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# MILITARY TECHNOLOGY ADAPTATION AND DEVELOPMENT IN CHINA

by

David Reeths

FINAL REPORT
APPENDIX II



Project on National Technological Competitiveness and the Barriers to the Revolution in Military Affairs

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## Executive Summary

The primary goals of this paper are to assess the ability of the People Republic of Chinaís ability to create, manufacture and market technology based products, especially defense technologies, and to examine the ability of the PRC to exploit a future Revolution in Military Affairs. This analysis examines the history of Chinese technology policy as well as organizational links between business and government, the role of foreign investment, educational, social and economic reform and popular values and attitudes within China in order to gain a better understanding of what Chinaís military technology base will look like roughly fifteen to twenty years in the future. While these indicators reveal that the Peopleís Republic of China has made important and substantial advances in reforming and expanding its technology base, there are still substantial barriers to rapid technological progress.

Chinaís ability to adapt advanced military technologies has been hindered first and foremost by a trend of dramatic and sudden shifts in technology policy at the national level. From its inception till the early 1960s, China was reliant on the Soviet Union for technology transfers as well as on the arbitrary decision-making procedures and rigid mechanisms for development that characterized the Soviet model of technology design, development and production. With the deterioration of relations between the Soviet Union and China in the late 1950s and early 1960s as well as the relative chaos of the ensuing Great Leap Forward and the development of a ìpeopleís warî strategy for national defense, the Chinese defense and technology industries became displaced both geographically and in an organizational sense.

Currently, China is undergoing another shift. It is moving from an emphasis on self-sufficiency and the primacy of military technology towards an integration of military and civilian technological development as well as increased reliance on foreign multi-national corporations.

At the core of Chinese technology policy is a fundamental and unwavering faith in the ability of their best and brightest to perform almost magical feats of reasoning and prediction. This faith is seen in the Chinese insistence on leap-frogging over intermediate levels of technology and concentrating on new and high technologies that China has shown little capacity to adapt or develop.

This deterministic mode of thinking may impede the efficient development and adaptations in military technology in another important sense. The Chinese do not seem to distinguish between a military technical revolution and the much broader concept of a revolution in military affairs. This emphasis on the technical aspects of military change raises questions as to whether the Chinese will be able to properly absorb any new and high technologies into their military if they ever become able of adapting such technologies.

China is further hindered by a limited number of sources for R&D funding. The Chinese have stated their spending goal for R&D to be 5% of GNP, but they are currently nowhere near that mark; instead hovering around 0.5%. The Chinese government is attempting to involve industry more actively in this funding process, but by so doing the government runs the risk of increasing the influence of the market on technological development and decreasing the influence of the state.

Where the Chinese have proven effective in moving toward more efficient development, adaptation and production of new technologies has been on the ihumanî side of the equation. Educational resources continue to improve in China as does the mobility of the increasing Chinese intellectual resources. With economic and social reforms leading to a better standard of living in some parts of China, more of the vast numbers of Chinese students studying abroad are returning home. This trend will almost certainly produce dramatic increases in both the quantity and quality of science and technology human resources available to the Chinese military-industrial structure. Still, there are serious legal questions concerning intellectual property rights, especially between the Central government and local authorities who may see lax enforcement of copyright laws as a means to increase the flow of resources into their locality.

The Chinese appear to be taking a dual-track to weapons modernization with one track stressing the short-term and the other a bit more far-sighted. The short-term plan is to acquire the best available military technology and production expertise through non-standard means of diffusionôoffsets, hiring of foreign scientists. The longer- term plan centers on building the basic Chinese technology base through primarily commercial activitiesôtechnology transfers through foreign MNCsôwhile also improving the domestic science and technology infrastructure and environment. If such improvements can be sustained, China will be more likely to create the conditions necessary for broad-based innovation in high technology industries within fifteen to thirty years.

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"Because national defense high technology is by its nature having multiple technologies, the differences between defense and civilian technology is becoming smaller and smaller. The trend of the interchangeability between the military and civilian is on the rise, allowing the technical foundation for an accelerated modernization of national defense and to realize the steady improvement of weapons."

--Vice Minister of the Commission on Science, Technology, and Industry for National Defense Huai Guomo, in 1993

**China Case Study- Introduction**

This paper examines the factors relevant to the People's Republic of China's attempts to expand its capacity to create, manufacture, and market technology-based products, especially defense technologies. Our analysis probes a variety of indicators of future technological capacity and will focus on what China's military technology base will look like early in the twenty-first century, roughly fifteen to twenty years in the future.

Our approach in Phase II is the use of an intensive case study. In the China case study we examine explicit or implicit national strategies for development and support of high technology industries, as well as whether there are organizational links between business and government that will allow for the transfer of civilian technologies to the military. The values and attitudes of the populace and government toward high technology development and their implications are also addressed.

In addition, we survey the current and likely future status of Chinese capital markets, and the role of foreign investment in the Chinese economy. We also investigate how China's educational structure has affected its potential to become a technology-based industrial nation and how the Chinese are addressing the deficiencies of their educational system. We examine research and development expenditures, the evolving notion of intellectual property rights, technology diffusion processes within China (including the roles of foreign corporations), and the development of technical human resources. Our analysis also focuses on how market and non-market forces are creating incentives for Chinese firms to more efficiently use available resources.

Through our analysis we conclude that while the People's Republic of China has made significant advances in reforming and expanding its technology base, there are still substantial barriers to rapid technological progress. China's ability to develop a capacity to innovate in high technology industries is hampered by lingering malaise from its command economy period as well as the difficulty of addressing multiple, and often conflicting, domestic policy arenas. The sum effects of these processes will likely prevent China from achieving an ability to produce cutting-edge weapons systems within the fifteen to twenty year period addressed by this case study.

**China's Technology Development Institutions**

Whether China will be able to achieve a capacity to indigenously innovate and produce effective weapons technologies will determine how the U.S. military must respond and prepare to meet the needs of the 21$^{st}$ Century. While the ability of the Chinese to achieve this goal is still in doubt, it is clear that Chinese leaders are well aware of the link between a high-technology capacity and national power. General Ding Gengao, Chairman of the Commission on Science, Technology and National Defense Industry (COSTIND), stated in 1994 that "Weapons modernization is, in the final analysis, determined by the modernization of our defense science, technology, and industry." (Pillsbury, 156)

China's current strategies for technological development are directly related to past attitudes and decision-making processes that have gradually evolved since the founding of the PRC. Therefore, any attempt to determine the extent and direction of China's progress must begin with a careful examination of both past and present institutions responsible for weapons technology development and production. Since the birth of the People's Republic of China in 1949, these institutions have undergone several periods of profound change.

Immediately after the birth of the PRC, the Chinese Communist Party (CCP) was understandably preoccupied with consolidating their control of the country in order to ensure the survival of the new nation. The Korean War also consumed much of the elite decision-makers' time and energy during the early 1950's. But by 1953, the CCP felt comfortable enough with their immediate situation to turn their attention to more long-term development of the nation. Thus, the modernization and production of weapon systems was made an extremely high priority. The CCP established a system of technology transfers that was governed by two fundamental characteristics: 1. a dominant role for the Soviet Union as the supplier of new technologies and 2. the preeminent demand for defense technologies. (Feinstein and Howe, 2)

Transfer of technology from the Soviet Union was extensive. The transfers included whole production plants, as well as blueprints, technical literature, training programs and personnel exchanges. The Soviets also recognized that development required basic technical skills and a knowledge base, and they assisted the Chinese in upgrading and transforming their system of higher education. This assistance included establishing a network of research and design institutions directly patterned upon the Soviet model. (Feinstein and Howe, 3)

This production structure and educational system together constitute the "Soviet model of science and technology development and production." The Soviets closely directed the CCP in formulating an extremely ambitious long-term science and technology development plan. The plan, though, was seriously flawed. The timetable for development was overly optimistic, and in retrospect, the Soviet model of science and technology development and production contained many barriers to the development of high-technology innovation in all but a few well-defined areas.

