking in his or her boots.

AD
Exactly. Right. And even if you look at some of the areas that are, quote unquote "sensitive" for example, you know the Consular Officer has no idea whether that is real… whether the person who's applying for a visa is really a sensitive person from a military, you know, or whatever point of view, or is really you know a typical scientist who's looking at basic types of things. It's difficult.

PR
Most of what you have in the last sentences …I could highlight by quoting Murray Gelman when the situation was going on in Los Alamos, the guy from Taiwan or wherever he was from…

AD
Wen Houli.

PR
Yeah. ..said "You know, its' very important…" and I think he got this from somebody else, but he was the one I heard it from, said "It's very important obviously for the United States to protect its nuclear secrets, but it's even more important for us to develop nuclear secrets worth protecting in the first place."

AD
Right. Right. The funny kind of thing, even Teller said that he would do away with the classification because it's really the advanced knowledge that's most important.

PR
Exactly. And the only way you get that in a world in which science and technology are manifestly international is to cooperate throughout the world in your particular field and take advantage of the best brains and labs and developments you can find. You don't have to be childish about it. I mean you don't have to deliver bombs to other people, and all, and there's certainly some things you don't want to share freely, but there are those industrial and in many other ways as well…I regard…I think the United States should regard the development of science and technology around the world as very much in our interests. I mean, I think the worse mistake we could do would be to act like a bunch of soybean farmers who don't want other people to produce more soybeans. Because

science and technology is measureless and infinite in its scope in what it has to contribute, and I think the more it's developed the better for all people. You have to develop a world in which people can live sustainably and compatibly and science and technology are really a lot of the key to that. So, basically in answer to these last several questions I would do anything I can to remove barriers to people getting together and cooperating. I would look on it not as a game where we're trying to protect everything, and that's our basic motivation; I would look on it as a game in which we're trying to share as much as possible, and then at the end of sharing we'll think about what needs to be protected. I go at it, in other words, from a positive rather than a negative point of view, because in almost every case – and this can only get to be more – I mean. Look, China, and India too, are producing many more graduates than we are, funding much more stuff than we are, and if we act like oh, well we're not going to play with you now, just ask if they're going to play with us as they develop more and more ability, more and more discovery, more and more things that we could use very well. I think we're all in it together and the fewer barriers, the more we can do to…It's not that we need to fund science and technology in China, although to some degree that might in certain circumstances be a good idea, but boy…Well there of course, you could have other problems you know only too well from NSF…That is we think about matters on such a short term in the United States. You know, you make an agreement about an internationally-funded telescope in the United States and a year later disapproving it and defunding it. It's extremely difficult to make long…big science and technology relationships. There's practically no other country that operates that way.

AD
Well, I can tell you a story. I was …I decided when I was at NSF that we should have a decade of science policy dialogues because we're both facing the twenty-first century and the knowledge-based economy and so on, and we need to know what each other is doing. I was told that NSF doesn't do ten-year programs. You know, so.. But, we did it anyway.

PR
We've also got a ridiculous situation in the United States, which is ridiculous only in hindsight, but which again you know very well, that almost no branch of government is really authorized to deal with foreign countries at all. I mean, when you come right down to it, they're almost all directed to deal only with the United States; and they can only deal with foreign countries when that's judged to be very much in the interests of the United States. I mean, the State Department, which is charged to do that, has no money for those programs basically.

AD
Absoultely none.

PR
But adding the extra foreign angle it becomes like the Flora of North America, I mean the Flora, the major book and inventory of plants in the United States…

[Turn Tape Over]

PR
…are very important to us.

AD
Well, you obviously have had a long experience with , and involvement even from birth being tied to China. Let me ask this question even if there is no particular thing you have [to say] about it, but can you think of any negative aspects of the S&T relationship?

PR
You mean negative consequences that might arise?

AD
That have arisen of might arise, yeah.

PR
Well, I've already talked about obstacles, but you mean something different like they would find out something that would enable them to do something?

AD
Possibly that, right.

PR
No, I really can't.

AD
Okay. What about lessons learned? I mean, you've spoken about some of the things. I think you've implied them, but what lessons would you draw from the relations since the 1970s and can you think of any ways those lessons might be applied to current or future issues of importance to you?

PR
You know, I don't operate my life according to grand goals. I'm kind of operating on step to step…doing things step by step and having long term goals in mind, and China or any other country or any other relationship, if you really want to get philosophical about it… We have a way in the United States of trying to get to the end of everything instantly. You know, I want this, and I want that. It doesn't work in China, but I think it rarely works at all. I know a company where early meetings in China – a company which is reasonably successful there now – where their early meetings in China were often annotated in their notes DTNO, which means Drank Tea, No Outcome. But you really need that. After a while in China you learn patience and you learn that getting to know people is extremely important. You learn, for example, that if you don't spend time with people, that it's considered extremely rude - you know that very well- just to come into a room and say "Hi, I'm a foreigner and ready to sign." Things that in America are considered normal. I suppose… As a matter of fact, I'll say parenthetically, when I finally met Amy Tan, I told her that I learned more about China from her books than I did

from being in China. She's a very keen observer. You know what I mean…what Chinese like and don't. So, I think one big thing that one can learn is patience, that you don't get there over night and that people aren't ready to make an S&T or any other kind of agreement immediately. Get to know them; spend some time; drink some tea; get with it. And Americans are often at cross purposes with just about everybody over that issue.

AD
I agree with you. I couldn't agree with you more. In my own experience at NSF, the fact that I have been involved, or I was involved in U.S.-China relations from the early 70s through 2005 when I retired was a tremendous asset to me, because I got to know the people; I was constantly involved with the situation; and the more I got to know people, the more there was trust built up, especially with the NSFC and the Chinese Academy of Sciences. I mean, we've know these people for twenty-five-thirty years, …

PR
And you've gotten great benefit from it and so have we.

AD
We've trusted them; they've trusted us. I've been able to do things that other couldn't do, and I say that humbly not because of any great prowess on my own part, but simply because I was there, I was around for a long time, and sort of I proved my bona fide place in wanting to do something important between the U.S. and China.

PR
It's not simply…and let me take off a bit on when you said "not particularly because of me" You know, a lot of people say to me, as I'm sure they do to you and with real justification, "why you really know a lot about China." You know, when anybody says that I just laugh. …(unclear).

AD
I do too. I feel like…

PR
I know some people…Anybody who thinks any foreigner or anybody who thinks they know a lot about China is an idiot.

AD
I feel exactly the same way. I know a few people. I've been around a long time, and if what I know id of any use to somebody, fine.

PR
You approach it with humility.

AD
Right.

PR
Approach it with humility. But you know, but then of course, to give you two examples of eventually where you go with this that are just kind of fun, we've got a house now that we're moving gradually and using it on weekends. So I said, "Gee, it would be nice to get a Taihu stone to put in front and maybe some of those bamboo stones. So, I wrote to the former retired head of the Nanjing Botanical Garden because I knew he knew about things like that. And he said, "Oh, good Lord, you know, I mean we've been trying to figure out something we can do for you for years. So tell us what you want and we'll send them to you at our expense immediately." Then the people in Beijing wrote and they said, "Well, we know that your seventieth birthday is this year, so we'd be delighted on behalf of all of your colleagues here to pay for your first class transportation for you and your wife back to China, so that you can celebrate your birthday in the country where you were born.".

AD
Oh, isn't that great!

PR
If you want to celebrate your birthday here, we think it would be appropriate since you were born here.

AD
Wow.

PR
You know, that's a big test. That's where you finally get, and I'm sure you've had comparable…If people know you're willing to pout out for them, they're more than willing to … Well, I'll give you another example, not to boast, but, in Latin America, everybody says you never get any answers from there, they're so awful. You know what I mean? Guess what? I always get answers immediately from everybody. You know why?

AD
Because you've invested well…

PR
Because I've always put them first. If I ever approached anybody there for my whole professional career going back to the 1950s I've always said what can I do for you. People don't bother doing that and boy do they lose.

AD
I tend to believe this: that the relationships with individual Chinese show a very deeply ingrained feeling or sense that the have of the importance that has to be attached to trust and to friendship, and that this I hope will overcome some of the conflicts that we have as government-to-government and so on. Do you?

PR
I think so too.

AD
You think that way.

PR
Oh, absolutely. I think that the Flora of China project in bringing together hundreds and hundreds of people from both sides, and as I said with Russians, with Europeans, with Japanese, with many other places where we've brought Chinese botanists into cooperation with the people that best could deal with their specialties, I feel like the waves of doing that radiate out and affect lots of attitudes.

AD
I think it's very hard though to try to state that to people who might not know Chinese so well but have studied China per se, have studied, you know, what the aggregate Chinese enterprise is trying to do vis a vis military or commercial or economic ends and they see these conflicts looming in the future between us and China.

PRT
But, how you deal with them is the first thing. What I agree with, the question is not is that true, the question is how do you deal with them effectively? And you deal with them effectively by knowing people. There are two choices. You can either sit around and moan about it, saying you are unreasonable and that you'd better shape up or we won't deal with you; or you can know people, get to know them better and better and get to change structures and attitudes. I mean, we've certainly done that in botany. I mean, we've done that in Russia as well. And you get the kind of things that you think are important and that are internationally supported inside the country by operating that way. The alternative would be to say, oh I think these are bad people and I won't have anything to do with them.

AD
Yes.

PR
My God! I'm sure you've read the new biography of Mao.

AD
Honestly, I haven't, but I noted what you said about it [in a separate letter] and I was going to ask you about that. You said on one of your email messages that you weren't sure that you really had understood what was going on.

PR
Well, I would put it like this. In the period 1949 to the end of the Cultural Revolution, there was so little news of China that everything was presented to be the worst it possibly could be. What we were getting was that people were being killed and maimed and

people we knew weren't really there anymore and what was it. And then, you know, we came out of that and we began dealing with China, and Nixon went there, and Edgar Snow was writing all that stuff. I sort of reacted in the other direction because of what you will recognize as sort of an unending optimism on my part. Which was "Oh, you know, it really wasn't that bad. Of course it got bad- in the Cultural Revolution, but that was just an aberration, blah, blah, blah…" So, I kind of went off in that direction in kind of an unknowing way, although I knew more about the Cultural Revolution because of reading a whole variety of books about it that were available now and then. But I had not the slightest ..you know, it was not only as bad as we thought it was, it was much worse.

AD
Yeah. Yeah.

PR
Much worse. But boy, you read that book, you must read it. It's extraordinary.

AD
Do you recall who the author is?

PR
The same as the other, Wild Swans, and then her husband who's English. You read Wild Swans?

AD
No, I'm sorry. I have to confess I haven't read that either.

PR
My God, those are two fabulous books. Wild Swans is the literal story of her family from the late 20s in Manchuria through the Cultural Revolution, and what it clearly indicates, not only indicates but you can really feel it when you finish, is the utter senselessness of the Cultural Revolution, the fact that even though her father was a totally good Marxist, and doing everything right, it didn't save him from being screwed at all. And you've got to know that about the Cultural Revolution. The other book really puts you in the picture before the Cultural Revolution.

AD
Very interesting.

PR
I mean Russia had the U.S. as infiltrated as they did China and everywhere else. He was just like…It would be like saying… oh, I don't know, some past things.

AD
Extremely interesting. Let me ask you one final question. You've been very forthcoming, and I really, really appreciate it. As you look to the future, what would you do or what would you suggest to improve the S&T relationship?

PR
Well, remove all barriers to the extent possible to the free exchange of scientists and engineers and medical people; provide more funding for joint conferences and for fellowships in both directions; and in general foster a cooperative spirit by working on topics that both sides could find worthwhile. I think those are the main things I'd do.

AD
Let me add one specific question to that. Would you recommend or would you think it would be helpful for a national level group to be looking, overlooking what's happening with China, such as the CSCPRC did, in its early days, recognizing that the times have changed?

PR
On a continuing basis or for a study?

AD
Basically on a continuing basis. Would that be beneficial or not

PR
Well, you know, I'm not sure. As I said, I got in the early 80s to the point where I thought probably with normalized relationships people would find lots of ways to cooperate and it wasn't necessary to institutionalize it as much. I am however,…I would however be in favor of some mechanism that could assess the strength and vigor and outcome of the S&T relationships with China on an ongoing basis. I don't know what that mechanism would be. That's the only reason I'm …(unclear).

AD
No I understand. It's a cold question to ask right off the bat.

PR
I know…I think the same … well, as you know, I have a very different philosophy about international programs from the ones that's sort of played out since Erich Bloch. I think its very important for us to understand the state of development of S&T throughout the world on an ongoing basis, and to interact with it and to do more than just try to give grants to enhance American science, and we have no real mechanism for doing that. Well, it's come a little bit in that direction, but despite that kind of more push for INT [Division of International Programs of NSF, now called the Office of International Science and Engineering] it doesn't seem to be really….

AD
Yeah.

PR
I'm for building the ability in NSF to assess science and technology around the world, and to actively look for ways that connections with American science can be enhanced. so I would say my answer to your question would be probably yes both for China, and in

general. That particular relationship is so important. But I would do that for India and for many other directions too, even for Russia. I'd do it for Russia. In principle, I'd try to track the development of science and engineering and possibilities for connections with American science and engineering around the world.

AD
I appreciate this conversation very much. It's been illuminating. I appreciate all that you've contributed to the field, and I find also that you and I share a lot of perceptions about the importance of the S&T relationship and about the importance of the individual relationship, the person to person…

PR
That's all there really is finally.

AD
…and how that plays out. Let me thank you foe the time you've spent. I will transcribe this and send it to you, and you may do with it as you wish when you see it, amend it or augment it or change it, whatever you wish to do. Again, thank you so much for your time and patience.

AD
It's not actually going to be published, is it?

AD
No. I don't intend to publish it per se. What I intend to do is make the transcript and the tape available…For example, what I have in mind, the George Washington University has now the files of the CSCPRC. I thought maybe I would approach them so that students and scholars now and in the future could listen to these things and read them and see what were the people who were most involved in the establishment of this relationship, what were they thinking thirty years after the establishment.

PR
Oh, I'd like that. Then I don't have to look at it as something that's going to be printed ..transcript of a verbal…

AD
No. If I choose for example, as I'm writing this paper for the next meeting of the U.S.-China Joint Commission, if I were to find it necessary or important to quote you at any point I will definitely send you a transcript of my…

PR
Oh, don't need to, don't need to.

AD
Oh, I do want to just to make sure that I've got things right and you can tell me whether I've gotten it right or gotten it wrong. Okay

PR
Anything I've said, as far as I'm concerned, is perfectly openly available to anyone for any purpose.

AD
I appreciate it. Thank you very much.

PR
And I'll sign that form. Resend that form and I'll sign it and get it back to you.

AD
I gave it to Mary Dunger, and I think she probably has it.

PR
Oh, she probably has it. Okay.

AD
Okay. Thank you very much.

PR
You bet. Good luck with the project.

AD
Oh, I appreciate it. Bye, bye.

PR
Bye, bye.

Soaring Eagle, Flying Dragon:
Industrial R&D and Innovation in the United States and China

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I. Introduction

The task attempted in this paper is to compare and contrast US and Chinese industrial R&D. This is obviously an enormous endeavor and could fill an entire volume. Given time and space constraints, this paper seeks merely to outline the key variables and brief chronological histories that characterize industrial R&D in both American and Chinese contexts. In so doing, the paper examines the influences that society, government, and industry have had on how industrial R&D has been pursued and practiced in each country over time. The final section discusses the possibility of a convergence of US and Chinese industrial R&D philosophies, practices, and principles based on the driving forces unleashed by the latest round of globalization. In brief, the paper argues that though the United States and China have unique historical experiences, have achieved different levels of development over varying periods of time, and along distinct paths toward enhanced industrial R&D capabilities, globalization has hastened China's industrial and technological development and fostered China's ability in a short period of time to mimic much of what has worked well in the American experience that there are today more similarities in both countries' national innovation systems and approaches to industrial R&D than there are key differences. As both countries struggle to meet the demands of an increasingly global market environment —and become increasingly interdependent in pursuing innovative opportunities— the approach each is taking to enhance industrial R&D is looking in important ways very much like the other's. If true, this convergence is likely to continue into the foreseeable future, with perhaps unexpected results.

A. A Note on Terminology

Before comparing industrial R&D in China and the United States, it is vital to first make clear what constitutes R&D and its distinction from related terms and concepts. This paper focuses specifically on industrial R&D, which is defined as research and development activities (or engineering and design efforts) for the specific purpose of advancing business opportunities and industrial capabilities. This contrasts with science as the process of discovering and testing phenomena for the purpose of understanding their fundamental nature. In other words, science seeks understanding for its own sake; industrial R&D seeks advances for the sake of applying research results to commercial endeavors –if not always immediately, then eventually.

Industrial R&D has three main forms: basic, applied, and developmental. This paper employs definitions for R&D as applied by the National Science Foundation:

- *BASIC RESEARCH.* The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. *In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be performed in fields of present or potential commercial interest.* [Emphasis added]

- *APPLIED RESEARCH.* The objective of applied research is to gain the knowledge or understanding to meet a specific, recognized need. *In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.* [Emphasis added]

- *DEVELOPMENT.* Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.[2]

These definitions, while useful to distinguish the different motivations that underlie researchers' aims, tend to assume a linear development model: from idea, to application, to adaptive design, through development, and marketing. But advances made in the latter stages can, in turn, also lead to new ideas, new applications, and new processes. In other words, in practice, industrial research is more akin to a cyclical, multi-dimensional process. This is particularly true as the number, type, and variety of possible inputs to different parts of the process have expanded with the advent of disaggregated international production chains and global R&D.[3] For example, the need to more easily write Chinese characters in a digital format to meet the demand of Asian consumers led to development of Microsoft's "digital ink" technology by researchers at the company's R&D lab in Beijing, a technology that is now an integral part of Tablet PCs sold in the West. Thus, research in the industrial context should be viewed as a complex interactive process rather than a simple linear one.

In defining terms, it is also necessary to distinguish the terms invention and innovation. Here are employed definitions utilized by the National Institute of Standards and Technology (NIST)[4]:

- INVENTION is "a commercially promising product or service idea, based on new science or technology that is protectable (though not necessarily by patents or copyrights)."

- INNOVATION is "the successful entry of a new science or technology-based product into a particular market."

Another way to distinguish the two is to think of innovation as the commercialization of a new product or service. To highlight the distinction, an example of invention would be moveable type (a concept credited to China and dating back to 1045 AD but at the time not widely adopted due to the overwhelming number of Chinese characters) whereas Gutenberg's 15th Century printing press and the eventual typewriter are considered innovative descendants of this basic idea.

Lastly, in discussing industrial R&D in the Chinese context, the paper focuses on developments on the Mainland while acknowledging the important influences that Greater China has had on the PRC's development processes.

II. INDUSTRIAL R&D IN THE UNITED STATES

This section, and the one that follows, lay out some of the key concepts and evolutionary trends in the US and Chinese approaches, respectively, to industrial R&D. Adapting an approach employed in an earlier volume that explores the relationship of industry and technology, this and the following section examine briefly the societal, cultural, governmental, macro-economic and industrial influences that have helped to shape each country's approach to industrial R&D over time.[5] Understanding these past and pervasive influences is essential to comprehend what commonalities and differences exist that will likely shape future US and PRC competition and cooperation in industrial R&D endeavors in what is an increasingly global enterprise.

In the US case, industrial R&D has evolved through several distinct stages of development, including the industrial revolution of the late 18th and early 19th Centuries, followed by what could be called the machine and mass production revolutions of the late 19th and early 20th Centuries, to the more recent computer and information-age revolutions of the mid-20th Century. Invention and innovation have been critical to advances and strategic shifts in industrial R&D during these eras, but so too have been the national and international environments in which these advances were realized.

A. Societal & Cultural Influences

From our founding, the notion of the independent pioneer, entrepreneur, and/or inventor has had a strong appeal to the American psyche. Several of the Founding Fathers —Jefferson, Franklin, and Madison— were well known and admired not only for their political views and achievements but also for their innovations and inventions. The Enlightenment notion of acquiring skills in not just one area of mastery, but in a wide array of subjects, was ingrained in these early American leaders. This same spirit, though somewhat dissipated in the interim, still permeates American culture as the ideal notion of a scholar-statesman-entrepreneur.[6]

Also fundamental in these early Americans' outlook was the belief that progress was not only possible, but essential, through the application of new ideas, processes, and technologies designed to improve the lot of humankind. Moreover, it was the responsibility of leaders to promote and reward such advances. So important was this endeavor in the American mindset that patent holders through the 19th Century received certificates signed by the president and secretary of state, beginning with George Washington and Thomas Jefferson, respectively.[7]

Related to the importance granted innovators in US society, Americans have over two-plus centuries developed an inherent faith in technology as a primary solution to most problems. This helps explain in part the stereotype of the American as optimist. In other words, if all or most problems can be resolved through a technological or other sort of innovative approach, there is less reason to worry about problems remaining unresolved or festering too long.[8] Whether true or not, this widely held presumption leads to an expectation across American society that someone will eventually solve the problem through technology — whether it be the government or industry. As discussed later, these expectations are strengthened further by the existence of an open marketplace, which tends to reward innovative solutions to common problems.

Not surprisingly, Americans have developed a certain amount of pride in US technological achievements. We also herald the pioneers – old and new - who have helped usher in technological and industrial change: from Ben Franklin to Thomas Edison, and from Henry Ford to Bill Gates. These men are remembered not so much for their patents but for their ability to advance technology in ways that fundamentally change industry and, ultimately, the American way of life. Thus, it is the practical application of technology that is most valued in US culture and industry.

Notably, the financial rewards for such advances are also impressive in the American context, particularly in an era of investment shareholders. As a result, US entrepreneurs have an incentive to think big. This is not the only incentive, of course. But, combined with the typically optimistic American outlook that "anything is possible," the potential for vast financial rewards often drives entrepreneurs to not only think big, but to do so in an innovative way. For it is only through industry's wide-spread adoption of innovative technologies that one can gain massive monetary reward. To paraphrase an oft-repeated phrase "nobel scientists are not known for their wallet size." Put another way, although many Internet pioneers credit Vannevar Bush as the conceptual "father of the internet" based on his *Atlantic Monthly* article of 1945 entitled "As We May Think," Bill Gates' vision of a computer on every desk in America is arguably far more famous for having been realized through his innovative approach to linking computer software systems via a new disc operating system (DOS) program introduced to the market nearly 40 years after Bush's article first appeared. As a result, over 90 percent of the world's computers still rely on some version of Microsoft software, and Bill Gates is the world's richest man.[9]

Another important aspect of this dynamic, however, is the willingness to take risks and to fail, and even to fail in a big way. In this sense, failure, while not encouraged, is tolerated — as a step toward eventual success. American society so values the independent, pioneering spirit that we tend to accept the occasional failures that "thinking big" entails and admire those willing to take risks and overcome such challenges in order to try again. This expectation plays an important, if subtle, role in US industrial R&D in that some degree of failure is typically factored into R&D efforts. Moreover, this notion underlies the concept of venture capital, which provides essential seed money to start-up ventures, which are by their very nature risky investments. Once again, financial rewards play a role in that it is only by taking substantial investment risks that one can reap large-size monetary rewards.

In all of these ways, American culture and society impact and spur on US industrial R&D. Innovators are valued and rewarded, sometimes handsomely, which fits well within the notion of "the American dream" and the pursuit of happiness and prosperity.

B. Government and Macro-Economic Influences

Another fundamental concept underpinning the US approach to industrial R&D is a limited role for government. That is not to suggest, however, that the US government plays an unimportant role. In fact, federal funding of R&D in support of industry has come to be considered an absolutely vital contribution to US competitiveness.

Although the history of industrial R&D in America traces back two centuries, the modern R&D system and agreed-upon US government role in shaping it dates back to the mid-20th Century in the years following the end of World War II. The aforementioned Vannevar Bush, who served as Director of the Office of Scientific Research and Development under President Franklin Roosevelt, is credited with generating the consensus that still holds today that large-scale government funding of basic research is vital to US industry's long-term vitality. Moreover, Bush is remembered today for his vision of the need for large-scale government-funded research programs designed to promote continued innovation in key industrial sectors and across different R&D communities (i.e., government, industry, and academia). This represented a significant change from pre-war thinking, which typically viewed government funding of private sector R&D as a corrupting influence.[10] As Christopher Hill notes, at that time:

> *Some attempts were made in the U.S. Congress in the mid-1930s to create a program of government support of industrial research, but these attempts were roundly rejected, not only on ideological grounds but also because influential members of Congress believed that important inventions came from the minds of individual creative men like Edison, and that organized R&D could contribute nothing useful to the furtherance of new technologies.*[11]

Yet, the success of large-scale, government-funded science and research projects during the war convinced Bush among others that such investments, if continued, would reap long-term rewards for both defense and commercial endeavors. In addition, efforts such as the Manhattan Project had demonstrated the utility of cross-community R&D collaboration among industry, the newly formed government-sponsored research labs, and university researchers working under recently devised government grants and contracts.[12] Thus, Bush's 1945 report to the president recommended that, "If the colleges, universities, and research institutes are to meet the rapidly increasing demands of industry and Government for new scientific knowledge, their basic research should be strengthened by use of public funds… The simplest and most effective way in which the Government can strengthen industrial research is to support basic research and to develop scientific talent."[13]

The legacy of this vision is still apparent today. US Government funding of R&D at present amounts to $135 billion in appropriated FY2006 funds.[14] This is more than some countries (including China) spend on total R&D each year. US federal R&D spending, while comprising less of overall US R&D expenditures than in decades past, still constitutes on average 34 percent of US R&D spending since 1990.[15] Recent slips in overall levels of US R&D funding (which reached an historic low point in 2002) have been largely due to reductions in the share of industry-sponsored or private-sector R&D funding; nominal federal R&D expenditures continue to grow. To the general public, as well, the return on investment from adopting Bush's vision over these many decades is clear: in the planes we fly, the cars we drive, the I-Pod and I-Tunes music we listen to, download via the Internet, and play on computer laptops. The deliberate and long-term investment by the government has led to a bounty of innovations and a generally healthy and competitive industrial R&D sector.

A recurring pattern in federal spending on R&D in the United States is the tendency over the past half-century to increase R&D expenditures in times of international crisis, conflict, or with the emergence of global challengers. Spurred on by World War II, US federal R&D expenditures continued to rise during most of the Cold War, during the Vietnam era, and now again post-9/11. Similarly, the emergence of industrial competition from Japan and, more recently, from China is reflected in rising levels of federal R&D spending. On the other side of the coin, periods in which government R&D expenditures fell or stagnated align with periods of relative calm in the international system and/or enhanced confidence in US technological leadership (i.e., in the mid-late 1970s and again in the 1990s following the end of the Cold War and the period just after the first Gulf War). In other words, increased federal spending on R&D in the United States tends to reflect a degree of paranoia — that whenever a challenge emerges, more federal dollars are committed to help maintain US technological and innovative leadership. Whether this pattern can and will continue with the rise of global R&D competition remains to be seen.

Over time, the share of US Government funding of R&D devoted to different forms of research has remained generally stable, though the balance of R&D funding has changed. Through the late 1980s, funds devoted to development dominated federal R&D spending; since then the pieces of the pie have shifted somewhat, with basic and applied research together garnering the major share (60 percent) of government R&D expenditures.[16] This increased focus on basic and applied research via government expenditure is due to two key factors: 1) the steady increase in industry R&D funding, which favors development; and 2) the perceived need for more fundamental research to support US industry in the face of new challenges in a global economy and to improve defense capabilities post-9/11.

When taken together, federal and industry spending on R&D present a different national R&D portrait, with development comprising a full 60 percent of overall funding, while basic and applied R&D garner only 19 and 21 percent, respectively. Thus, despite the past decade's enhanced focus on *government*-sponsored basic R&D, the overall share of national spending on basic research (including industry expenditures) has in recent years stagnated, prompting concerns from the scientific and industry communities that federal spending on fundamental research needs to increase further to offset industry's growing emphasis on more near-term applied research and development work.

Heeding these calls, President Bush announced in his 2006 State of the Union speech a new *American Competitiveness Initiative*, which will increase federal spending on fundamental research over the next decade by dramatically raising funding levels for the National Science Foundation (NSF), the Department of Energy's National Laboratories, and the National Institute of Standards and Technology (NIST). Congress is also promoting increased emphasis and spending on science, research, and education in order to enhance US long-term competitiveness.[17] The private sector has weighed in, as well, by publishing a series of prominent reports outlining dynamic new and continuing challenges in the international science and global industrial competition that demand a reinvigoration of US R&D efforts by both government and industry. Among these have been the "Basic Research White Paper—Defining Our Path to the Future," a special edition of *R&D Magazine* issued back in May 1997 that assessed trends in basic R&D spending and raised concerns about their future impact on American innovation (a report sponsored by both public- and private-sector institutions); the

National Academy of Sciences-sponsored report published in October 2005 entitled *Rising Above the Gathering Storm* — authored by Norman Augustine and requested by a bipartisan panel of Senate leaders, this report calls for increased government funding of science, research, and education resources; and *Benchmarks II: Benchmarks of our Innovation Future*, due to come out in late 2006, a product of the Task Force on the Future of American Innovation — a collection of industry associations, leading companies, and private research institutes also concerned about recent declining trends science, technology, and research.

But while US government funding plays a critical role in promoting long-term R&D investment, the government's approach remains largely *laissez faire*. What this means is that the federal role is supportive, more than it is directive. Both officials and corporate leaders in the US agree that innovation requires government to take a generally hands-off approach to determining future innovations — that this is a practice best left to the researchers and to industry to follow where the science and technology (rather than policy) leads them. That said, however, the government does certainly place emphasis and spend dollars on areas of science and technology that it views as critical for long-term development and/or that are under-resourced by the private sector, whether through lack of interest or costs that are excessive for any one company or industry to pursue independently. An example of this is the semiconductor industry, which the US government has subsidized, most prominently in aiding the formation of SEMATECH, a public-private sector R&D consortium established in the late 1980s.

In the years following the end of World War II, US government spending on R&D outpaced that of industry by a substantial margin. This pattern changed in 1980, when industry began its steady rise in R&D spending; the latter would come to far outstrip overall government R&D expenditures. Today, US industry R&D spending constitutes nearly two-thirds of overall national R&D.

C. Industry Influences

Industrial R&D and the innovations that result are arguably the life-blood of American society. That is to say that industrial R&D is not equivalent to merely corporate R&D. Rather, it includes a wide array of actors and communities that participate in industrial R&D-related endeavors. This is what makes for such a dynamic and relatively successful innovative system. The notion of developing a National Innovation System (NIS) originates from an understanding of the importance of this type of broad interaction, partnering, and networking across different parts of society, which in turn feeds a wide range of inputs into the scientific and industrial research process.

