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NIE 13-7/2-86 VL

Science and Technology in China's Modernization

National Intelligence Estimate
Volume I—Key Judgments and Discussion

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THE NATIONAL FOREIGN INTELLIGENCE BOARD CONCURS, EXCEPT AS NOTED IN THE TEXT.

The following intelligence organizations participated in the preparation of the Estimate:

The Central Intelligence Agency, the Defense Intelligence Agency, the National Security Agency, and the intelligence organizations of the Departments of State, the Treasury, and Energy.

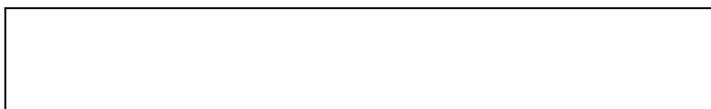
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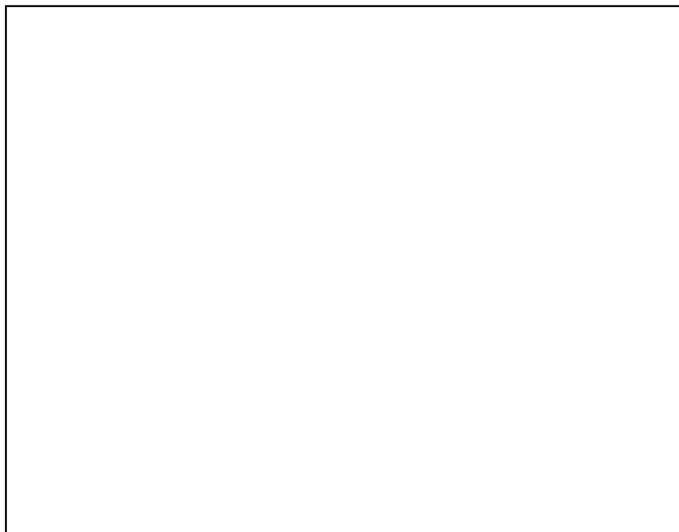
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NIE 13-7/2-86/1

SCIENCE AND TECHNOLOGY
IN CHINA'S MODERNIZATION

VOLUME I—KEY JUDGMENTS
AND DISCUSSION

Information available as of 25 June 1986 was used in the preparation of this Estimate, which was approved by the National Foreign Intelligence Board on that date.

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SCOPE NOTE

The United States, as a matter of policy, supports the modernization of China. The principal assumptions underlying this policy are that a more modernized China will be more open to Western ideas and influence, will develop a larger stake in global stability, will be less prone to act in a destabilizing manner, and will be better able to withstand pressures from the USSR. At the same time, Chinese leaders believe that advances in science and technology are critical to modernization. Furthermore, they conclude that the success of their modernization programs will depend to a very large extent on how effectively they can acquire and master foreign technology. [redacted]

This Estimate deals with a central issue in both US policy and China's modernization plans: the outlook for science and technology (S&T). The Estimate assesses the S&T environment, the prospects for significant advances in priority areas over the next 15 years, and the effects of S&T achievements and failures on both China and the outside world. In reaching these judgments, the Estimate assumes both political and social stability and general continuity in modernization policies in China based on the conclusions of the recently completed National Intelligence Estimate NIE 13-7-86, *China's Second Revolution*. It also assumes that China will not gain control over the scientific and technical resources in Taiwan. [redacted]

While science and technology are widely used as a single term, they embody two different concepts. Science refers to the pursuit of knowledge through the systematic study of the physical world and its phenomena, while technology refers to the application of such knowledge for practical purposes. Chinese officials have found it increasingly important to emphasize the distinction, because the objectives of science and technology differ, as do their results. Science, with its objective of understanding what happens in nature and why, generally involves long-term, open-ended research. Technology has a more short-term focus on how to achieve specific results, usually involving direct economic benefits. The emphasis in China has clearly shifted to technology. Likewise, this Estimate focuses mainly on technology along with the institutional structure that conducts research and acquires technology for China's industry. This Estimate, which covers an extremely wide range of topics, is the first NIE on the subject. It will be supplemented by additional studies in more depth. [redacted]

Our findings and analysis for this Estimate are in two volumes:

- Volume I—Key Judgments and Discussion.
- Volume II—Annex A: Priority Technologies.