The Soviet production model consisted of two fundamental characteristics that arrest the evolution high-tech innovation: 1. Arbitrary decision-making and 2. Rigid mechanisms for technology development. First, under the Soviet model, decision-making in the S&T arena was notably arbitrary. The whims and preferences of individual leaders determined the direction and pace of the endeavor. In China's case, Mao Zedong demanded rapid development, and more realistic approaches to development were denounced as rightist. The importance of individual decision-makers in this system meant that success was premised upon the ability of the individuals in charge to process and utilize information perfectly as well as a highly efficient system of information transfer to the decision-makers. Neither was available in China during this period. The now infamous experience of the Chinese in developing "backyard steel mills" during the Great Leap Forward illustrates how the arbitrariness of the decision-making was detrimental to the S&T development of the nation. (Spence 1990, 580)

Only a very few military and closely related projects that were afforded extremely high priority status achieved any real degree of success, mainly nuclear weapons and rockets. While these projects were able to overcome arbitrary decision-making because of the resources that Mao and the PLA directed to the programs, they were still caught up in other detrimental mechanisms of the S&T organization. These factors, which will be discussed in the next section of this study, retarded further development of these projects such that even the "successes" failed to advance markedly over the first production models. Furthermore, technological problems continue to plague even these high-priority projects. (Feinstein and Howe, 78)

Second, the Soviet model also produced rigid mechanisms for technology development. Though centralized control of the process led to successful transfer of a limited number of technologies from the USSR, the institutions and organization of the model denied the active interactions necessary to produce a system of innovation and productivity growth. (Feinstein and Howe, 4) A key deficiency of the system was a tremendous gulf between the research and development facilities and the industrial enterprises. (Feinstein and Howe, 3) On an organizational level, research and development and manufacturing were located in parallel and separate departments within the S&T community. This meant that once an initial version of a product was produced, R&D had very little contact with the factories.

The contact that was able to occur was often distorted as it was filtered through several layers of organizations and officials. If a particular factory had a need they believed could be effectively articulated through the protracted intercommunication procedures, they needed to send a request to the production department of their associated bureau. The production department would then decide whether to forward the request in some form to the bureau itself.

If the bureau decided to act upon the request, they would convey yet another form of the request to their R&D department. The R&D department would then task the request to a research and design institute. Thus, even if the request was eventually passed to an institute, the R&D team would have had *no direct contact with the requesting factory*, and the request would have been filtered through several organizations, each with their own goals and operating procedures. This again illustrates how important individual decision-makers were to the system. Overcoming these obstacles meant establishing personal networks that could assist in information transfer and bypass several layers of intervening agents.

Additionally, because the parallel organizations of R&D and production were often competing for resources within the same bureau, their relationships were usually highly competitive and often antagonistic. This situation was exacerbated by the extreme fluctuations in funding allocations to each bureau from year to year, again caused by the arbitrary nature of planning and prioritization at the highest levels of the CCP and the central government. Thus, the bureaucratic nature of the relationships stifled communication and was rigid and restrictive. (Feinstein and Howe, 74) Production staffs had little impetus to over-burden themselves by consuming large amounts of time attempting to upgrade products when they knew that even solving immediate R&D related problems would consume a great deal of their ever fluctuating resources.

In house production support was also inadequate. The few maintenance technicians that were located on the production side were unable to provide more than a minimal technological support. (Yu, lecture 3/31/98) The centralization of decision-making and separation of the departments and the parallel organizational structure led to a lack of horizontal linkages. The result of this deficiency was that the system was able to develop initial versions of products that were operational, but the technology involved stagnated as the R&D staffs moved on to other tasks assigned by the ministry.

Another important deficiency of the Soviet system was its lack of income incentives, for both firms and individuals, and price incentives. Because the success or failure of the R&D teams was judged above and separate from the production of the final output, there was little incentive for the teams to consume time and resources making the actual manufacture of the product as cost-effective and as efficient as possible. Once a product was "good enough", it was rational for the team to rapidly move on to the next tasked assignment. (Feinstein and Howe, 74) R&D teams were also separated from their peers by layers of bureaucratic walls, which led to little exchange of acquired and developed knowledge and no positive competition between separate R&D institutions.

The production side also operated under an incentive system that obstructed innovation. Because of the extreme backwardness of the economy and the pressures exerted by a burgeoning population, the Chinese planned economy clearly rewarded increases in output above all other concerns. This created a situation where quality became secondary, and the time necessary to improve product design or production processes was viewed as detracting from output. Product redesign and production process improvement were therefore against the interests of enterprise directors whose bonuses and chances for advancement were based almost solely upon exceeding targeted output. (Feinstein and Howe, 75)

The lack of income and price incentives also affected the pace and quality of manufacturing. Shop floor individuals also had a strong incentive to fight aggressive production increases that would lead to the factory exceeding their quota. Because the individuals directly generating products were aware that sudden increases in production would create unreasonable expectations that the growth could and would be sustained over time (which would then lead to skyrocketing quotas), they rationally eschewed rapid increases in production. (Yu, lecture 3/31/98)

**Macro Societal and Political Hindrances**

The various elements of the Chinese S&T community, including scientists and technicians, government officials within the defense and production ministries, and even factory managers, had little opportunity for success under these organizational and institutional conditions. The lingering effects of these processes constitute a formidable barrier to economic and technological progress. In addition to these difficulties, the Chinese S&T community was also constantly buffeted by a turbulent social and political climate. The S&T community was detrimentally affected by several intense macro-level phenomena that influenced and corrupted their ability to product high-technology products and weapon systems.

The first major event that assailed the Chinese S&T community was the deterioration of the relationship between the PRC and the Soviet Union, by far their primary source for technology transfer. Early in the 1950's, it became clear to the CCP leadership that they could not rely upon the USSR to be a limitless ally. Stalin's failure to support Mao in his decision to resolutely aid their communist allies on the Korean peninsula planted seeds of mistrust and animosity in both leaders' psyches. Mao became convinced that Stalin would not follow through with his promise to provide the PRC with atomic technology, an instinct that proved an accurate assessment of the situation.

As the political relationship between the countries deteriorated throughout the 1950's, technical relationships were gradually terminated. In September 1960, all 1,360 technical advisors from the Soviet Union were withdrawn, taking their blueprints with them. (Spence, 589) The newly transplanted industries in the PRC were thus cut off from needed replacement parts and related technical knowledge. China's S&T establishment, which was completely dependent on the Soviet Union for almost every aspect of their attempt to achieve technological development, was devastated.

The CCP was deeply affected by the Sino-Soviet Rift, and the principle of "self-sufficiency" became a guiding axiom for China. The Chinese leadership became extremely wary of any relationship that could put the nation in a position of dependence. However, the Sino-Soviet Rift was just the first major catastrophe that disrupted China's S&T community and impeded their ability to produce high-technology innovation; the Cultural Revolution and its tumultuous consequences loomed just on the horizon.

The early 1960's was a period of both shining success and glaring failure for China's technological community. As mentioned earlier, their most notable success was producing a functional nuclear weapon; the first successful atomic test was conducted on October 16, 1964. (Spence, 598) However, outside of a few extremely high-priority projects whose resources and development were managed by top leaders of the party and PLA, S&T development stagnated. The Sino-Soviet Rift also renewed fears that the PRC was vulnerable to land attack, and the CCP quickly diverted vital resources away form direct technological development in an attempt to improve their strategic condition.

In an attempt to assure that the nation would be able to hold out against sudden loss of Northern and Coastal territory (presumably due to an invasion by the Soviet Union or the Nationalists in Taiwan), in 1965 the CCP ordered the relocation of a large portion of the military industrial complex to inland, mountainous regions. This was necessitated by the defense strategy chosen, "people's war". This strategy consisted of allowing for the loss of vast amount of territory during an invasion in order to preoccupy the enemy while a vast counter force was mobilized from the Chinese population. (Pillsbury 1, 3) "People's war" required that some defense industries be located outside of the vulnerable zones adjacent to potential adversaries. The relocated defense industries, the so called "3rd Line Industries", were thus further isolated from civilian S&T resources, including the bulk of the nation's higher education institutions. (Yu, lecture 3/31/98)

The almost fanatical adherence to this policy of self-sufficiency, combined with the consequences of the "people's war" defense strategy and the existence of few indigenous scientific resources, left the Chinese S&T community with few options in strategies for technology development. The Chinese leadership directed the S & T community to rely on copying and reverse engineering as the primary mechanisms for assimilating high-technology. (Feinstein and Howe, 4) But, due to the lack of sophisticated knowledge of the underlying technologies upon which the high technology items were based, these efforts based upon copying and reverse engineering were largely unsuccessful.