The main players in the US (and, today, most others') NIS are industry, government, and academia. Research and innovation in each sector can contribute to advances in the other sectors. While not necessarily an always-smooth process, the free flow of ideas and a permissive regulatory environment facilitate the synergistic, innovative possibilities among these three communities. Space does not allow for a full accounting of the importance of these interactions. But suffice to say that industry, as the main performer and funder of US industrial R&D today, can benefit enormously from the interactions among, and clustering of, corporate, government, and university research. The latter, in particular, allows both deliberate and serendipitous connections that can lead to new concepts and innovative products, processes, or services.

Yet, it is important to note that not all university-government-industry tie-ups result in improvements in R&D or marketable innovations. A study of Cooperative Research and Development Agreements (CRADAs) in 1998 found that companies that had productive R&D relationships with federal labs reported little overall benefit (though some cost savings) from these interactions while companies that did *not* end up with new commercial products as a result of their R&D relationships with the labs reported substantial benefits. These were likely in more upstream areas such as basic R&D inputs rather than in downstream, marketable contributions.[18] In other words, it matters most, at least in the American context, *how* these R&D partnerships function, not simply that they exist.

It is also important to recognize that what is today considered a model for innovation was not necessarily planned that way. Rather, the US NIS is more the product of trial and error, happenstance, and evolution. Though Vannevar Bush recognized decades ago the value of cross-cutting research collaboration among government, university, and industry researchers, the shape that the US NIS eventually came to take could not be predicted nor designed. Instead, it was a focus on promoting, empowering, and financing greater interactions among these communities that allowed their relations to evolve in a generally mutually advantageous manner. This understanding underlies the consensus among both industry leaders and government officials in the United States that policy solutions are not necessarily the best, and certainly not the only, means of enhancing industrial R&D.

Moreover, much like government funding of R&D, corporate R&D in America is driven in large part by paranoia. As Intel's Andy Grove famously once said, "Only the paranoid survive." By this he meant:

> *The more successful you are, the more people want a chunk of your business and then another chunk and then another until there is nothing left. I believe that the prime responsibility of a manager is to guard constantly against other people's attacks and to inculcate this guardian attitude in the people under his or her management.*[19]

Continuous R&D and innovation, therefore, are central to long-term corporate survival. Being unprepared for a radical innovation can spell death (or merger and acquisition) for small and large-sized firms alike. For most US companies, survival is indeed the goal and sustained, strategic R&D investment is the means. Leading high-tech firms in the United States spend, in comparison to enterprises in other parts of the world, a tremendous amount on R&D. IBM tops the list among IT enterprises at over $5 billion allocated to R&D in 2006. Other top spenders on R&D in 2006 include Pfizer ($7b), General Motors ($7b), Boeing ($1.8b), Microsoft ($5.7b), Intel ($5b), and DaimlerChrysler ($8.5b).[20] In 2002, the amount that individual US firms spent on R&D in total exceeded the R&D appropriations of the entire G7 countries combined.[21]

But another model of innovation emerged as well during the enormous influx of investment capital that flooded the market in the "dot.com" heyday. The latter instigated a relatively new phenomenon of start-up companies that sought to develop innovation mainly (though not necessarily only) for the purpose of getting rich. In this period of investment largesse, many made their fortunes by establishing and quickly selling small start-up firms that had achieved modest innovative successes to much larger firms seeking to stay ahead of their competitors. Thus, promising technologies that emerged from Silicon Valley entrepreneurs and start-up firms during the 1990s, for instance, were often quickly snapped up and simply acquired by bigger players like Microsoft, Hewlett-Packard, and Cisco Systems. While this was a defensive act on the part of established firms, it represented a new, more offensive overall approach to innovation where the end goal became selling the firm and/or its technology, pocketing the riches, and then starting a new firm and running through the cycle again (if possible). Consequently, it became not only acceptable to fail in an innovative endeavor, but also acceptable to succeed, repeatedly, at several different ventures. Though this period of hyper investment largely ended with the "dot.com bust" of 2000, the notion still survives and motivates young entrepreneurs seeking to make their fortune via a break-through innovative idea, which they do not today necessarily need to scale to market themselves.

The latter phenomenon fits well into the outsourcing trend and emerging, global race for innovation. Corporate leaders the world over are on the hunt for just such start-up, fresh, and waiting-to-be marketed technologies and concepts, as well as the innovators behind them. Before turning to that topic, however, a look at industrial R&D in the Chinese context will be instructive in illuminating the global R&D picture.

D. Looking Forward: US Industrial R&D

US spending on R&D exceeded $300 billion in 2004. This accounted for more than a third (38 percent) of the world's total spending on R&D that year.[22] While this level of spending would suggest a healthy outlook for US R&D, many scholars, scientists, and CEOs are alarmed by what they see as clearly new and fundamental challenges to the US R&D system. China has a large part to play in the new global R&D competition; understanding China's philosophy, policy, and practices of industrial R&D will be essential to the long-term competitiveness of US industrial R&D.

III. INDUSTRIAL R&D IN THE PEOPLE'S REPUBLIC OF CHINA

This section presents a brief overview of the societal, cultural, governmental, and corporate influences on China's approach to industrial R&D, and contrasts them with those described as important in the American context. The first observation, of course, is that China, as compared to the United States, has both a longer and shorter history in this regard, due to several historical periods of change and upheaval. China has a well-known, long and distinguished history of invention. Yet, China's recent advances in industrial, technological, and scientific endeavors are making headlines around the world, due primarily to the relatively short timeframe in which these advances have been made. Though China's road to developing a modern NIS and industrial R&D capabilities dates back only a quarter century, the PRC has made great strides in this short time. In many ways, China's approach to industrial R&D mimics the US system, which is by design. However, there are numerous ways in which China has also taken a different or adapted approach from that of the United States.

A. Societal & Cultural Influences

China's rich and long history of technological innovation stretches back over millennia. While following a path perhaps more circuitous than that of the United States, a clear theme of valuing and promoting science and technology is apparent throughout Chinese history. China is well-known as having invented such ubiquitous items as paper, porcelain, gunpowder, the compass, and print type. Industrial R&D, as an outgrowth of the pursuit of S&T, however, is relatively new to China's economy. Nonetheless, PRC enterprises are moving quickly to become competitive in this arena. Just as in the US case, Chinese society and culture are impacting the way in which industrial R&D in the PRC is developing.

One of the recurring themes throughout Chinese history that continues to resonate today is the degree to which Western influence should properly impact China's own technological and innovative efforts. China has long had a mixed view on the value of Western expertise, wanting both to exploit it for the betterment of China while not becoming too beholden to, or dependent on, foreign capabilities. The same dilemma existed in ancient times, during the Qing Dynasty, and continues still today. Such concerns are evident in the current 11th Five-Year Plan and Mid- to Long-Term National S&T Plan, both of which emphasize the need for indigenous and independent innovation — clearly an effort to reduce dependencies on foreign technology by becoming more capable and, therefore, more competitive with foreign firms.

Yet, despite these concerns, China has repeatedly reached out to the global community and, in particular, to the United States, to learn from international exchanges and to adapt this learning to aid China's own development.[23] Thus, Chinese students arrived to study in the United States as far back as the Qing Dynasty, when over 100 students attended leading universities such as MIT, Harvard, and Columbia.[24] Today, there are over 100,000 Chinese students studying abroad, an average of 60,000 in the United States alone.[25]

This same approach underpins China's approach to industrial R&D. Much of China's recent achievement in developing more competitive, high-tech, home-grown enterprises can be traced back to a strategy of partnering with numerous foreign firms across a myriad of different activities in the period prior to China's WTO accession. This partnering approach allowed PRC firms to gain extensive expertise from (or, at minimum, exposure to) some of the world's leading high-tech and innovative companies, providing insights into their history, successes, and ways of doing business, including industrial R&D.[26]

This seeking out of foreign education, partnerships, and investment obviously is driven to some degree by necessity —China is trying to catch up to, and become competitive with, the United States and other advanced, high-tech economies. The best way to do so is to follow the path that technology leaders have already laid out, tried, and tested. However, the extent to which China has accepted foreign input, investment, and insights is probably unprecedented among developing countries. Moreover, this approach carries some risks, as well, especially if these efforts ultimately fail to achieve their aims. The idea of increasing dependence for foreign technology and expertise is by no means an uncontroversial issue in China today. In fact, some have termed it China's "technology trap."[27]

Such a risk-oriented approach also does not seem to fit within the confines of traditional Chinese culture that, at least as seen through Western eyes, does not appear to value risk-taking. The concept of "saving face," which is so important in Asian culture, would seem to make risk-taking a particularly hazardous venture. This dissonance might best be explained by China's traditional appreciation of, and value placed on, education and learning. This is not only an historical tendency, but can be witnessed first-hand on the streets of Shanghai, for instance, where students, officials, and businessmen all rush along busy streets to attend classes offered all over town on a variety of skills and topics. For these reasons, the fact that PRC officials have been willing to accept such risks and to learn from the United States and other industrial and innovative leaders over a period of two-plus decades is a factor that must be considered in assessing China's future industrial R&D capabilities and strategy.

Yet, the PRC government's apparent risk-inclination with regard to R&D funding has yet to entirely infuse China's industrial sector. Individual researchers and project leaders (whether in industry, government, or academia) tend still to be relatively risk-averse. This may well be due to the potential costs of losing face in the event of a failed research effort or to the pressure to perform and to provide a quick return on the government's extensive R&D investments.[28] Whatever the cause, this apparent disconnect is likely to forestall significant industrial R&D advances in China. At the same time, however, China's leading scientists and researchers enjoy considerable acclaim and status. This includes contemporary stars such as Li Jun and Chen Jin (until the truth about his fraudulent research claims were recently uncovered) as well as past icons such as the four leading scientists who originally proposed the 863 research program to Chinese leader Deng Xiaoping. Moreover, it will be interesting to see if this constitutes a trend, with a shift from the traditional focus on the talent and achievements of academic and government researchers to industry innovators. This is in part reflected in Chinese leaders' highlighting of the role of industry innovators, their achievements, and contributions to advancing China's economy through a growing number of prominent national award programs.[29] In addition, this practice could well ameliorate the Chinese researchers' typical risk-averse approach. Yet it is also not hard to imagine that as more R&D funding derives from re-invested industrial expenditures and/or from foreign and domestic venture capital firms, that this risk-averse mentality could even more quickly transform into an American-like drive for acclaim and the financial rewards that accompany innovative and marketable ideas.

In another similarity with American culture, Chinese society has tended to look to technology as a means of problem solving. The Great Wall, itself, is an example of an engineering a solution to the problem of persistent foreign invaders. Listening to Chinese today talk about their future, a certain amount of faith is evident in China's likely ability to find technological solutions to challenges such as environmental pollution, health concerns, and more daring endeavors such as space travel. Much like in the US case, this is a natural outgrowth of transitioning from a largely agricultural society to a modern, industrialized, and complex social network and economic system. Thus along with the perceived faith in technological solutions is likely to grow a great deal more national pride in China's technological achievements. This has already been apparent in the case of China's advances in space, nuclear technology, and more recently in commercial technological achievements. Advances in industrial R&D are likely to benefit also from this technomania and growing popular emphasis on innovative solutions to China's socio-economic challenges. This can-do spirit will undoubtedly be on display at the 2008 Beijing Olympics.

Evidence of the latter is apparent also in the growing reputations of leading Chinese high-tech enterprises, which are themselves transforming into multinationals. Legend (known overseas as Lenovo and on the Mainland as Lianxiang), Haier, Huawei, Evermore, and Baidou are among the early Chinese contenders who have gained international recognition for their growing national and international competitiveness; they are certainly not the last of their kind.

How did these enterprises arise and become competitive in the first place, and to what extent did entrepreneurialism and risk-taking factor into their success? The case of Haier is instructive. As Peter Nolan explains:

> *Far from being the product purely of the free market, Haier's growth is explained by a combination of the entrepreneurial drive of its CEO, Zhang Ruiming, allied to the strong support of the local government in Qingdao City and Shandong Province. Haier received strong financial support from the local government through their relationship with the local banks; was supported by the government in its merger with other local firms, in negotiations with other governments to take over their local firms in gaining permission to list on the domestic stock market; and through the preferential allocation of high quality industrial land to help it expand through establishing a science park.*[30]

As Haier's and other Chinese companies' businesses have expanded, so too has their need for enhanced industrial R&D capabilities. Accordingly, up to a quarter of China's large- and medium-sized enterprises now have established "technology development institutes" or other forms of R&D as part of their business activities.[31] As in the above example, the PRC Government has played a leading role in the ability of these enterprises to undertake R&D as well as in promoting innovation as a key part of China's future economic development.

B. Government and Macro-Economic Influences

In contrast with the US government, the PRC government plays a more direct and intervening role in China's industrial R&D sector. This is obviously due to our different political and economic systems, but also to China's late-stage development, which argues for a continued need for greater government intervention —or, at least, promotion— of industrial R&D efforts. The mandate to reform industry and state-sector enterprises to be more productive and efficient, the ability of the central government to enforce these institutional changes, as well as China's interest in implementing such improvements as quickly as possible lead one to expect a greater degree of government intervention than would likely take place elsewhere. Yet, as the PRC has achieved greater success in its reform efforts, it appears that the degree of government prescription may be lessening, as indicated by official comments regarding aims outlined in the "National Medium and Long-term S&T Development Program from 2006 to 2020" and the 11th Five-Year Plan, which emphasize the idea of these plans as guidelines rather than directives.

Since its founding in 1949, industrial R&D in the PRC has transitioned through several stages of development. There is not space enough here to discuss these time periods in depth. But the following outline briefly characterizes each stage of China's development and changing approach to industrial R&D and innovation over the years.[32]

- *Soviet Industrial Model* (1949-1965) — characterized by a centralized, top-down system where government-funded research institutes dominated industrial R&D but were largely divorced from the industry sector responsible for production.

- *Cultural Revolution* (1966-1976) — a period characterized by mass campaigns and political upheaval resulting in little productive industrial R&D.

- *Open Door Policy* (1977-1997) — a time of serious reform of the industrial and government sectors, so as to allow greater interaction between researchers and industry as well as between domestic and foreign industry. Notably, it was during this period that the CCP-issued "Decision on Reform on the S&T Management System" (1985) instructed PRC research enterprises to "jump into the sea" with industry so that "scientific and technological work…be oriented to economic construction." Beijing later would adopt the policy of "grasping the large and releasing the small," which was and remains a principal effort to promote national champions among China's leading firms. Also during this period, in March 1983, China's state-funded program (863) for "cutting-edge high-tech issues" was initiated, as was the 973 program in March 1997 promoting basic research through government-funded projects, among other S&T and research-oriented initiatives.

- *NIS Development* (1998-present) — this stage represents China's more recent efforts to pull together in a more interdisciplinary and horizontal fashion its diverse and numerous R&D resources into a nascent, modern NIS. Part of this effort includes promoting greater industry-university-government research collaboration, but at still-very modest levels compared to the United States, Japan, and other OECD country rates.

As this brief chronology suggests, China has shifted its approach to industrial R&D significantly and several times over a relatively short period of time. And although China's strategy for enhancing industrial R&D as part of its overall national S&T strategy continues to be outlined in old-style, five- and fifteen-year plans, the underlying approach today comes near to approximating other countries' national science and technology strategies, not unlike those issued by other Asian or European officials. As articulated by Chinese President Hu Jintao, China's aim today is to pursue a "scientific concept of development" (*kexue fazhan guan*). Part of this strategy involves "strengthening of indigenous innovative capabilities" as outlined in the Mid- to Long-Term S&T Plan announced in January 2006.

What does this mean for industrial R&D in China? The PRC's latest, 11th Five-Year Plan (FYP) for 2006-2010 calls for, among other things, increased national spending on R&D in order to reach an R&D intensity (R&D expenditures/GDP) of 2.0 percent by 2010; enhanced and enlarged high-tech development zones but with greater attention paid to developing regional clusters (e.g., tying Shanghai's industry and development more closely to nearby Nanjing, Hangzhou, and Suzhou so as to promote regional competitive advantage instead of counterproductive intra-regional competition) and establishing what appear essentially to be technology corridors of differing levels of development (i.e., an eastern high-tech zone; a central manufacturing, assembly and low-tech industrial production zone; and a separate Western zone where development and technology would flow as conditions permit as part of China's "Go

West" campaign). The idea is clearly to promote greater cross-regional and complementary industrial development so as to both improve and expand industrial capacity across the Chinese Mainland.[33] But what this also means is that, if this strategy succeeds, China will in effect be pursuing technology development and R&D activities across three broad and disparate levels of economic development. The question arises, therefore, whether this will aid China's efforts to grow more horizontal linkages, communication, and cooperation across China's R&D communities, or whether it will suppress it, as researchers in each corridor focus on their own areas and develop at different rates and levels of capability. China's current "informatization" campaign seeks to further link Chinese researchers, scholars, officials, and others via enhanced virtual computerized networks, but this may or may not be enough to overcome regional disparities in industrial development and R&D levels.

Here it should be pointed out, however, that what arguably sets China apart from other developing countries also seeking to develop a modern NIS by attracting increased levels of foreign direct investment (FDI) and foreign R&D investment is the PRC's long-term efforts to both incentivize FDI though a variety of measures such as tax rebates, generous lease, and preferential loan terms, and the extensive central and provincial government as well as municipal and local-level investments made over two decades in infrastructure (i.e., improved transportation, communication, energy, and other foundations for economic development) that are designed to entice foreign and domestic high-tech investors. In this, and in terms of sheer scale, China is without peer, at least among developing countries. This "field of dreams" approach, while not without difficulties, has proven to be a generally successful approach to attracting large volume, and high value-added forms of FDI, and at a fairly early stage in China's industrial development.

Thus, it is not surprising that the 11th FYP also encourages further domestic and foreign direct investment, particularly of a high value-added nature, including R&D as well as technical training and other forms of technology transfer and expertise that will aid China's own industrial, technological, and innovative capabilities. Imbedded in this plan is the need for improved exploitation of foreign assets and investments by domestic firms. In short, China is largely staying the course set long ago that seeks to exploit foreign technology and experience as a means of leap-frogging Chinese industrial and scientific development, if in a more effective and accelerated manner than in the past. In this, China could be said to be going "all in" on globalization — in other words, seeking to make the most of the historical opportunity afforded by the present phase of economic globalization.

For Chinese industry, this means continued government support for R&D efforts at national, provincial, municipal, and local levels (in the form of capital investment, government-backed bank loans, high-tech development zones, incubation centers, etc.) in strategically important sectors such as telecommunications, nano- and biotechnology, among others. The form that this assistance takes may change or improve, but the basic philosophy remains the same: the role of government in promoting industrial R&D in China remains central, but is increasingly more supportive rather than entirely planned and prescriptive as in the past.

C. PRC Industrial R&D

As the above two sections have depicted, there are numerous differences in the way that the United States and China have approached industrial R&D and innovation throughout our separate histories. Yet, industrial R&D in China today bears a strong resemblance to that found in the United States and other advanced economies. A prime reason for this probably lies in the fact that industry in pursuit of innovation (not to mention survival) will look to employ whatever approaches are proven to work. In doing so, some adaptation might be necessary to adjust to local conditions, but the basic concepts prevail. Thus, while on the surface US and Chinese industry might look very different, in fact, there appear at the foundation to be numerous and growing similarities.

To illustrate both the commonalities and distinctions, it might be useful to compare the innovative process as it functions in China, that is, how industry in China transforms an innovative idea into an actual, marketable product or service. For example, in describing the basic steps his company took to become a successful and innovative enterprise, a Chinese corporate representative outlined the following six steps (paraphrased here):

1. Identify a niche market
2. Develop or acquire a license to introduce new technology
3. Lobby regulators to open up a new marketing sector
4. Obtain government support to build new customer base
5. Devise a business plan
6. Build to scale[34]

Much of this list would look familiar to US CEOs, though the order might differ. But there are two intermediate steps (namely, the third and fourth) that this industry leader had to take that would not often be found in a US business plan (barring perhaps in the case of a government contract). The need to interact more directly and pervasively with government agencies and officials that this plan suggests on the part of individual firms is foreign to most US industry (as witnessed by the difficulties faced by early entrants into the China market!). Yet, these additional steps are not necessarily barriers to successful industrial R&D and innovation for those enterprises that learn to work the system, though they may well hike up the costs over time. That said, US industry certainly does lobby for government assistance — the main difference being US industry's outsourcing of this function to industry associations and professional lobbyists in Washington. Given the advantages of this approach for individual firms, it would not be altogether surprising if a similar approach is adopted in the not-too-distant future in China. For one thing, this more indirect approach could help reduce, though not eliminate, corruption, which typically feeds on such close, personal, industry-government collaboration.

At a more micro, company level, industrial R&D in China also looks more and more like that found anywhere else around the world. As noted earlier, Chinese enterprises are expanding their R&D spending, assets, skills, and personnel. Though PRC firms typically do not spend as much on R&D as do companies in other [developed] countries, the level of corporate R&D spending has begun to grow and become a more standard feature in Chinese business practices. In fact, interestingly, enterprise R&D intensity is higher among large- and medium-sized PRC firms (4-5 percent) than it is currently among US firms (3.5 percent).[35] Leading PRC firms, in fact, now boast of their R&D spending as a sign that they are rising competitors with their domestic and foreign counterparts. It is perhaps not surprising then that the industry sector today dominates overall R&D spending in China's national R&D accounts, first surpassing spending on R&D by government research institutes a decade ago. Industry also today claims the largest share of researchers (60 percent) in China compared to universities (17 percent) and state research institutes (which reached a low of 19 percent) as of 2003. As proclaimed in the latest *China Science and Technology Indicators 2004* report, "After nearly 20 years of S&T system reform, research institutes no longer occupy a dominant position in national S&T activities, and enterprises' status in the NIS has been on [a] steady increase."[36] That said, the university and government research communities in China remain vital, if indirect, contributors to China's R&D efforts.

Yet, the R&D-intensive firms described thus far in the Chinese context still represent the exception rather than the norm. As described by Premier Wen Jiabao earlier this year, there are, in fact, three distinct types of Chinese enterprises pursuing three different approaches to industrial R&D, namely those involved in:

- *Indigenous innovation* (conducting R&D independent of foreign inputs)
- *Integrated innovation* (presumably a mix of domestic and foreign R&D inputs)
- *Acquired innovation* (wholly reliant on foreign R&D and technology inputs)

While those entities involved in the first-tier (indigenous innovation) are beginning to look more and more like other multinationals (complete with overseas investments and R&D centers, as promoted under the "Go Abroad" campaign), the latter two types of "innovative" entities are more uniquely Chinese. The key to their success lies in an improved ability to acquire, absorb, and integrate foreign technologies, techniques, and practices. Continued high levels and advanced forms of foreign direct investment will be critical to their ultimate success and evolution. But Chinese officials appear confident that this will be the case, projecting on average $100 billion in FDI each year over the next five years. And, as China's latest five- and fifteen-year plans make clear, PRC officials see globalization as a phenomenon that is here to stay for some time, at least another 10-20 years; US analyses also support this view.

Whatever its duration, China must make the most of this historical opportunity. As the list of innovative enterprises suggests, industrial R&D in China remains a still-evolving endeavor. In fact, a majority of Chinese enterprises still face an array of systemic challenges, as Richard Suttmeier points out, for example:

> *On a funding per researcher basis, the Chinese contingent of professional manpower is by international standards still supported at low levels. In the face of exciting new research challenges that cross disciplinary and organizational boundaries, members of the technical community have much to learn regarding the importance of interdisciplinary cooperation.*[37]

Nonetheless, the trend line Chinese industrial R&D and innovation is broadly positive (all things being equal), and China's strategy clear: to enhance the country's industrial R&D capacity with industry increasingly in the lead role as part of a broader effort to develop a modern and globally competitive NIS not unlike that of the United States.

D. Looking Forward: Industrial R&D in the PRC

Trying to predict China's future course is a foolish proposition. The potential dangers and evident opportunities are enormous. In other words, China could make remarkable progress in its pursuit of innovation, make steady but slow progress, or lose significant ground due to unexpected national, regional, or global events. Nevertheless, it appears that China's strategy is to make the most of a unique point in history when engaging (directly and virtually) the international environment and global, innovative community including CEOs, scientists, researchers, officials, and others with innovative insights working within China's borders as well as internationally. Such an environment offers China unprecedented access to advanced industrial and innovative knowledge and understanding. In this sense, China has already leapfrogged — by pursuing horizontal linkages across the global economy to advance innovation before these same sorts of linkages have formed completely within and across the whole of China. It is a bold endeavor with many lessons still to be learned not only for China, but for the United States and other global observers as well.

IV. Globalization: Driving Toward Convergence in Industrial R&D and Innovation ?

As the above discussions indicate, there are important, underlying similarities in US and Chinese approaches to industrial R&D. While taking different paths in developing our respective NIS and industrial R&D processes, both systems today appear to place similar emphasis on the following key factors with regard to industry-led innovation[38]:

- Industry's ability to respond to new technologies and new ideas in the marketplace, ideally in a rapid fashion.
- Private-sector enterprises that are adaptive and flexible enough to accommodate change, and more rapidly than can academic or government researchers.
- Pursuit of greater efficiencies in industrial innovation.
- The pursuit of national and international talent, skill, and innovations to be adopted or adapted to local market needs.
- An emphasis on capital investment in promising, new start-up ventures (though noting that, in the Chinese case, much of this funding derives from government sources).
- The overall mobility of factors, the willingness to move manufacturing or research to more productive locations, the willingness to license technology, and the ability to retrain workers.

Similar approaches are also evident in terms of the supportive role ideally played by the government or public sector[39]:

- Government funding for basic research and development.
- Protection of intellectual property, copyright, trademarks, and the legal system of judges and courts that help defend these rights.
- Aiding efforts to set technical standards.

- Agricultural and manufacturing extension services.
- Procurement decisions by agencies.
- General programs lending more tailored assistance to certain types of businesses.
- Enacting policies such as taxation and the granting of tax credits.
- Improving the educational system.
- Developing transportation and information infrastructures that facilitate commerce.
- Assisting trade through export financing, protection against unfair trade practices by other countries, identification of trading opportunities, and efforts to open markets.

Thus, when viewed from this perspective, US and Chinese approaches to industrial R&D and innovation do not appear so different. The explanation lies in part in China's adoption of many lessons learned through the evolution of other NIS, particularly the United States', which has allowed the PRC to put in place similar processes or policies with a high expectation that they will succeed more than not. But part of the explanation also, arguably, lies in an evolutionary and increasingly global convergence of industrial and innovative approaches, a trend driven mainly by changes and enhanced opportunities in the transnational business environment. As one observer notes:

> *In its next incarnation, globalization will be more about interpenetration. China selling an endless flotilla of its manufactures to the rich countries, or Indian outsourcers winning jobs in everything from customer service to tax accounting to online help with homework, is hardly news any more. In its most momentous form, however, interpenetration means that the world's emerging economic powers will begin to globalize each other, creating new sectors in each other's markets, infusing each other with capital, and drawing on each other's giant pools of talent.*[40]

The same dynamic applies to industrial R&D. The recent systemic change in global production processes (i.e., the disaggregation of production or commoditization and modularization of once-national production and supply chains such that components can be researched, developed, produced, assembled, and marketed in many different locations around the world) is fostering a more generic global vs. national approach to industrial R&D. The latter, of course, drives innovation as well as production toward more generic or uniform (though not necessarily less complex) platforms, which explains in part the appeal of open-source software. These re-engineered and now 24/7 processes have shifted the emphasis on industrial production and R&D from the traditional, vertically integrated model to promotion of more horizontally organized processes on both the national and international level. The outgrowth of this trend, of course, has been rapid outsourcing as well as global offshoring of manufacturing and R&D.

This is true in the US case as well as for leading PRC firms. US outsourcing and offshoring of industrial R&D has grown at an impressive rate over the past several years.[41] The same is also occurring with regard to some Chinese enterprises as well. The firm Huawei is a good example if still the exception for PRC companies overall, with its overseas R&D centers in Europe, Asia, and the United States.[42] What these offshore investments share is the objective of exploiting innovative environments outside national boundaries in pursuit of greater global market share. However, in China's case, this overseas activity is taking place before China has fully succeeded in establishing and exploiting similar horizontal linkages within its own domestic economy.

As a result of these phenomena, leaders —especially in developing countries— are adopting a more or less common approach toward creating a viable NIS and increasingly knowledge-based, FDI-friendly economies. As outlined in the latest *World Investment Report*:

> *In most of these [developing] countries, the starting point has been a long-term vision of how to move the economy towards higher value-added and knowledge-based activities. The success of some Asian economies is no coincidence; it is the outcome of coherent and targeted government policies aimed at strengthening the overall framework for innovation and knowledge inflows. In some form (and to varying degrees), they have actively sought to attract technology, know-how, people, and capital from abroad. They have invested strategically in human resources, typically with a strong focus on science and engineering; invested in infrastructure development for R&D (such as science parks, public R&D labs, incubators); used performance requirements and incentives as part of the overall strategy to attract FDI in targeted activities; and strategically implemented IPR protection policies.*[43]

This strategy looks a lot like the US NIS model; China, as an early adopter among other developing states of this approach, has today a competitive advantage over its peers.

Yet, under this type of global, industrial innovation system, horizontal linkages in the form of the ability to partner and to network with both national and international partners becomes even more vitally important — for both the international initiator and the domestic receiver. As a preferred and growing location for foreign-invested R&D, in particular, China is in a position to play a central role in the development of these new global industrial dynamics; it provides the PRC with a rare opportunity to shape (at least to some extent) how this trend evolves, how fast, and in what direction.

If this is, indeed, the case and geographic (national) location becomes of little import —as Tom Friedman's *The World is Flat* argument goes—, then the future challenge before both American and Chinese industry leaders and innovators may be not in how *much* innovation each country achieves on its own relative to others, but how well, how fast, and how consistently they are able to do so *and* to exploit others' innovativeness. In this scenario, current measures of industrial R&D and innovation will prove insufficient, and new indicators will become necessary to mark innovative progress under such conditions.

Already, in fact, new ideas, concepts, and proposals are emerging with regard to conceiving, conducting, evaluating, and exploiting global innovative activities. IBM, for instance, is taking the lead in developing new global R&D networks that are both traditional and virtual in nature in order better to capture innovative ideas percolating around the world. Open source platforms, which IBM is also encouraging, also promise new business models and innovative solutions for global R&D collaboration. In addition, there is a growing notion that much innovation can be initiated at the end stage of production, or at the user's end. As explained by a prime advocate:

> *The user-centered innovation process … is in sharp contrast to the traditional model, in which products and services are developed by manufacturers in a closed way, the manufacturers using patents, copyrights, and other protections to prevent imitators from free riding on their innovation investments. In this traditional model, a user's only*

role is to have needs, which manufacturers then identify and fill by designing and producing new products…However, a growing body of empirical work shows that users are the first to develop many and perhaps most new industrial and consumer products. Further, the contribution of users is growing steadily larger as a result of continuing advances in computer and communications capabilities.[44]

If the latter turns out to be true, China's 1.3 billion potential consumers and investment in "informatization"-oriented, modern infrastructure could add substantially to the PRC's competitive, innovative advantage in this new, global industrial age. It also holds promise for future US innovation capacity, but only if these sorts of US-China and other international R&D collaborations and their opportunities as well as hazards are more fully understood both by practitioners and policymakers.