[redacted]
Annex C: China's Science and Technology Agreements, 1978-86.
[redacted]

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KEY JUDGMENTS

Overall, the outlook for the modernization of science and technology in China is favorable:

- Political support for S&T modernization is strong, consistent, and growing.
- Foreign technology is being acquired on an unprecedented scale, and large numbers of Chinese are being educated abroad in science and engineering.
- Research facilities are being better equipped, and management is improving.
- Direct links are being established between research centers and the industrial establishments that are to benefit from the research.

The pace of S&T modernization, however, will be slow for at least a decade because of continuing difficulties in assimilating technologies. For the most part, the labor force is unskilled and poorly motivated, and managers are inefficient. In addition, the infrastructure of technical support, communications, transportation, and energy is inadequate. These problems are compounded by a cumbersome bureaucracy with a penchant to overcontrol society through central planning. This results in low productivity, poor quality control, and slow absorption of new technologies. Cumulatively, they pose a formidable obstacle to improving China's technology levels, upgrading industries, and closing the technology gap with the West.

While these limitations affect the pace at which modern technologies can be absorbed, a more agile and responsive S&T system is nonetheless evolving. Individual scientists and engineers enjoy increasingly attractive opportunities and incentives, better qualified S&T managers are pushing more relevant research, and overall funding for research and development is increasing. The supporting infrastructure is improving the flow of information, S&T journals are flourishing, and research facilities are becoming more independent. Out of this environment we expect S&T to provide important contributions to increased productivity in China, which is the basic objective of modernization.

In addition, S&T modernization will probably accelerate military research and development programs. Important beneficiaries include

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China's ground, naval, air, and ballistic missile forces. Foreign technology, in particular, is likely to play a key role in reducing by several years the time it takes to solve critical developmental problems. China already has reached agreements for the purchase of military equipment and technology with 15 countries (see annex D for details).

China may be able to narrow somewhat the gap in selected industrial technologies with the industrialized world over the next decade. The degree of any such narrowing is uncertain, but catching up fully with the West in any of these areas is very unlikely. The general outlook for progress in high-priority areas is summarized below and discussed in more detail in annex A:

Microelectronics	Gap will widen
Computers	Gap will widen
Telecommunications	Gap will remain or widen.
Automated manufacturing	Gap likely to persist.
Transportation	Gap will remain fairly uniform
Energy	Gap will narrow
Special structural materials	Gap may narrow
Biotechnology	Gap will narrow.

Foreign technological assistance is likely to be instrumental in overcoming critical obstacles in both military and civil modernization programs. Demands on S&T from both military and civil users will increase, and China will step up efforts to acquire foreign technology, particularly from the United States. This situation will provide both risks and opportunities.

Of course, China will try to avoid becoming overly dependent for technological assistance on the United States or any other country. To that end, Beijing is establishing a broad network of S&T relationships. Although China currently acts mainly as a consumer of high technology, eventually, Beijing may become a stronger competitor in certain world markets as S&T modernization results in more efficient production.

Sino-Soviet S&T relations are also likely to expand somewhat as China seeks to diversify S&T relationships. At the same time, Soviet-trained scholars in their midfifties may increasingly assume leadership positions within China's scientific community. However, the extent of improved Sino-Soviet S&T relations is likely to be limited because high technology tends to be more accessible in the West. Also, many of China's new S&T leaders are highly critical of Soviet S&T management and they have pressed for reforms along Western lines, despite their

¹ The Director of the Bureau of Intelligence and Research, Department of State, believes that the linkage among research, technology acquisition, assimilation, and production by China's defense industries are not made sufficiently clear to judge the resulting effects on military modernization.