In late 1966, fearing that the Chinese Communist Revolution had been captured by lingering elements of foreign and bourgeoisie elements of thought in the Chinese culture, the CCP encouraged a movement that would blossom into the Great Proletarian Cultural Revolution. (Spence, 603-606) The Central Committee initially attempted to protect scientists and technical personnel from the growing swarms of fanatical Red Guards, but Mao and his designated successor Lin Biao only encouraged even further radicalism of the movement. By the winter of 1966, all schools and colleges had been closed down, and the teachers, scientists, and technicians that made up China's S&T community became some of the key targets of the Cultural Revolution. Only a few critical sites such as the Daqing oilfield technical facilities and the research facilities devoted to the development of a hydrogen bomb were protected by the only functioning organization in the country, the PLA. (Spence, 610)

The Cultural Revolution once more cracked an already weak S&T establishment. The political upheaval that followed the death of Lin Biao after an apparent failed coup in September of 1971 added additional distress to the Chinese S&T community. It wasn't until 1972, when the political climate became more stable and more favorable to Western influences (as a strategic buffer against the Soviet Union), that any significant attempts to address China's poor S&T position were begun.

**Reestablishing Foreign Relations**

In 1972, after political relations with the United States and Japan had been normalized, the PRC attempted to rapidly bolster its technical position through a series of whole plant imports in areas of immediate concern, such as steel making. However, Chinese expectations of their ability to assimilate foreign technology in the 1970's again outstripped reality. (Feinstein and Howe, 5)

This review of the history of China's attempts to achieve a capacity for sustained high technology innovation shows that the leadership has really only been able to make this a critical goal on a sustained basis since 1978. Between the period of extreme isolationism ushered in by the Sino-Soviet rift and prior to the Deng Xiaoping era of reform, the CCP had unwittingly insulated itself from the grim reality of its technological standing. The PRC's only window to the tremendous acceleration in the pace of technological development that was occurring in the West was its diplomatic core, and until Nixon's visit in 1972 even this was limited due to the formal recognition by a majority of nations of the Guomindang government on Taiwan. The lack of formal recognition of the Communist government by foreign powers also reinforced the long-standing trait of xenophobia that is a part Chinese culture.

Even after rapprochement with the West, Chinese diplomats proved to be a poor source of information. Because the selection criteria for the diplomats was largely based upon ideology, rather than more objective qualifications, diplomats were unwilling to bear the bad news to the premier leadership. Thus, the same ideological characteristics that made a cadre a good candidate for selection to the Chinese diplomatic service also proved detrimental to their producing objective comparisons between the PRC and the West. (Yu, lecture 4/21/98) Deng's accession to the position of preeminent leader ushered in profound transformations in China's self view and S&T development strategies. China today is infatuated with technological progress, and the quest for high technology has indeed acquired a cult-like following in some Chinese decision-making circles.

**Deng and the Reform Period**

The sum of the impediments to technological progress led to conditions where the creation of sustainable innovation was impossible, especially in the R&D intensive high-technology arena.

After the death of Mao Zedong in 1976 and the resolution of the power struggle that ensued thereafter, Deng Xiaoping emerged as China's preeminent leader. Deng immediately set in motion a process of fundamental reform of the Chinese economy. One of the most important changes that occurred during the 1980's was a shift in the types of technology that the China attempted to assimilate. During earlier periods, especially the 1970's, their focus was on obtaining extremely advanced, cutting-edge technologies. In the 1980's, the focus gradually shifted to obtaining "advanced, appropriate" technology. (Yu, lecture 4/7/98) As the immediate security position of the PRC steadily improved, the government's priority in S&T development became the renovation and improvement of conventional industry. (Yu Chapter 11, 1) The specific public policy programs that were created during this period to develop the China's technology capacity will be discussed later in this piece.

**Science and Technology in the 1990's**

Because China's basic level of technological competence improved dramatically since the reform period began in 1978, beginning in 1991 there was a further shift in the types of technologies designated for acquisition. Instead of "advanced, appropriate" technology, the emphasis has been on "high or new" (new to China) technologies. (Yu, lecture 4/7/98) The government also explicitly promoted rapid development of high-technology industries. One reason for this shift was the recognition that development of these industries would help improve the international status of the PRC and international perceptions of China's national power. (Yu Chapter 11, 1) This international status was perceived to be important because the CCP needed to construct alternative sources of popular legitimacy in preparation for Deng's absence as a cohesive force. The CCP believed they needed to improve one of their strongest claims to legitimacy, the rising nationalistic pride that had accompanied recognition and more active Chinese participation on the world stage.

During the mid to late 1990's Chinese leaders appeared to believe that the country had reached a level of S&T development that allowed for more rapid absorption of advanced, even cutting-edge, technologies. The leadership on occasion pointed out that the maturation and liberalization of the Chinese domestic market forced a change in this direction. They noted that the rapid development of the Chinese economy has meant that domestic firms faced increased competition from foreign firms that entered the Chinese market; by 1998 over one half of the 500 largest firms in the world were actively participating in the Chinese domestic market. (Yu, lecture 4/7/98)

Several guidelines have been put in place to direct this latest round of reforms. One of the most important guidelines of the reform period is making domestic economic development the number one priority of the reforms. This includes explicit directions to coordinate macro level changes in both the economy and the overall societal picture. During the period of "Socialism with Chinese characteristics", or market socialism, more emphasis has been placed on the quality of the product. This is quite different than strictly judging performance on the quantity produced as in the past under the planned economy system. (Yu, lecture 3/31/98)

Additionally, the Chinese expect that the participation of more decision-makers from higher levels of government and a more democratic (within the CCP) and a "scientific" approach to policy formulation will produce better results than in the past. (Yu, lecture 4/7/98) New, more "scientific" methods of decision-making based upon analysis of standardized, empirical data are expected to bring relevant factors from local conditions and broad effects of each production project into the calculus of the decision-making process. Recognition of this attempt to coordinate economic and societal development can allow for much clearer understanding of many controversial aspects of Chinese S&T policies. *It is vital to recognize that the CCP still fears societal chaos and reforms attempt to balance stability and economic growth, even at the cost of short-term rapid economic development.*

Another guideline of the reforms has been explicit direction to consistently support the development of production technology or applied technology. This was a fundamental shift from a concentration on producing seemingly single-use technologies specifically for military use. (Yu, lecture 4/7/98) Chinese decision-makers believed that they could improve the production process through the twin forces of market demand and expert guidance that industries focus on quality as much as quantity.

The decision-makers responsible for S&T development have also tried to encourage closer relationships between R&D departments and production departments through incentive reformulation. Part of this organizational reconstruction is making the likely overall economic benefits and manufacturing potential of specific proposals a consideration in selecting a portion of the basic research that will be supported. This reform is also intended to encourage closer relationships between R&D and production and design, thereby helping the Chinese to evolve a more rapid cycle for the development and implementation of new technologies. (Yu, 4/7/98)

One of the most important strategies that the PRC has followed to reform their S&T system has been the targeting of specific higher technologies for acquisition. This has been accomplished by direct government involvement in determining what types of foreign investment and involvement will be allowed into the domestic market. The Ministry of Foreign Affairs, after consultation with the State Commission on Science and Technology, annually publishes in *Beijing Review* a three-tiered list of technology areas that are 1. "Prohibited from foreign involvement", 2. "Restricted in specific ways from foreign involvement", or 3. "Encouraged to have foreign involvement". In addition to promoting the development of certain technologies, the list also serves to help prevent Chinese firms from attempting to purchase technologies that are already well established in the nation, thereby helping to prevent duplication and the out flow of needed capital.

The government also plans to strengthen the nation's manufacturing enterprises and have them play a key role in S&T growth and development, calling manufacturing "the main battlefield for technology development." (Yu lecture, 4/7/98) Organizational change will be the major factor in accomplishing this goal. As mentioned earlier, in the past the manufacturing facilities had very little control or access to R&D resources. Production processes and technologies were expected to improve through the use of projects that used mass mobilization of the general population as a research team. The mass mobilization strategy dictated that every high school, university, and research institute would attempt to work on the problem, even if the institution did not possess resources appropriate for research on the problem. The reformers of the 1990's acknowledge the futility of this type of R&D strategy. In order to improve the nation's R&D in high technology, manufacturing facilities will be encouraged to cooperate with and develop ties to nearby institutes and universities.

An additional factor which restrained production advances was that factory managers had to answer to two very different authorities, the local or regional administrators and the central government. These authorities often had very different priorities. This also helped to solidify the importance of gains in "quantity", the one measure that was inherently appealing to both levels of authority, as the primary measurement of success and improvement in factories. The government has also been making an explicit attempt to allow firms to be controlled more by market forces and less by the "two legs" of local and central government. (Yu. lecture 4/7/98).