In short, it is not only in trade terms that the United States and China are growing increasingly interdependent. It is also true in terms of future innovative capabilities. To succeed in enhancing industrial R&D in the 21st Century will require more intensive international interaction, learning, and communication than ever before if each country is to prosper from the emerging global, technological, industrial paradigm.

ENDNOTES

[1] The views expressed herein are personal and in no way reflect a view of the US Government, Department of Defense, or US Naval War College. For their insights and comments, the author would like to thank both American and Chinese reviewers, especially Alex De Angelis and Ma Lianje.
[2] National Science Board (NSB), *Science and Engineering Indicators 2006*, "Chapter 4 -- Research and Development: Funds and Technology Linkages (Arlington, VA: National Science Foundation, 2006), p. 4-8. Hereafter referred to as NSB, *S&EI 2006*.
[3] See Pete Engardio, "Scouring the Planet for Brainiacs: Worldwide Innovation Networks are the New Keys to R&D Vitality – and Competitiveness," *Business Week* (October 11, 2004).
[4] These definitions are taken from Lewis Branscomb and Philip Auerswald, *Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development*, Executive Summary, prepared for Economic Assessment Office, Advanced Technology Program, National Institute of Standards and Technology (NIST-GCR 02-841) (Gaithersburg, MD: NIST, November 2002), p. 1, available online at http://www.atp.nist.gov/eao/gcr02-841/gcr02-841.pdf.
[5] See B.R. Williams, *Technology, Investment, and Growth* (London: Chapman and Hall Ltd, 1969).
[6] Subsequent movements such as the Romantic period around the time of the US Civil War and the "scientific" or "systems" management movement around the turn of the 20th Century also helped popularize the notion of inventiveness and innovation as positive qualities and vital to US prosperity. Ruth Schwartz Cowan, "American Ideas About Technology," *A Social History of American Technology*, Chapter 9 (New York: Oxford University Press, 1997), pp. 201-219.
[7] The US Attorney General also signed early patents. With the establishment of a separate superintendent of patents position in the State Department in 1802, the superintendent became the official signatory on US patents. See US Patent and Trademark Office, and Jeff Louderback, "Creating a New Generation of American Ingenuity," *News Blaze* (July 31, 2006).
[8] Cowan notes that with the industrial revolution came a greater dependence on technology, whether we like it or not. In today's complex, industrial society, it is virtually impossible to exist without any form of technological assistance, direct or indirect. Ruth Schwartz Cowan, "Industrial Society and Technological Systems," *A Social History of American Technology*, Chapter 9 (New York: Oxford University Press, 1997), p. 151.
[9] Yuki Noguchi, "Gates Casts a Long Shadow," *Washington Post* (June 16, 2006), p. D1.
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Basic Research: A Comparison of the United States and China

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Contents

I. Evolution of American Scientific Policies during the Past 60 Years

1. 1945-1950:Establishment of Science &Technology System

The American Government invested very little in basic research before World War II; scientific research was subsidized by educational institutions or private foundations. The war strengthened the relationship between science and government, and it also highlighted the military's essential role in basic and applied research. Science & technology played an important role in the war, which helped America to win the war, so science won the unprecedented value and attention from both government and public. Both government and the public realized that government's participation would be helpful to national development in many fields. Although some scientists opposed government's direct involvement in scientific research, the prewar primarily private-fund-supported system was out of date. It was an inevitable trend for the federal government to be involved in scientific research in a large scale.

President Franklin Roosevelt sought advice from a distinguished group of scientists assembled by Vannevar Bush on the best way to organize government support for science after World War II. There were several reasons for President Roosevelt's interest in enhancing the role of government in the support of scientific research. The first was for the nation to continue to benefit from the expertise of the individuals and institutions that participated actively in the war effort. The second was to ensure that a strong pipeline of new talent would be created that would continue to develop technologies that could support the military and U.S. industry in the future. The third was that many of the science projects that prominent scientists wished to pursue were much larger and more basic than the capacity or interests of private and industrial supporters to fund.

The report written by Bush and his colleagues entitled *Science - the Endless Frontier* and transmitted to President Harry Truman in July 1945, provided the template for post-war U.S. science policy. This report put forward the reason why government should fund scientific research and it emphasized the idea that government should continually support scientific research. The report aimed to enhance basic research, develop education, solve the demand for talents so as to overcome the shortcoming, pointing out that that there were no uniform national science and technology policies in the past. In addition, in the report, Mr. Bush advocated the government should establish a specially new organization to support universities' basic research, which was named the National Research Foundation, and soon it was renamed the National Science Foundation (NSF). Although NSF obtained Congress' authorization and was not written in law until May1950 and was different from Bush's suggestion to a great extent, many of ideas were represented in the organization of NSF.

Science – the Endless Frontier profoundly influenced American science & technology policy evolution and development. The National Science Foundation (NSF), newly established in 1950, as well as other important research funding departments such as the Office of Naval Research (established in 1946), the Atomic Energy Commission (established in 1946) and the National Institutes of Health (which began supporting research in US medical schools in 1948), constituted American Government's new science & technology funding & management system.

2. 1950-1972:Military, Science& Technology Competition in the Cold War

The cold war and the military technology competition between America and the Soviet Union became the primary impetus of American scientific policy from the time the Soviet Union exploded the first atomic bomb in 1949 to the Berlin Wall confrontation in 1961 and the Cuban missile crisis in 1962. This competition stimulated the American Government to widely support science & technology and maintained the unprecedentedly high military expense budget and scientific research fund investment in peace time. A major impetus for the increase in U.S. government support for scientific research and science education was the launch by the Soviet Union of the first successful earth orbiting artificial satellite, named *Sputnik*, in October 1957. This event created a crisis of confidence in the United States, given that there had been several earlier failed attempts by the government to achieve this milestone.

The federal government's research and development funds increased by a factor of four from 1957 to 1967. Nearly all scientific disciplines have all made progress for generous funding from federal government during these 10 years. A series of large-scale science research projects have been implemented and a lot of American research universities have become world-known. President Johnson has put forward *Great Society*, with the goal of enlarging federal government functions, under the influence of which, NSF undertook much wider responsibility and this stage became the prime stage of NSF's development. The American Government has increased its investment in natural scientific research and science education. NSF's allocation was increased from $40 million in 1957 fiscal year to $465 million in 1967 fiscal year.

The federal government also made the efforts to enhance scientific research management in this period. In 1957, President Eisenhower appointed the President's Scientific Advisory Committee and a full-time presidential science advisor. In 1962, President Kennedy has established the Federal Science and Technology Coordinating Committee to enhance the federal government's coordination and management in science and technology. Other cabinet departments and independent agencies, including the Department of Defense (DOD), Department of Health and Human Services (HHS), National Aeronautics and Space Administration (NASA) also set up their own advisory bodies to provide guidance on their scientific & research work.

3. 1972-1980: Shift from Military Competition to Social Problem Solving

Economic crises, in the late 1960s and early 1970s, forced the federal government to reorient its funding priorities. In the middle and late 1970s, American competitiveness was challenged by Japan and Europe so that technical products' share reduced in both home and world market. All of this caused Congress and the public federal government to develop some researches closer to national demand. So America's basic research shifted somewhat to solve social problems and promote technology advancement.

The golden era of the US National Science Foundation (NSF) ended with President Johnson's term. The increase of Vietnam War expenses and other expenses forced the shrinking of civilian research funds. NSF budget started to freeze. NSF still subsidized basic research as its primary mission but it has also experienced attempt of supporting applied research as guided by the national demand in the late 1960s and middle 1970s.

NSF promoted one of the most controversial projects in history *Research Applied to National Need (RANN)* from 1969 to 1977. In 1968, NSF's charter was revised to support applied research, so NSF established an engineering dominant program in 1969 --- *Interdisciplinary Research Relevant to Problems of Our Society (IRRPOS).* This program emphasized environmental quality and urban development management. IRRPOS expanded into RANN, whose plans responded to the suggestions of Office of Management and Budget (OMB), and requested NSF to concentrate more scientific resources on applied research demanded by a national strategy. In 1972 fiscal year, $81 million out of NSF's $622 million budget was used to support applied research. However, many people worried that this kind of large-scale applied research plan would separate NSF from its core mission, which is to subsidize basic research. Different from other NSF research units, RANN was social task-oriented, whose attention was put in the areas such as pollution, transportation, energy and other urban and social problems. It attempted to unify the enterprise and scholarly research organizations and hoped the enterprise would finally support part of its projects. RANN never received the welcome form NSF scientific mainstream culture and it was continuously in trouble. In 1977, it was abolished by the suggestion of a special committee of National Scientific Board (NSB). However, in some respects it has continued in one form or another until this day, with a growing emphasis on fields such as nanotechnology, health and advanced computing dominating NSF's research agenda.

In the 1970s, national defense and the space research funds growth stagnated and the federal government research and development funds declined in inflation-adjusted terms from 1968 to 1980. But research funds increased in some priority fields, such as medicine, environment and energy. It should be emphasized that, after World War II, the United States established a solid foundation for national defense, strengthened federal laboratory construction, trained massive scientific research personnel, which have accumulated rich experience for shift to civil technical and international commercial technology competition.

4. 1980-1992: Industrial Competitiveness Promotion

The Iranian hostage crisis began during the presidency of Jimmy Carter. In November, 1980, Ronald Reagan was elected American president. During the Carter administration, Iran detained American hostages. The petroleum exporting countries ran up oil price and Japan pursued and wanted to surpass America to become the world's leading economic power. Economic recession and high unemployment rate were shaking America's confidence. This was a period when American research began to be revived. Companies started to establish more research partnerships based on universities where areas of information technology and biological technology were most successful. States had more investments in the local universities and institutes to attract high-tech and skilled workers.

The United States reconsidered its decrease in international competitiveness. Many of reports held that the primary cause was the lack of a set of comprehensive national science and technology policies aimed at both national security and international competitiveness. In view of these questions, the federal government started to formulate a series of laws concerned with science and technology policies and to adjust science &

technology policies. Instances of these include: *The Stevenson-Wydler Technology Innovation Act*, *Patent and Trademark Act Amendments of 1980* (The Bayh-Dole Act) in 1980, *Small Business Innovation Development Act* in 1982, and the *National Cooperative Research Act* in 1984, *Technology Transfer Act* in 1986.

The above policies emphasized on partnerships in the commercialization process of research achievements, cooperative research among industries, universities and government, and the development and commercial application of civil technologies. At this time, the U.S. government's research and development fund increased continually so did the industrial research and development investments, which surpassed the federal government's investment in 1985.

5. 1992-2000: Science to Serve National Goals

In the 1990s, American scientific policies paid more attention to the impetus function of science toward social and economical development. After President Clinton came to power, his administration formulated a series of measures to promote science and technology to serve economic growth.

In 1994, the Clinton administration issued a report named *Science in the National Interest*, which was the first presidential statement on science policy since 1979. *Science in the National Interest* set five main goals for U.S. Science Policy and corresponding policy measures. The five goals were: (1) Maintain leadership across the frontiers of scientific knowledge. (2) Enhance connections between fundamental research and national goals. (3) Stimulate partnerships that promote investments in fundamental science and engineering and effective use of physical, human, and financial resources. (4) Produce the most outstanding scientists and engineers for the twenty-first century (5) raise the scientific and technological literacy of all Americans. Under the guide of this policy, US scientific policy presented as wide investment in scientific fields, shift of basic research funds to the universities and unification of education and research.

The Clinton administration strengthened the science and technology management system, perfected the policy-making mechanism and strengthened the function of White House Office of Science and Technology Policy in its coordination between science and technology policy and planning. The Federal Coordination Committee on Science, Engineering and Technology (FCCSET) composed by the main federal science and technology agencies and representatives, was promoted into National Science and Technology Council (NSTC), which was responsible for formulating federal science and technology investment, research and development strategy. Earlier, President George H.W. Bush had restored the PCAST (President's Council of Advisers on Science and Technology) to provide consultation on science and technology from the private sector for the president. During the Clinton administration, PCAST participated in decision-making along with the NSTC.

When the Cold War ended, the federal government's investment in research and development dropped, while industrial investment increased by large steps. In federal research development investment, the non-national defense investment accounted for more and more and surpassed the national defense research and development investment for the first time in 1994. This kind of investment pattern accorded with the goal of science & technology serving national economic growth.

6. American Scientific Policies during the 21st Century

The Bush Administration's science & technology policies changed a lot after the *9/11* event. A new priority primary target was anti-terrorism and defending national security. A second target was to maintain economic growth; a third was to maintain and improve people's quality of life. All of these depended on scientific discovery and new technological progress. In July, 2004, the White House Office of Science & Technology Policy (OSTP) issued a report named *Science for the 21st century* and it emphasized *science is a key factor in safeguarding the country's future security, prosperity, improving people's healthy standard and life quality, and it will be always the key point of America.*

The report notes that the first step is to guarantee the investment in R&D in order to keep the preeminence of US scientific research. The President's 2005 budget requested commits 16 percent of total discretionary budget authority to R&D, which reached a level of $132 billion. Funding requested for R&D in 2005 is the highest level ever, and among the highest in recent decades when measured as a share of discretionary funding or gross domestic product. The report also outlined the sketch of corresponding policies and active measures in light of the up-dated need and development of science and technology.

In January 2006, in his State of the Union Address President Bush announced *The American Competitiveness Initiative* (ACI) *to encourage American innovation and strengthen our nation's ability to compete in the global economy.* This ambitious strategy will increase federal investment in critical research, ensure that the United States continues to lead the world in opportunity and innovation, and provide American children with a strong foundation in math and science. The *American Competitiveness Initiative* commits $5.9 billion in FY 2007, and more than $136 billion over 10 years, to increase investments in research and development (R&D), strengthen education, and encourage entrepreneurship and innovation.

Bush proposed in the 2007 fiscal budget strong commitment to double over 10 years investment in key federal agencies that support basic research programs in the physical sciences and engineering – the National Science Foundation (NSF), the Department of Energy's Office of Science (DOE SC), and the Department of Commerce's National Institute of Standards and Technology (NIST). At the same time, the goal of reducing taxes on industrial research and development is to lower them to $86 billion in 10 years.

II. Historical Evolution of Chinese Scientific Policies During the Past 60 Years

1. 1949-1956: Resumption and Construction of Chinese Science

There were no more than 50,000 science and technology personnel and no more than 500 specialists engaged in natural sciences research when the People's Republic of China founded in 1949. At that time, scientific research was extremely weak. Due to the special history, new China's science and technology enterprise comprehensively followed the Soviet Union's model in organization, institution, management, strategy, planning, and education.

The Central Government established the Chinese Academy of Science in November 1949 by merging the former Academia Sinica, Peking Research Institute and some industrial and social scientific research institutions. In March 1953 the Chinese Academy of Science sent a delegation to the Soviet Union to investigate and learn the Soviet's experience and later became the highest academic and institution in rank and a national comprehensive research center. In June 1955, the Academic Division of the Chinese Academy of Science was established. This was a symbol that *Chinese outstanding scientists could attend the leading work of Chinese science and technology enterprise in a more organized way.* [1]

The Ministry of Education started to rearrange universities and colleges in 1951 so as to cooperate with the Soviet Union in aiding projects in terms of demand of professional experts. In 1957, when the universities and colleges finished the rearrangement, management system, discipline establishment, curriculum, teaching and textbook system, all comprehensively having copied from the Soviet Union's experience. The educational scale was enormously expanded, and the urgent need of talents for economic development was solved, but it also had the negative effect such as being narrowly specialized, with the separation between teaching and scientific research.

On the basis of Soviet help with construction and equipment support, China made remarkable progress in industries like electric power, coal, petroleum, steel and iron, non-ferrous metal, automobile and aircraft. Industries and provinces, autonomous regions, and municipalities directly under the Central Government established a series of scientific research institutions one after another.

China had dispatched large numbers of students to study in the United States, Japan and England from 1946 to 1948 and 3,000 went back to serve the homeland by the spring of 1957. From 1951 to 1960, 15,000 students were dispatched as interns to the Soviet Union and Eastern Europe. The majority of them became outstanding figures and the backbones in Chinese scientific research and various professions.

After seven years' endeavor, the Chinese science and technology enterprise began to take shape. More than 9,000 researchers were working in research institutions had increased to more than 380 from 40 in 1949. The disciplines also increased. This progress laid a solid foundation for subsequent large-scale national defense, economic and social constructions.

2. 1956-1966: *Great Scientific System* Characterized With Plans

Two major plans, namely, *Long-term Science and Technology Development Planning from 1956-1967* and *Science and Technology Development Plan from 1963-1972,* helped China step onto the development path of "*planned science*".

1 Guo Moruo, report on the establishment of Academic Division of Chinese Science Academy, Science Report , June, 1955

The 12-year-plan from 1956-1967 proposed 57 important science and technology missions and decided on 616 key research topics. Among these, four urgent measures (computer, semiconductor, automation and electronics) and two confidential urgent measures (atomic bomb and missile) in 1956 opened the prelude of China's technological development in atomic bomb and missile. After the missile technology made breakthroughs, the satellite research plan started to enter the national plan in January 1965.

The 10-year-plan from 1963-1972 formulated the guidelines of *self-dependence and catching up*. At that time, the Sino-Soviet alliance was destroyed and developed into hostile relations. America started to enter Vietnam in 1961. China's international environment was extremely bad. The 10-year-plan proposed to concentrate on solving urgent and important science and technology problems in economic development. It set the principle of *laying the solid foundation and grasping two ends*.. "*Grasping two ends* " means agriculture and science and technology related to food and clothing on one side, and science and technology of advanced national defense on the other. '*Laying the solid foundation"* means enhancing industrial science and technology rapidly, especially basic industrial technological level and basic scientific research level.

Before the *Great Cultural Revolution,* '*Great scientific system'* corresponding with China's planned economy obtained great success. The featured achievements were nuclear technology, astronautics technology, synthesized bovine insulin, discovery of Daqing Oil Field. In addition, science and technology played a vital role in grain production, medical care, transportation construction, resources investigation and disaster defend, etc.

3. 1966-1976: Cultural Revolution's Stagnation

The *Great Cultural Revolution* seriously undermined Chinese science and technology. Scientific research management agencies were nearly out of function, researchers' creativity suffered persecution. Basic research closed the door to the outside. Science and research stagnated. Although defense projects and key engineering constructions (for example Gezhou Dam Hydro Power Plant and Nanjing Changjiang Bridge) continued to obtain success. The science and technology gap between China and the Western countries increased.

4. 1976-1999:*Scientific Spring* Brought by Reform and Opening

In 1978, the Central Committee of CPC convened a profoundly significant national scientific congress. It dispelled chaos and restored order for the whole society. The right guidelines were set for scientific and technology. China's science and technology enterprise has entered a new development phase.

Academic divisions were restored at the Chinese Academy of Science in 1980. Many outstanding scientists renewed their work in 1980. The doctoral and master degree systems were introduced in 1981. Natural sciences funding system began to try out in 1983. The national key laboratory construction plan began to be implemented in 1984; a post-doctorate research system was started on a pilot basis in 1985; the National Natural

Science Foundation was established in 1986, and it implemented science appraisal and democratic policy-making funding mechanism to the basic research. In 1987, the National Science & Technology Commission organized investigations on the national basic research situation and development and formulated *National Medium and Long-term Science and Technology Development Program*. In 1989, a national basic research and basic research application meeting convened. It proposed explicitly that the basic research was one of three levels of China's science and technology developmental strategy, and China's basic research must be stably persisted. In 1990, the National Science and Technology Commission formulated *the Eighth 5-year-Plan of National Basic Research and Applied Basic Research.*

The Central Committee of the CPC and the State Council issued the *Central Committee of the CPC and State Council's Decision on Accelerating Science and Technology* in 1995 and it explicitly proposed a *strategy of invigorating the country through science, technology and education.* And to further strengthen basic science research. China started to formulate and implement *National Key Basic Research Development Plan* ('973 Plan') in March, 1997. In the same year National Basic Science Training Fund was set up, which aimed at strengthening undergraduate education and training reserve talented persons. The 973 Plan together with National Basic Science Training Fund constituted two main channels that Chinese government supported the basic research.

In 1998, the Knowledge Innovation Project of Chinese Academy of Science officially started. In 1999*, Program of Invigorating Education for the 21st Century* ('211 Project') started. These two great plans advanced basic research construction with Chinese characteristics.

5. Chinese Scientific Policies Devoted to Indigenous Innovation during the 21st Century

After more than 20 years of reform and opening, China's basic research has made remarkable progress and the basic research management system frame with primarily indirect regulative method has been established. Each kind of special plan, comprehensive arrangement, overall planning and deployment has impelled China's basic research development and has trained basic research backbones.

In the 21st century, Chinese government and scientific & technology circle have all realized China's scientific research is in the crucial period of tracing indigenous innovation, and from quantities expansion to quality enhancement. Although China's basic research has made considerable achievements, there is still a big gap with the world's advanced level, and especially the indigenous innovation achievements are quite few. Papers with high quality are few and the papers' citation rate is still lower than the world average level. Scientific research infrastructure, especially basic research supporting condition is still obviously behind the international standard level.

The *National Guidelines for Medium- and Long-term Plans for Science and Technology Development* was issued in 2006, which has programmed the scientific work in the future fifteen years. The guidelines set a target to raise the weight of China's research and development expenditures in GDP to 2.5 percent or above, with an S&T advancement contribution rate reaching 60 percent, and a reduced dependence on foreign technology by at least 30 percent. It also expects that the increased number of Chinese invention patent grants and citations of Chinese S&T papers will make China sit on 5th place in the world. The guidelines point out that China's S&T development will head for a set of general objectives up to 2020: significantly enhancing China's proprietary innovation capacity, remarkably raising China's S&T capacity in promoting economic and social development and safeguarding national security, and providing an enhanced S&T support for building a full-fledged well-to-do society. China also strives for a noticeably fortified position in basic scientific research and frontier technologies, expecting a range of S&T findings of international importance. The efforts will turn China into an innovation-oriented nation, and lay a solid foundation for China's becoming a world S&T power in the mid-century.

The guidelines established the principles of *indigenous innovation, emphasis-based surpassing, and development supporting and directing the future*. Basic research has the unique function of improving China's independent innovation ability. Strengthening indigenous innovation is the main content of independent innovation as well as the ultimate mission of basic research.

In the future period of time, Chinese scientific policies will devote to develop *primitive indigenous innovation*, provide impetus for significant key breakthroughs, general technology and sustainable and coordinated development, and make contributions to cultivate emerging industries and lead the development of future economy and society.

III. American Basic Research Management System

As is its political system, the U.S. federal government's S &T management system is pluralistic. The federal government does not establish departments to manage science & technology development. However, it adopts the pattern of *disperse management and central coordination. Disperse management* refers to the fact that each related department and organization of the federal government subsidizes and manages the activities according to its special mission.

Central coordination is mainly realized by the federal government's scientific development plan and budget decision-making process.

1. American Government S&T Plan and Budget Decision-making System

The science & technology development plan and budget of the federal government are decided by administrative departments led by the president and Congress. The administrative departments are responsible for proposal, coordination and demonstration of scientific development plan and budget; and the Congress is for examining and approving the science & technology budget.

Administrative departments of science & technology development plan and budgets' policy-making. There are three administrative levels of science & technology development plan and budget policy-making. One is National Science and Technology Council (NSTC); the second is White House Office on Science & Technology Policy

(OSTP); the third is relevant federal government departments and organizations subsidizing and managing research and development activities. Each level has different responsibilities in S&T planning and budget decision- making.

The NSTC was established in 1993, which is an authoritative organization for the president to coordinate federal government science, space exploration and S&T policy. The president is the chairman, and the Director of OSTP its vice-chairman. Its members consist of heads of cabinet departments and independent agencies undertaking important science & technology responsibility, as well as other White House officials. Its primary mission is to guarantee S&T policies and plans consistent with the national objectives; comprehensively coordinate various problems resulting from budget limit and federal departments' overlap in planning science & technology; formulate cross-department research and development strategies and corresponding comprehensive investment plans; guarantee to consider science & technology factors in federal government's related policy-making, plan formulation and implementation; unify coordination of policies related to international science & technology cooperation .

NSTC played a leading role in American science and technology planning and decision-making when President Clinton was in power. After Bush Jr. was in power, NSTC still existed, the legal status has not changed. But President Bush was no longer the chairman, and it was posted by Jack Marburger, director of OSTP. In S&T policy consultation, President Bush has laid more emphasis on PCAST. OSTP and the Office of Management and Budgets (OMB) undertake comprehensive coordinate functions in scientific policies.

The White House Office of Science & Technology Policy (OSTP) was established in 1976. It has been always been an organization providing the president with scientific policy consultation. The director of OSTP is also the president's advisor, whose main task is to provide scientific analysis to the president when the federal government enacts important scientific policies, plans, budgets and projects. The organization is responsible for coordinating the government department's formulation and implementation of their science & technology budgets and policy; cooperate with private organizations; and guaranteeing the federal government's technical investment; helping economic development, environmental quality and national security; establishing good partnership between thee federal government, local authorities, other countries as well as scientific communities; and appraisal of the scale, quality and effect of federal science &technology investment. The White House OSTP and OMB usually meet federal departments and scientific circles consulted in planning scientific & research budget, to determine priority projects, keep the balance between federal departments as well as basic research, applied research and experiment development.

The federal government's cabinet departments and agencies propose their respective S&T plans, and requested support of corresponding research and development funds budget according to their mission. A majority of these S&T plans are formed from bottom to top. It seems that the S&T plans and budget decision-making process are explicit and fixed, but the actual decision-making process is extremely complex.

Congress' participation in science & technology plan and budget decision-making. The US Constitution entrusts Congress with legislative power, budget examination and approval authority, which involves government budget, organization establishment and rescission, and all the important rules and regulations involved in science & technology have to be authorized by Congress. The House and Senate set up different committees responsible for their related fields. Among them, the committees related to technical planning and budget decision-making in the Senate include: Appropriations Committee, Budget Committee, Commerce, Science & Transportation Committee, and Energy and Natural Resource Committee. The committees of such in the House of Representatives include: Appropriations Committee, Science, Spatial and Technical Committee, and Environment National Resources Committee. In addition, there are three policy-making supporting organizations in Congress, namely: Congressional Budget Office, Chief Audit Office and the Congress Research Service.

After president submits his S&T proposal to Congress during the last days of January, related committees of Congress will hold a series of public hearings and invite government officials and people from all walks of life to attend and express their opinions. The committee may authorize, revise or even veto the proposal. After the committee has discussed the proposal, it will be delivered to the Senate and Houses to have public debate. After it has passed in Senate and Houses, namely passed by Congress, then signed by president, it will establish the president's science and technology budget.

Consultation Organization for S&T Planning and Decision-making. In America, some organizations (such as different government departments and Congress) have played a vital role in providing S&T policy consultation, which have constituted an essential part in science &technology development planning and decision-making processes. These organizations include the standing science & technology consultation committees of the president and Congress, such as PCAST, the National Biology Ethics Advisory Committee, the National Academy of Science, the American Science Promotion Committee as well as all kinds of S&T specialized organizations.

Factors Influencing S&T Planning and Budget Decision-making Processes. America's public policy decision-making is a complicated process, which is open, multiple, and elite-based. In the policy-making process, various policy-making bodies must consider many political factors. The policy-making bodies mainly include the White House, Congress, various government departments and organizations, members of Congress, and all kinds of lobbies (or interest groups, such as large-scale energy companies, environmental protection organizations). Because these bodies have different status, interests, and viewpoints, the political factors in consideration are also different.

The administrative departments always strive for more budget support for their own plans. Among them, the Department of Defense and Department of Health and Human Services, are the most powerful and influential departments, for one of them concerns national security, and the other concerns people's life, and they also have obtained more research and development budgets. Speaking of administrative departments and Congress, the president presumably makes decisions in terms of overall national benefits, such as environmental issues, national objectives, national security, economic competitiveness, and quality of life of U.S. citizens. Congress makes decisions more out of constituency interests and partisan perspectives. The lobbies, major enterprises, specialized organizations and environmental protection organizations will make decisions consistent with their respective interests and attempt to influence science & technology development planning and decision-making processes. Public welfare-oriented science organizations (for example the National Academy of Science) and other not-for-profit scientific research organizations try to influence decision-making from imperatives of development and the internal needs of science & technology as well as enhancing the organization's academic prestige by providing authorized analytic reports to the president or Congress. So the final policy-making result will be an accepted scheme through different organizations' compromise and bargain. Generally speaking, the administrative opinion will dominate, that is to say, the American science & technology plans are based political decisions considering national benefit and a feasible basis through different organizations' compromises.

2. Main Government Departments of Funding and Managing Basic Research

There are six departments (organizations) funding and managing basic research. They are Health & Human Service department (HHS), National Science Foundation (NSF), Department of Energy (DOE), National Astronautics and Space Administration (NASA), Department of Defense (DOD), and Department of Agriculture (USDA). The proportion of the basic research budget of these organizations to the total amount of federal government's basic research budget is above 95 percent. (See Table 1)

Table 1 Basic research fund and R&D fund of American six federal government organizations (FY2003) Billion of US dollars

Department(organization)	Basic research fund	R&D fund
HHS	14.1	27.6
NSF	3.4	3.9
DOE	2.6	8.2
NASA	2.4	11.0
DOD	1.4	58.6
USDA	0.9	2.2

HHS mainly supports American's biomedicine research, whose research and development budget is only inferior to DOD, and is situated the second in the federal government department. Half of HHS' R&D total fund has been used in supporting basic research in universities and hospital, and this part of fund entrust NIH to manage.

The Department of Energy (DOE) mainly supports research and development work related to energy and related fields and it encourages and participates in international cooperative research and development concerning energy and environment problems. Besides supporting DOE's attached research developments, part of them entrust the federal research and development centers which are managed by private enterprise to run, and the basic research project entrusts the federal research and development center which managed by the university to carry on. Some universities also manage laboratories that do applied research, such as Brookhaven (BNL), Los Alamos (LANL), Livermore (LLNL) and Argonne (ANL) National Laboratories.

The National Astronautics Space Administration (NASA) is in charge of American space research and development, more than 90 percent of whose scientific research are entrusted to private enterprises and universities to manage. The entrusted way is similar to that of the Department of Defense (DoD).