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Soviet training. Furthermore, China is moving away from the Soviet S&T model in many respects and may narrow much of the technology gap between them and perhaps even surpass the USSR in some areas, such as certain types of computers. These developments are possible because Beijing enjoys far better access to foreign technology than Moscow does, and because China's leadership has demonstrated a far greater willingness to introduce bold changes.

Large numbers of Chinese students will be studying in the United States as part of the growing US-China S&T relationship. This can be an impetus to better mutual understanding, despite reservations by some party ideologues about the danger of "spiritual pollution" from foreign education and more general concerns about Chinese students who go abroad to study but do not return.

The leadership in Beijing is trying to anticipate the full scope of consequences that S&T modernization is likely to bring. The widespread education of Chinese abroad and the rise of scientists to more influential positions may increasingly influence thinking on political issues. We already see signs of a much more "open" China. While such trends are not likely to undermine the fundamental control exercised by the Communist Party, thinking within the party may increasingly be open to a wider set of influences.

Overall, S&T modernization is contributing to China's economic and military strength, and, as a result, China is becoming more open to selected Western ideas and influence, is developing a larger stake in global stability, and, at the moment, remains disinclined to act in a destabilizing manner. While enhancing China's military capabilities, we do not foresee that S&T modernization will lead to any substantial shifts in China's military balance with the USSR. The balance of forces with other potential adversaries in East Asia is also unlikely to change dramatically over the next 10 years. Despite China's development of new weapons based on foreign technology or purchase of some Western arms, it is unlikely that China can either absorb the technology or field sufficient numbers of more advanced weapons before the late 1990s.

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DISCUSSION

The Changing Environment

Perceptions, Goals, and Priorities

1. The strong emphasis on science and technology by the highest political levels in China is likely to continue. This support is based on the view that a dangerous gap exists between China and the major world powers, and that this gap primarily is due to the wide and growing disparity in technology. The leadership also shares a strong desire to reverse the trends that have led to a weak and vulnerable China, dependent on outside sources for an increasing variety of important products.

2. In response to these perceptions of a large and growing gap between China and the world, the "Four Modernizations" began in earnest in 1978 focusing on agriculture, industry, science and technology (S&T) and defense. The goals of this process are loosely defined, usually calling for a quadrupling of economic output between 1982 and the year 2000. According to Chinese statements, as much as half of the gain in productivity over the next few decades is to come from science and technology. The goals, however, are less important than the process of modernization in which the Chinese leaders have demonstrated a willingness to introduce substantial changes to the economic and research systems.

3. Although the modernization process has been remarkably open to ideas from the West, the goal remains a more modern and efficient socialist system, with the Communist Party in full political control. But the party is no longer committed to Maoist notions of egalitarianism that proved particularly stifling to the scientific community in the past. Instead, market forces are being introduced as a means to modernization, but not as the end objective.

4. As part of the modernization process, thousands of technologies have been identified as important in various Chinese modernization studies, plans, and programs. But for the most part, efforts to upgrade domestic S&T capabilities and acquire foreign technologies are focused on eight areas. These areas generally have broad industrial and military applications,

such as microelectronics, or address particularly weak links in China's modernization, such as energy and transportation. Currently, the highest priorities are accorded to:

- Microelectronics.
- Computers.
- Telecommunications.
- Automated manufacturing.
- Transportation.
- Energy.
- Special structural materials.²
- Biotechnology.

Key Variables

5. China's leadership is increasingly well informed on the requirements for S&T modernization, and, accordingly, their objectives have become more realistic. In particular, their main purpose is to more closely link research and production, thus strengthening industry, agriculture, and the military. China began introducing S&T reforms in the early 1980s to improve the management and organization of research and development. The March 1985 Central Committee decision on S&T reform and several associated measures provide the basic guidance for S&T modernization. The success of these efforts will depend largely on the seven variables discussed in the following paragraphs.