**S&T Personnel and Basic Research**

Another area of S&T policy that has recently received renewed emphasis as part of the reforms in the 1990's is the need for more basic scientific research. The Chinese now recognize that their basic scientific research suffered in the 1950's, latter 1960's, and early 1970's. This was because of the turbulent nature of their international situation and the great political and social movements that almost continually rocked their nation, especially the Great Leap Forward and the Great Proletarian Cultural Revolution. One result of these periods of upheaval was that their best scientists and technicians often fled the country in search of a more stable working environment. (Yu. lecture 4/7/98) Generally poor living standards also contributed to the loss of many of China's best minds to Western nations.

There are signs that this "brain drain" is slowing. Though many of the students who participated in international student exchanges since the beginning of the reform period in 1978 have decided to remain in their adopted nations, a considerable number of students have returned to the PRC. Of the over 250,000 Chinese students who have gone abroad to study at foreign institutions of higher learning, over 80,000 have returned home. (Qin, 194-195) As Chinese living standards continue to increase and should the PRC continue the current trend toward a more open society, it is reasonable to believe that more students will return from their overseas studies.

The Chinese believe that as available resources increase, they will be able to provide social and political stability that will support *stable* *and continual basic research.* Part of the expression of this priority has been improving the funding for research and development. Much of the targeted portion of GNP that is to be spent on R&D nationally is to be directed toward basic research. This should also help to attract and retain qualified technical personnel.

**Societal Change**

Some observers also believe that as the overall average technological proficiency of Chinese society rises, the nation will be better able to assimilate high technology. Many policies of China's reform period have contributed to rising technological proficiency, some to an unanticipated degree. For example, China's "one child" policy has had the unintentional effect of increasing the average resources available to children in urban areas (where the policy has been most effective). In the 1990's, computer purchases and use in China has skyrocketed as families scrambled to equip their "little emperor or empress" with the most fundamental instrument of high technology. Furthermore, as of early 1998 over a half million Chinese had access to the World Wide Web. (Yu, lecture 4/7/98) While this is a small proportion of the Chinese population, in absolute terms it is one of the largest online populations outside of the United States.

Perhaps the most important guideline for China's high technology development plans has been more sophisticated use of available foreign technology. (US Department of Commerce- Global Strategies) Past emphasis on domestic development through copying and reverse engineering in order to maintain self sufficiency at all costs has declined. Instead, the S&T community has recognized that while acquisition of foreign technology is important, more resources must be devoted to assimilation and absorption of available technologies. (Yu, lecture 4/7/98) The additional "know how" required for actual operation of the technology that can lead to better assimilation and absorption can often constitute over 20% of the transfer costs.[1]

*Therefore, if the Chinese are going to allocate the same amount of resources for technology transfer, selection of which projects to pursue will become even more important.* However, it should be remembered that the comparison must be between fewer projects transferred at a much more complete level or more projects transferred with less success (with the likelihood of few long-term gains). Should the government insist on playing an extremely active role in technology selection (rather than allowing market conditions to operate), then there is a great risk of mis-selection of projects and waste of resources.

**Management Reforms**

The shift in the focus of technology transfer is not the only major change in Chinese S&T policy. The government has encouraged concurrent management reforms that are structured to encourage innovation in China. At the individual level, the core mechanism of the management reforms that promotes high technology growth *is to treat high technology as a "commodity", or intellectual property, and compensate those responsible for information creation.* The reforms attempt to put into place an active technology market with a large and mobile core of scientists, engineers, and technicians. (Yu, lecture 4/14/98) Several

[1] Note: This figure was determined through study of the rather favorable conditions inherent in transfer from parent companies to overseas subsidiaries; assimilation in China will often be conducted in much more difficult conditions. (Feinstein and Howe, 19)

types of reform policies have been implemented that support this mechanism.

Modernization of the mechanisms of research fund allocations has been a focal point of the reforms. In the past, the state was the only source of funding for S&T research. This was largely a symptom of the lack of cross linkages between R&D and industry and the lack of a market structure. Within the state allocation system funds were distributed based upon the size of the research institution and the number of staff members. (Yu, lecture 4/14/98) Little regard was given to the costs of the work or the quality of the work being done. When state budget funds were lacking, across the board reductions were usually implemented.

The lack of funding stability was particularly disastrous for high technology projects because of the large proportion of budgetary items in both labor costs and capital expenditures that are fixed costs for these technologies. This dependence on fixed costs is a fundamental characteristic of high technology. It is reasonable to assume that when push came to shove research directors sacrificed maintenance and other subsidiary expenses in order to ensure the payment of staff salaries to their colleagues who served under them.

Under the latest round of reforms, the government and the S&T community are attempting to diversify the sources of research funding. One way this is being accomplished is through encouragement of developmental research and applied research with near term benefits. Because of this explicit focus, once a small amount of seed money has been granted by the state, industry is expected to become interested in the research earlier and contribute funding earlier in the development cycle.

This end may prove difficult, though, due to another of the fundamental attributes of high technology research - *high-risk*. High technology research is by its very nature a high-risk endeavor, and a very small percentage of the projects initiated will furnish technologies that will prove competitive in terms of profit, in civilian products, or in terms of quality and cost, in defense products. (Johnson) The government's success in attracting funds from industry into all but a few very promising projects may be difficult. However, in the near term a general shortage of scientists, engineers, and technicians seems to be attracting industry to technical institutes; fifty-seven research institutes that used to receive all of their funding from the central ministry are already raising more than half of their funding from outside sources. (Yu, lecture 4/14/98)

Still, we are not likely to see a modern venture capital market emerge at any time in the near future. During the late 1980's and early 1990's, the government attempted to create a "venture capital" market, but found that most Chinese investors were not sophisticated enough to prevent wide-spread fraud. Instead of helping to develop small enterprises, the venture capital market became a tool of speculators and charlatans. Thousands of people lost their life savings in pyramid schemes, and the public outrage that traditionally follows large-scale scams can threaten economic reform.

In order to allow time for the Chinese investors to become more savy while still insuring the availability of some venture capital, the government is trying to encourage Hong Kong and Taiwanese investors to state. One problem that has already become apparent is that few of the students who return from receiving higher education abroad enter into basic research; most of the best and brightest enter industry. (Yu, lecture 4/14/98) While this is an encouraging sign that a market place for technology is developing in the PRC, if the government is unable to find a way to attract its best students into basic research, then there is little chance that the nation will be able to accomplish their goal of expanding the leading edge of high technology research. However, the Chinese military may be able to use advanced, but not leading edge, technologies in novel ways in order to construct a competitive force.

**The Chinese Defense Sector**

The post-reform defense sector has suffered from "a problem of identity; one day they are told to go out and make money, and the next told to pay attention to political objectives." (Frankenstein and Gill, 399) However, the indigenous industries that supply the PLA also realize that they can look forward to a growing Chinese defense budget, one of the few growing defense budgets in the world. Like the many other large state owned enterprises, some of these defense firms are still having trouble adapting to rapidly changing conditions and increasing competition, especially on the international front. After almost a decade of semi-dormancy, Eastern European nations are reemerging as competition for foreign military sales. ("Buyers, Please", *The Economist*)

The PRC has also become quite accustomed to using forms of nonstandard diffusion in attempting to acquire high technology, such as off-set agreements and ownership arrangements that revert to the Chinese partner after a specified period of time. These types of arrangements are especially prevalent in high-technology weapons transfers. China has probably leveraged the oversupply of the arms market to its advantage better than any other nation. As China's economy has grown since economic reform began in 1978, their resources have grown steadily. Unlike the rest of the world, China and its neighbors have used their increasing resource bases in a clear arms race to improve both the quality and quantity of their weapon systems. The continuing over capacity of the global arms market has meant that they have had no shortage of prospective arms vendors.

As the Middle East arms buying boom of the early 1990's declined, China's spending continued to increase, and it became a premier purchaser of advanced weapons. China's growing economic might made it a target for sales growth for most defense manufacturers, often despite the concerns of the companies' governments. This work will not attempt to catalog all of the major weapons transfers that have taken place in recent years (see Gill and Kim and various *Jane*'s publications for many examples). In 1994 China purchased over a billion dollar's worth of high technology weaponry from Russia alone, including advanced Su-27 fighter aircraft and missile systems. (Carey, 5) The Chinese have also taken advantage of economic turmoil in the former Soviet states by attracting top weapons scientists to assist in their ability to assimilate Russian defense technologies. (Carey, 5)

China is also using agreements with foreign multinational corporations (MNC's) to help improve their technological standing. Chinese research institutes and universities are attracting the attention of leading MNC's for several reasons. First, many of these institutions are extremely strong in fundamental sciences, and second, the companies see the joint research opportunities as an occasion to enter the Chinese market through the backdoor, that is, using research relationships to gain access to sales within the Chinese domestic market. (Rotman, S10) For example, DuPont has several research programs underway at several Chinese institutions, including research on organic synthesis, polymer science, and computational chemistry. The Western companies are called upon to provide assistance in developing production processes, an area of Chinese weakness. Assimilation of advanced production processes must be a key component of successful modernization of Chinese defense production.