The Department of Defenses' expenditures are greater than those of all other departments in the federal government, whose total amount of scientific research funds have accounted for 50 percent of the federal total for many years. DOD allocates funds directly to development facilities, and signs entrusted research contracts with research organizations, industrial enterprises and universities to conduct research and development related to DOD's development. The overwhelming majority of scientific research fund of DOD (about 95 percent) is used in supporting applied research and experiment development, and a very small amount (3-4 percent) to support universities basic research.

The US Department of Agriculture (USDA) is one system with huge research divisions, which include the Belz Vyell National Agriculture Research Center, four regional federal agriculture research labs, 68 awarded land agriculture colleges and universities, and 50 state-established agriculture experimental stations. It totals 488 agricultural, educational, experimental research and technical promotion organizations, which has formed an agricultural research management system with education, scientific research and promoted application unification. Most of USDA's scientific research funds has been applied into the development facility of the system, among which the basic research fund accounts for 40 percent of total scientific research funds.

The National Science Foundation (NSF) is an independent agency of the federal government, which is primarily responsible for funding the basic research, education and infrastructure construction of the American universities and other academic organizations, so that to guarantee the comprehensive and coordinated development of American science in various disciplines. NSF's continuing mission is set out in the preamble to the *National Science Foundation Act of 1950* (Public Law 810507): NSF's mission is to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

NSF's basic mission has not changed, but the corresponding duty has been adjusted for many times since it has been established 55 years. At present, it has 12 basic tasks, summarized as three kinds:

(1) Project funding: fund science and engineering research projects, strengthen American research abilities; develop various levels of educational projects, enhance American citizens' scientific accomplishments; set up graduate scholarships, train reserve scientific talents; and establish instruments and facilities supporting scientific research;

(2) Policy service: appraise various disciplines' development condition and actual need; collect and analyze the related information of American science & technology resources; summarize the related progress to federal government fund subsidizing basic research and applied research of scientific research institutions; encourage the formation of national policies of promoting basic research and science projects,

education and submit reports on these matters to the president and Congress each year;

(3) Scientific service: impel the communication home and aboard; support scientific development and social application; enhance research and educational innovation; develop the plans of strengthening women, minority and other special associations for participating in science & technology activities.

IV. Management and Planning System of Chinese Basic Research

1. Management System of Chinese Basic Research

After more than 20 years of reform and opening, the Chinese basic research management system reform has made remarkable progress, and has established basic research management system of indirect regulative method, strengthened the basic research macroscopic decision-making and coordination mechanism, established funding system and contract systems in allocating research funds, which has advanced the development of China's basic research.

Generally speaking, China's basic research management system is highly centralized. Under this kind of pattern, the Chinese government has centralized the power of basic research's policy, planning, management and funding allocations into specific management departments and funding departments, while other departments are responsible for policies and short-term projects formulation and implementation.

The structure of national basic research management is divided into three levels: policy-making, coordination, and execution. The National Science & Technology Leading Group is the top policy-making body. Coordination is carried out through the Inter-ministerial Coordination Leading Group of the National Basic Research Execution is carried out primarily by the Ministry of Science and Technology (MOST), the Ministry of Education (MOE), the Chinese Academy of Science (CAS), the National Natural Science Foundation of China (NSFC), the National Development and Reform Commission, the Ministry of Agriculture, the Ministry of Health, the Ministry of Land and Resources, and the Ministry of Information Industry. Among these, MOST, MOE, CAS, and NSFC are dominant in the overall planning and budgeting for national basic research and for important national basic research plan formulation and implementation. Other departments participate in related basic research management according to their respective functions (Figure 2).

National Science & Technology Education Leading Group. The Chinese State Council established the National Science & Technology and Education Leading Group in 1998 chaired by the premier. The members include the Director of the National Development and Reform Committee, the Minister of Education, The Minister of Science and Technology, the Director of the National Defense Science& Technology Industry Committee, The Minister of Finance, the Minister of Agriculture, the President of the Chinese Academy of Science, the Assistant Secretary of the State Council, and President of the National Natural Science Foundation of China.

The primary task of this Leading Group is consider the development of national strategies and significant policies for science, technology and education; discuss important tasks and projects for science and technology; coordinate significant items related to science and education between departments of the State Council and provincial and local authorities.

Inter-ministerial Coordination Leading Group of National Basic Research Program. The chair of the National Basic Research Coordination Department is the Minister of Science & Technology. Its principal members are the leaders of the National Development and Reform Committee, the Ministry of Education, the Chinese Academy of Science, the Chinese Academy of Engineering, and the National Natural Science Foundation of China. The responsibility of the National Basic Research Coordination Department is to monitor the formulation and implementation of national basic research policy and planning and developmental strategies. This department also promotes the coordinated implementation of national basic research plans as well as various corresponding plans related to other aspects of science and technology.

Ministry of Science & Technology. The Ministry of Science & Technology manages and coordinates technical work assigned by the Chinese State Council. Its primary task includes

1) study and propose macroscopic strategic policy for technical development and the laws and regulations of science and technology; study the major issues of science and technology to promote economic development; improve the construction of the national science and technology innovation system, and sharpen the nation's capability in science, technology, and innovation.

2) organize and establish medium and long-term plans and annual plans of national civil science and technology development; study and establish policies for basic research and high technology development; assume responsibility for significant basic research plans, high-tech research development plans, and development of industrial production and environmental protection.

3) strengthen high-tech industrial production and applied technology development and promotion; study the reasonable disposition of technicians' resources; propose related policies to maintain technical personnel's enthusiasm; create related policies to provide a good environment for technicians; and undertake science and technology popularization.

4) study and draw up the policies for international science and technology cooperation and exchange.

Ministry of Education. The Ministry of Education is in charge of managing education and language. In technical management, the Ministry of Education coordinates with the Ministry of Science & Technology to draw up national basic research policies and development plan; plans and instructs the natural sciences, philosophy and social sciences research of the universities; macroscopically instructs universities and colleges' high-tech applied research and promotion, scientific research achievements; coordinates and instructs the universities and colleges to undertake national significant scientific research projects and defense-related science and technology projects; instructs the universities and colleges' key laboratories and engineering research center development construction.

Chinese Academy of Science. The Chinese Academy of Science was established in 1949. It is the highest academic organization of national science &technology and the comprehensive study development center of national science and high-technology. The Chinese Academy of Science includes five disciplinary divisions (division of mathematics and physics, division of chemistry, division of biology, division of geography, and division of technical science), as well as 11 branches (Shenyang, Changchun, Shanghai, Nanjing, Wuhan, Guangzhou, Chengdu, Kunming, Xi'an, Lanzhou and Xinjiang), 84 research institutes, one university, two institutes, four literature information centers, three technical supporting organizations and two news publication units, which are distributed in more than 20 provinces. In addition, it has also invested and established 430 science and technology enterprises (including transfer system unit), involved 11 professions, including eight listed companies. The Chinese Academy of Science management policy is national strategy demand-oriented, world front science oriented. It aims towards the enhancement of original science innovation, strengthening key technology innovation and integration, climbing the world science and technology peak, continually makes basic, strategic, forward-looking significant innovation contributions for our country economic development, national security and social sustainable development.

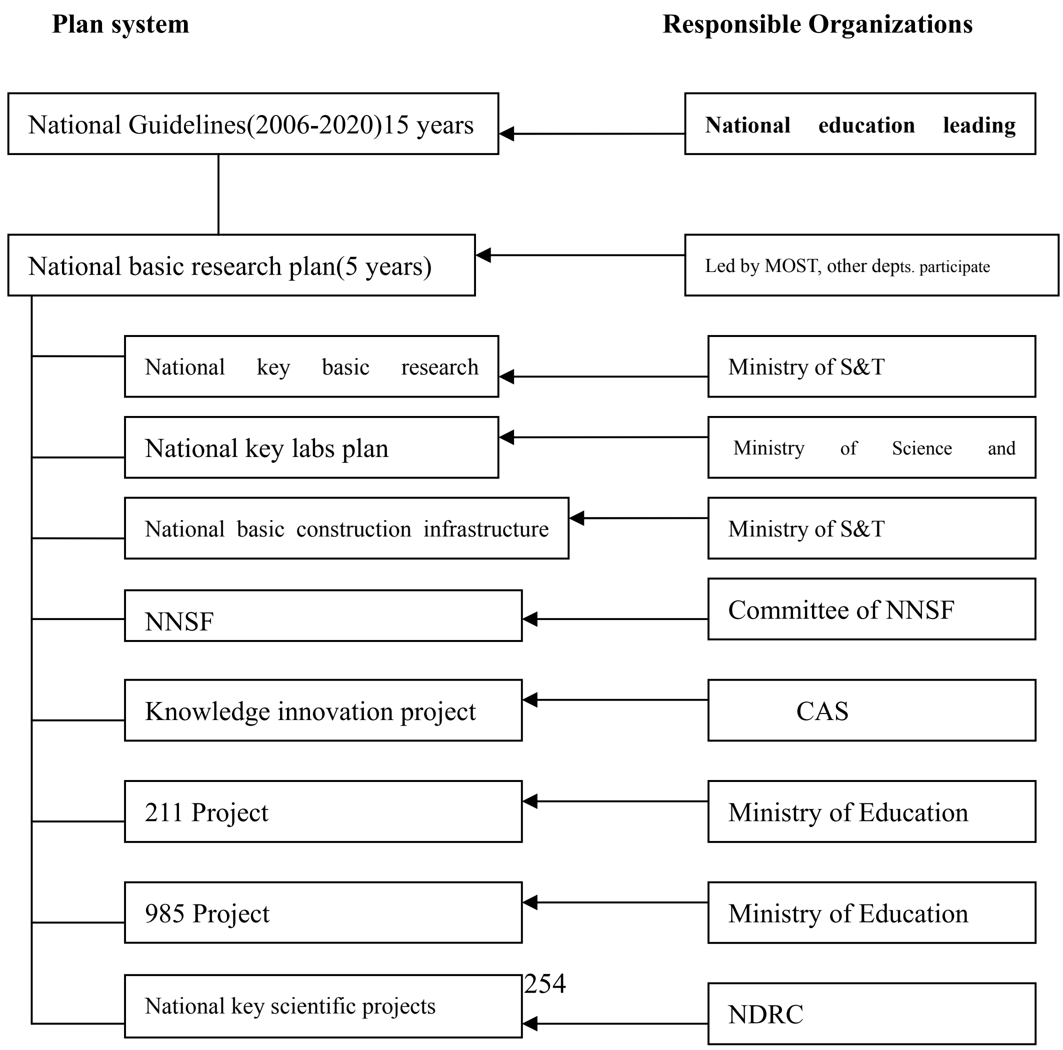
National Natural Science Foundation of China. The National Natural Science Foundation of China (NSFC) was established in 1986 as a subordinate institution of the State Council charged with managing national natural sciences funds. Its primary tasks are to utilize state financial allocations for funding basic research according to national science& technology development policies; discover and train talents; coordinate with the Ministry of Science & Technology to draw up policy and development plans for national basic research; establish international cooperation with foreign governments' counterpart agencies. Since its establishment, the NSFC has implemented advanced scientific research funds subsidization, established the appraisal principle of depending on experts, developing democracy, supporting according to selection and fairly reasonable, established the operational mechanism of science democracy, equality of competition, and encouragement of innovation, established the management system of consultation, policy-making, execution and surveillance inter-coordination, gradually completed three level of surface, key and significant projects, the subsidization system of talents project. The NSFC has become one of the most important channels of the Chinese government's funding basic research.

National Development and Reform Commission (NDRC) and other departments. The National Development and Reform Commission is the macroeconomic regulation and control department to comprehensively study and draft economic and social development policy and instruct overall economic reform. At the same time, it also has important scientific management functions, manages social enterprises such as science & technology, education, culture, and health. It is charged with promoting the balanced development of the national defense and the national economy; supporting the national innovation competence's infrastructure construction, including large science engineering, research and experimental systems and scientific supporting systems. It proposes important issues related to economic and social coordinated development and promotes social enterprises development policy and coordination.

Other ministries such as the Ministry of Agriculture, the Ministry of Health, the Ministry of Land and Resources, the Ministry of Information Industry, the Ministry of Forestry, the Environmental Protection Administration, the Meteorological Administration, the Earthquake Administration, and the Oceanic Administration, cooperate in the implementation of national basic research plans, and manage the related basic research activities consistent with their missions.

2. Programming & Planning System of Chinese Basic Research

The characteristics of programming& planning system of Chinese basic research are *overall* plan, branch implementation. *National Guidelines for Medium-and Long-term Plans for Science and Technology Development (2006-2020)* is the top level plan, which has made the overall plan to Chinese science and technology work for the next 15 years and has the commanding function of national science and technology work; *2006-2010 National Basic Research Plan* is the second level plan, which implements the objectives and goals of these national guidelines, makes a comprehensive plan for national basic research work for the next five years, and has the instructing function for formulating and implementing a national basic research plan as well as various departments' basic research work. China basic research plan and the plan system are shown in Figure 2.



National Key Basic Research Development Plan. Originally, the National Science and Technology Leading Group decided to formulate and implement a *National Key Basic Research Development Plan* in the third meeting in June, 1997, and afterwards the Ministry of Science & Technology organized and implemented the *National Key Basic Research Development Plan* (i.e. *973 Plan)*. The 973 Plan's strategic targets are: enhance original innovation, solve the vital scientific problems of social economic and social development in a deeper plane and wider field so as to improve China's independent innovation ability and solve major problem solving ability, and provide science support for national future development. Its primary mission is to support the most important scientific issues relative to the national economy, including social development and technical development, encircled agriculture, energy, information, resources environment, population health, and materials. Activities under the 973 Plan include multi-disciplinary comprehensive research and providing a theoretical basis and scientific foundation for solving problems; deploying cutting-edge basic research that is related to important national projects; training outstanding talents with high scientific quality and innovation adapted to the demands of the 21st century; construct high level scientific research bases which can undertake national key science and technology projects, and establish comprehensive, trans-disciplinary scientific research centers.

Between 2001 and 2005, the 973 Plan supported 143 key projects of vital importance to technical development and the national economy, in which there are 17 related to agriculture, 15 items related to energy 18 related to information, 18 related to resources and the environment, 29 related to population and health, 18 related to materials, and 27 related to synthesis overlapping and important scientific endeavors. Total investments in these projects between 2001 and 2005 were 4 billion Yuan.

National Key Laboratory Plan. The National Key Laboratory plan started in 1984. After more than 20 years development, the plan has become an important part of China's national science and technology innovation system, serving as an important base of the country's: (1) organized high level basic and applied basic research, (2) system for attracting and training outstanding scientists, and (3) carrying out high level academic exchange. The plan constitutes the appraisal and management system to encourage innovation and competition. Through 2003, the central government invested 1.08 billion yuan in the plan. At the end of 2003, there were 161 national key labs and 5000 fixed personnel supported by the plan, which cover most fields of China's basic and applied basic research. (See Figure 4)

Total amount of yearly national key laboratories distribution

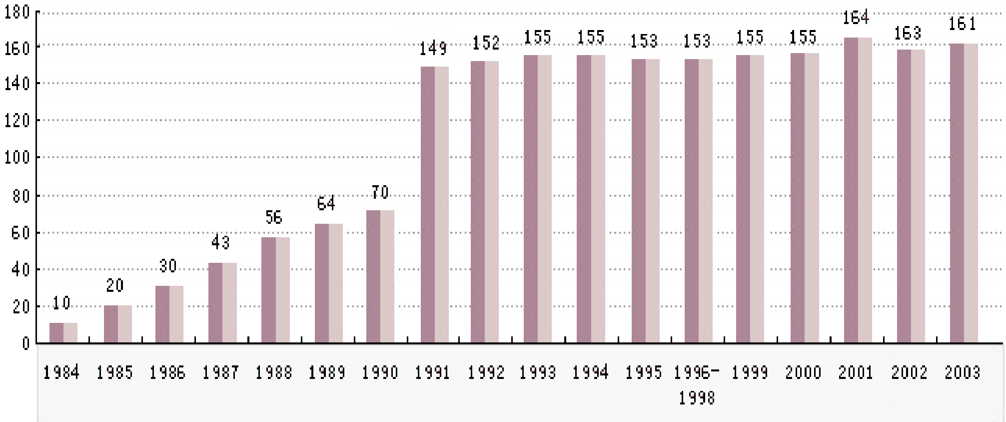


Figure 4 yearly national key laboratories distribution (1984-2003)

National Science and Technology Infrastructure Construction Plan. The Ministry of Science & Technology related and other related government organizations started the National Science and Technology Infrastructure Construction Plan in 2004, which has become an important part of the National Guidelines for Medium-and Long-term Plans for Science and Technology Development *(2006-2020).* The Ministry of Science & Technology has included technical infrastructure construction into the 115 Plan, as well as the Infrastructure Construction and National Basic Research Plan (973), and High-tech Research and Development Plan (863).

The general goals of national science and technology infrastructure construction are: (1) to establish policies, laws and regulations adapted to infrastructure construction and management; and (2) to establish a research and test base for sharing large-scale scientific instruments, technical resources, scientific data infrastructure, technical literature infrastructure, and network science and technology environment infrastructure, in order to provide an environment of fair competition for technical innovation and enable all people to enjoy the achievement of advances in technology.

National Natural Science Fund. The National Natural Science Fund is an important channel for the Chinese government's funding of basic research. At present, it consists of two separate components: *projects* and *talents*. The science fund continues to grow stably. The annual amount of the fund grew from 80 million yuan in 1986 to 3.4 billion yuan in 2006. The National Natural Science Foundation Committee has invested approximately 18 billion yuan to support approximately 100,000 outstanding scientific research projects. The science fund has insisted on supporting basic research to cultivate a innovation achievements, played an important role in technical innovation; trained many young science and technology talents and innovation teams; promoted balanced disciplinary development; sought to unify knowledge and technological innovation; and expanded international cooperation and exchange. (Figure 5)

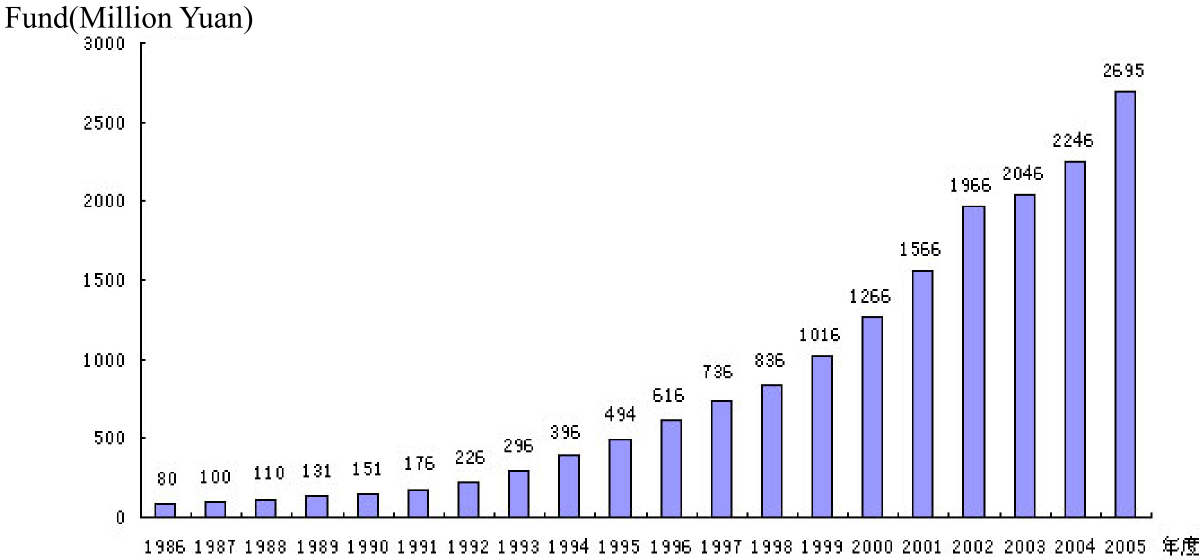


Figure 5 Increase of NNSF allocations from 1986 to 2005

Knowledge Innovation Project of the Chinese Academy of Science. The State Council decided to establish an experimental Knowledge Innovation Project led by the Chinese Academy of Science in June, 1998. The project was divided into three stages: the started phase from 1998 to 2000, the comprehensive propulsion phase from 2001 to 2005, and the optimized perfect stage is from 2006 to 2010.

The general goals of the are to: establish the Chinese Academy of Science a high-tech knowledge innovation center; constitute a scientific research base with international advanced level scientists and technicians to promote China's high-tech industrial development; serve as technology knowledge, scientific theory, and technical talent library.

***211 project* and *985 project* of the Ministry of Education.** In 1997, the Ministry of Education started to implement the *211 project* authorized by State Council's *Program of Invigorating Education for the 21st Century* ('211 Project'), namely, to face 21st century, emphasized the construction of about 100 key universities, colleges and one batch of key disciplines. The *211 Project* has equipped necessary and advanced instrumentation for scientific research in several key disciplines, enhancing the ability of several universities to undertake significant scientific research.

The Ministry of Education has implemented the *Program of Invigorating Education for the 21st Century* in May 2005, aims to establish additional world-class universities. (Shortened as *985 Project.*)

National Key Scientific Project. The National Key Scientific Project is intended to encourage China's basic research and scientific enterprise development. In the Seventh *Five-year Plan Period*, China constructed the Beijing Electron Collider as one of ten key scientific projects. In the *Ninth Five-year Plan Period*, China successively implemented five additional key scientific which have not only provided powerful support for significant unprecedented research progress, but also improved China's international scientific research status and prestige. At present, there are 19 important scientific projects that China has either completed and are under construction. The implementation of these national key scientific projects has greatly improved China basic research condition, played an essential role in improving China knowledge innovation ability. It has contributed towards advancing disciplinary development, the training of outstanding talented persons, the maintenance of national security, and the participating in international cooperative projects. During the *Eleventh Five-year Plan Period*, China will invest 6 billion yuan in 12 additional key scientific projects.

V. Input & Expenditure (Investment & Outcome) Comparison of Sino-America Basic Research.

1. Analysis of American Basic Research Funding

From 1953 though 2004, the annual average increase of basic research investments and total R&D investments in the United States were 6.2 percent and 4.6 percent, respectively. That is, the annual average increase in basic research investments were 1.33 that of total R&D investments, and 1.89 times of the annual rate of increase in GDP. During these 51 years, GDP in the United States increased from $1,973 billion (or a GDP per capita of more than $10,000), to $10,180 billion (or a GDP per capita of more than $30,000) – that is, by a factor of four. Annual basic research investments increased by a factor of 20.22 – from $2.387 million to $50.6 million. During this same period, annual total R&D investments increased from $26.8 billion to $270.8 billion – that is, by a factor of 9.10.

During the 51 years between 1953 and 2004, the ratio of basic research funds to GDP in the United States increased from 0.1 percent to 0.5 percent nearly quadruple, indicating that American research subsidization is not synchronized with the national economy. It is obvious that basic research is of great importance to national development in the United States.

There is a close relationship between the ratio of basic research to total R&D investments and the R&D funding structure. The higher the federal government's support for total R&D support, the higher has been the ratio of basic research to total R&D investments.

During the past 51 years, the federal government's investments in basic research have accounted for at least 57 percent of the total, and as much as 71.1 percent. Industry has been the second largest supporter of US basic research, accounting for at least 13.9 percent and at least 33.5 percent. It needs to point out that universities support for basic research grew continuously during these 51 years, that is from 1.3 percent to 10.3 percent and has become the largest third supporter since 1978. Not-for-profit organizations are the fourth supporter. Their Its lowest proportion was 4.6 percent in 1968 and the highest was 8.9 percent in 2002. Non-federal is the fifth supporter, whose lowest proportion was 1.4 percent and the highest was 4.8 percent during the past 20 years.

The proportion of the federal government's basic research to total R&D funding has continually increased, from 9.5 percent in 1953 to 38.6 in 2004. However, the ratio of the government's basic research funding to total R&D funding has been relatively small, ranging from 4.3 percent to 7.9 percent. But its R&D funds' total amount is quite large, so it is always the second supporter during 51 years.

Universities are the principal performers of basic research in the United States. The ratio of basic research expenditures by universities to total basic research expenditures has been more than 50 percent for many years, and has exceeded 60 percent for approximately the past 20 years.

Basic research is the principal R&D activity of American universities. The ratio of basic research performance to total R&D performance has been over 60 percent for nearly 40 years and reached 71.4 percent in 2004. Not-for-profit organizations have also taken basic research as an important R&D activities, basic research shares ranging from 35 to 55 percent. The ratio of basic research performed in federal government facilities to total R&D performance has increased from 10 percent to nearly 20 percent during the past 51 years. The ratio of industry's basic research performance to total R&D performance is quite small; that is, from three to six percent.

2. Analysis of China's Basic Research Funding

China's basic research funds has increased fast in recent 20 years, that is from 450 million yuan in 1987 to 11,700 million yuan in 2004, especially, this growth tendency has further strengthened since 1995. However, total R&D expenditures have also increased rapidly in recent years, rising from 55.1 billion yuan in 1998 (or 0.69 percent of GDP) to 196.6 billion yuan in 2004 (or 1.23 percent of GDP), with the result that that the ratio of basic research to total R&D investments increased from 5.24 percent in 1998 to 5.96 percent in 2004. In 1999, China's research institutes performed 33.4 percent of all R&D in the country; by 2004 that proportion had declined to 22.0 percent. During the same period, the proportion of R&D performed by universities increased from 8.1 to 10.2 percent, while that performed by enterprises increased from 55.4 to 66.8 percent. Between 1998 and 2004, the total R&D performed by Chinese universities increased from 5.7 billion yuan to 20.1 billion yuan. The proportion of basic research to total R&D performed increased from 16.6 percent to 23.9 percent over the same period, with the proportion of university basic research performed to total national basic research performance rose from 32.9 to 40.9 percent.

3. Comparative Analysis of Chinese and American Basic Research Funding

The ratio of basic research to total R&D as well as to GDP has increased continuously since 1990 in both the China and the United States. However in 2004, the ratio of China's basic research expenditures to total R&D expenditures was one-third as much as that of the United States, while the ratio of China's basic research expenditures to GDP is was one-seventh that of the United States (Figure 6).

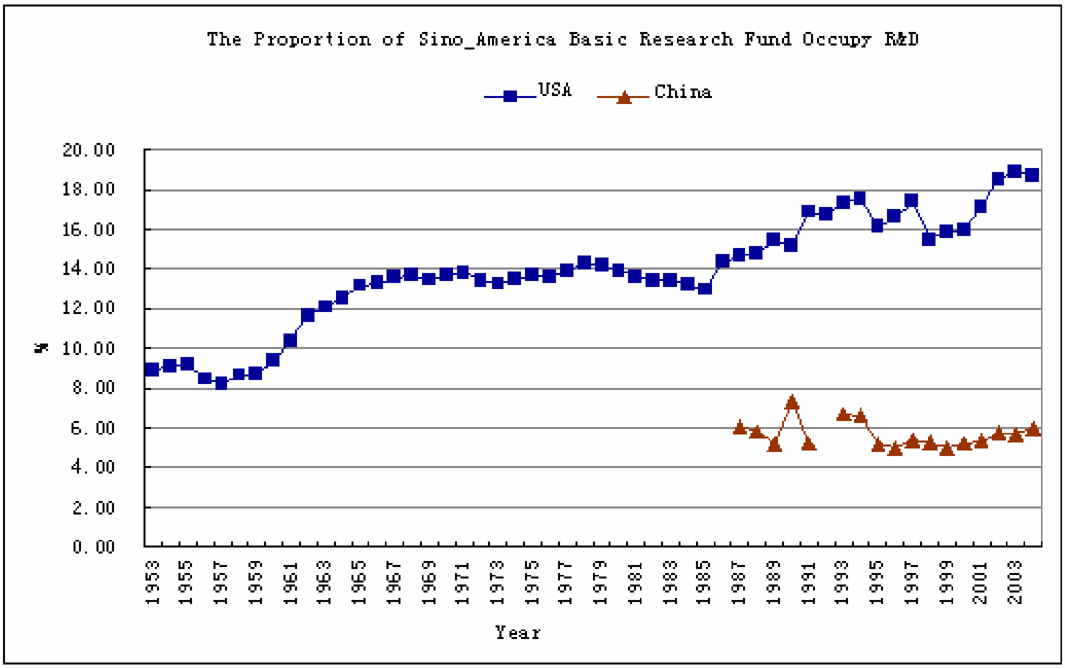


Figure 6 Proportion of China and America basic research funds to R&D funds

China has no statistical data about the breakdown of basic research expenditures by source. However, it is estimated that more than 80 percent of basic research expenditures come from the central government (i.e., National Natural Sciences Fund, 973 Plan, part of Chinese Academy of Sciences' Knowledge Innovation Project, part of Ministry of Education's 211 Project and 985 Plan, and part of National Key Laboratory Plan), probably about 5 percent comes from various provinces, autonomous regions, and municipalities. Enterprises, universities, research institutions, and other organizations invest very little in basic research.

By comparison, US basic research funds come from multiple sources. For example, in 2004 the ratio of the support for basic research derived respectively from the federal government, industry, university, not-for-profit, and other non-federal organizations to total basic research expenditures was 61.8 percent、16.4 percent、9.6 percent、8.8 percent, and 3.4.

Chinese universities and research institutes are two principal performers of basic research in the country. The ratio of Chinese universities' basic research performance to total national basic research performance has increased recent years, that is from 32.9 percent in 1998 to 40.9 percent in 2004. The comparable ratio for research institutes has decreased, from 59.3 percent in 1999 to 44.2 percent in 2004. Additionally, some enterprises, including enterprises attached to research institutes as well as high-tech enterprises also engage in some basic research.

The ratio of basic research to total R&D performed by Chinese universities increased from 16.6 percent in 1998 to 23.9 percent in 2004. The comparable ratio for research institutes increased from 7.7 in 1998 to 12 percent in 2004. By contrast, the proportion of basic research performed to total R&D performed by American universities was above 60 percent in 1963 and reached 71.4 percent in 2004.

4. Comparative Analysis of Sino-American Basic Research SCI Papers

The number of Chinese papers published in SCI (science citation index) journals increased on an annual average of 19.1 percent between 1997 and 2004, the proportion of such papers to all SCI papers increased from 1.84 percent to 5.43 percent during that same period, while China's rank in SCI papers increased from 12th to 5th. During that same period, American's SCI papers increased by an annual average of 1.8 percent, while its rank has remained first.

Chinese SCI papers were cited 842,000 times between January 1, 1994, and August, 31, 2004, an increase of 27.9 percent compared with 658,00 ten times from 1993 to 2003. During that period, China's national citation rank rose from 19th to 18th. In terms of frequently cited papers, China's rank rose from 127 to 124 during this period.