6. **Political Stability.** Political instability disrupted two previous attempts at S&T modernization in 1956 and 1962 and poses the greatest threat to the current program. But the prospects for political continuity are good.³ Political support for S&T is likely to continue to

² Includes advanced composite materials, metals, and ceramics such as high-strength carbon fibers and high-temperature resistant alloys. (C)

³ See NIE 13-7-86, *China's Second Revolution* (Secret) May 1986, for a discussion of the political outlook. (C)

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Table 1
Estimated S&T Personnel

	1980	1985	1990
Bachelor degrees in natural science	17,000	23,000	28,000
Bachelor degrees in engineering	51,000	113,000	120,000
Total	68,000	136,000*	148,000
Graduate degrees in science and engineering	3,000	8,000	15,000
Chinese students - scholars in United States	4,000 to 5,000	14,000 to 15,000	20,000 to 25,000
Cumulative total Chinese students sent abroad since 1979 ^b	10,000 to 13,000	30,000 to 50,000	110,000 to 150,000

* By comparison, the United States awarded about 190,000 similar degrees annually and the USSR about 450,000 in the early 1980s.
^b Data on total Chinese students sent abroad vary widely.

Note: Academic degrees were reinstated in 1981, so 1980 data reflect estimated equivalent four-year studies.

This table is ~~Secret~~

grow for at least the next several years. Nevertheless, the modernization process will be long, and the political leadership will change substantially over the next decade.

7. **Opposition to China's modernization program** has been minimal. Some senior party officials, such as Chen Yun, object to the pace of reform and some of the details. They argue that opening China to Western influence has had unacceptable side effects, including increased corruption. But overall, the leadership is increasingly united on the need for S&T modernization and the direction that reforms should take.

8. **S&T Personnel.** Surveys by the State Science and Technology Commission (SSTC) in 1978 concluded that the shortage of skilled personnel was the most serious S&T problem. Recent articles reaffirm that this continues to be a major bottleneck. Ambitious educational goals were established, and Chinese students were sent abroad in unprecedented numbers. The early goals have not been met, but strong efforts to upgrade the quality of science and engineering education continue. Also, widespread study of English and Japanese has been reinstated in China's schools, and foreign textbooks have been introduced. Graduate student enrollment in 1985 was up over 60 percent from 1984, but the results are still meager for a country of over 1 billion people. In 1985 only about 8,000 masters degrees and 58 doctoral degrees were conferred.

9. The process of increasing the quantity and quality of S&T personnel in China will be slow (see table 1). A major shortfall is engineers. A study in the early 1980s by the State Planning Commission indicated that China's universities were producing only about 40 percent of the engineers required, whereas they were able to satisfy about 75 percent of the current demand for scientists. This situation is compounded by a shortage of qualified faculty and the rapid increase in enrollment of S&T students. In addition, the cost of upgrading science and engineering at existing universities and opening new universities will be expensive. To help, the World Bank is making loans available for educational development programs. In addition, China is seeking foreign scholars, particularly from the United States, to improve science and engineering instruction in China.

10. To alleviate some of these domestic shortcomings, China will continue to send large numbers of students abroad. Educational exchange programs have been established with over 50 countries, although the majority of Chinese students come to the United States. Currently, some 15,000 to 17,000 Chinese students are studying in the US and about 2,700 in Japan. About 70 percent of these students study science and engineering (see inset). While sending students abroad has helped fill important gaps, a shortage of midlevel technicians will continue to

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Chinese Students and Scholars Abroad

- Policy?** • Encourage both private and government sponsored education and training abroad.
- Who goes?** • Initially, faculty and staff from leading universities and research institutes.
- For what?** • About 70-percent math, science, engineering. Most at graduate level.
- How good are they?** • Perform about as well as US students, in many cases much better. They tend to be serious and hard working.
- How many?** • Figures uncertain, but some 13,000 to 17,000 now in the United States, out of 30,000 to 35,000 currently abroad worldwide.
- US already has trained over twice as many Chinese as were trained by the USSR, although the US training has tended to be for shorter periods.
- Results on return?** • Of those who have returned, many go back to their former organization. Their numbers are becoming significant at leading universities and research centers. Some problems reintegrating, particularly if abroad for over two years. Those who do not go abroad often are jealous; friction results.
- Most make significant research contributions.
- Many hold seminars; establish information networks.
- Most underutilized because of inadequate facilities, although facilities are also being upgraded.
- Most have positive attitude toward reforms.