**Other S&T Organizational Changes**

Two of the most promising developments that will help to promote the continued growth of the Chinese economy and the further development of high technology industries are the rapid growth of "information" infrastructure and advances in management procedures that has taken place in the last decade. Much of China is now being linked by satellites, fiberoptics, and microwave stations, thereby skipping several generations of technology. The number of telephones in China nearly doubles each year. Accounting procedures have also been reformed and improved through the integration of information technology and computer systems into local and regional governance. For example, as late as the mid-1980's it took nearly a month to determine government cash flow in Sichuan Provinence, but this basic accounting can now be accomplished in a single night. (Yu, lecture 4/21/98)

**Advantages of the Chinese Market**

In the five year plan that began in 1997, China announced that it plans to make a strong effort to lessen the importance of labor intensive industries in the Chinese economy. These industries are currently the core of their industrial base. (Yu, lecture 4/28/98) This transformation to production processes that utilize greater levels of technology is to be undertaken gradually and is expected to take approximately ten to fifteen years.

While many other nations in Asia have stated similar goals, China has an advantage that none of these countries can match. Because their huge domestic market is a tremendous enticement for global firms, the PRC can control the terms of trade and market access like few other nations. The Chinese have proven themselves very capable of controlling access to their market (for many good examples, see Stross, 1990). The three tiered technology access list that was mentioned earlier is an example of the type of policies that the PRC's decision-makers are using to further this objective. In 1995 the value of high-technology products exported reached $10 billion, a 58% increase over 1994. However, high-technology exports still constituted only 6.8% of total exports. (SSTC, *Science...*)

Further recognition of a long term commitment to developing continuous, indigenous innovation in cutting-edge high technology can be found in the State Science and Technology Commission's singling out of "selected newly rising industries". This policy of singling out certain types of high technology industries is an attempt to focus China's developmental resources on industries that are likely sources of domestic innovation. Through the mastery of key technologies and development in major industrial fields, a strong base for innovation within firms (especially large former state owned enterprises or SOEs) is hoped to be created. (Yu, lecture 4/28/98)

In late 1996 the State Economic and Trade Commission (SETC) issued a guide which identifies the key technologies that are to be developed through the year 2000. The guide identifies 166 technologies that "have good market prospects and are expected to have great impact on the national economy." Eighteen industrial sectors are included in the 166 technologies including power, petroleum and natural gas, coal, railways, other transportation, telecommunications, iron and steel, nonferrous metals, chemistry, petrochemistry, building materials, electronics machinery, shipping, light industry, textiles, construction, and medicines. (Xindeco Business Information Company)

The guide is meant to provide direction to large and medium sized SOE's in their efforts to modernize and become competitive. However, the SETC has also selected six companies for priority development and awarded each company $2.4 million per year for the next several years to develop new technologies. While this amount is not extremely significant in Western terms, it does constitute a relatively large amount in purchasing power parity terms, and it is symbolically important because it exhibits the government's commitment to the reform and transformation of the SOEs. The six "famous brands" are Baoshan Iron and Steel Corp, electrical appliance producer Haier company, computer manufacturer Founder Group, Jiangnan Ship Building company, and electronics giant Sichuan Changhong. The companies are expected to match the government's funds with their own R&D funding from internal revenues as part of the program. (Xindeco Business Information Company).

**Government Programs to Create Innovative Capacity**

The Chinese Central government has established several programs that support the development of a capacity for indigenous cutting-edge innovation in high technology. Though the success of the United States Armed Forces in the Gulf War using high technology weaponry is often identified as the impetus for the increase in Chinese aspirations for high technology weaponry, the 863 program is evidence that other factors influenced the PRC's push toward modernization. Ronald Reagan's announcement in the mid-1980's that the US had prioritized the development of a space-based defense system not only challenged the Soviets, but also the Chinese who were deeply concerned about the technology advantage held by the United States. Deng Xiaoping realized his nation was in no position to manufacture and run a weapon system of this technological sophistication. Policy initiatives such as the 863 program were created as a way to close the existing technological gap between China and its potential rivals. (Yu, lecture 5/5/98)

The 863 program (so called because the program was launched during a March 1986 meeting of the State Science and Technology Commission or SSTC) is a fifteen year program that promotes research in selected fields of high technology. The plan specifically aims to facilitate national economic growth through the use of advanced science and technology in manufacturing. (Institute of High Energy Physics or IHEP) This focus of production efficiency is a marked change from the former emphasis on economic growth. The former emphasis was economic growth through bringing more resources or inputs into active use within the economy.

Through the 863 program, high technology research and development centers have been opened inside China, and up to 1996, 20,000 "high technology researchers", from Ph.D. scientists to technicians, had been trained because of the project. At a meeting celebrating the tenth anniversary of the 863 project, it was determined that during the remaining five years of the project biology, information technology, automation, energy, and new materials would be the focal points for supported research. (IHEP)

The 863 program has also been supplemented by the creation of research centers whose task it is to bring together the results of 863 supported research. These centers "attack" advanced technology and merge the R&D results of selected nation-wide research teams. The centers integrate and apply the results of the research conducted under the program and in order to produce marketable high technology. One example of this type of center is the National Research Center for Intelligent Computing Systems (NCIC) in Beijing, part of the Chinese Academy of Sciences. The center is staffed by 15 Ph.D. level scientists and more than 20 post-graduates. In order to accomplish its mission of producing marketable computer technology, the center carries out academic exchanges and other efforts that encourage international cooperation and information transfers, such as hosting foreign guest lecturers. (NCIC)

It is important to note that such centers are located in centers of technology creation, such as the university corridor in Northwest Beijing. This creates opportunities for the positive externalities such as economies of scale for support enterprises and the exchange of ideas and staff that clusters of high technology firms produce. These centers can also be the source of spin-off companies such as the Dawning Company, a computer manufacturing firm, that emerged from NCIC in 1993. (NCIC) The Dawning Company has produced a massive parallel computer system capable of 1.58 billion[2] calculations per second. (US Department of Commerce- Information Technologies)

In 1997, after the ten year anniversary of the start of 863, China began planning the second stage of the 863 program. The so-called "super 863" program (S-863) is a ten year plan that will cover the period of 2001-2010. This effort is expected to be broader than the original 863 and is to include even greater funding for selected programs. (Yu, lecture 4/28/98) The initial direction of the program was laid out five years before its implementation in order to "ensure persistent development of high technology in China" according to Zhu Lilan, vice-minister of the State Science and Technology Commission. (IHEP)

The S-863 program is also directly linked to the modernization of China's domestic weapons production. Infrastructure expansion supported by the State Science and Technology Commission and COSTIND are believed to provide the ability for China to domestically produce large warships, potentially including carriers in the 300,000-ton range. (Bruce Blanche, 10)

In 1988 the State Science and Technology Commission created the "Torch" program "designed to develop China [sic] high and new technology industries." (Business China) The Torch program was created with five goals in mind. The first goal of the program was to create an appropriate environment for the development of "high and new"

[2] Note: For comparison, systems of 2 Billion calculations per second are subject to export control in the United States.

technology industries. This was to be accomplished through integrated medium-term and long-term planning, information exchanges, and the creation of a venture investment mechanism. Representatives of the Torch program are also tasked to help formulate policies, laws, and regulations that would assist in the development of high technology industry. (Business China)

The second goal of the program was to assist in the creation of effective and well managed High and New Technology Industry Development Zones. The third goal of the program was to identify localities and industrial research institutions that when supported would develop technologies in five key fields: 1. New materials, 2. Biotechnology, 3. Electronics and Information, 4. Mechatronics (Automated Production), and 5. Energy technologies, essentially the same fields emphasized in the 863 program.

The fourth goal of the program was to internationalize the high technology sector in China. Cooperative relationships were to be established with leading S&T, financial, industrial, and commercial communities around the world. These relationships would not only allow for technology transfer, but they would create opportunities for Chinese products to compete on the international market through the use of partners' market access and distribution networks. The fifth task of the Torch program was to identify and train qualified technical personnel and S&T entrepreneurs.