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The Status and Effects of Technology on Economic and Foreign Relations between China and America since the Normalization of China -U.S Relations[1]

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In the long history of human kind, science and technology have always been the revolutionary driving forces[2]. Their great influence has penetrated into all the spheres of our life, from international patterns, structure of social civilization, form of war, strategies and tactics, to other small aspects in our lives. They also have influenced Sino-US relations to which great paid great attention is currently being paid.

There are many factors having influences on Sino-US relations, such as hot topics of economics and trade, Taiwan problem, human rights and religion, which are well known. However, these hot topics are with bilateral qualities: on the one hand, they are major factors influencing Sino-US relations; on the other hand, they are the outcome of the accumulated conflicts between the two countries, and the result of the influence of other factors including science and technology. Nevertheless, the factor of science and technology is functioning at a deeper level which is not as striking as these hot topics. This article aims to give a brief analysis on the status and function of scientific and technological factors in Sino-US relation after its normalization.

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[1] This background document is the research result of the authors, representing only the authors' point of view.

[2] In history, science and technology only developed slowly or stagnated for some periods, but never stopped progressing, so as to drive human society to develop. By comparison, trends of thought, isms or campaigns of society have the possibility to violate the orientation of social development, making society retrogress. From this point of view, science and technology are obvious the revolutionary driving force.

I. Review of the History of Sino-US Scientific and Technological Cooperation

On Jan. 31st, 1979, Deng Xiaoping visited America, and signed with President Carter the Agreement for Scientific and Technological Cooperation between China and the United States (the Agreement for short in the following text). As the first formal cooperation agreement between the two countries, it set up the framework for the bilateral scientific and technological cooperation and exchanges, inaugurating a new and vigorous domain for the bilateral relations. Until now, the Sino-US scientific and technological cooperation has gone through a history of 27 years. In these 27 years, Sino-US scientific and technological cooperation has always received great attention of the leaders of the two governments. Despite some periods in winding courses, Sino-US scientific and technological cooperation has made progress on the basis of equality and mutual-benefit on the whole, establishing stable, thorough, long-term mechanism for bilateral scientific and technological cooperation and exchanges with the features of large scale, broad range of domains, and effectiveness. In the same time, under the drive, lead and encouragement of government scientific and technological cooperation, half-governmental and non-governmental scientific and technological cooperation and exchanges have been developed. So after 27 years of development, Sino-US scientific and technological cooperation has achieved a good result. The bilateral scientific and technological cooperation has not only completed a series of projects with international leading level and with major economic and social significance, such as Beijing Electron Positron Collider and the China digital seismic network, but also driven China to make use of advanced experiences and bring in the advanced system from foreign countries such as IPR protection and supervision of nuclear security.

Sino-US scientific and technological cooperation has had a positive influence for Chinese scientific and technological circle to learn the current situation of international development of science and technology, to learn the advanced management methods of science and technology from foreign countries, and for the scientific and technological domain to open up to foreign countries. Bilateral cooperation in the domains of climate changes, earth observation, ocean, environmental protection, infectious disease prevention and energy, which involve international problems, will have profound influence on future life of the people of the two countries. Scientific and technological cooperation improved the development of science and technology, economy and society of the two countries, make the bilateral economic relations closer, raise the living standard of the people, so as to make great contribution to stabilize and improve the development of Sino-US relations.

Sino-US relations keep on changing and developing. Before officially signing the Agreement for Scientific and Technological Cooperation between China and the United States, the two countries used to undertake some activities, though small and simple, on scientific and technological exchange that were of great importance to the ultimate establishment of diplomatic relations between them.

In April, 1971, the world was shocked by the news on U.S. ping-pong team's visit to China, an event that opened the door to Sino-U.S. communication from isolation since 1949. At that moment, Prof. Arthur Galston, a plant physiologist from Yale University, and Prof. Ethan Signer, a microbiologist from MIT, who were about to visit Vietnam at the invitation of North Vietnam, immediately wrote to the Chinese embassies in Canada and France and the British office, applying for a visit to China after the trip in Vietnam from April 23 to May 10. Upon the approval of Mao Zedong and Zhou Enlai in person, on May 10 the two American scholars flied from Hanoi to Nanning, and afterwards visited Beijing, Shanghai, Hangzhou and Guangzhou successively. In the afternoon on May 19, they were received by Zhou Enlai and Guo Moluo, then Vice Chairman of the NPC Standing Committee and President of Chinese Academy of Sciences. After visiting Guangzhou on May 24, they headed for Shenzhen on a special train and left the country. As the first two American scholars to China for academic exchanges since 1949, Professor Galston and Signer's visit proved to be a great success of tremendous impact. Their successful visit was called by the U.S. press the "opening the second round of Ping-Pong Diplomacy". Soon after returning to the United States, Professor Galston wrote to Mr. Guo Moluo, suggesting a visit by a Federation of American Scientists (FAS) delegation to China. Upon Zhou Enlai's approval, a FAS delegation of six members, led by the FAS president Professor Marvin Goldberger, visited China for three weeks in May, 1972.

The FAS delegation, while in China and after returning home, invited China several times to send a scientific delegation to visit the United States. At that time, though having received a visit by American scientists, China had not sent any one to visit America due to the still sensitive Sino-US relations. Besides, most scientific research in China was in a stagnant state then, and a large number of scientists were working on the farms instead of laboratories. However, in order to promote the development of Sino-US relations, Mao Zedong and Zhou Enlai finally decided to send a Chinese scientific delegation to visit America. But due to political considerations and other reasons, the delegation could only visit America after the Chinese ping-pong team finished its visit there, and should visit Britain, Sweden and Canada before going to America. The leader of the Chinese Scientist Delegation was Professor Bei Shizhang, then a member of the NPC Standing Committee and Presidium of National Political Consultative Conference and director of the Institute of Biophysics, Chinese Academy of Sciences; the deputy leader was Bai Jiefu, then head of Beijing Science and Technology Commission; and members included Professor Zhang Wenyu, then director of the Institute of High Energy Physics, Professor Qian Renyuan, then deputy director of the Institute of Chemistry, and Professor Qian Weichang of Tsinghua University. While the delegation was in the United States, the Committee on Scholarly Communication with the Peoples' Republic of China (CSCC) was in charge of reception work, while the United States government also attached great importance to the visit.

During the period of over five years from the latter half of 1972 to the formal establishment of

Sino-US diplomatic relations, the United States, through efforts of Committee on Scholarly Communication (CSCC), sent to China a total of 36 scholarly delegations involving 430 people, or six delegations involving 72 people on annual average. Meanwhile, China, in the name of China Association for International Science and Technology Cooperation (while actually through the undertakings of Chinese Academy of Sciences) sent to the United States a total of 43 delegations involving 454 people, or seven delegations involving 75 people on annual average. Delegations of both sides involved a wide variety of professions, including not only natural sciences, engineering sciences, social sciences and humanities, but also some domains related to industrial and agricultural production.

During the stage from April 1971 to late 1978, Sino-US scientific and technological exchange and cooperation mainly took the form of delegation exchange visits, with limited exchanges through other channels. Of course, there were visits paid by some individual American scholars or other small scholarly groups, but of limited number. On the Chinese side, there was hardly any individual scholar or other forms of visiting scholars to visit the United States besides above-mentioned delegations.

The year 1979 was a critical one for Sino-US scientific and technological cooperation, and a turning point of the journey. The year was of great significance to both peoples, for the milestone event for Sino-US scientific and technological cooperation happened during that year. On January 31, 1979, Mr. Deng Xiaoping visited America and signed the Agreement for Scientific and Technological Cooperation between China and the United States with President Carter in Washington. Meanwhile, a governmental ministerial China-U.S. Joint Commission on S&T Cooperation was established to implement the agreement, a move that marked the beginning of real cooperation between China and the United States. From then on, Sino-US scientific and technological exchanges and cooperation had been developing rapidly. Afterwards, under the general agreement, during the 9 years from then to the end of 1987, relevant departments of the two governments signed agreements, protocols or understanding memoranda on scientific and technological cooperation 27 subfields. Governmental departments engaged with Sino-US official scientific and technological cooperation included 27 on China side, with 16 ministries and commissions and 11 national bureaus, and 18 on the US side, with seven ministries and 11 independent administrative departments. During this phase, Sino-US scientific and technological exchange and cooperation mainly took the form of Joint Commission and Working Group meetings, project development meetings, delegation exchange visits, cooperative researches, joint explorations, observation and inspection and various forms of academic conferences. In terms of exchange and cooperation scale, there were over a hundred of its kind, involving hundreds or even thousands of personnel exchanges.

During this phase, Sino-US semi-official scientific and technological exchange and cooperation, i.e. exchange and cooperation between China and the CSCC declined accordingly in status, mainly because of the emergence of large official direct communication and rapidly developing non-governmental channels. Nevertheless, semi-official scientific and technological exchange and cooperation between the two sides were still playing a unique role.

The Sino-US scientific and technological relationship has always been subordinate to the political relations between the two countries and reflecting its status quo. In the first half of 1989, Sino-US scientific and technological exchange and cooperation developed smoothly as ever and marched steadily forward. Some major issues arising in exchanges and cooperation, intellectual property right and technology transfer in particular, were moving in the direction in favor of settlement through continuous negotiations, with IPR clauses or appendixes in some cooperation protocols concluded in an agreement. However, after the Tiananmen incident, although the US government did not expressly declare to stop Sino-US official scientific and technological exchange and cooperation, in fact, the official scientific and technological relationship had been seriously affected. For some time, it was stuck in a stagnant state, and semi-official and non-governmental scientific and technological exchange and cooperation also made little progress.

In the early 1990s, the United States lifted its sanctions imposed on China, making scientific and technological exchange and cooperation between the two countries possible again. During this phase, US investments in China increased, subsequently bringing more technology transfers. By May, 1999, US-led NATO bombed the Chinese embassy in Yugoslavia by mistake, and the US Congress took the opportunity to release the Cox Report, thus leading to subtle changes in scientific and technological exchange and cooperation between the two countries.

Major events during this period that had promoted Sino-US scientific and technological exchange and cooperation between the two countries were:

- In 1991, to accommodate organizational structure changes in Chinese departments in charge of scientific and technological work since its signing, the Agreement underwent some modifications, including a new appendix about IPR protection and allocation likely to arise during scientific and technological exchange and cooperation between the two countries.

- In January, 1992, China and the United States reached an agreement on IPR issues in scientific and technological exchange and cooperation between the two countries, thus creating conditions for the extension of the Agreement.

- In April, 1994, Song Jian led a scientific delegation under the Chinese government to the United States to take part in the sixth Joint Commission Conference on Sino-US scientific and technological cooperation. The Conference restored after an interval of seven years, a move that comprehensively restored the Sino-US scientific and technological cooperative relationships and also promoted the restoration and development of the political relations between the two countries. In January the next year, the second session of the sixth conference was held in Beijing. By then, Sino-US official scientific and technological exchange and cooperation had been rapidly resumed.

From 1995 to the first half of 1996, Sino-US relations suffered some fluctuations around issues such as human rights, intellectual property rights and most-favored nation treatment. The State Science and Technology Commission then proposed holding a "Sino-US Forum on Sustainable Development, Energy and Environment", a campaign initiated by leaders from the two countries in 1995, to break the deadlock in bilateral relations, which won the support of two governments. The forum was held in Washington April 24 to 26, 1996, and turned out to be a success, adding impetus to Sino-US relations.

In March, 1997, during his visit to China, the US vice president Al Gore and Premier Li Peng co-chaired the U.S.-China Environment and Development Forum and delivered a speech. This seminar was aimed to exchange ideas on environment and development issues and further explore the cooperation on science, environment, energy and commerce. It also covered working group meetings in four specific fields including sustainable development, environment policies, energy policies and commercial cooperation, which exchanged opinions on the said issues and explored the possibility of undertaking further bilateral mutual-benefit cooperation in the future.

In October, 1997, during Mr. Jiang Zemin's visit to the United States, the two sides issued a Sino-US Joint Statement, which affirmed the accomplishments in Sino-US scientific and technological exchange and cooperation, and pointed out that the Sino-US Science and Technology Joint Commission would continue to guide bilateral scientific and technological cooperation programs and further solve national and international problems by means of science and technology. The Sino-US agreement on peaceful use of nuclear energy, negotiated in 1985 and laid aside for over a decade, was approved by the US Congress. President Jiang Zemin's visit injected new vitality to open up a new prospect for the scientific and technological cooperation between the two countries.

On June 19, 1998, in an interview with a Chinese journalist before his visit to China, President Clinton said that Sino-US bilateral scientific and technological exchange and cooperation over the past two decades was one of the most successful areas in Sino-US relations, and both sides should constantly strengthen scientific and technological cooperation on biology and medical science which is of huge potential value to people in the two countries and around the world. Mr. Clinton held that scientific and technological cooperation undertaken by the two governments had played a positive role in maintaining global biodiversity, which with the growth of the global economy, was of increasing importance to future global ecological environment. Besides, bilateral cooperation on earthquakes had increased the capability of predicting and handling disastrous weather, while developments in cooperation in medical science had played a large part in cancer treatment.

In April, 1999, during his visit to the United States, Mr. Zhu Rongji and US vice president Gore co-chaired the opening ceremony of the second session of Sino-US Seminar on Environment and Development. Zhu Rongji pointed out that since the 1980s, China and America had undertaken proactive and fruitful cooperation on environmental pollution. In particular, during Jiang Zemin's visit to the United States in 1997, the two sides signed the Agreement on Energy and Environment Cooperation between China and the United States. And during President Clinton's visit to China in 1998, both sides signed an Intention statement of Sino-US Cooperation on Urban Air Quality Monitoring, which further promoted Sino-US cooperation on environmental protection. However, Sino-US Cooperation in the environment domain was not, in terms of both depth and breadth, commensurate with the status of the two big countries, and the potential of bilateral cooperation was far from being tapped. The United States had advantages in environmental protection technologies, capital and human resources, while China had a huge market potential for environmental protection. Once both sides joined hands to overcome all obstacles and create favorable conditions, Sino-US cooperation in environment domain would surely enjoy a bright future. After the opening ceremony, Zhu Rongji and Al Gore attended a round table conference on energy and environmental protection held by the heads of over 10 major US energy and environmental protection companies. They also showed up in the signing ceremony of intentional cooperation documents on environmental protection.

In 2000, George W. Bush said while campaigning for the presidential election that he would endeavor to expand the overseas market for American high-tech products and reduce government interference in domains such as energy and environmental protection. After 9/11, anti-terrorism campaigns brought about new opportunities for Sino-US relations and cooperation. During this phase, Sino-US scientific and technological cooperation stepped on the track of healthy and orderly development. Cooperative domains and forms deepened, cooperative breadth and depth reached an unprecedented level.

On January 14, 2000, China and the United States held the ninth Joint Commission Conference on Sino-US Scientific and Technological Cooperation in Hawaii. It happened to be the 20th anniversary of the signing of the Agreement for Scientific and Technological Cooperation between China and the United States, so at the same time as celebrating the anniversary, both sides reviewed and summarized the accomplishments in Sino-US scientific and technological cooperation over the past 20 years, laying emphasis on cooperation in fields including basic sciences, environmental protection, hygiene and health, scientific disaster reduction, agricultural and industrial scientific information. The conference identified a framework for Sino-US scientific and technological cooperation in the coming new century, and specified cooperation direction and methods. Both sides also agreed to specially establish a working group on water resource under the Joint Commission.

On March 28, 2000, the US Secretary of Education, leading a delegation to China, signed with Chinese Minister of Education the Agreement for Education Exchange and Cooperation between the governments of the People's Republic of China and the United States. According to the agreement, bilateral education exchange and cooperation activities include personnel exchange, delegations and study groups, material exchange, direct exchange between educational institutions and scientific research institutions as well as individuals. The agreement also specified activity expenses, facilitations and relevant legal issues.

On May 28, 2000, China and the United States signed the Sino-US Internet Memorandum of Understanding jointly worked out by the Internet industry, a move indicating that China has joined the research and development league to develop jointly with the United States the second generation Internet technology.

In 2000, many Memoranda of Understanding and protocols under the framework of the Agreement for Scientific and Technological Cooperation between China and the United States were renewed, such as the Memorandum of Understanding on Water Resources Management and Protection, the Protocol for Scientific and Technical Cooperation in Earthquake Studies, and the Protocol on Cooperation in the Field of Railroad Science and Technology.

In April, 2001, the Agreement for Scientific and Technological Cooperation between China and the United States was renewed by means of exchanging diplomatic documents, its validity term extended for fives to April, 2006. Meanwhile in the same year, many protocols and cooperation memoranda were renewed, such as Implementing Accord on Cooperation in the Field of High Energy Physics, and the Protocol on Cooperation in the Field of Nuclear Physics and Controlled Magnetic Fusion.

In April, 2002, the 10th Joint Commission Conference on Sino-US Scientific and Technological Cooperation was held in Beijing; the executive secretary meeting was held in Guilin in November. During the year, the commercial exploration appendix for renewable energy was renewed, with the stress on helping China to meet its energy demand, promoting and speeding the commercialization of renewable energy in China.

On December 11, 2002, Xu Guanhua, the Chinese Minster of Science and Technology, and Daniel Evans, US Secretary of Commerce, signed the Protocol on Cooperation in Civil Industrial Technology and Scientific and Technical Information, which further specified the protection and sharing of relevant information. Exchange secrets and exclusively owned information during the cooperation are protected according to the appendix on intellectual property rights in the Agreement for Scientific and Technological Cooperation between China and the United States. Unless otherwise provided in separate written agreements, scientific and technological information arising from cooperation activities under the protocol is open for use by scientists around the world, but with information involving investment disclosure and seeking for patent protection, its exchange should be postponed, and its invention rights and interests shall be handled according to the appendix on intellectual property rights.

In January, 2003, the US Geological Survey and Chinese Ministry of Water Resources renewed the Protocol for Scientific and Technical Cooperation in the Study of Surface-Water Hydrology; in October they signed the Appendix on Electricity-driven & fueled Battery Automobile Technology Development to replace the exploration and research appendices. In November, the Sino-US Health Protocol was renewed, and the US Department of Health and Human Services allocated $34 million to support the cooperative research and technology support under the protocol. In December, the Chinese State General Administration for Quality Supervision, Inspection and Quarantine, and the US Department of Commerce signed a protocol, which permits exchange of scientific and technological information and experts, joint research and development, and exchange of samples and standard materials. In the same month, the US Environmental Protection Agency and Chinese State Environmental Protection Administration reached a Memorandum of Understanding on scientific and technological cooperation in the field of the environment, which covered a large number of potentially cooperative fields.

On January 12, 2004, the Secretary of Energy, Spencer Abraham, joined China's Science and Technology Minister Xu and Beijing's Vice Mayor Fan to sign the Green Olympic Protocol for Beijing's 2008 Olympic Games. Two joint working group meetings were convened in held in 2002 and 2003 respectively, which put forward new cooperation proposals.
In October, 2004, China and the United States successfully held the 11th Joint Commission Conference for Sino-US S & T cooperation in Washington, DC.

In November, 2005, President Hu Jingtao and President Bush met and explicitly proposed giving the Sino-US Joint Commission further play, encouraging governmental departments, scientific research institutions and industries to strengthen scientific and technological cooperation.

In April, 2006, during his visit to the United States, President Hu Jingtao renewed the Agreement for Scientific and Technological Cooperation between China and the United States, with a further extension of five years. Presently, the 12 Sino-US S&T Cooperation Joint Commission Conference is in preparation and planned to be held in Beijing October 18 and 19, 2006.

Every year China and the United States undertake a large number of scientific and technological cooperation projects under the framework of the Agreement for Scientific and Technological Cooperation between China and the United States, and have achieved great results. Sino-US scientific and technological cooperation has played a positive role in Sino-US relations.

II. Features of Sino-US Scientific and Technological Cooperation at the Present Stage

During recent years, Sino-US scientific and technological cooperation has developed greatly. Reviewing the current situation of Sino-US scientific and technological cooperation, there are a number of features as follows:

A. Advanced cooperation mechanisms

One of the main reasons that accounts for the rapid development of Sino-US scientific and technological cooperation are advanced cooperation mechanisms. The two sides have established two mechanisms for the planning and coordination of scientific and technological cooperation between the two countries, namely the Sino-US Scientific and Technological Cooperation Joint Committee (Joint Committee for short) and the Science and Technology Executive Secretariat (Executive Secretariat for short). The major task of the high-ranking Joint Committee is to identify the themes of Sino-US scientific and technological cooperation and to work out the direction for future work. The Chinese chairman of the Joint Committee is the Minister Science and Technology while the American chairman is the Director of Office of Science and Technology Policy (OSTP) at the White House. The Joint Committee holds a meeting every other year in each of the two countries in turn, although it is required in the agreement that there should be a meeting annually. The positions of the executive secretaries of the agreement are held by division chief of the international cooperation bureau of the Ministry of Science and Technology of the PRC and the director of Scientific and Technological Cooperation Office of the US Department of State. During recent years, the Executive Secretariat holds a meeting in the year between the Joint Committee meetings in order to avoid a time space as long as two years. At the Executive Secretariat meeting, delegations from the two countries review the achievements of each protocol systematically, discuss problems and work out solutions. Relevant logistic issues of cooperation, such as venue, delegation and business trip arrangements, and plans for scientific and technological cooperation in the future are also under discussion. If it is considered necessary to revise the agreement in the form of appendix, attachment or new protocol, such revisions are to be confirmed at the Executive Secretariat meeting with the consent of both sides. The result of the Executive Secretariat meeting are reported to the Joint Committee meeting in a series of progress reports on bilateral scientific and technological cooperation.

Thanks to the Joint Committee meeting and Executive Secretariat meeting on a regular basis, Sino-US scientific and technological cooperation has been developing in a smooth and sound way. Advanced cooperation mechanisms are among the major factors accounting for the success of Sino-US scientific and technological cooperation.

B. Large scale of cooperation and exchanges

During recent years, the scale of Sino-US scientific and technological cooperation has been enlarging, involving almost all government departments in China. During the last 27 years, 50 protocols were signed and more than 30 of them remain valid. For example, cooperation on high-energy physics between the Chinese Academy of Sciences and the US Energy Department; cooperation on education of graduates and cooperative scientific research between the Ministry of Education of the PRC and the United States; cooperation memorandum between the Ministry of Water Resources of the PRC and US Geologic Survey, US Department of Agriculture and US Bureau of Reclamation; cooperation on water resources with the US Environmental Protection Agency; agreements of scientific and technological cooperation and exchanges on agriculture between the Ministry of Agriculture of the PRC and relevant departments of the US government; agreements on scientific and technological cooperation on sanitation between the Ministry of Public Health of the PRC and relevant departments of the US government, memoranda of understanding on Sino-US cooperation on AIDS; scientific and technological cooperative activities under the framework of the Sino-US memorandum on emerging and re-emerging infectious diseases; agreements on scientific and technological cooperation on transportation between the Ministry of Communications of the PRC and the US Department of Transportation; exchange visits between the Ministry of Civil Affairs of the PRC and the US Economic Affairs Administration; technological exchanges and mutual assistance on disaster reduction and response; scientific and technological exchanges under the framework of Sino-US memorandum of understanding on national parks and other natural and cultural heritage between the Ministry of Construction of the PRC and the US Department of the Interior; personnel exchanges between the Chinese Academy of Engineering and the US National Academy of Engineering; scientific and technological cooperation under the framework of agreements on basic science research and seismological research between the National Natural Science Foundation of China and the US National Science Foundation; scientific and technological cooperation under the framework of agreements for peaceful use of nuclear technology on nuclear energy, nuclear technology, nuclear safety, and environment; a memorandum of understanding on management between the National Defense Science and Technology Industry Committee and the US Energy Department; comprehensive oceanography research under the framework of the Sino-US agreements on science and technology on climate change research and observation, ocean data exchanges and marine ecology between the State Bureau of Oceanic Administration and relevant departments in the US government; technological exchanges and high-level visits under the framework of Sino-US agreements on statistics between the State Statistical Bureau and the US Census Bureau; scientific and technological cooperation and exchanges on national earthquake station networks and other aspects between the Seismology Bureau and the US Geological Survey; cooperative activities under the framework of Sino-US agreements on scientific and technological cooperation on surveying between the State Bureau of Surveying and the US Geological Survey; environmental protection policy, management and technology in accordance with memoranda on environmental science and technology between the State Environmental Protection Bureau and the US Environmental Protection Agency; exchanges and cooperation on multilateral or global environmental issues such as climate changes, protection of the ozone layer, biological diversity and management of chemicals; cooperation under the framework of cooperation protocols on measuring and standards in the fields of measuring, standards, certification and approval, quality control and equipment safety between the State Bureau of Quality and Technical Supervision and relevant departments of the US government; scientific and technological cooperation under the framework of Sino-US natural protection agreements and Sino-US forestry cooperation memoranda in the fields of protection of wild animals, management of natural resources, protection of endangered species and protection of fish; the Sino-US Mining Safety Cooperation Program between the State Administration of Work Safety and the US Department of Labor; staff training, scientific and technological exchanges and cooperative R&D between the China Meteorological Bureau and relevant US government agencies; and scientific and technological cooperation on earth and mineral sciences between the China Nonferrous Metal Industry Association and the US Department of the Interior.

The scale of non-governmental scientific and technological cooperation and exchanges is more extensive.

C. Various forms of S&T cooperation

During recent years, there have been a variety of Sino-US scientific and technological cooperation forms, which develop from inspection, academic conventions and exhibitions to multi-channel, including cooperative research, joint design, joint surveys, joint labs and research institutes, inviting foreign experts for technology consultation and feasibility research, joint ventures using high and new technology, and encouraging Chinese scholars who are studying abroad to return home and set up bases of scientific research and education.

D. S&T cooperation becomes more practical and effective

During recent years, Sino-US scientific and technological cooperation has become more and more practical. Win-win scientific and technological cooperation has been conducted according to the actual situation of complementarities. With the advancement of cooperation mechanisms, increase in enthusiasm from both sides, and the development of transportation and communications, bilateral scientific and technological cooperation will become more effective.

E. More attention attached to protection of intellectual property rights

Protection of intellectual property rights (IPR) is one of the major problems in S&T cooperation. With the development of Sino-US S&T cooperation, unprecedented attention has been attached to the protection of IPR. As early as at the Uruguay round of GATT, developed countries such as the United States considered IPR as an important topic for discussion. The US government also made a suggestion to the Chinese government that provisions of protection of IPR be added to Sino-US S&T cooperation agreements and trade cooperation agreements. Through negotiation, agreements on IPR in S&T cooperation agreements and trade cooperation agreements were reached in April 1991 and January 1992, respectively. In order to enhance legislation on IPR, the Chinese government also revised or worked out relevant laws and administrative regulations. For example, the State Science Committee (now Ministry of Science and Technology) worked out Guidelines for Protection of Intellectual Property Rights Concerning Scientific and Technological Cooperation and Exchanges with Other Countries in February 1995, serving as a set of guidelines for relevant departments, provinces and cities. In fact, regarding Sino-US S&T cooperation, the Chinese government plays a significant role. It needs to promote and protect the development and safety of national science and technology through rules and regulations. Therefore, protection of IPR has become a key issue in Sino-US S&T cooperation.

III. Significance of Sino-US Scientific and Technological Cooperation to China

Sino-US scientific and technological cooperation is mutually beneficial and of great significance to both countries. In particular, it greatly strengthens China's capability for indigenous innovation, promotes scientific advancement in China, drives modernization in China, and speeds up the establishment of an innovative country as well as a relatively well-off and harmonious society.

A. Stabilizing bilateral relations

Sino-US scientific and technological cooperation has been playing a stabilizing role for broader Sino-US bilateral relations. The political relationship between China and the United States fluctuates greatly with political and economic development, leader changes and other factors. In contrast, the scientific and technological relationship between the two countries has always been the foundation for stabilizing the overall bilateral relations. The progression and continuation of scientific and technological cooperation activities at all levels of the two countries relies more on factors such as scientific and technological accomplishments, research preferences and approved budgets, rather than regional political interests. The close ties between Chinese and American scientists has made it possible to maintain free communication even when relationships between the two countries are stressed. China and the United States agree that their scientific and technological relationship is mutually beneficial, the kind that constitutes a constant and stable factor in recent bilateral relations between the two countries.

B. Improving scientific workers' technological capability and China's capability in research and development

In recent years, through Sino-US scientific and technological cooperation, by going abroad, attending international scientific and technological scholarly conferences, exhibitions, technological seminars and taking Sino-US training courses, a large number of scientific and technological personnel received practice, learned overseas advanced sciences and technologies, and improve their technological capability, thus enhancing our scientific workers' ability to undertake research and development.

C. Learning overseas advanced ideas and mechanisms, as well as scientific managerial methods, and improving domestic scientific and technological management and policy

Through Sino-US scientific and technological exchange and cooperation, we have learned from the United States advanced ideas and mechanisms as well as scientific managerial methods. For example, we listen several times to American and American Chinese scholars' opinions before compiling scientific development plans and formulating scientific mechanism reform schemes. The China Seismological Bureau also investigated the United States legislation on disaster reduction and drew from their experience before formulating our disaster reduction laws and regulations. The Chinese Academy of Sciences, too, referred to the advanced practices in the United States in creating systems and regulations with respect to funding systems, colleague appraisal, personnel flows, and management and operating methods of large public equipment.

D. Promoting domestic policy reform

Sino-US scientific and technological cooperation has been promoting and directing the reform of domestic policies in China by providing relevant information. For example, in the field of remote sensing, the US Geological Survey and the Chinese Academy of Sciences undertook joint research and exchange on correction, enhancement, classification and analysis of remote sensing pictures. In 1997, from pictures of 17 Chinese cities and regions taken by No. 5 earth resource detection satellite of NASA in 1987, 1991 and 1995, we learned that the ongoing exploration activities in China have resulted in a cultivated-land-lost speed twice or 1.5 times more than expected. In addition, the remote sensing information also showed that the Chinese local governments had exaggerated the land area affected by Yangtze River flood in 1998 by 10 times in an attempt to maximize disaster relief aid.

The US Geological Survey and the Chinese Haihe River Hydro-conservancy Committee are cooperating in conducting joint research on relative water quality assessment and on the eutrophication of water in a reservoir in the Haihe river basin. This research will identify the origin of nutrients and measurements that mark a need of nutrition reduction as well original phosphorus, thus enabling the reservoir water to meet ideal quality standard to qualify as a drinking water source. Subsequently, the Haihe River Hydro-conservancy Committee will formulate a plan to reduce the reservoir nutrition load by changing or regulating land use based on the above-mentioned data. This research builds up a bridge between examination on nutrition load and other pollutants in waters and formulation of nutrition load reduction strategies by using scientific and technological data.