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handicap S&T development. Faced with such problems, more factories are being encouraged to increase vocational training programs at home and abroad. Management training has also become more popular, and several management training centers have been established in cooperation with foreign countries, such as the US-supported management training center at Dalian. []

11. Foreign education will continue to be a critical part of improving S&T in China. Despite reservations by some party ideologues about the danger of "spiritual pollution" from foreign education and concerns about students who do not return to China, the leadership will continue to send students and scholars abroad. However, Government-funded scholars now account for about 40 to 50 percent of the Chinese who study abroad, and this share will probably decline as the government tries to shift more of the financial burden of education to local authorities in China, to overseas Chinese relatives, and to foreign universities and foundations. Such efforts to broaden training and education will nevertheless expand China's pool of skilled S&T personnel in the long run. In the meantime, China will continue to experience a shortfall in S&T talent. []

12. *Access to Foreign Technology.* China cannot close the technology gap alone, so foreign technology will play a critical role in the modernization effort for at least the next decade. A variety of mechanisms will continue to be employed to acquire foreign technology. Business arrangements, including direct purchases, foreign investment, and joint ventures, provide one major avenue for technology transfers. These arrangements often include provisions for training workers and managers in modern production techniques. In addition, technology gained through visiting scientific delegations, students and scholars studying abroad, and foreign publications that are incorporated into S&T data bases will, in the long term, contribute to China's modernization. []

13. Access to foreign technology requires favorable policies and practices both on the part of China and Beijing's trading partners. For its part, China has taken several steps to facilitate the acquisition of foreign technology, including new legislation, such as the patent law, to protect foreign investors. Also, special economic zones have been created with preferential tax treatment and land use provisions to attract foreign businesses. The results have been somewhat disappointing thus far in terms of technology transfer to these zones, mainly because investment has been lower than anticipated, and participation has mainly involved assembly of relatively simple products for export. Nevertheless, China continues to seek ways to provide attractive opportunities for foreign investors. For example, recently Beijing promised some foreign firms more access to China's large domestic market in return for technology, but limited access is likely to remain a serious obstacle to improved commercial relations. Moreover, Beijing has begun to penalize

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firms that do not offer know-how and technical assistance with their hardware. In May 1985 the State Council formally tied future purchases of advanced equipment to technical cooperation, and Beijing subsequently added midlevel technology sectors such as motor vehicles. []

14. From the business perspective, much of the initial enthusiasm for trade with China has declined because many firms are not making profits that can be repatriated. In addition, they are finding that the cost of doing business in China is very high, and they are often frustrated in dealing with the Chinese bureaucracy. Consequently, some firms may be less likely to make technology available on attractive terms. But, on balance, China should continue to enjoy good access to foreign technology. Foreign trade agreements are increasing, and new joint ventures continue to be chartered in record numbers. The relaxation of export controls by the United States and COCOM has also improved China's chances for gaining advanced technology through legal channels. []

15. An additional way to acquire foreign technology involves covert and illegal methods. This approach probably accounts for a small percentage of the total volume, but, it is used both to acquire priority items expeditiously and to gain controlled technologies. []

[] We believe covert and illegal methods of acquiring technology will very likely continue, despite the generally good access China enjoys using legal means. This is because Beijing fears that important technologies could be denied in the future. []

16. Japan and the United States are likely to remain the focus of China's efforts to acquire advanced technology. Japan has established an extensive marketing network in China, aggressively pursued sales, and offered attractive financing packages. But Japan has been rather protective of its know-how. The United States has been more forthcoming with technology and has become an increasingly important source of China's imports, particularly high-technology items (see figure 1). While the United States has gained a larger share of the Chinese market, Beijing is being careful to avoid becoming overly dependent on a single source by diversifying foreign purchases to Western Europe and elsewhere. []