The Chinese have already had success improving the level of basic sciences research, but because they consider basic sciences to be a cornerstone of modernization, they are continuing to use government funds for support of basic science research. Another government program, the "Scaling the Heights Program", is designed to consolidate a small number of highly trained and very promising young scientists. (Yu lecture 4/28/98) It is hoped that this core of scientists will be able to create a critical mass for innovation of cutting-edge high technologies. The government hopes to eventually spend about 10% of their total R&D budget on this and similar programs.

**Reform of the Higher Education System**

Expanding use of post-doctorates in research is itself a sign that China has significantly altered its system of higher education to become more like the systems of Western nations. At the urging of an influential scientist, Deng Xiaoping in May 1984 established a post-doctoral system in China, and the system was put into practice in July 1985. (CPC, "Use Imported System to Train Chinese Talents") This change brings the PRC's educational system much more in line with Western organizational standards, though there are important differences in the Chinese post-doctoral program.

The Chinese system is organized and funded by the government's "China Postdoctoral Council" made up of both scientists and government officials. The system emphasizes unified planning and gradual technological development. The council has supported the development of the post-doctoral system through such varied means as constructing housing for the post-docs and their families and expediting residency transfers. (CPC "Use...)

The program grew rapidly, expanding from supporting one post-doctoral student in 1985 to support for 728 post-docs in 1993. Over 80% of the postdoctoral programs are in the sciences (44.1%) and engineering (36.5%), with the rest largely conducting agricultural (4.7%) and medical research (9.0%). (CPC, "Use...") In the West, post-doctorates are widely viewed as a tremendous source of productive capacity because they are "uniquely motivated" by the need to establish a positive reputation for themselves in order to find work after leaving the program.

**Government Reorganization**

The 1990's have finally seen the emergence of a coordinated state industrial policy effort. Prior to the 1990's there were fourteen separate industrial departments within the central government, each of them with their own set of policies for industrial development. (Yu, lecture 5/5/98) However, after the decision was made in 1989 to integrate S&T policies and the state industrial policies, there has been an attempt to create an overarching framework for and a relationship between these areas. This merger was partially prompted by the end of the Cold War. After it became clear in 1991 that superpower military rivalries had lessened, Deng replaced the stress on the need to "go high tech" from military competition to economic competition. (Yu, lecture 5/5/98) Deng feared that if the PRC did not immediately press for economic growth using its comparative advantage of a relatively inexpensive and highly skilled labor force, then the increasing use of more advanced production technologies would slowly erode their economic prospects before a solid base had been achieved.

There are also signs that the government is streamlining in order to promote a simpler organizational structure. Before the recent round of consolidation there were forty-two ministries; that number has been reduced to twenty-nine ministries. Also, the promotion of a leaner organizational structure is being accompanied by large-scale reductions in the number of personnel in the government S&T bureaucracy. (Yu, lecture 4/28/98) This again reflects the new hands off approach of the Central government. Where the government formerly described the relationship as being analogous to a chauffeur driving a limousine, they now say that their role is much more like police managing traffic on a highway system. (Yu, lecture 5/5/98)

**Creation of Mega-Firms**

One controversial aspect of the Chinese S&T modernization program is an emphasis on creating extremely large firms. These firms, which are envisioned as cousins to Japanese keiretsu or Korean zaibatsu, would be multi-layered and produce a wide variety of products. China does not currently have a domestic firm among in the list of the world's 500 largest companies, and Chinese decision-makers clearly believe that the advantages of such gigantic firms outweigh their potential shortcomings.

Though the PRC's planning economy produced many extremely large state owned enterprises, Chinese firms have failed to become gigantic conglomerates largely because of a characteristic left over from the days of the PRC's strict planning economy, the intense competition between varying levels of government in the bureaucratic hierarchy. Though Western observers often viewed the planning economy as extremely coordinated and centralized, in reality there was extreme competition between "state owned" and "local state owned" enterprises for resources. (Yu, lecture 5/5/98) Central government controlled industries, the "state owned" industries, were and still are often in competition with regional government or other local government controlled industries. The planning system was replete with conflicts of interest. Local officials naturally preferred using resources produced in their area, even if better products were available else where in the nation or abroad. In addition, bureaucratic divisions and rivalries effectively prevented the formation of conglomerates. The dispersion of industries and resources to create the central inland industrial base of the "3rd Line" also prevented the formation of firms with a scale similar to keiretsu or zaibatsu.

The state-sponsored development of these mega-firms has largely been accomplished through mergers of failing SOE's with flourishing enterprises; the mergers can often look much more like take-overs. (Yu, lecture 5/5/98) Another part of the creation of mega-firms has been the State Asset Management Company's sale of state assets to "the public", the public often meaning the most successful former SOE's that have already had their ownership issues settled.

**Involvement of the PLA in Business**

The PLA has used its heavy involvement in the commercial sector to acquire high technology goods suitable for both civilian and military applications. In 1993, the PLA used a company that they controlled, Galaxy New Technology, to acquire high-speed telecommunications systems from Lucent Technologies. From 1997 to 1998 over 46 supercomputers were also transferred to the PRC without direct approval from the commerce department. Some of these unmonitored technology transfers have involved extremely sensitive equipment with broad military and civilian applications. The Chinese Academy of Sciences received without approval a Silicon Graphics computer that performs 6 billion operations per second. The academy is responsible for coordinating research on long-range missiles and nuclear weapons. (Phinney 2) The US's General Accounting Office (GAO) also reported that

SCM Brooks Telecommunications, a US limited partnership, also transferred sensitive technologies to the PRC through Galaxy New Technology. (GAO 1) In addition, the GAO found that sensitive machine tools that had been sent to China as part of a joint venture agreement with McDonnell Douglas were diverted to a Chinese facility engaged in military production. (GAO 2)

**Some Difficulties of the Reforms**

Though the reform period has seen the introduction of foreign competitors into the Chinese domestic market (which resulted in important changes in the incentive structure for Chinese industries), these changes may not continue at their current rapid pace. The late 1990's have seen a tremendous backlash against reductions in tariffs (the primary mechanism through which the reformers have introduced competitive pressures). A strong nationalist and protectionist movement is also emerging in the general population. (Yu, lecture 4/2/98) The Asian financial crisis will almost certainly exacerbate the situation and strengthen this movement.

Even if this movement curtails or reverses the opening of the Chinese domestic market, its net effect on the pace of technological development within the nation is hard to determine. While the pressures to become more efficient and modernized production processes may weaken, if even the current level of foreign *and domestic* competition is maintained, Chinese industries will still be forced to modernize or perish. A more closed Chinese domestic market may actually slow the pace of industry consolidation, thereby helping to abate the social instability caused by plant closures and rising unemployment. It may also provide the additional time for growth that many small and medium size industries desperately need before they are forced out of existence by the big players that the central government is strongly supporting. In the West these smaller firms have often proved to be much more dynamic than their giant, ponderous cousins.

Working against the pressures for maintaining a closed domestic market are the forces that are pushing for China's entry into the World Trade Organization (WTO). Decision-makers at the highest levels of Chinese government are convinced that entry into the WTO will be predicated on a more open market. Toward this end, the Chinese mission to the WTO has promised to remove even non-tariff barriers such as licensing by 2010. (Yu, lecture 4/21/98)

However, the promise of open, unfettered access for international competition only applies to manufacturing. Though manufacturing has had strong guidance by the central government during this period and much of the domestic market is open to foreign competition, the Chinese service market, including insurance and financial services, is still extremely closed. (Yu, lecture 4/21/98) Because of the Asian financial crisis and the common perception that the closed nature of the Chinese service sector provided some insulation from the economic turbulence that rocked (and is rocking Asia), this is unlikely to change in the near term.