Both promoting land management reform and monitoring water quality in the Haihe River with joint efforts of the US Geological Survey by using remote sensing data have proved that Sino-US scientific and technological cooperation is playing a boosting role in the Chinese government's efforts to drive China towards more sustainable agriculture and resources management practices. Some other Sino-US scientific and technological cooperation activities have improved our capability of monitoring the environment, including establishing an air quality monitoring network, an online water quality and quantity monitoring system, a hydrology monitoring and measurement procedures, and measurements of precipitation shift.

E. Achieving a series of national advanced technological accomplishments

China and the United States have undertaken thousands of scientific and technological cooperation projects, involving tens of thousands of scientists. The significant achievements in Sino-US scientific and technological cooperation cover domains such as basic research, high-tech, and civil technologies. Some achievements are leading internationally, such as the China Remote Sensing Satellite Ground Station, the Beijing Electron Positron Collider, the China Seismic Network, the discovery of the largest spiral-shaped galaxy in the universe, research on substitute technologies for freon emitted by domestic electric refrigerators and the production of ultra energy-saving freon-free refrigerators, the formulation of laws and regulations on supervision and management of nuclear safety, and model factories for joint and circular power generation by gasification.

F. Achieving obvious social benefits

China has achieved obvious social benefits from Sino-US scientific and technological cooperation. For example, the China Earthquake Administration has set up advanced broad-band, dynamic, digital seismographic equipment, and the Chinese digital seismic network through Sino-US cooperation. The data recorded by the seismic network and also the data of the international digital seismic network from the United States, play important roles in seismic research, earthquake forecasts, international seismic research cooperation, and earthquake prevention. In Sino-US cooperation and investigation on cancer and cardiovascular diseases, it was discovered that Chinese males suffers most from esophagus cancer, stomach cancer and liver cancer, while US males suffers mostly from prostrate cancer, colo-rectal cancer and liver cancer. Also a lot of cancer samples with scientific value are obtained. The research on the ontogenic factors from the aspects of regional features is valuable to the anti-cancer treatment, prevention of cancer, and the public health.

IV. The Current Role and Function of Science and Technology in Sino-US Relations

A. A wide gap between China and the United States in science and technology strength

From the point of view of science and technology, the most significant feature of Sino-US relations is the wide gap between China and United States in science and technology strength. To some extent, the basic pattern, situation and many specific problems of Sino-US relations are relevant to the gap, which is the result of mutual influence between science and technology factors and other factors, especially political factor.

In academe, the overall scientific and technological strength is usually measured by a special index system. In this system, the United States is always ranked as first. China is in the middle or lower level as for overall strength, despite that for some advantaged index, China is ranked near the front. There is an obvious gap between China and United States. In the following paragraphs, a brief explanation will be given according to different index systems.

One frequently used index for evaluation of a country's scientific and technological competitiveness is the *World Competitiveness Yearbook (WCY)* issued by the International Institute for Management Development (IMD), Switzerland. This yearbook has been issued once in a year since 1986. It gives analysis and evaluation on the international competitiveness of countries or regions, and offers their ranks. Because of its scientific and comprehensive index system which reflects factors influencing the international competitiveness of countries or regions, its evaluation and ranking are authoritative. Since 1994 China became the object of its evaluation, China has been around the 25th to 28th. China was ranked 29th in 2003 and 24th in 2004i. The United States has continued to hold the first rank for many years.

One of the authoritative scientific and technological periodical, *MIT Technology Review*, published a series of articles introducing the R&D focus and scientific and technological level of seven countries, including the United States, Germany, Holland, China, Brazil, Chile and South Africa. According to these articles, it is clearly demonstrated that China has a wide gap in scientific and technological strength compared with major countries in the world. Some parts of data are listed as follows:

Data Reflecting Scientific and Technological Levels

Nation / Item	The US	Germany	Brazil	China
Planted Areas of Genetically Modified Crops	47.60 m ha.		5 m ha.	3.70 m ha.
Average Cost of Internet for Every 20 Hours	14.95 Dollars	14.10 Dollars	27.99 Dollars	10.14 Dollars
Subscription of Cable TV Per Thousand	255	250	14	75
Proportion of Hi-tech Products in End Product Exported	32%	16.60%	19%	23%
Information and Communication Expenses Per Capita	2358 Dollars	1252 Dollars	205 Dollars	58 Dollars
Employees of Big Information and Communication Technology Enterprises	3.50 m	751600		191600
Sale Income of Big Information and Communication Enterprises	938.0 b Dollars	153.0 b Dollars		30 b Dollars
Internet User Per Thousand	551	412	82	46
Mobile Phone User Per Thousand	488	727	201	161
Purchase of Prescription Drug	345.0 b Dollars	25.0 b Dollars	5.0 b Dollars	
Proportion of R&D Expenditure in GDP	2.60%	2.5%	0.80%	0.60%

A more specific index, such as those for international papers, can be used as the index for comparison of the science and technology level between China and the United States. International papers refer to papers published in leading international magazines or periodicals, and included in international authoritative indexing systems. This index is an important sign of scientific and technological research level. The three well-known international indexing systems of papers are SCI (Science Citation Index), EI (Engineering Index), and ISTP, Index to Scientific & Technical Proceedings. The number of papers included in these three indexing systems can partly reflect the level of science and technology of a country.

2000 Top 10 Countries with the Most International Scientific and Technological Papersii (unit: piece)

Nation	SCI	EI	ISTP	The total number of papers included in the three indexing systems	Proportion in the total number of scientific and technological papers	rank
The United States	305616	56586	54887	417089	29.80	1
Japan	78942	24994	19522	123458	8.82	2
UK	88678	12383	13990	115051	8.22	3
Germany	75324	12234	17762	105320	7.52	4
France	53469	8906	11429	73804	5.27	5
Italy	36482	6257	8557	51296	3.66	6
Canada	37867	6597	6482	50946	3.64	7
China	30499	13163	6016	49678	3.55	8
Russia	29099	4623	5873	39595	2.83	9
Spain	24543	3742	3860	32145	2.30	10
Total Number of International Scientific and Technological Papers	967,663	227,670	204443	1,399,776	100.00	

According to the data of this table, China has a comparatively wide gap with the Western developed countries, and a still wider gap with the United States. The conclusions are approximately the same when the more specific subjects or domains are concerned.

B. The influence of science and technology on the international status of China and the United States

The factor of science and technology has different meanings when it is studied at different angles. At the angle of international relations, the significance of science and technology to America is that its science and technology advancing at very fast speed in recent years gives America hegemony and the dominant position in the world[3].

3 The influence of science and technology on Sino-US relations can be analyzed from two angles: first from the vertical line, that is, the development and progress of science and technology influence China and United States respectively, so as to influence the bilateral relations; second from the parallel line, that is, science and technology as the bridge and agent influence the Sino-US relations.

In history, there were strong slavery or feudalism empires in succession with advanced science and technology. However, the gap in science and technology between these empires and between their neighboring countries or regions was not as wide as that between Western and Eastern counties after the industrial revolution. Therefore, none of these empires could conquer the whole world. Only under the drive of science and technology created by two unprecedented science and technology revolutions could world-wide hegemony broke through the limitations (like geography, climate, manpower, etc.) encountered by traditional hegemons. All the older hegemons, like Spain and Portugal, the earlier ones, the later British Empire, and today's America, based their advantage on their leading science and technology. Furthermore, their peak periods approximately coincided with the time of their leading position in science and technology. From the middle of the 19th century to the early 20th century, America took the lead in the second science and technology revolution, which directly led to its rise before and after the two world wars. At the end of the World War, it took the lead in developing nuclear weapon, and as a result had the ability of mass destruction. From then on, it kept its leading position in developing science and technology, took the lead to enter into the third science and technology revolution and in turn the new epoch-making information era, and finally became the hegemon in the real and virtual world. No empire in history can bear comparison with present America in powerful strength and high status.

The key point of the influence of science and technology on world hegemony relies on the point that science and technology changes the connotation of "strength"[iii]. It is traditionally thought that strength is military power. Formerly when there was low technology percentage composition in weapons that strength usually referred to a strong army plus appropriate application of strategies and tactics. After the scientific and technological revolution, the value of weapons increased many times. The result of wars often depended on weapons. This principle was more obvious in modern times.

Another important index to measure strength is resources. The development of science and technology greatly enhances the importance of resources[iv]. In the pre-industrial civilization, people knew little about the value of petroleum, coal and all kinds of mineral resources. However, the scientific and technological revolution made resources turn into the necessary blood of modern industry. Under the condition of equivalent strength of science and technology, the occupation and control of resources became the key factor to decide the strength of countries. Therefore, the remote areas and islands, with inclement geographical environments but rich resources, became targets to contest.

The influence of science and technology on China is just the opposite to that on the US. Before the modern times, Chinese civilization once took the lead in the world. Ancient Chinese science and technology developed to a high level, with many major results which exceeded western countries for hundreds or even thousands years. China consequently became the key force in the international relations system of the East Asian region. However, after the scientific and technological revolution, ancient Chinese science and technology was outshone compared with modern western science and technology. In front of western countries armed with modern science and technology, China was so vulnerable and suffered a disastrous decline of international status. From then on, the objective which several generations of Chinese fought for was to learn western modern science and technology ceaselessly in order to realize the revival of our nation.

Since opening up and reform, China has worked on its development with high speed. Now it has become the world's fourth economy, the third largest trading power of the United States. Nevertheless, it is definite that the laggard situation of Chinese modern science and technology has not been changed fundamentally. The economic growth of developed countries such as the United States mainly relies on the progress of science and technology. In comparison, the success of China at present mainly depends on cheap labor, great input and consumption of resources, land occupancy, and preferential policies. It is the extensive development mode, depending on the import of key equipment and core technology, with poor self-innovation ability, and with the low status in the international industry division chain. The above situation will definitely influence the future development of the Chinese economy. According to the prediction of some scholars and think-tanks, China will exceed the United States to become the world biggest economy, even the first super nation[4]. However, this lacks the power of persuasion only from the angle of science and technology. China has no advantage over the United States on whichever of present scientific and technological strength, scientific and technological innovation ability, or innovation system. As for resource reservation and acquirement, China is not better than the United States. As for the use of resources, China has the problem of high input and low output. With all these problems and factors, how can China exceed the United States?

C. The influence of science and technology on Sino-American bilateral relations

Generally speaking, the gap of strength (refers to comprehensive strength including scientific and technological strength, with the later considered as the basis) between China and the United States determines the unbalanced and asymmetric relations between China and the US:

The gap of science and technology determines the basic situation of strong America vs. weak China. Because science and technology lay the foundation for the United States to be the super nation, in Sino-US bilateral pattern, it resulted in a strong United States vs. a weak China, active United States vs. passive China. The United States has the ability to act at its will, while China only follows its lead for most of the time. The United States can carry out

4 For example, according to the research of the world famous accounting and consulting firm PricewaterhouseCoopers (PWC), in 2050, China will exceed the United States and become the biggest world economy. According to the result of an investigation of BBC, China will exceed the United States and become the biggest world economy in 2026. For reference, please see *Experts Say China Will Become the 1st Economy in the World*, VOA Chinese News, May 22nd, 2006.

economic sanctions and military containment with respect to China, but China has no ability to carry out anti-sanction or anti-containment actions. The United States maintains relations with China in order to change it, but China has neither ability nor ambition to change the United States.

For example, the Taiwan problem involves Chinese core national interests. The Chinese government maintains a firm stand on this problem insisting that Taiwan is an inseparable part of China, and the Chinese government fights against anyone who wants to separate Taiwan from China. However, America intervenes in Chinese internal affairs over and over again. It not only releases Taiwan Relations Act, treating Taiwan as the political entity, but also sells advanced defense weapons to Taiwan, even threatens in public to carry out coordinated defense with Taiwan. In the world, only America intervenes in Chinese internal affairs in the way of national legislation. If China is forced to crush Taiwan independence by force, only America has the desire and ability to take the risk to stop China.

Another example is that since the 1990s, many major incidents involving Sino-American relation have brought great damages to China, such as the Yinhe incident, the incident of NATO warplanes bombing the Chinese Embassy in Belgrade, and the plane crush incident. If these incidents happened in Europe in modern history, any of them would lead to war between countries. However, America as the only super country in the world has the strength much stronger than China. Besides, allied with many countries, its military alliance system covers the whole world. Any conflict with America will possibly destroy thoroughly China’s economic development, and also throw the nation and its people into a desperate situation beyond redemption. Based on the clear knowledge of this, China tries its best to avoid any unnecessary conflict with America, and maintains strategic opportunity for peaceful development. All the performances of Chinese government, such as China’s cautious reaction to the Chinese military threat theory, and the release of the peaceful development theory, reflect the continuance of this strategic thinking.

Hi-tech export control by the United States with respect to China is the major reason for the substantive Sino-US trade deficit. Since the thaw in Sino-US relations, the key content of United States policies with respect to China includes hi-tech export control on China (including military technologies and dual use military and civilian technologies) and civilian technical cooperation. These two components have the opposite effects. The former is the root for the deterioration of the Sino-US relations, but the later is the key to stabilize Sino-US relations.

After the founding of the PRC, the United States regarded China as its rival in ideology and carried out policies of political isolation, military containment, and trade embargo. As for science and technology, the United States strictly followed the 1949 Regulations of Export Control to carry out its technological blockade on China. As for international affairs, the

United States carried out technological control with respect to China through the regulations of the multilateral export control formulated by the Coordinating Committee for. Multilateral Export Controls (COCOM for short) aimed at socialist countries. Along with the thaw and reconciliation in Sino-US relations, the United States gradually relaxed the technological control on China, but maintained many discriminate policies, such as military hi-tech and nuclear technology. After China and the United States set up diplomatic relations, the United States further loosened export control on China. In 1980s, for the need of react together towards the "Soviet Union threat", Sino-US relations entered into a period of honeymoon. China was regarded by the United States in terms of "friendly non-alliance". And the United States relaxed its technological control more. Under this situation, in 1988, Sino-US hi-tech trade reached its peak. According to US statistics, in that year the amount of application of export to China reached 6900, with the total export value of $3.6 dollars, of which 91 percent was approved. The rest was not approved because of technical reasons like the lack of export license or information[v].

The 1989 Tiananmen incident stopped further progress in Sino-US relations. The United State carried out a series of new sanctions and controls, unilaterally terminated all the Sino-US exchange and cooperation projects involving military technology and advanced technology. After 1990s, al though the United States relaxed its control on member countries of COCOM because of the disappearance of the "Soviet threat", it adjusted its relevant polices in 1994 because of the dissolution of COCOM. However, Sino-US relations could no longer go back to the bilateral relations in 1980s with friendliness as the basic tone. China no longer enjoyed the "non-alliance" treatment. Along with the takeoff of the Chinese economy, some persons from western countries started to drum up for a "China threat" theory, which add oil to the fire regarding Sino-US technological exchange.

During the administration of President Clinton, Sino-US relations developed with a lot of ups and downs. The United States pushed comparatively loosened export policies once for a time, such as releasing the control of advanced computer exports, delivering the right of examination and approval of commercial satellite exports by the Department of Commerce, and relaxing export limitations cipher software. But all the policies only lasted for a very brief time. Under the influence of the "China threat" theory, plus the so-called Chinese ballistic missile proliferation problem, and the 1996 Taiwan Straits crisis, the US right wing started a round of anti-China measures. At the end of the 1990s, the US Congress issued the Cox Report, and revealed the Li Wenhe incident, and the Lucent's secret correspondence revealed incident, giving the world an image that China was taking every opportunity and every means to flinch US technologies. These incidents seriously damaged Sino-US relations. The United States gradually stricter export controls of technology to China has influenced the present situation.

Additionally the United States has also intervened in the control of technology exports to

China of its allies. The most typical example was that under the pressure from the United States, the European Union has not been able to lift the Ban of Arms Sales to China since 1989.

In the economic and trade domain, the hottest topic is the substantive trade deficit which leads to the problem of exchange rate of RMB. This problem is actually a reflection in the economic and trade domain of the gap in science and technology between China and the United States, and the over-precaution of the United States towards China. According to the US statistics, the 2005 Sino-US trade surplus was $201.6 billion (the Chinese statistic was $114.2 billion). Some US Congressmen continually forced the Bush government to take actions to "punish" China's so-called unfair trade behavior. However, according to China, the US control of hi-tech export to China is an important reason for the large US-China trade deficit[vi]. Because of the gap in science and technology between China and the United States, the US is in the upper position of the international division chain, mainly exporting hi-tech added value products, while China exports mostly labor intensive products. The US-China trade deficit is not the result of Chinese trade barriers, which cause obstacles US products entering into the Chinese market, but the result of the US limitation of hi-tech exports to China. Chinese leaders express their willingness many times that China is not willing to pursue the trade surplus, but to continue to take proactive measures to resolve the trade imbalance step by step. However, it is unfortunate that the United States is not willing to cooperate.

The United States has tried to disprove the Chinese stand. For example, Peter Lichtenbaum, Assistant Secretary of Commerce for Export Administration, said during the last year that export controls are not obstacles to the overall US-China bilateral trade. In 2004, among all the products applying for the license of export to China, the total value of products not approved was only $10.80 million. The total value of US exports was $34.7 billion, with the US-China trade deficit of $162.0 billion[vii]. Larry Wortzel, former military attaché in the American embassy in Beijing and director of The Heritage Foundation's Asian Studies Center, wrote an article recently to advocate that the United States should maintain hi-tech export controls. He cited the statistics published by the Department of Commerce that in 2005 the total amount of United States exports to China was $39 billion, of which the value of products requiring export licenses was $3 billion, and the value of products rejected by the Department of Commerce was $12.50 million, only 1.5 percent of the total export volume to China[viii]. US officials and scholars tried to use these statistics to prove that export control did not lead to the Sino-US trade imbalance. But they failed. These statistics only demonstrated the opposite result. Neither Lichtenbaum nor Wortzel explained clearly that without export controls, or with export controls relaxed, Chinese applications would not maintain the present level. If it was clear that a technology export would not be approved by the United States, would China still be willing to apply? That is to say, the annual volume of applications is already the result of the influence of US export control policy. It is not reliable for the United States to make use of this point to defend itself. That is because as early as 1988, the amount of Sino-US hi-tech trade deals had reached $3 billion. After nearly 20 years, according to the close relation of Sino-US economy and trade, is it normal for the hi-tech trade deal to remain at $3 billion?

IPR protection——cooperation in disputes. IPR protection is a long-term problem in Sino-US relations. According to the United States, China does not take sufficient measures to fight against pirated software, movies, and other US products. In 2005, US Trade Representative issued the 2005 Trade Evaluation Report Related to Trade Barriers. The report pointed out that because of the inefficiency of Chinese efforts to fight against and punish piracy and counterfeiting, the rampancy of these activities had done serious harm to all the domains of the US economy. As for the implication of Chinese IPR protection, the United States praised China's obvious progress on the relevant law framework, but acutely pointed out the inefficiency of executing the law during the process of fighting against piracy and counterfeiting. It is said in this report that China did not effectively fight against the piracy of US movies, software, and other intellectual property, and that the rampancy of Chinese piracy and counterfeiting causes serious harm to all domains of the US economy, causing about $16 billion to US enterprises each year.

The Sino-US IPR protection problem emerged for the first time in the 1980 Sino-US Trade Agreement. In the article 6, the protection of patent, brand name, and copyright offered by one party shall be corresponding to the similar protection offered by the other party. In the next 20 years, during the rapid development of Sino-US economic and trade relations, the disputes in IPR protection gradually became serious. Especially since the mid 1980s, Sino-US disputes over IPR protection have been at swords' points many times. After 1996, Sino-US disputes about IPR protection have clamed down. But under the quiet surface, it was fighting and combat between the two countries. Besides, the United States has erected all kinds of trade barriers to realize its objective of IPR protection, so that the disputes on textiles, batteries and software continued to occur.

However, for the past 20 years, although Sino-US disputes about IPR protection occurred many times, they were all resolved satisfactorily in the end. According to the suggestion of the United States, China and the United States have held a round-table conference on IPR protection every year since 2003. Until now, there have been two such conferences, each reaching consensus on the IPR protection.

Behind the Sino-US disputes, the Chinese government has achieved great success in enhancing IPR protection, through withstanding pressure, and taking all kinds of effective measures.

In April, 2004, the Chinese government issued New Progress in China's Protection of Intellectual Property Rights (White Paper). This white paper gave a comprehensive introduction to the efforts of Chinese government on IPR protection and its major achievements. This was the second white paper on IPR protection since 1994. It listed a large quantity of data and facts to expatiate on recent progress of Chinese IPR protection in the last 10 years from the following aspects:

1. Basic Situation of the Protection of Intellectual Property Rights;
2. Patent Protection;
3. Trademark Protection;
4. Copyright Protection;
5. Intellectual Property Rights Protection for Audio and Video Products;
6. Protection of New Varieties of Agricultural and Forestry Plants;
7. Customs Protection of Intellectual Property Rights;
8. Public Security Organs Act on Criminal Infringement on Intellectual Property Rights; and
9. Judicial Protection of Intellectual Property Rights.

It is said in this white paper that China commits itself to establish and improve a relatively complete system of laws and regulations that cover a wide range of subjects and is in line with generally accepted international rules; to establish and improve a coordinated and efficient work system and a law enforcement mechanism; to strengthen administrative law enforcement in IPR protection; to heighten the awareness of the general public about IPR; and to actively fulfill international obligations to protect IPR. While strictly executing its international obligations in IPR protection, China has devoted great efforts to adjusting and improving international rules regarding IPR protection in order to benefit all countries of the world for sharing the fruits and interests brought by the progress of science and technology.

Science and technology as keys for the rejuvenation of China. In international politics, science and technology are closely related to culture. According to some scholars, different cultures in different regions have no differences in terms of superiority or inferiority, but only difference in diversity. But supported by science and technology, cultures present different strengths or weaknesses. American culture, related to advanced science and technology, gains a strong position and spreads throughout the world along with the tide of globalization driven by advanced science and technology. In comparison, eastern cultures including Chinese culture are at a disadvantage. Even some non-mainstream western cultures (like French culture) cannot avoid a similar fate. In addition, the tendency of the spread of strong culture is enhanced by the invention and application of high-tech (such as information technology). It is almost the same as a colonizing war in the field of culture.

The topic of relationships between culture and science and technology is especially important to China, which is reflected in the famous Joseph Needham proposition. The core of this proposition is why Chinese science and technology kept ahead in the world in ancient time, but dropped behind in modern times? When answering this question, people will definitely encounter another question, that is, was there any real science and technology in ancient China? The answer of Dr. Joseph Needham to the first question is the reason lies in the differences in social and economic system between China and western countries. As for the second question, many scholars think that in ancient China, there was actually no science in the meaning of modern times. What ancient China won over western countries was technology, not science. According to their explanation from the cultural aspect, Chinese lacks the training of metaphysical abstract thinking in modern science. The mainstays of Chinese traditional culture, Confucianism, Taoism and Buddhism, have the feature that they are not good at abstract thinking. For example, the Chinese invented gun powder, but did not go into questions like the principle of explosion, or the composition of charcoal and sulfur, the essence of atom. Since the time of the Emperor Wu of the Han dynasty, the Chinese gave exclusive dedication to Confucianism. But Confucianism cannot serve as a philosophy which can guide the development of science and technology. In its four books and five classics, Confucianism has little dealing with science. Under the influence of Confucianism, ancient Chinese culture' technology was based on empirical experiences. Without the entrance of western science into China, it is still a question of whether China could develop a modern scientific system independently. If this idea is valid, it can be concluded that modern science and technology are exotic things to China. This also means that in the contest of developing science and technology, China is in the inferior position at the very beginning. Besides, the laggard position of science and technology is an adverse condition to the rejuvenation of China.

Problems in Sino-US scientific and technological cooperation. Although from an overall perspective Sino-US scientific and technological cooperation is developing smoothly, some deficiencies and problems exist, especially those in which non-science and technology factors disturb normal scientific and technological cooperation and exchange. These problems mainly include:

1. A series of conflicts in US policy on China leading to serious restrictions on further scientific and technological cooperation between the two countries. After the Cold war, the United States has always implemented two kinds of policies on China: on the one hand to give pressure from the outside to restrict and guard against China; on the other hand, to force internal changes expected by the United States by means of exchanges. Under this the stick and the carrot policy, the argument of containment or contact inside the US government and the propaganda of the China threat by US media and politicians cause interference to Sino-US relations. As long as the Sino-US strategic relationship has no clear orientation, Sino-US scientific and technological relation will definitely be influenced.

2. The US limitation of hi-tech cooperation and trade with China stops the further development of Sino-US scientific and technological cooperation.

3. The visa problem for Chinese visiting scholars to the United States has been improved, but still has serious influence on bilateral scientific and technological exchange and cooperation, even causing many Chinese scientists to lose, to some extent, their confidence in Sino-US scientific and technological cooperation.

4. The negotiation mechanism for shared expenditures in cooperation is incomplete. There is no effective mechanism to fund cooperation.

VI. Conclusion

In January, 1979, China and the United States officially established diplomatic relations. At the end of January of the same year, Vice-premier Deng Xiaoping visited America, and signed the Agreement for Scientific and Technological Cooperation between China and the United States with President Carter. This was the first official cooperation agreement between the two countries, which set up the framework for bilateral scientific and technological cooperation and exchange, and opened up an important and vigorous domain for bilateral relations. According to the Agreement, the two countries carried out comprehensive cooperation on agriculture, energy, nuclear security, health and sanitation, environment and geoscience, on the basis of equality and mutual benefit. Until now, the two countries have signed over 30 scientific and technological cooperation agreements and memoranda of understanding, and cooperated in dozens of domains with different patterns. At present, bilateral scientific and technological cooperation has become the largest external scientific and technological cooperation for each of the two countries.

As for the implementation of the Agreement, both China and the United States have awarded it a high evaluation. According to the Chinese evaluation, Sino-US scientific and technological cooperation is mutually beneficial cooperation of importance to the people of the two countries. Cooperation not only has an influence on the domain of science and technology, but also offers a channel for further broader communication and exchange between the two countries. It therefore stabilizes overall bilateral relations. Especially in difficult times, this cooperation helped to ease the tension and stimulate the willingness to improve bilateral relations. Sino-US scientific and technological cooperation has become an important part of the overall Sino-US relationship. That is, it has made contributions to the development of Sin-United States relations[ix]. The report on US-China Science and Technology Cooperation transmitted by the Department of State to the US Congress in 2005 points out that this Agreement (which was one of US-China agreements with the longest duration) has more functions than merely improving scientific and technological cooperation between the two countries. It offers a channel of reasonable communication and exchange for the two countries without any interference of other factors. At the same time, it provides the influential Chinese scientific and technological circles with an incentive to maintain the peaceful development of relations with the United States, and stables the changing bilateral relationship[x].

Science and technology are closely related to Sino-US relations. If mathematical terms are used, in Sino-US relations, the science and technology factor is an independent variable, that is, in itself its progress influences Sino-US relations. At the same time, it is a dependent variable, that is, it is influenced by and changes with overall Sino-US relations. Meantime, to some extent, it is a constant which keeps those relations comparatively stable.

Whether the bilateral relationship is an independent variable, a dependent variable, or a constant, it has important influence, even a decisive influence on Sino-US relations. Some may regard this claim as bombastic. Especially when the science and technology relationship is considered a dependent variable, it most obvious feature is its passiveness. For example, in politics, the decisive factor is the opposition of social systems and ideology between China and the United States. Another example is that Taiwan problem is the result of the Chinese civil war and the Cold War pattern. Indeed, the initial factor deciding the basic pattern of Sino-US relations was not science and technology. But the later promotes the former to be stable and long-lasting. This is the importance of the science and technology factor.

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U.S. Science and Technology and the Role of the Federal Government

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The paper presents a brief history of U.S. science and technology policy following World War II; describes how research is managed and funded in the United States; outlines how the federal government interacts with universities and private industry; discusses science and engineering (S&E) workforce and education issues the country is facing; and offers brief comments on the future direction of U.S. science and technology policy.[i]

I. A Brief History of Modern U.S. Science and Technology Policy

A New Role for Government Following World War II

During World War II, the United States and its allies recognized the tangible benefits of science and engineering research and development (R&D), with the development of radar, sonar, the proximity fuse, early computing, synthetic rubber, and penicillin, all important innovations which helped the nation's successful wartime effort. But the icon for science, physics in particular, was the Manhattan Project and the atomic bomb.

As the war drew to a close, Vannevar Bush, Director of the Office of Scientific Research and Development and wartime advisor to Presidents Roosevelt and Truman, wrote the legendary report *Science – the Endless Frontier*. Bush's argument was that science and engineering helped win the war and would be a crucial part of the nation's peacetime efforts. Bush encouraged the idea that most of the nation's federally funded research should be carried out in universities, where many of the best scientists were located and generations of scientists and engineers would be produced. Bush also maintained, with great zeal, that military research should be in civilian hands. Bush's report and subsequent government actions established an unwritten compact between U.S. science and the American public, wherein the federal government would use tax dollars to fund academic research. In turn, university researchers would carry out the research, publish their results in the open literature, and produce the next generation of scientists and engineers. This agreement set the tone for the next half century of U.S. federal research and higher education and led to the flowering of the American research universities, which are among the world's truly great institutions of higher learning[ii]. By integrating research and education, they have been essential components of U.S. science and technology and are unique in the history of education.

In the five years following World War II, Congress formed the National Science Foundation (NSF), the Office of Naval Research, and the Atomic Energy Commission (AEC), which evolved into the Energy Research and Development Administration (ERDA) in 1975 and the Department of Energy (DoE) from 1977. These agencies along with the National Institutes of Health (NIH), parts of which date from the 19th century, and the National Aeronautics and Space Administration (NASA), and several defense agencies – the Office of Naval Research, the Air Force Office of Scientific Research, the Army Research Office, and the Defense Advanced Research Projects Agency (DARPA or, in some years, ARPA) – are the main players in U.S. federal science and engineering R&D today.