17. *Management.* A key focus of S&T modernization is to reform research management. The Chinese Academy of Sciences (CAS), universities, and ministries with large R&D components are targets of efforts to motivate scientists and better integrate their research with the production process. In particular, research institutes are being encouraged to seek contracts with industry. Already these contracts account for an average of about 20 percent of the operating budgets of research institutes. As part of this effort, over 100 technology trade fairs were held during 1985 that led to research contracts valued at more than \$700 million. Reforms also call for research institutes to become more independent and competitive. CAS may divest itself of some of the nearly 120 institutes that it currently manages, but this is likely to be a contentious issue. In any event, the Academy leadership is supposed to give up day-to-day management of the institutes as more responsibility is shifted to the institute directors. Under the reforms, directors in both military and civil research facilities are to have greater control over their budgets and personnel, including authority to hire and fire staff members. These and other changes in the scientific community represent a clear move away from the Soviet model, which has not served China well over the past 30 years, in the view of the leadership. []

18. These reforms have been in varying stages of discussion and implementation for nearly six years. Thus, to overcome inertia and bureaucratic infighting, a series of "Leading Groups" have been formed with high-level political clout. The S&T Leading Group, headed by Premier Zhao Ziyang, is designed to cut through the many layers of the bureaucracy, which often stifle innovation and change. Another Leading Group, under Li Peng, coordinates the development of the high-priority electronics industry. This coordination includes electronics research, production, and applications. The proliferation of these oversight groups, however, suggests that they too may be having trouble implementing reforms. Key organizations in the S&T community are depicted in figure 2, and annex B describes the organizations and key personalities in more detail. []

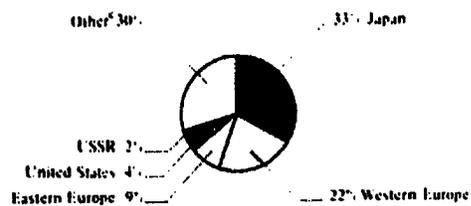
19. Science and technology policy in China is formulated mainly by the State Science and Technology Commission (SSTC) for civil matters and by the National Defense Science, Technology, and Industry Commission (NDSTIC) for military issues. Together, these supraministerial organizations are responsible for managing S&T modernization. They are particularly concerned that the modernization process be smooth

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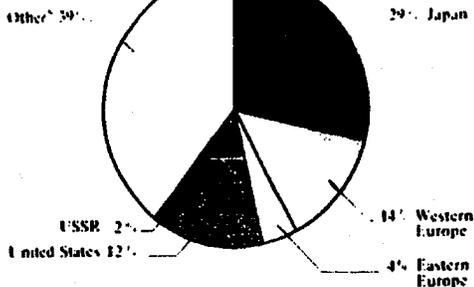
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Figure 1
Changing Sources of China's Imports^a

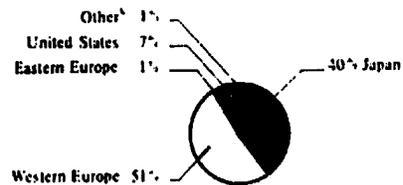
Total Imports^b
1975 - \$7 billion



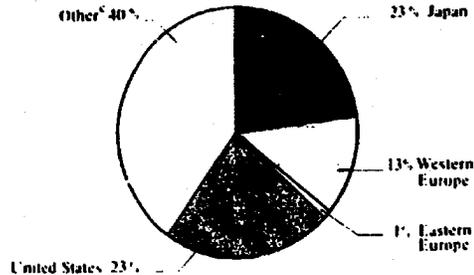
1985 - \$40 billion



High Technology Equipment Imports^b
1975 - .09 billion



1985 - \$2 billion



^a These charts reflect commodity imports, such as scientific instruments, telecommunications equipment and computers. Other important technology transfers, such as training personnel in manufacturing processes, may be part of joint ventures or other arrangements that are not included in commodity trade data.

^b Estimates.

^c "Other" is largely re-exports through Hong Kong of Western products.