**Concerns within the Chinese S&T Community**

A major concern of the S&T Community in China is that though the government gives lip service to building a research and development capacity free from government control, the actual implementation has been extremely lacking. Critics of the government's performance note that most of the money for research and development is still tied to the government, especially military research, and that the target goal of devoting 5% of GNP to R&D has not transpired. According to State Science and Technology Commission statistics, in 1995 national expenditures on Research and Development were only 28.6 billion RMB, or 0.5% of Chinese GDP. (SSTC, *Science...*)

Many scientists point out that they still have a long road to travel before they overcome the traditional hurdles that resulted from the separation of the intelligencia from the labor and production forces. Few senior scientists can forget that not so long ago researchers were punished by banishment to industry. In addition, the greater level of workforce mobility that has developed among the S&T labor force has had some discouraging results. Instead of freeing up the resources to modernize the obsolete and decaying state enterprises, the workforce mobility has resulted in a net drain from the state enterprises. New and promising scientists and engineers have greater freedom to choose where they will work. These individuals have largely chosen to work abroad if possible, find employment in foreign firms within China, or begin their own ventures. State enterprises appear to be the employment choice of last resort for most new and promising S&T personnel. (Yu, lecture 4/28/98)

The prospects for the future are all not all negative. Positive forces affecting the S&T community seem to be counterbalancing many of the negative trends and traits. China's civil service still enjoys considerable prestige and privilege, and government positions still attract many of China's best citizens. One of the most important S&T institutions in the nation, the Chinese Academy of Sciences, recently underwent a major renewal. Many leading scientists from every major scientific field were recently added to the academy in order to "freshen the pot" of decision-makers and leaders in this fixture of the Chinese S&T community. (Yu, lecture 4/28/98)

In addition, new companies that are created by scientists as they boldly embark on private ventures are more likely to be sources of high technology innovation than most of the stagnant state industries ever were. As mentioned earlier, in the West these smaller firms have often proven to be much more dynamic sources of innovation than larger firms that are, by their nature, slower to act and often extremely cautious. As the Chinese industrial base continues its current trend of consolidation, the gigantic firms that emerge from the competition will likely be able to draw upon a large number of small but extremely flexible firms that have been founded by entrepreneurs or as spin-offs of research institutes for innovative concepts. Western firms have found buyouts of small, dynamic firms to be an effective strategy for the acquisition of cutting-edge technology.

**Regional Disparity**

Another potential difficulty confronting the S&T modernization efforts is the disparity in regional development. While the Eastern part of the country has seen dramatic improvements in living standards and large scale economic development, the Western and Central parts of China have lagged behind, though conditions have improved nation-wide. Though the government is transferring large amounts of capital from the successful coastal enterprises to SOE's in the Northeast and "rust belt" of the Chinese interior, this uneven development will likely continue for many years. The phenomenon may actually accelerate if China's economic situation deteriorates and the central government attempts to follow the Chinese practice of "whipping the fast horse". (Yu, lecture 5/5/98)

If the disparity between the East and the rest of the nation continues to grow, it could be a source of social turmoil, especially in a nation that until a few years ago took pride in equality above all else. The government is taking steps to address this potential problem, most importantly through capital transfers and improving the inland transportation system through the creation of trunk transportation lines. (Yu, lecture 5/5/98)

Efforts to redistribute economic gains have not always gone smoothly. Earlier attempts to address regional disparity created more problems than they solved. For example, because the development of the Eastern portion of the nation was linked to the creation of special economic and technology zones, some Chinese decision-makers encouraged the creation of inland special technology zones. As a result, by 1992 there were more than one thousand special technology zones in the country.

Instead of promoting the development of inland areas, though, the creation of special technology zones became a tool for land speculators. (Yu, lecture 5/5/98) The government responded quickly by protecting crucial farmland and limiting the number of zones in the nation. Currently there are fifty-two High Technology Industry Development Zones in China under the guidance of the Torch program. (Business China) This again illustrates how government action can actually prove counter productive to developmental goals, at least in the short run.

**An Example of SOE Reform**

While the reform of the Chinese economy has certainly affected every domestic firm, information on the specific effects on large firms that produce technologically sophisticated products is not readily available. One available case that illustrates the effects of the reform processes and the courses of action for the development of high technology military equipment that the Chinese government is advocating is the example of Sichuan Changhong Electronics Group. Changhong was formed as a defense firm producing airborne radar systems for the PLA Air Force, and has existed in some form for over thirty years (Yu, lecture 4/21/98) (Hajari). Changhong remains an extremely important producer of military electronics.

In the late 1980's Changhong, like many other defense firms, was encouraged by the central government to enter into the production of civilian products. The Central government encouraged this course of action as part of more general economic reforms. It is clear that early on some decision-makers saw defense conversion as an important mechanism to grow and modernize the Chinese economy.

They believed defense conversion could be a catalyst to accelerate the introduction of the forces necessary to compel the defense industry establishment into the realm of modern high technology production. These forces for modernization were access to foreign technology, a restructuring of the management and workforce incentive structures, and the introduction of competitive pressures that demanded product quality and continuous product innovation. (Yu, lecture 4/21/98)

In the late 1980's Changhong entered into a joint development agreement with Panasonic; the agreement included at grant of $240,000 from Panasonic as well as technology transfer. (Unicom Media Limited 1) Panasonic and Changhong agreed to jointly produce televisions for the Chinese domestic market. It called for a gradual transfer of the technical expertise necessary to produce the product, as well as a gradual escalation of the amount of production actually performed in China. At the beginning of the project, Changhong only produced the shells of the televisions and assembled the final product. Panasonic produced all of the more sophisticated components of the televisions.

As the relationship progressed and the technical knowledge necessary to produce the more complex components was assimilated, Changhong manufactured a greater portion of the systems. Once Changhong developed a more thorough technological sophistication, they moved to production of more advanced television technologies. The company developed their own bus control circuit as well as picture-in-picture technology. (Yu lecture, 4/21/98)

Since the beginning of the defense industry conversion period, Changhong has advanced from simply filling television shells to developing their own circuits. Changhong's progress has included non-technical improvements, too. Changhong now provides better after-sales service for consumers in the Chinese market than their Asian competitors. (Yu, lecture 4/21/98) Evidence of their improving quality standards can be found in their expansion into product export to most of Asia in direct competition with Japanese and Korean giants.

The company has seen its television production capacity grow from zero in the early 1980's to approximately 8.5 million sets per year. (Unicom Media Limited 2) More important for its ability to develop a capacity to create high technology innovations is Changhong's commitment to research and development. The company's R&D has largely been driven by market forces. There is general recognition within Chinese industry that competition from foreign firms means that the only way to avoid obsolescence is to upgrade the industrial system. (Yu, lecture 4/21/98) Even the most successful firms such as Changhong are actively and constantly attempting to upgrade their process and production techniques through a variety of acquisition and development strategies, including arrangements with technology leaders such as America's Amiga, C-Cube, Philips, and Universal and Japan's Toshiba Corporation. (Yoshida)

For Changhong the upgrading of technologies has meant a concerted effort to master digital technologies. Because Changhong believes that the next step in their developmental progress must be the export of finished products to the advanced industrial economies, they see the United States' plan to have all digital televisions by the year 2006 as a deadline for mastery of digital technology that must be met. (Yu, lecture 4/21/98) They are also trying to introduce product lines--large screened televisions, for instance--that are more to the taste and means of consumers in advanced economies. (Yoshida)

An unnamed Chinese firm, almost certainly Changhong, has developed a high-definition television projection tube, according to the Ministry of Electronics "top ten technology breakthroughs of 1995". (US Department of Commerce-Information Technologies) The digital technologies that Changhong is being forced to master are an extremely important part of the current Revolution in Military Affairs. Though a list of the particular technologies that Changhong is producing for the PLA is not available in open sources, most of the advanced C3I systems that are an integral part of joint force operations are based upon secure digital technologies.

**Reform of the PLA**

After decades of stagnation, the PLA has entered into a period of profound change and significant reform. However, the ultimate goal of this period of change has yet to be determined. Chinese defense strategy is beginning to move away from the "people's war", and since the development of "fist units" in each of the seven military regions in the late 1980's (Gill and Kim, 64), resources have been focused toward "local war under high tech conditions". (Dibb, 352)

Part of this modernization effort has been reform of PLA training. The training reform can be characterized by its experimental nature. The Chinese use different commands to experiment in different aspects of modern warfare. (Blasko, et al, 496-497) This emphasis on experimentation bodes well for Chinese innovation in operational concepts and could be the foundation for innovation in the organization of the PLA. An important part of this experimentation has been attempting to find "new methods using existing equipment to defeat high technology weapons of a potential enemy while providing selected units with limited amount of newer, more modern technology." (Blasko, et al, 491)

Because much of the reform was inspired by the success of the US military in the Gulf War, the training reform has also emphasized combined arms and joint operations, including frequent opposing force exercises. Simulators, computerized war games, and command post exercises have also become more common. (Blasko, et al, 491) But despite this movement in the direction of preparation for "local war", there appears to be a growing competition between two groups with fundamental differences in their preferred modernization strategy.

The "local war" group supports a gradual approach to modernization that would involve the upgrading of weapon systems over a long period until the PLA reaches Western technology levels. The other group believes that the PLA's best chance at becoming world-class military power is by skipping several generations of weapon systems. These advocates believe that China can become the leading force in what they believe is an inevitable revolution in military affairs. (Ahrari, 471) This debate is just beginning to come to a head.