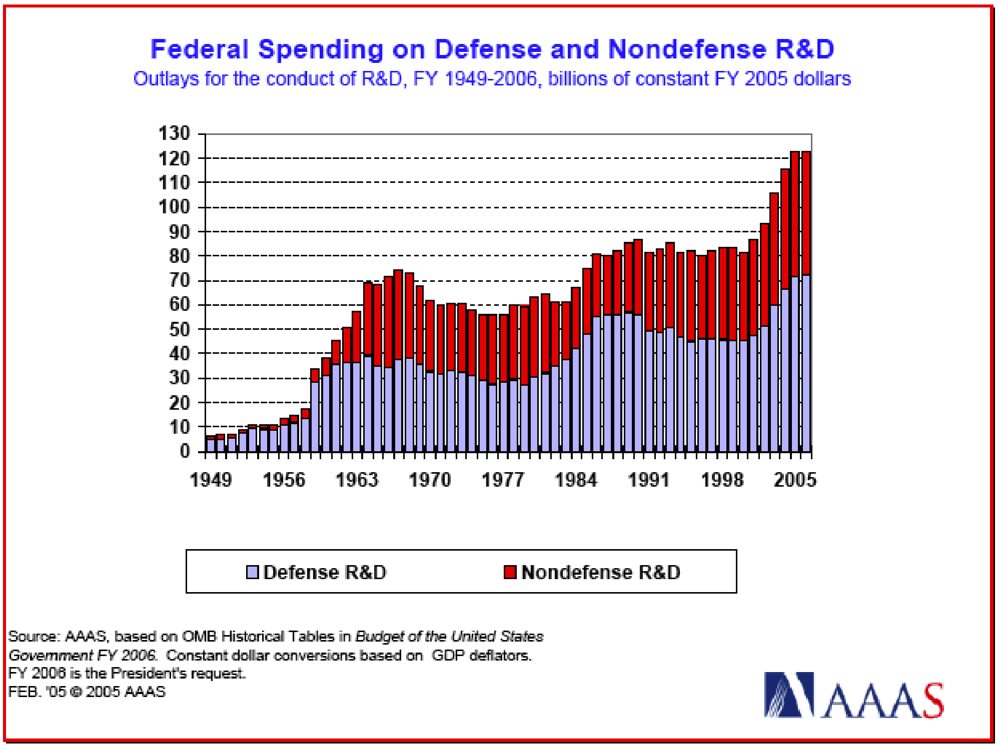
As it turned out, universities were not destined to be the only research institutions. Government operated (intramural) laboratories like the NIH laboratories and NASA centers, as well as federally funded research and development centers (FFRDC), such as Fermi National Laboratory, Jet Propulsion Laboratory, National Center for Atmospheric Research, and the MIT Lincoln Laboratory, would also pursue a large portion of U.S. R&D. These national laboratories were expected to provide a service that was complementary to the research activities of the universities, for example, by constructing and operating large research facilities (accelerators, fission reactors, fusion experiments, wind tunnels, rocket launch facilities, supercomputers, and in recent years, synchrotron light sources, neutron sources and many others.) It was also anticipated that national laboratories would maintain a cadre of excellent scientists and engineers who could focus their minds and energies on national needs (e.g. in national security; energy; agriculture, health; human space flight; weather; the environment) in addition to generating new fundamental knowledge and technologies through basic and applied research.

In some cases, the national laboratories were managed directly by the federal agencies. In other cases, the FFRDCs in particular, the management and operations were (and are, today) contracted out to companies, universities or other non-government entities. The defense agencies continued to support defense-related R&D in universities and their own laboratories. Private industry also made substantial investments in R&D, early examples being laboratories operated by Bell Telephone (Bell Labs), Hewlett-Packard, General Electric, Westinghouse, IBM, Texas Instruments and Xerox.

B. Science During the Cold War

Peacetime and President Truman's Marshall Plan soon gave way to the Korean and Vietnam conflicts and a lengthy arms-race standoff with the Soviet Union, based on a strategy of mutually assured destruction (MAD). As the cold war continued for nearly a half century, the framework and goals of U.S. foreign policy and science policy were affected. Federal funding of R&D (see figure 1) which grew steadily after WWII, jumped abruptly during the Eisenhower Administration after the Soviets launched Sputnik I in 1957, which led to the U.S. Apollo Program and the moon landings. In addition to space-related R&D, defense R&D funding experienced two growth periods, during the cold war, once after Sputnik and the second during the Reagan Administration in the 1980's. Defense R&D also shifted strongly to the development and testing of large defense systems, leaving basic research well behind.

Figure 1



Realizing that the nation would need a highly educated and trained workforce to compete with the Soviet Union, in 1958 Congress passed the National Defense and Education Act (NDEA), which provided funding to bolster all levels of education, including graduate studies in science and engineering.

As the cold war dragged on, notably without a single nuclear weapon being used, the nation began to focus on other non-defense objectives, such as health, energy and the U.S. economy. In 1971 President Nixon announced the “war on cancer,” which spawned multi-decadal growth in the NIH budget. In the late 1970s, responding to the OPEC oil scare, President Carter stated that energy was “the greatest challenge our country will face in our lifetimes.” In 1977, he launched an ambitious energy policy with significant investments in energy R&D, which were substantially cut back, once oil prices returned to tolerable levels.

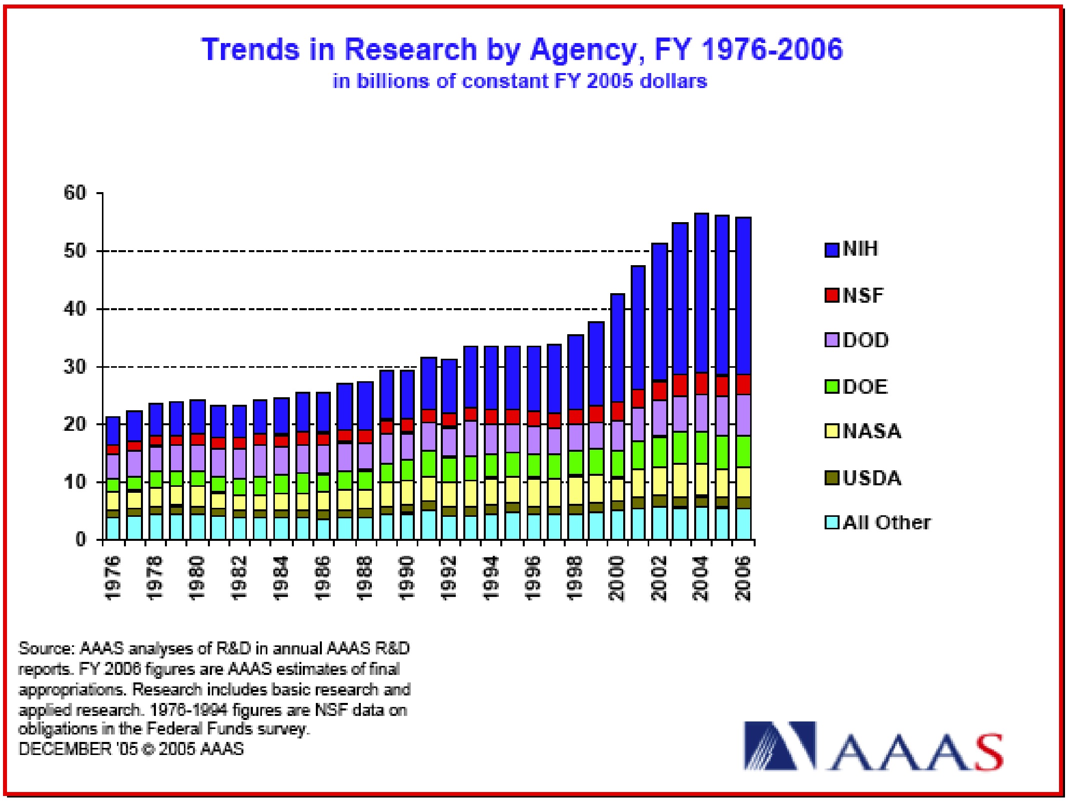
In 1973, defense agencies’ support of basic research in universities was dealt a heavy political blow by the Mansfield Amendment (an amendment to an appropriations funding bill), which stipulated that all defense research had to have a clear connection with a military application. During the Reagan Administration, when defense R&D grew along with the overall defense budget, universities once again played a major role, particularly in computer science and engineering, through substantial funding provided by DARPA. However the Mansfield Amendment was something of a turning point in what had been an enormously successful basic research partnership between the defense agencies and universities. The Mansfield Amendment is an example of how Congress exerts its authority by forcing agencies to change their policies and practices. Unfortunately, members of Congress are not always familiar with the detailed workings of federal agencies, most of which are large and complex. As a result, Congressional actions (such as this amendment) can have unintended consequences. Mansfield did not intend to sever the working partnership between defense agencies and universities; but Congress makes laws – sometimes ambiguous ones - and the agencies must interpret what those laws mean. The results can be quite negative.

C. Science After the Cold War

In the almost two decades since the dismantling of the Soviet Union and the end of the cold war, many areas of federally supported research, including the physical sciences and engineering, have moved further down the list of national priorities. The nation has focused on domestic social issues such has health care, education, jobs, crime, retirement benefits and, following 9/11, homeland security. NIH funding for biomedical research grew steadily for several decades[iii] (until the last few years), due to its obvious importance to medicine, but research funding at other agencies, such as NSF, DoE, and NASA, did not receive the same priority; and those budgets grew slowly or not at all. (see figure 2)

At the same time, these agencies' programs changed, reallocating their budgets to reflect national priorities in such areas as computing and the Internet; modern materials; biotechnology; environmental challenges, including global warming and climate change; and nanotechnology. NSF expanded its support of Engineering Research Centers and established Science and Technology Centers, as well as other centers designed to promote interdisciplinary research and cooperation with industry. Indeed, all agencies that support research have felt the need to focus more of their resources on interdisciplinary problems that are deemed to be particularly important to society. While the rationale for some of these changes are often compelling, core funding for disciplines like chemistry, physics, mathematics and non-biomedical biology has been eroding for decades. Ironically, although the most vexing high-priority national issues have large social components, funding for research in the social sciences has not reflected these priorities.

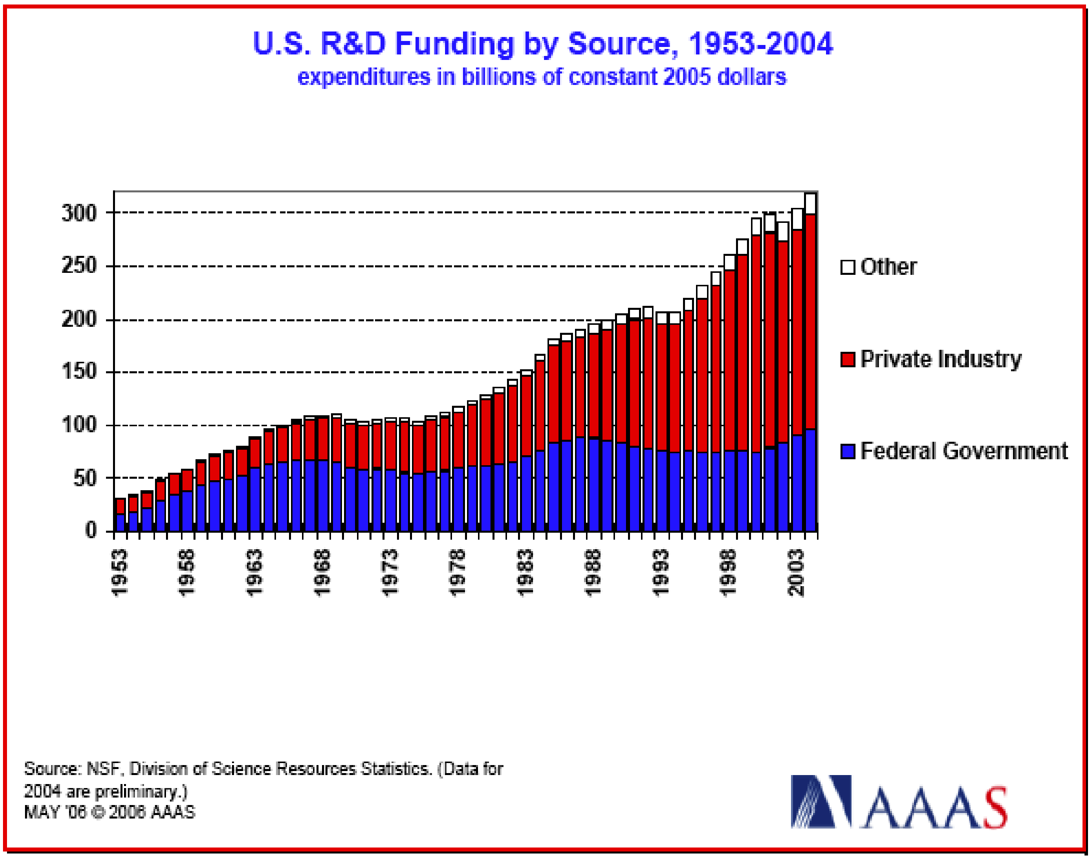
Figure 2



D. Industry Investments in Science and Engineering

Over the last few decades, while overall federal funding waxed and waned and the gap between federal biomedical research funding and all other non-defense research continued to widen, private funding of R&D, largely from major corporations, grew steadily, overtaking the total federal investment in 1979. (see figure 3) Industry currently spends (from non-federal funds) approximately $200 billion per year (2004) on R&D, which is about 70 percent of the total national U.S. investment in science and technology, which was about $312 billion in 2004. (NSB SEI 2006)

Figure 3



In part, this increased industrial focus on R&D may have been stimulated by the R&D Tax Credit (now called the Research and Experimentation (R&E) Tax Credit); however that specific federal contribution has been relatively small. In 2001, the R&E tax credit was approximately $6 billion. More likely these R&E funds have encouraged industry to perform more long-term, high-risk research than it would otherwise do.

At the same time, industrial support of university research, while still small, has been growing, (about seven percent of total academic research expenditures in 2003) and has had an impact on the academic culture. This private investment was stimulated, in part, by the 1980 Bayh-Dole Act, which allowed universities and their faculty researchers to patent inventions based on federally-funded research and help move technologies to market, while collecting licensing fees. These partnerships with industry have influenced the way universities operate, re-defined the notion of knowledge generation and changed the overall academic culture. The Bayh-Dole Act provides another example of how Congress can directly affect the policies and practices of federal agencies in order to accomplish some larger objective, in this case, to encourage the transfer of knowledge and technologies from university laboratories to companies in the private sector.

As a result of the Bayh-Dole Act, universities (and university faculty) can own intellectual property that results from federally supported research, hence can benefit financially from licensing fees. As a result, universities have had to learn how to negotiate with industry and address possible conflict-of-interest concerns. Federal agencies, through their funding programs, have encouraged the university-industry collaborations. Students and companies have benefited from such cooperation since companies can learn about the students and evaluate their potential, while students can learn about the corporate world before launching their careers.

U.S. industry invests roughly twice as much in R&D (primarily carried out in its own laboratories) as does the federal government; and industry measures carefully the value of this investment. Hence, industry focuses on short-term applied research and development, where the problems are well defined and useful results are probable. The investment by companies in basic research that is appropriate to universities is a small part of their total R&D funding and is often for the purpose of maintaining a connection with some of the best scientists and engineers in the country, as well as gaining early access to their students, who are potential company employees.

Federal agencies have also been influenced by increased industrial interest in cooperation with universities and national laboratories and Congressional pressures to encourage that cooperation. For example, the NSF, which focuses its support on basic research in universities, has paid increasing attention to encouraging applications of research results. It has attempted to do this through its early RANN (Research Applied to National Needs) program, which operated from1971 to 1977, as well as through its support of engineering and other interdisciplinary research centers and by encouraging cooperative arrangements with industry. Even the criteria used to evaluate proposals were changed in 1997 to include not only "intellectual merit," but also "broader impact" of the proposed work, which could include its potential for applications to societal needs. It is a difficult balance to maintain a strong focus on excellent basic research but, at the same time, encourage applications.

In comparison with U.S. industry, the federal government is less able to measure the impacts of its investments in R&D – especially basic research – on the economy or other areas of national need. In 1993, the Congress passed the Government Performance and Results Act (GPRA) stipulating that all activities of the federal government should be measured against performance objectives. Federal agencies are learning how to do this; but progress in some areas of activity is slow. While Congress may be pushing for additional accountability, surveys show that the American public, by a large majority, is pleased with the results of the federal investment in R&D and perceives direct benefits from those investments.

II. U.S. Science and Technology Today

The U.S. federal science and technology system, today, is a superposition of hundreds of diverse programs operated by dozens of federal agencies, each largely independent of the others, although six agencies account for over 90 percent of federal R&D expenditures:

DoD, the Department of Health and Human Services (primarily NIH), NASA, DoE, NSF and the Department of Agriculture.

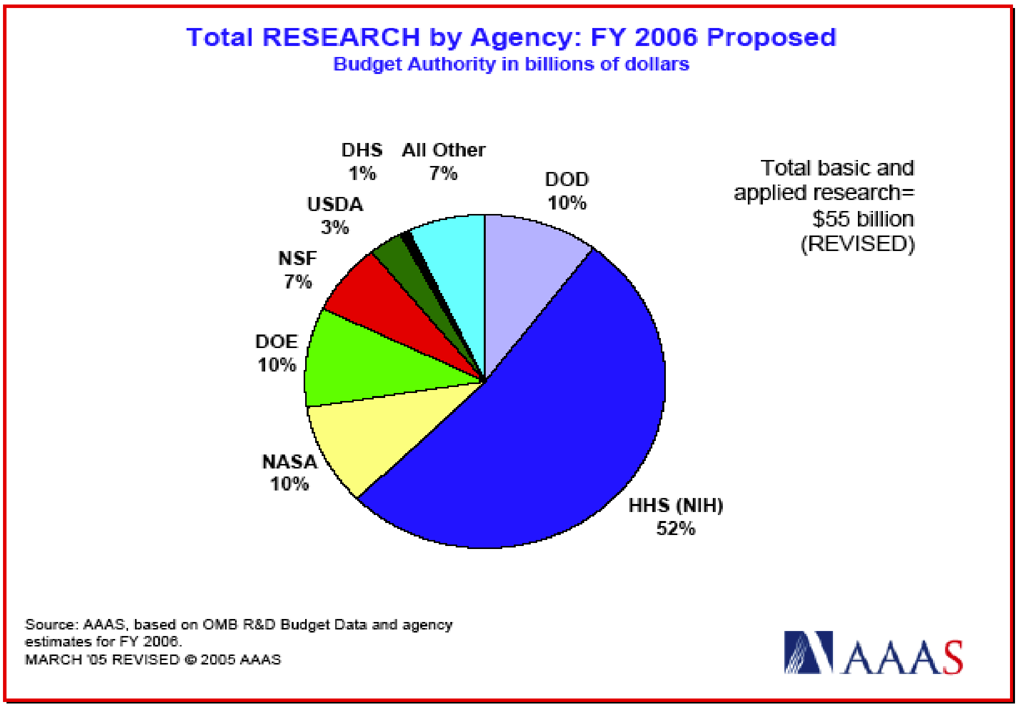
It is impossible to describe the whole without giving some detail about each of the parts – what each program in each federal agency does and the relationships between the agencies and the White House, Congress, industry, and the outside world. However, one can get a sense of the system by examining some of the characteristics of R&D funding and the annual budget process.

A. Federal Funding of Science and Engineering Research and Development

While the level of total federal R&D funding in the United States has been relatively stable in recent decades, research is not necessarily a priority and does not have "privileged" status with regard to funding. Non-defense R&D funding (which is mainly research) has tracked overall non-defense discretionary spending for the last three decades. Defense R&D funding (which is mainly development) has been more closely tied to overall defense spending; and the ratio of defense to non-defense funding has increased sharply since FY2002, reflecting the events of 9/11 and the priorities of the current G.W. Bush Administration. [NB: the federal government's fiscal year extends from October 1 of the previous calendar year through September 30.] Also, in recent decades, development, which is primarily contracted out to industry, has been a much higher priority for DoD than research. Moreover, the research community has perceived a shift in definitions over time, with work that was formerly labeled as applied, now being included in the category of basic.

Currently, the federal government provides approximately $135 billion (FY2006) in annual R&D funding, of which $77 billion (55 percent of the total) is for defense-related work and $57 billion (45 percent of the total) is for non-defense R&D. (see Table)[iv]. Of the non-defense R&D funding, about 80 percent goes to four agencies: NSF, DoE, NIH, and NASA. (see figure 4).[v]

Figure 4



Figures are not available for industry's investment in R&D in 2006; but as noted previously, the U.S. industry generally funds R&D at approximately twice the level of the federal government.

B. International Comparisons of R&D Spending

International comparisons are difficult for many reasons, including budget definitions and ambiguities in currency conversions, but they do give some sense of levels of activity and national priorities. In dollars, the United States leads the world in R&D expenditures ($312 billion in 2004, or 38 percent of the world's total R&D), followed by Japan (13 percent) and China (12 percent). [NB: dollar equivalent expenditures for other countries are calculated using Purchasing Power Parity rather than Mercantile Exchange Rates.] (see figure 5).

Another traditional metric for comparison is the ratio of total national R&D funding to GDP in 2004. In 2004, the United States spent 2.68 percent of its GDP on R&D (including public and private funding sources). This is below Sweden (3.98 percent), Finland (3.48 percent), and Japan (3.15 percent), according to data from the *Organization of Economic Cooperation and Development, Main Science and Technology Indicators, 2005* (see figure 6).

Table – U.S. Federal R&D Funding (as appropriated) for Fiscal Year 2006 (budget authority in billions of dollars)

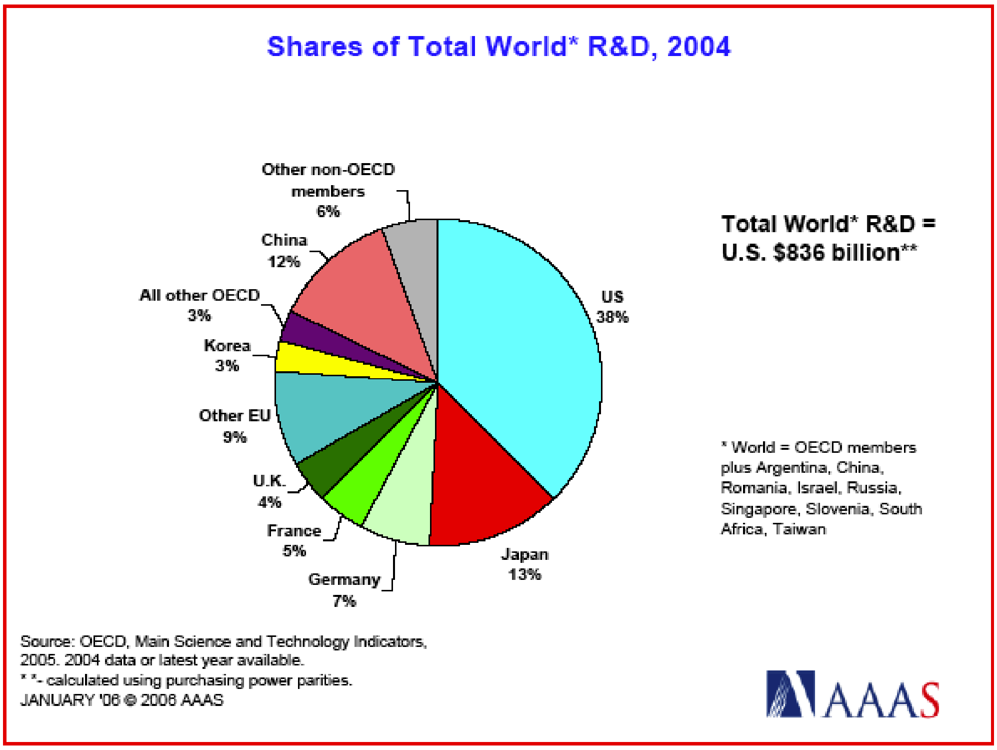
Research and Development	
Research	
Basic	26.7
Applied	30.3
Total Research	57
Development	73.2
Total Research and Development	***134.8***
Federal Science & Technology*	**62.6**
Defense	
Defense Research	
Basic	1.5
Applied	5.2
Total Research	6.6
Defense Development	
Adv. Tech. Dev. 6.3a	6.6
Total Defense R&D	***77.4***
Non-Defense	
Non-Defense Research	
Basic	25.2
Applied	25.1
Total Research	50.4
Non-Defense Development	6.9
Total Non-Defense R&D	***57.3***

*The category of Federal Science and Technology includes all basic and applied research as well as defense technological development (coded as 6.3a) and was recommended by the national Academies, some years ago, as a better way to show the true federal investment in advancing science and technology.

In the case of the United States, a larger percentage of its national R&D funding is provided by private industry than is the case for most other major countries, with the exception of Japan. Also, the United States spends a larger percentage of its federal R&D dollars on defense (large systems development and testing) than do most other nations.

With the growth of national GDPs and R&D investments has come the globalization of science, which is reflected in publications by non-U.S. authors and co-authors. The world has seen a 50 percent increase in research articles in the 15 years from 1988 to 2003; but the U.S. share of those has decreased from 38 percent to 30 percent while the EU-15 and East Asia shares have gone up, the latter by a factor of seven, from two percent to eight percent in 15 years. International co-authorship has also increased markedly, from eight percent to 20 percent for the world. The United States leads in co-authorships with U.S. co-authors appearing on 44 percent of all such papers.

Figure 5



C. U.S. – China Cooperation in Science and Technology

Scientific cooperation between the U.S. and China occurs on many levels, from collaborations involving individual investigators and small groups to centers and larger organizations. Given the rapid growth of China's investment in science and technology and its rich and growing talent pool in science and engineering, the opportunity exists for much stronger cooperation with the United States. Indeed, expanded cooperation would appear to be in the interests of both our countries.

Much of the existing S&T cooperation takes place under the U.S. – China Agreement on Cooperation in Science and Technology, signed by President Jimmy Carter and Premier Deng Xiaoping in 1979. Under this agreement, the two countries have engaged in cooperative research in a wide range of areas, including: agriculture, fisheries, energy, earth and atmospheric sciences, chemistry, physics, geology, health, natural disasters, and civil industrial technology. Most U.S. federal agencies are engaged in some level of U.S.-China cooperation. However the degree of involvement varies considerably from agency to agency (a few examples will be given below); and, overall, funding provided for these activities is very small. U.S.-China cooperation in science and technology was a topic for the April 2006 visit of Premier Hu Jintao to the United States. Several important agreements and MOU were signed during that visit.

The NSF works with the National Natural Science Foundation of China (NSFC), operating under an agreement or Memorandum of Understanding (MOU) that covers a broad range of possible cooperative activities. The NSF has a number of programs that provide funding to U.S. researchers (and students) interested in China. Funding is available for travel, workshops, short visits, and summer institutes for graduate students. NSF research grants are not made to Chinese institutions; however, U.S. institutions receiving NSF grants may provide support for Chinese research collaborators as well as U.S. researchers. The NSF has established an office in Beijing with the objectives of promoting collaboration between scientists and engineers; acting as liaison between NSF and agencies, institutions and researchers in China; and monitoring and reporting on science and engineering developments and policies in China.

DoE provides a second important example of U.S.-China cooperation under several protocols of the umbrella agreement. DoE supports R&D collaborations in the areas of high-energy physics, nuclear fusion, energy (including fossil) efficiency and renewables (including technology development and utilization), climate science, peaceful uses of nuclear technology, and environmental science and technology. In the area of high-energy physics, cooperation focuses on the decision to upgrade the Beijing Electron-Positron Collider (BEPC) and its detector (BES).

NIH has a long history of scientific collaboration with China. Currently, NIH supports cooperation in the areas of health and medicine through several agreements including: NIH – Chinese Academy of Sciences Agreement, U.S.-China Public Health Agreement, and U.S.-China S&T Agreement. Cooperative R&D activities cover a very broad spectrum of health and medical areas, including HIV-AIDS and other infectious diseases, cancer, heart disease, and others.

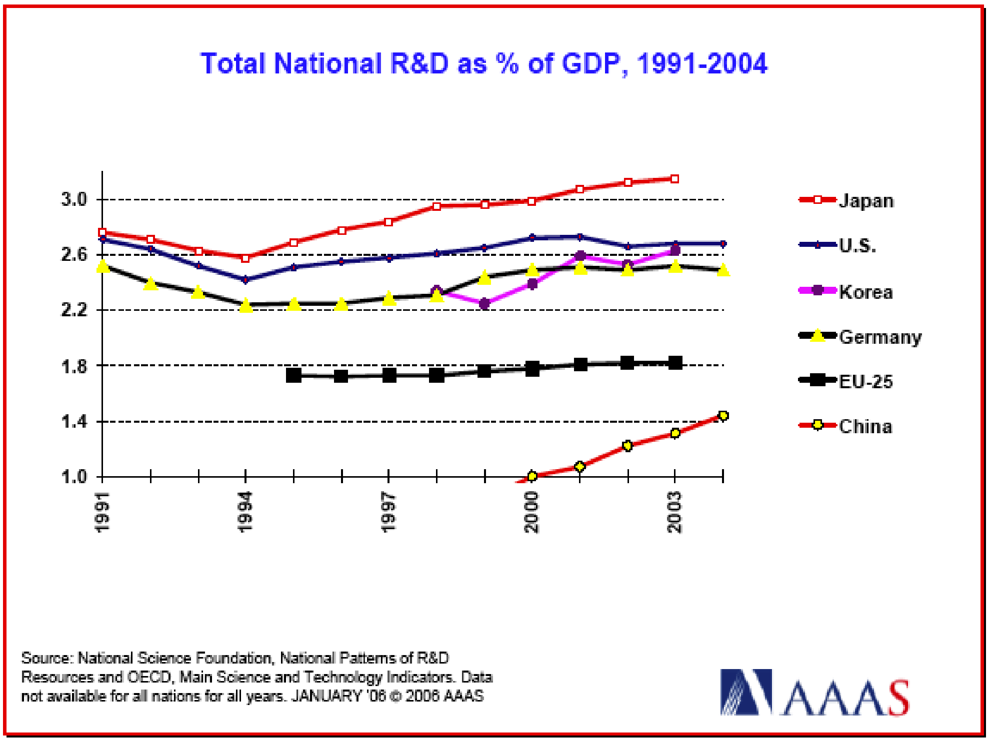
III. Federal Management of U.S. Science and Technology

The U.S. federal government's management of science and technology, including R&D programs, reflects the strong separation of powers and system of checks and balances, embedded in the U.S. Constitution, between the Executive branch (President, Vice President and federal agencies) and the Congress (Senate and House of Representative). The process used to develop the federal budget illustrates the point.

A. The President's Annual Budget Request

The president initiates the annual budget process by preparing a budget "request" for Congress to consider. Preparation of the request is a top-down and bottom-up process, wherein the president sets out his or her overarching priorities and the federal agencies respond. There ensues a period of negotiations between the White House and the agencies, leading to the president's final budget decisions and the preparation of the budget request documents by the Office of Management and Budget (OMB).

Figure 6



In the case of R&D funding and other science and technology policy, the Office of Science and Technology Policy (OSTP) is generally called upon for advice on agency priorities. The Director of OSTP (appointed by the President and confirmed by the Senate) traditionally serves as the President's "Science Advisor" (an informal term) and, in the two previous Administrations, also held the title of Assistant to the President for Science and Technology, reporting directly to the President. The internal White House budget discussions among presidential aids and with agency heads can be heated. What is required is an optimal mix of diplomacy and assertiveness. The entire process of preparing the president's budget request, the negotiations with the agencies and the internal White House discussions, is internal to the executive branch of government and not disclosed to the pubic or the Congress. Only when the president sends his budget request to Congress is it made public.