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Figure 2
China's Key Science and Technology Actors

Leading Groups

Science and Technology Leading Group	Electronics Industry Innovation Leading Group
Head Zhao Ziyang	Head Li Peng

State Council Commissions

State Science and Technology Commission	National Defense, Science, Technology, and Industry Commission	State Economic Commission	State Planning Commission
Minister in Charge Song Jian	Minister in Charge Ding Jitengao	Minister in Charge Lu Dong	Minister in Charge Song Ping

Academy of Sciences and Key Ministries

Chinese Academy of Sciences	Ministry of Ordnance Industry	Ministry of Electronics Industry	Ministry of Posts and Telecommunications
President Lo Jixi	Minister Zou Jiahua	Minister Li Teying	Minister Yang Taifeng
About 117 research institutes	Subordinate research facilities unknown	3 research academies; about 30 research institutes	About 25 research facilities

Ministry of Aeronautics	Ministry of Nuclear Industry	Ministry of Astronautics	Ministry of Machine Building Industry
Minister Mo Wenxiang	Minister Jiang Xinxiang	Minister Li Xu'e	Minister Vacant
About 25 to 35 research facilities	Number of research facilities unknown	About 25 to 35 research facilities	About 40 research facilities

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because they believe that too rapid modernization could be disruptive. To improve management of this process, a complete census of the S&T community will be taken every three years, with the first census expected to be finished by mid-1986. In addition, SSTC has instituted semiannual surveys of the S&T community to provide feedback on various issues such as job mobility. This survey information provides an independent check on S&T data reported through normal channels. These and similar developments point toward a more efficiently managed S&T system.

20. Leadership of S&T in China is passing from a group of scientists, now in their late sixties and early seventies, who have had substantial training in the West, to a group in their fifties who are primarily Soviet trained. Interestingly, this transition also has coincided with a move *away* from the Soviet model for S&T in China. The new leadership, including Song Jian and his Soviet-trained colleagues, has been critical of Soviet S&T management, and they have pressed for reforms along Western lines. As a result, the emerging science policies are very eclectic, and two broad

research and development strategies are apparent. The traditional, highly centralized strategy still characterizes much research and development in China. This approach focuses the necessary resources to achieve rather narrow, specific objectives. This approach has resulted in notable successes including thermonuclear weapons and the Galaxy supercomputer. At the same time, Beijing intends that a more decentralized structure will evolve and foster S&T advances in microelectronics, computers, and other areas. This strategy emphasizes competition among more independent research facilities. []

21. At the individual level, providing incentives to scientists is a major focus of S&T reform, and from the perspective of the Chinese scientist, the plans are encouraging. Living conditions and opportunities for job mobility should improve, albeit slowly. Scientists are now able to obtain patents on their discoveries and do private consulting work for profit. Also, more direct rewards for excellence in research are to be granted. Special incentive award funds are being established, and a National Natural Science Foundation (NNSF) has been formed that will provide scientists with a greater voice in the allocation of research funds. The NNSF, once it becomes fully functional, should also enhance the quality of research through a peer review process rather than relying entirely on administrators to make funding decisions. Promotions may also come quicker, and Beijing is trying to increase opportunities for job mobility. Research facilities are being encouraged to compete for scientists and engineers, but competition and job mobility are not developing as Beijing planned. The job mobility initiative is one of the more controversial aspects of reform because institutes do not want to lose key scientists and the older scientists enjoy the security of the current system that provides lifetime tenure. Other controversial measures include an emphasis on youth. Over 70 of the CAS institute directors have been replaced in the last three to four years by younger, better trained scientists. In some cases, the new directors were selected from outside the institute in a major departure from traditional practices. []

22. Another major change in management style is the general opening to the West. For example, several laboratories are to be opened to foreign researchers. Also, foreign scientists frequently serve in important research advisory positions. Similarly, an association with overseas Chinese members of the CAS is being formed to help monitor research abroad. In addition, returning Chinese students are being urged to retain their foreign contacts. These efforts to open the S&T system to outside influence are likely to continue and

have largely beneficial consequences for the pace and quality of research in China. Furthermore, the effects are likely to extend beyond the immediate S&T community. []