It is important to note that even if the Chinese should decide to take the "RMA" course, the course that this group advocates is not consistent with more sophisticated views of a Revolution in Military Affairs. First, the Chinese do not appear to discern between a military technological revolution and a revolution in military affairs. This could lead to the underdevelopment of non-technological components of military reform. Second, the Chinese "RMA" advocates tend to avoid discussion of the many obstacles that China will face, and there is "an almost zealous certainty that China, not the United States, will be the first to exploit the RMA in two or three decades." (Pillsbury 1. 4) As the Chinese often do, the "RMA" advocates seem to be slipping back into a neo-Marxist mode of deterministic thinking.

Though the resources available to the military are growing, it is probably not possible for China to support both of these visions. The question has then become which view will garner the lion's share of resources. At the present time it would appear that the "local war" group is in a dominant position, partially because the advocates of the RMA view do not have a senior leader serving as their patron. (Pillsbury 1, 9) The fact that the PLA has continued to acquire more advanced weaponry (especially advanced aircraft and submarines from Russia) would appear show that there is strong support within the senior leadership for the gradual modernization advocated by the "local war" group.

Despite this, there is evidence that some aspects of the "RMA" view have entered into mainstream PLA doctrine. The PLA seems intrigued by the potential of information warfare. "An information war is inexpensive, as the enemy country can receive a paralyzing blow through the Internet, and the party on the receiving end will not be able to tell whether it is a child's prank or an attack from an enemy." (Ahrari, 473) Chinese resources would also seem to be well disposed to developing a substantial capability in this type of warfare. The items that would be of most use for information warfare are mostly dual-use, meaning there are readily available on the open market. Most importantly, the primary resource needed for this type of warfare is human capital, something China is quickly developing in abundance.

**Conclusions**

Through a combination of directed effort and market forces, the body charged with developing a capacity to sustain innovation in high technology has begun to create the conditions necessary for success. However, it is likely that their effort will not see complete attainment of this goal for at least a decade, if it survives the difficulties that will undoubtedly arise during that period. Whether the basic scientific knowledge and organizational structure needed to support the current emphasis on "high or new" technology acquisition actually exists has yet to be seen, and is a matter of debate both within China and among external observers and analysts. There appears to be an attempt to telescope over a broad range of intermediate levels of technology. This type of "leap-frogging" is too reminiscent of many of the unsuccessful S&T policies of the past.

The Chinese often seem to be slipping back into a Marxist mode of deterministic thinking. The Chinese still show a great deal of faith in the ability of their best and brightest to perform almost magical feats of reasoning and prediction. This mode of thinking has real consequences in how they attempt to solve problems or achieve goals.

Our overall impression is that the Chinese still haven't overcome their belief that a group of extremely smart planners can bring about the creation of what ever it is that they are trying to create. The phrase "socialism with Chinese characteristics" isn't meaningless. At a rudimentary level, socialistic ideas still appear to hold much weight in the minds of Chinese S&T decision-makers. Though every government attempts to exert control over its technological position and Japan's technology success has often been linked to it's strong corps of decision-makers (Johnson), China's ability to participate in the Revolution in Military Affairs will largely be determined by the level of restraint government officials show.

The appropriate level of involvement for governments in the selection and promotion of technologies is a highly controversial topic. Though some government involvement in the promotion of technologies will be important in determining the pace and direction of China's technological advance, too much governmental involvement is potentially disastrous. Because China still has a limited number of sources for research and development funding within the nation, the risk of mis-selection is particularly high. The level of restraint that Chinese decision-makers show at the micro level will directly affect their chance of rapidly developing a capacity to innovate in high technology industries. Because "spin-on" relies on a large quantity of emerging technologies, their long-term ability to produce cutting-edge military technology will be particularly susceptible to meddling by decision-makers.

However, Chinese attempts to more actively involve industry in the funding process will further increase the influence of the market on technology development, thereby decreasing the chance that a government monopoly on allocation decisions will restrict the kind of technologies being developed. The creation of a quasi-public foundation with allocation committees composed of a mix of younger and older scientist should also prove to be a positive force toward the development of a broader range of technologies.

Government support for the creation of a few gigantic finns could become a problem. If a more well developed venture capital market does not develop in the next few years, and we think this is the likely scenario, the Chinese government and its military may find that they have "put their eggs into too few baskets." However, it is possible that the Chinese will be able to use the substantial resources of the over-seas Chinese community to create a foreign "domestic" venture capital system. Also, if the Chinese are able to create successful zaibatsu-like firms, then the tremendous resources and advantages of scale of these firms could pave the way for rapid growth in high-technology R&D and production. The success or failure of the largest firms in China will be an important indicator of the direction of China's over-all technological progression.

China's prospects for impressive gains in the human component of its Socioeconomic Infrastructure are bright. Educational resources in China continue to slowly improve, and the vast numbers of Chinese students studying at foreign institutions will almost certainly produce dramatic increases in both the quantity and quality of qualified S&T human resources available to the Chinese military-industrial complex. By observing how improving living standards, the opening of Chinese society, and increasing opportunities affect the number of student returning from study abroad, we will have the opportunity to better predict the pace of technological advance in China.

For example, if the number of Chinese students returning continues along the current gradual, positively correlated trend, then the pace of technological advance will also likely remain quite constant. However, if the relationship between the over-all status of S&T personal is non-linear, then we may see a surprisingly rapid increase in the number of students returning once living standards reach what the population as a whole considers an "acceptable" level. If we are to more accurately determine the pace of China's high-technology growth, this important indicator must be continually observed. The degree to which the government is able to allow for a free flowing movement of S&T personnel within the nation will be an important indicator of how successful the S&T reform movement will prove to be.

Another important indicator will be the pace of development of legal protection for intellectual property. Though the Chinese government seems committed to promoting domestic intellectual property as a commodity, this is a foreign idea to many of the government decision-makers and bureaucrats that will be called upon to create and enforce new statutes. There is also a fundamental conflict that exists between the Central governmental authorities and local authorities. The Central government is attempting to improve the status of the country as a whole and therefore are beginning to see the macro cost of lax enforcement of intellectual property law. However, local and provincial authorities have an incentive to overlook copyright infringement and other intellectual property issues if it increases the flow of resources into their locality.

Probably the most obvious indicator of China's prospects is the amount of R&D spending in the country. The target goal of devoting 5% of GNP to R&D has simply not been achieved, and it does not appear that this goal will be reached anytime in the foreseeable future. If China continues to spend only .5% of the GNP on R&D, there is little chance that they will be able to develop sustained innovation in high technology industries.

On the whole, China's prospects for eventually developing a capacity for innovation in high technology industries with military applications appear bright. However, the pace of the development remains slow. Though the Chinese will almost certainly develop a capacity to manufacture many of the advanced weapon systems of the current era, including cruise missiles and aircraft carriers (if they choose), we believe that the Chinese military industrial complex is unlikely to create platforms that will be on par with US systems deployed at that time. The Chinese will become a military force in the region, but in today's military terms, they are unlikely to become a peer competitor during the next twenty years.

The Chinese appear to be taking a dual track to weapons modernization, one short-term and one long-term. Their short-term plans are to acquire the best available foreign military technologies and production expertise through non-standard methods of diffusion such as off-sets and hiring of foreign weapons scientists. Their long-term strategy is to gradually build their basic technology base through commercial activities, especially technology transfers through foreign multinationals, while concurrently improving domestic technological infrastructure and the quality of its S&T community. If they are able to maintain the stability of their S&T system for an extended period of time, this program is very likely to create the conditions necessary for broad-based innovation in high technology industries, probably within fifteen to thirty years in the future.

The best prospects for the Chinese to become a peer competitor is through proactive involvement in a revolution in military affairs. China has the resources to become a leading force in information warfare, and they are showing signs that this is an area of acute interest. The PLA is also likely to become a leader in simulation and war-gaming. This practical emphasis should pay dividends in allowing the PLA to find organizational concepts and military strategies that emphasize their strengths and minimize their technological weaknesses.

The analogy that Chinese S&T decision-makers must become traffic police on an information highway instead of the chauffeur of a limousine is quite accurate. Still, these traffic police often seem to want to tell the drivers when they can go, where they are going, what auto to drive, and in extreme cases, they expect a bribe in order to allow traffic to flow. If the Chinese are able to over come these inhibiting tendencies and realize that they may even have to look the other way when firms act as speeders or try to blaze new roadways, then their ability to participate in the Revolution in Military Affairs will be greatly enhanced.

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