An example might help to clarify the respective roles of the different offices of the White House in advising the President on his budget request to Congress. In 2000, several White House offices, OSTP, OMB and the National Economic Council (which is actually the name of the office of the President's economic advisor), working with NSF, DoE and other federal agencies, developed a proposal (to the president) for a National Nanotechnology Initiative (NNI). The NNI, which would double the federal investment in nanoscale science and engineering in one year, from approximately $250 million/year to about $ 500 million/year, was part of a larger effort to increase funding for the physical sciences and engineering. Most of the White House senior staff were supportive of the initiative. However, providing all the proposed increases meant less funding would be available for biomedical research, funded by NIH (which, initially did not have a large role in the NNI), and other domestic priorities. Thus, a debate arose. The president held meetings in which his senior staff debated their positions. In the end, the president made the decision to include, in his budget request, the NNI, as well as the additional funding for the physical sciences and engineering and an increase for NIH as well.

Once the president's decisions have been made, the debate stops. Everyone in the White House and the federal agencies lines up to support those decisions in the next round of negotiations – with the Congress. In the example of the NNI, this process worked well because there was an opportunity for the president to hear the arguments on both sides of a disagreement among the senior staff on a budget matter. The same process was followed when other important policy matters were before the president.

B. Congressional Action on the Budget – Appropriations Process

The U.S. Congress –Senate (a 101 members group with two representatives from each state, plus the Vice President who serves as president of the Senate and can vote only to break a 50-50 tie vote of its elected members) and House of Representatives (a 435 member group based on state populations as a proportion of the country) – have key roles in all aspects of the federal government, including its R&D budget.

Once the president's budget request arrives in Congress (usually in early February of each year), both houses, the Senate and House of Representatives, independently, begin to prepare their responses, in the form of several appropriations bills, each bill written by one of the appropriations subcommittees and each bill authorizing next-year's funding for a group of agencies.

The Congressional appropriations subcommittees, which write the funding bills for federal agencies, wield considerable power. In addition to holding hearings and drafting appropriations bills, they exercise tight controls over what agencies do with their budgets. Any agency that wishes to deviate, even slightly, from the original budget, must obtain approvals from its appropriations subcommittee before proceeding. Agency heads spend a great deal of time negotiating these matters, which they see as micromanagement.

C. Roles of Federal Agencies in Funding R&D

In the U.S. system, all R&D funding flows through the federal agencies, which support R&D activities in universities, national laboratories, and, through contacts and special programs, industry as well. In the case of agencies like the Department of Energy (DoE), Environmental Protection Agency (EPA), Department of Agriculture (USDA), Department of Defense (DoD), and the Department of Health and Human Services (HHS), the agencies support R&D and apply scientific knowledge and technologies to meet a number of agency-specific national needs. The heads and top-level officials of these departments and agencies are presidential appointees, who must be confirmed by the U.S. Senate. By contrast, the majority of agency employees are experienced civil servants, permanent federal employees, many with long tenures in the agencies.

As mentioned earlier, the four agencies that are the largest supporters of non-defense R&D are NSF, NIH, NASA and DoE (see Figure 4), which together, fund most research in the physical sciences, biomedical research, social sciences and energy research. While each agency has a specific mission, given in the statutes, some of their programs overlap one another[vi]. When several agencies participate in large multidisciplinary research initiatives, e.g. the Global Change Research Program, Human Genome Project or National Nanotechnology Initiative, these efforts must be coordinated, with each agency responsible for a particular set of activities. That coordination takes place through the National Science and Technology Council (NSTC) and its committees. NSTC is a cabinet-level committee chaired by the president and operates out of the White House OSTP.

Within each federal agency, there are a number of tensions that continue to require reviews of existing policies and changes in policy when warranted. One such tension has most often been described as "big science" (usually meaning large facilities and, these days, large groups) vs. "small science" (usually meaning individual investigators or small-groups). Of course, this is a drastic oversimplification of the different modes in which research is being done. However, when large, expensive facilities are involved, there are serious issues for the agency. The point can be illustrated with NSF. NSF has traditionally focused on individual investigators and small groups. However, it also supports centers and institutes and funds the construction and operation of experimental facilities in many fields (examples are: Cornell's CESR accelerator and detectors; several optical and radio telescopes; fleets of research ships and aircraft; the Laser Interferometer Gravitational Wave Observatory (LIGO); detectors for the Large Hadron Collider at CERN; the U.S. research facilities in Antarctica; and many others.) For large facilities, especially construction, the projects must be carefully managed, costs accurately determined in advance, and schedules rigorously adhered to. For a relatively small agency like NSF, the unpredictability of budgets, presents a considerable challenge. The requirements of a large facility can squeeze out a large number of new individual investigator grants. There is no easy solution. The agency simply has to plan for such contingencies and soften the impact of a bad budget year. DoE has a longer tradition of funding the construction and operation of large experimental facilities and larger budgets. Even so, DoE can find itself with insufficient funds to move a construction project forward on schedule or operate an existing facility at the optimal level. Other agencies have similar challenges.

It is widely accepted by the U.S. research community, the federal agencies, and the White House and Congress that the success of the nation's research universities has been largely due to the use of a competitive system, in which unsolicited proposals submitted by university faculty are received by agencies, peer reviewed by experts in the field, and grants made to support the research. The grants are made through the faculty member's institution, which has the responsibility to insure that the money is spent as intended. There has been concern about so-called "pork barrel" funding, where a member of Congress places language in an appropriations bill that directs ("earmarks") funding for a particular project or institution in the member's state or Congressional district, without any reviews of the merit of the project. Proponents of the practice of earmarking appropriations argue that the money often benefits excellent science. That is undoubtedly true; but that would also be the result if the money were simply distributed at random across the country. The purpose of peer review is to set priorities at the grant level and insure that the best research is funded. As the practice of "pork barrel" funding grows, the integrity of the federal agencies' grant making system (peer review) is threatened.

IV. U.S. Federal Government's Role in Competitiveness and Innovation

The appropriate role of the federal government in anything having to do with private industry has often been a politically contentious matter in our free market system, but there is general agreement that the federal government has an important responsibility to fund basic research in universities, where discoveries are made and future scientist and engineers are trained, and insure an even playing field for companies at home and abroad. That said, whenever the nation becomes concerned about the competitiveness of its industry, e.g. in the 1980's and early 1990's, the federal government tends to respond with various kinds of stimulus programs[vii]. There is also considerable agreement that without a well educated workforce, the nations' future is not good.

A. Science and Engineering Workforce and Education

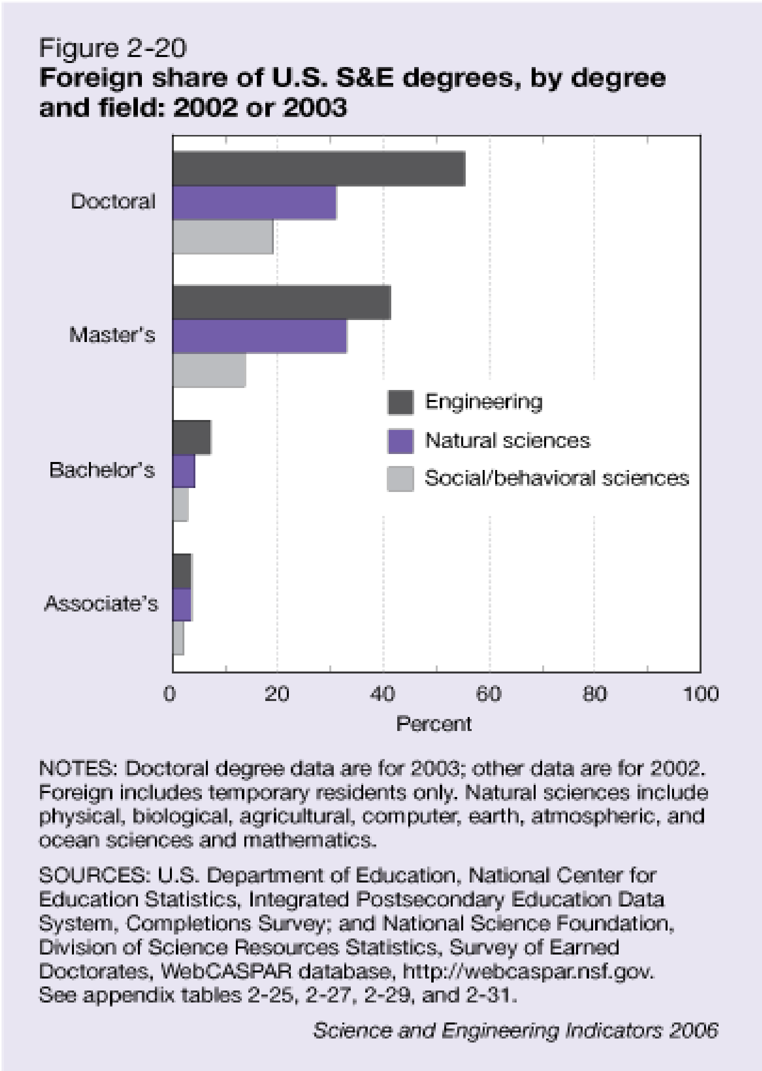
The size and makeup of the science and engineering workforce has been a growing concern for several decades. During the 1960s, science was elevated to a prestigious position in American society. As a response to Sputnik and later the Apollo program and with the help of NDEA funding, there was an influx of new scientists and engineers into the workforce. But as that generation begins to head towards retirement, not enough new scientists and engineers are coming through the ranks.

In recent decades the United States has been fortunate to attract talented women and men from other parts of the world, who came to this country to pursue their careers in science and engineering. In 2002-2003, over 50 percent of U.S. doctorates in engineering (and 30 percent in the natural sciences) went to foreign born individuals (see figure 7). But because of barriers – real (e.g. visas and export controls) and perceived – to entry into the United States, fewer young people are likely to come to this country for their education and careers[viii]. Recently, there has been great concern about a possible shortfall in the U.S. science and engineering workforce at a time when other nations, particularly in Asia, are making great strides forward.

In part, the lack of interest among U.S. citizens in science and engineering careers may reflect the quality of pre-university science and mathematics education in the United States. Simply put, American students test badly, when compared to their counterparts in other countries as measured by TIMSS (Trends in International Math and Science Study) and PISA (Program for International Student Assessment). U.S. students do reasonably well at the 4^{th} grade level, but scores decrease compared to other countries during middle school (6^{th} through 8^{th} grade) and fall well behind by the 12^{th} grade. The reasons are many, socioeconomic as well as inadequacies in the schools – and the two are often related. Many U.S. schools suffer from poor working and learning conditions; inadequate teacher compensation and classroom support; flaws in the preparation of teachers, particularly in science and mathematics; standardized testing; large classes and heavy teaching loads; to name a few. The situation is particularly dire in low-income urban and rural districts. And these are the districts that serve many of the nation's minority communities. For a number of reasons, the United States has seen a decrease in participation in science and math courses by women and minorities, when compared to their white male counterparts. This has resulted in programs at both the K-12 and university level to mentor and encourage women and minorities to take math, science, and engineering courses. There has been progress, but far too little for much too long. It is also true that the numbers of white males choosing careers in science and engineering has been decreasing.

The recent report[ix] of the U.S. National Academies, *Rising Above the Gathering Storm – Energizing and Employing America for a Brighter Economic Future*, sounds an alarm with the comment: ".. the committee is deeply concerned that the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength… we fear the abruptness with which a lead in science and technology can be lost – and the difficulty of recovering a lead once lost, if indeed it can be regained at all." The report includes bold recommendations for federal funding and other policy actions in the areas of K-12 education, higher education, research, and economic policy (to stimulate innovation). The report has been well received by both parties in Congress and by the White House. The president's budget request for FY2007, in particular his "American Competitiveness Initiative" reflects some of the recommendations, in part, perhaps, in response to the positive reaction by Congress.

Figure 7 (from Figure 2-20 of NSF, NSB Science and Engineering Indicators)



V. Thoughts on the Future of U.S. Science and Technology

The comments in this section are very much the opinions of the author and topics of ongoing debate.

The U.S. science and technology enterprise owes its success, principally, to two factors: The robust public-private partnership, established at the close of World War II between the federal government and universities and national laboratories, has led to decades of scientific discovery and invention, as well as generations of excellent scientists, engineers and entrepreneurs. Second, the intensely competitive American private companies have been able to swiftly translate new ideas and inventions into products and services for world markets.

But the world changes in 60 years. In part due to technology – computing and the Internet – it has gotten smaller and, in the words of author Tom Friedman[x], "flatter". In a world where large multinational companies can simply take their manufacturing, service divisions, even R&D facilities to whichever parts of the world can offer the skilled workers at a good price, the old arguments about having the best universities and research facilities on U.S. soil – and providing the necessary federal funding for them – become more complex.

At the same time, universities have become business operations, forming partnerships with companies, collecting license fees for patents on faculty research products, and providing a significant fraction of the funding for their faculty and students. The Vannevar Bush government-university partnership has become a three-way government-university-industry partnership.

The policy-making arms of the federal government have also changed, having become much more deeply partisan and ideological. Indeed the long-held tenets about the separation of powers and checks and balances are being challenged, today, in ways the nation has not experienced before. And, while the American public and most policy makers express strong support for science, some research is in conflict with certain vocal special interests, e.g. research on embryonic stem cells, which is opposed by certain conservative religious groups, and climate change (at least policy implications), which some industrial sectors consider threatening. In both cases, several state governments have moved forward with programs and policies of their own, which some see as indicators for where the federal government will go in the future. On these complex and controversial science topics, the research community (including social scientists as well as natural scientists and engineers) needs to be much more engaged in dialogue with the public and their elected representatives. Indeed, broad research collaborations between scientists who understand biology, chemistry and physics and scientists who understand people and organizations could significantly raise the level of public discussion and understanding of these scientific matters, that are so important to people's lives.

With regard to federal research funding, the situation is troubling. The president has requested significant increases for the research budgets of NSF, DoE and the National Institute for Standards and Technology (NIST) and indicates that he will continue to request increases for these agencies in the future. However, federally funded research, on the whole, is down. And with increasing pressure on federal discretionary funding, it is unlikely that total research funding will receive special treatment for the foreseeable future. Historically, total federal funding of non-defense R&D (most of which is research) has tracked overall non-defense discretionary spending. Since the latter is likely to remain flat or even decrease in the coming years (regardless of which political party controls the Congress and the White House), research funding is likely to follow the same path. Individual agencies might do better; but they will have to have very compelling arguments to win out over a large number of government agencies and programs, including some very popular ones.

In the area of education and workforce, the United States will continue its efforts to improve K-12 education, especially in science and math, and will continue to address the under-representation of minorities and women in most fields of science and engineering – but progress will be slow. The American public is supportive of science and most parents would be happy for their children to become scientists or engineers. However, most young people find other careers, e.g. business, law, medicine, and sports more attractive. It will require leadership at the top of government and ambitious federal programs, not unlike the NDEA of the cold-war era, to turn this around. The controversy over teaching evolution will continue on a local level and will be addressed through local elections and court decisions. U.S. business interests will increase pressure on the federal government to lower entry barriers to foreign born men and women who wish to come to the United States to study science and engineering and launch their careers in the our country. Barring future terrorist attacks or other incidents that cause a tightening of the borders, the United States will again open its doors. Indeed, U.S. science and technology cannot prosper unless this happens.

Whether the United States will continue to be a "leader" in science and technology is a question that is seriously being asked by many knowledgeable individuals, e.g., the National Academies' panel that published the report *Rising Above the Gathering Storm* (referred to earlier) as well as by prominent members of Congress. With the dramatic increases in investments in R&D being made by governments and multinational private companies all across the globe, particularly in Asia, U.S. science and technology in the future will be unlike that of the past. U.S. "leadership" will be defined increasingly in terms of the nation's participation as a partner in cooperative international research activities. U.S. researchers will be engaged in international collaborations at a level that is unprecedented in the nation's history, and U.S. federal agencies will need to adjust their programs to make that possible.

It is an undisputed fact that science and technology are vitally important to the health and general well being of people everywhere. It follows that governments should understand that funding R&D is an investment that pays very high returns for society, rather than a cost that taxpayers should bear. If U.S. policy makers begin to understand this notion, many of the challenges outlined above will not be so difficult to meet.

ENDNOTES

[i]The data referred to in the following sections were taken from two sources, the National Science Foundation, National Science Board Science and Engineering Indicators 2006 (see http://www.nsf.gov/statistics/seind06/)
and, particularly the budget information, the American Association for the Advancement of Science (AAAS) (see http://www.aaas.org/programs/science_policy/)

[ii] U.S. universities spend about $40 billion per year on R&D ($25 billion federal and $15 non-federal) and carry out 15 percent of all U.S. R&D activity and 55 percent of its basic research.

[iii] The NIH R&D budget is about $28 billion for FY 2006, compared with $4billion for NSF, $11billion for NASA and $4.5 billion for DoE's Office of Science and Energy R&D. Biomedical research (NIH) funding is now about half of total federal funding for research (rather than R&D) in all fields.

[iv] The funding levels given are for R&D (basic and applied research and development) and are based on data provided by the American Association for the Advancement of Science (AAAS), which may be found at http://www.aaas.org/spp/rd/fy06.htm.

[v] This pie chart illustrates the relative contributions of several federal agencies to total federal research funding (not including development). The chart for FY2006 is based on the resident's budget request rather than the final appropriated budgets.

[vi] For example, both NSF and DoE support similar research areas in physics. NSF and NASA both support astronomy and astrophysics. NSF, DoE and NIH support research in chemistry. In order to avoid undue duplication, program officers of the various agencies must be aware of what other agencies are doing. Also, there are high-level agreements, e.g., NSF supports ground-based astronomy while NASA supports space-based astronomy. NIH supports clinical research and NSF does not. DoE supports research in its national laboratories as well as universities, while NSF focuses its support primarily on universities.

[vii] In the 1980's, at a time when U.S. industry was facing severe competition from foreign companies and there was political concern about the United States losing its competitive edge, a number of laws were passed to address the situation. The Stevenson-Wydler Innovation Act (1980) and the Federal Technology Transfer Act (1986) encouraged federal laboratories to facilitate transfer of technology to the private sector, e.g. through Cooperative Research and Development Agreements (CRADAs), which number about 3000 today. The Bayh-Dole University and Small Business Patent Act (1980) permitted government grantees and contractors to retain title to intellectual property and encouraged universities to take out patents and license inventions to industry. The Small Business Innovation Development Act (1982) established the Small Business Innovation Research (SBIR) Program within major federal R&D agencies to fund promising research in small businesses. SBIR funding was about $1.6 billion in 2003. The Economic Recovery Tax Act (1981) established the R&D tax credit (now called Research and Experimentation (R&E) tax credit) to encourage industry to invest more on long-term R&D. In the 1990's, programs like Advanced Technology Program (ATP) and Manufacturing Extension Partnerships (MEP), both operated by the National Institute for Standards and Technology (of the Department of Commerce) were established to address similar concerns.

[viii] From 2000 to 2003, the foreign student share of U.S. first-time full-time graduate S&E enrollment fell for most fields. In computer science, the decrease was approximately from 70 percent to 50 percent; in engineering the decrease was from 60 percent to 50 percent. The decreases in other fields were somewhat less. There has been some recovery in the past few years; but the future is uncertain. Meanwhile other nations have increased their enrollments of foreign students.

[ix] *Rising Above the Gathering Storm –Energizing and Employing America for a Brighter Economic Future* (National Academies Press, Washington DC)

[x] see *The World is Flat* by Tom Friedman (Farrar, Strauss and Giroux, NY, 2005)

Sino-US Scientific and Technological Systems: A Comparative Analysis

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The Chinese and US scientific systems are quite different. By comparing these two systems, the Chinese national scientific system's reform and development can learn from the positive side of US scientific development. In the following comparison study, major aspects will be emphasized, including science and technology management systems, the research systems, research funding, technological transformation, intellectual property protection, and technology promotion.

I. Differences in Technology Management Systems

Technology management is an important part of any science and technology system. The US system is fragmented and decentralized. Technology legislation, law enforcement, and administration belong to the US Congress, the courts and the executive branch of government. In accordance with the principle of separation of powers, the US science and technology system is governed by the United States Constitution and the laws enacted by the United States Congress. The Senate Commerce, Science and Transportation Committee and the House Science, Space and Technology Committee have played important roles in the development of national science and technology policy. The US government has no specific technology management department; the US President coordinates scientific and technological work policy through his science advisor. In 1993, for strengthening the leadership functions the federal government established the National Science and Technology Council, consisting of the leaders of all relevant government agencies. At the same time, a non-governmental presidential advisory committee of science and technology was set up to involve representatives of the public in science and technology decision-making.

The US government's science- and technology-related organizations also have their own advisory committees to assist them with technology management. In addition, the US National Academy of Sciences, National Academy of Engineering, Institute of Medicine and the Smithsonian Institute's and other quasi-official and non-official bodies have a significant impact on technology management.

In contrast, China's science and technology management system is highly centralized. The Chinese government puts science and technology management, management-related production activities, and resource allocation management in one sector. Other sectors are responsible for the development and implementation of appropriate policies or short-term projects. The science and technology management structure can be divided into three levels: the highest level decision-making body - the National Science, Technology and Education Leadership Group; the implementation and coordination level -- the Ministry of Science and Technology, other ministries and local technology management organization; and specific scientific research institutions (universities, research institutes, and enterprises).

Among these, the primary responsibilities of the State Leading Group for Science, Technology and Education are to consider national science, technology and education development strategies and major policies, discuss and consider important technological and educational tasks and projects, coordinate the departments of the State Council and local departments with the technologies and education.

The main functions of the Ministry of Science and Technology are studying the proposed technology development strategies and macro technology to promote economic and social development strategies and policies for economic and social development; study and identify major scientific and technological development; and identify priority areas to promote the national technological innovation system; build and enhance the capacity of national scientific and technological innovation; organize and prepare civilian science and technology development by means of long-term and annual plans; strengthen basic research to develop high-tech policy plans; conduct research on the industrialization of the country's science and technology capacity-building; strengthen high-tech industrialization; develop and apply measures for technology outreach; conduct research on the rational allocation of resources by giving full play to science and technology experts; promote science and technology education; and develop scientific and technological cooperation and exchange with other countries.

Other ministries, such as the State Development and Reform Commission, Ministry of Education, Ministry of Agriculture, Ministry of Health, Ministry of Information Industry are also involved in science and technology management.

The primary responsibility of the National Natural Science Fund Committee is to use state funding to finance basic research; discover and nurture talents; and work with the Ministry of Science and Technology in developing national basic research principles, policies, and planning; and building academic networks and international cooperation mechanisms.

The Chinese Academy of Sciences is not only the highest scientific academic institutions, but also a high-technology organization. Since a large number of research institutions are managed by Academy of Sciences, it clearly is important to China's scientific and technological management system. The Chinese Academy of Engineering, the highest level advisory for academic engineering, also promotes the development of the science and technology projects. The China Association for Science and Technology, the mass organization of scientific and technical workers, is organized into scientific and technological disciplinary groups, as well as provincial level branches and affiliated disciplinary organizations. The organization aims to promote scientific and technological development and the popularization of science and technology.

II. Differences in Scientific Research Systems

US science and technology institutions can be classified into four major systems: the federal government systems, enterprise systems, institutions of higher education systems, and other non-profit system. In the federal system, the national laboratories are the main backbone. The most famous among them are the Los Alamos National Laboratory in New Mexico, the Oak Ridge National Laboratory in Tennessee and the Kennedy Space Center in Florida. Currently about 800 US national laboratories account for one-third of government research and development (R&D) funding. Enterprise technology occupies an important position in the country. About three-quarters of R&D is conducted by the enterprises, and three-quarters of US researchers are deployed in enterprises units. These units account for 60 percent of the national R&D expenditures. Large enterprises play an important role in R&D. Since the 1970s, small and medium sized enterprises (SMEs) have also played a significant role, particularly in science and technology, industrial development, and technological innovation.

American universities are the main sites for basic research. Among the 3,000 colleges and universities in America, more than 300 have graduate schools. Because higher education funding is dispersed in the United States, research universities compete intensely for teachers, students and research funds. Many universities are also closely linked with industry.

China's scientific research system is made up primarily of state-owned research and development institutions, universities, and enterprises. Among these, state-owned research and development institutions are an important factor. In 2002, there were 4,347 state-owned research and development institutions. Among there were 98 under the Chinese Academy of Sciences Institute. Also there are 68 state key laboratories and 52 key laboratories located in the Chinese Academy of Sciences institutes. There were 20.6 million R&D staff in state-owned research and development institutions. These kinds of institutions include the Chinese Academy of Agricultural Sciences (China's national agricultural research institutes), the China Forestry Sciences, the Chinese Academy of Medical Sciences and the China Environmental Science Research Institute. In 2002, China had 1,396 universities with 181,000 R&D staff. 96 key national laboratories are located in the colleges and universities. Like the United States, China is emphasizing more research in universities, particularly in natural sciences and humanities fields.

In the planned economy period, China's scientific resources were distributed to independent scientific research institutes, and research work was mainly conducted in independent scientific research institutes and universities. As China's scientific and technological reform developed, the country has achieved better scientific research results from independent research institutes by changing business strategies. In 2002, there were approximately 23,000 state-owned large and medium industrial enterprises, 10,000 of which were R&D enterprises with 400,000 R&D staff. To enhance China's industrial technology, the Chinese government has taken a series of measures to support building developmental pilot enterprises centers with the goal of developing more international first-class research and development centers to in five to 10 years.

III. Funding Differences

China and the United States differ in the number of funding channels for R&D. There are more funding channels in the United States: the federal government, private companies, universities, and non-profit institutions . In 1999, China’s national R&D funding amounted to 67.89 billion Yuan, about five-percent of which was for basic research. These expenditures were only 3 percent of US expenditures. Almost all of China's basic research funding comes from the government. Most enterprises have not invested in basic research. Universities expenditures for basic research are limited to a small number of pre-research costs and initial start-up costs. Moreover, virtually no non-profit organizations support basic research in China.

IV. Technology Convergence Transformation Differences

In the United States, most research focuses on companies and enterprises. According to US statistics, the proportion reached 72 percent in 1966. In China, government departments and affiliated research institutions are the main scientific research organizations. This has a direct bearing on the differences between the two countries in the convergence of scientific and technological achievements. Most research done in US enterprises and has a clear goal so that the demand for knowledge transformation results in reducing intermediate links significantly. At the same time, the United States venture capital is growing rapidly. It had reached $32 billion per year by 1998, about $56 billion per year by 1999, providing good conditions for the favorable outcome of high-tech transformation. In China, most research is done in Chinese Academy of Sciences institutes or universities. These lack the capacity for industrialization. On the other hand, enterprises rely on the interest and demand in selecting research areas. Thus the conversion rate is much lower so that the contributions of science and technology to economic development is much lower than in the United States.

V. Intellectual Property Protection Differences

The protection of intellectual property is the main difference between Chinese and US science and technology operations. American enterprises and institutions all regard protecting intellectual property rights as important. On one hand, the US government employs legal mechanisms for the protection of intellectual property rights. On the other hand, researchers constantly focus on intellectual property protection. Although government-financed basic research results are available to the public, other proprietary research results funded by government agencies or companies must be kept confidential. In order to apply for a patent, a project team makes its intention to file at the very beginning of a project. It also signs intellectual property protection agreements with visitors, visiting scholars and staff which participate in international conferences. In China, intellectual property protection has aroused great attention. Although many problems remain, China's government and the Chinese people are doing their best to improve the intellectual property protection environment and perfect related systems and measures.

VI. Technology Promotion Institutional Differences

In the United States, the government plays a significant role in the promotion of science and technology. Since 1980s, the federal government has assigned a high priority to the transformation of scientific and technological achievements into tangible products and processes, and set up full-time departments to co-ordinate and monitor the development and industrialization of scientific and technological progress. The government takes the lead in strategic planning, legislation, policy, finance, information, and education. It assists in access to capital, technical assistance, procurement assistance, and intellectual property protection assistance to promote science and technology directly and indirectly. The federal government has invested substantial resources in the promotion of scientific and technological achievements, including the evaluation of technology-based industrialization. In addition, the government also set up an independent technology transfer center to establish a national research database providing comprehensive conversion services to promote scientific and technological achievements for the development of technology-based industries. Two important institutions are the National Technology Transfer Center, and the Council of Federal Laboratories for Technology Transfer.

The transformation of scientific and technological achievements into tangible ends is a very complex process. Government policy effectively promotes the success of the transformation of scientific and technological achievements. Since 1980, the US government has adopted a series of laws and regulations promoting technology development, including the Bayh-Dole Act (1980), Technology Innovation Act (1980), Small Business Innovation and Development Act (1982), National Cooperative Research Act (1984), Federal Technology Transfer Act (1986), Integrated Trade and Competition Act (1988), National Competitiveness Technology Transfer Act (1989), Technical Priority Act (1991), Small Business Technology Transfer Act (1992), the National Technology Transfer and Promotion Act (1995), the Federal Technology Transfer Commercialization Act (1997), and the Technology Transfer Commercialization Act (2000).

Since reform and opening, China's government has strengthened the scientific and technological transformation and promoted legislative work; formulated the Law of Scientific and Technological Progress, and the Law on the Promotion of Scientific and Technological Transformation, among others. It has published reports on Decisions of the Central Committee of the Communist Party of China, and of the State Council, on strengthening technological innovation, development of high technology-based industrialization and other relevant regulations as the legal basis for relevant policies. But China’s policies and systems are imperfect. The establishment of government responsible government sectors and other departments to promote science and technology, the civil laws defining and building intermediaries, and the government's financial support mechanisms have no detailed provisions in the law. In the promotion of technological innovation and the promotion of small enterprises to small enterprises, such as technology transfer with no legal protection and benefits, the cooperation between the government and the business community in the lack of legal protection need to be strengthened.

China initially established a technological transformation system between the government and local service systems. Governments at all levels have full-time technology services sector, as most areas have semi-official and semi-private technology service markets. These technology service markets aim for the transformation of scientific and technological achievements, the provision of information, and the assessment of results. Some areas have also set up science and technology incubators and venture capital companies, but the systems are still not perfect and are far from meeting the requirements of transformation and the promotion of science and technology. National technological transformation has not been established. Barriers still exist between functional departments and between these departments and industry, such as unreasonable restrictions on science and technology by local governments on science and technology and backward local building regulations. Furthermore, the country's laws and regulations are not properly implemented, the intermediary service can not be effectively carried out, and the government's financial support is inadequate.

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