23. **Infrastructure.** For the most part, the research environment in China has not been conducive to technological progress. Many research facilities in China were outdated and frequently lacked equipment and related infrastructure to support research and development (R&D). Also, there generally was little sharing of information between research organizations. These conditions often resulted in the duplication of work as well as poor quality research. Such problems and their main causes are well understood in China and are the target of reform and other measures to upgrade the S&T infrastructure. For example:

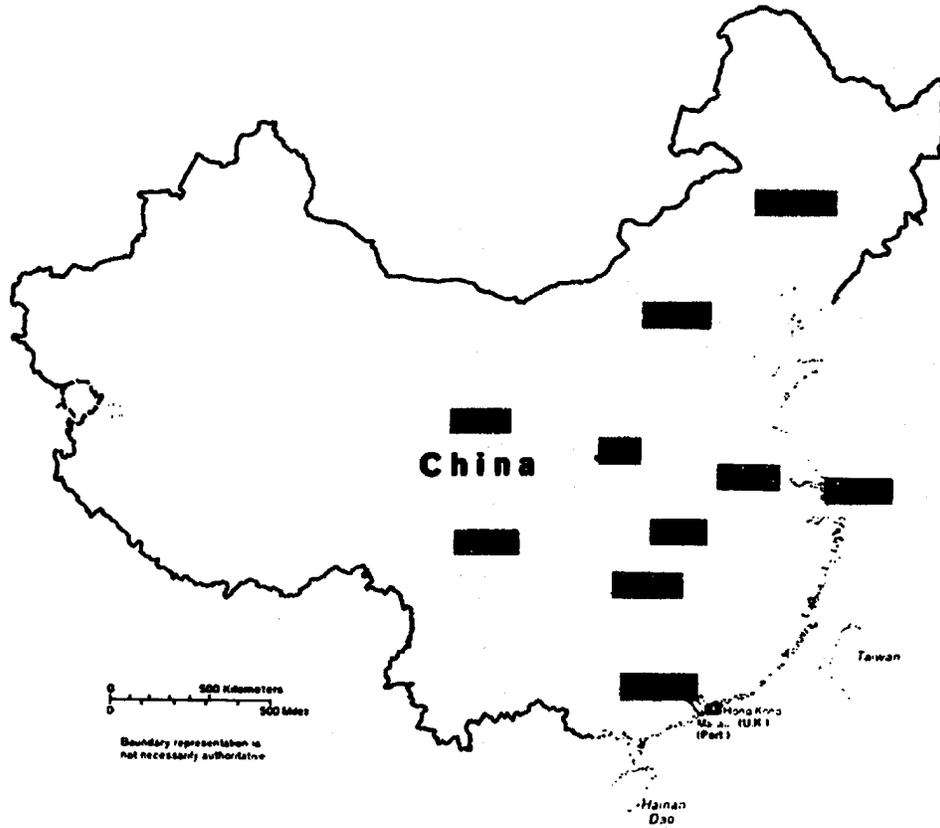
- Modern research equipment and scientific measurement devices have been accorded high priority for acquisition, both from abroad and from upgraded domestic production facilities.
- An international scientific and technical information system at the Institute for Science and Technology in Beijing has been expanded to include access to several foreign S&T data bases. Plans also call for extending this service to other cities in the next few years.
- S&T publications have proliferated since 1975, and the quality is improving.
- China has joined nearly 100 international S&T organizations to gain better access to information and foreign scientists. This also provides opportunities to train Chinese researchers through participation in multinational research projects.
- High-technology centers are being established around Beijing and Shanghai to concentrate advanced research and production resources. []

24. These and other efforts should improve the S&T infrastructure, although results will be uneven. The largest concentration of major research facilities will continue to be in the Beijing and Shanghai areas (see figure 3). Key research facilities will receive priority infusions of personnel and equipment. Despite reforms, old inhibitions against information sharing may be reinforced by the increasingly competitive nature of research in China. Thus, diffusion of information will continue to be slow. []

25. **Funding.** The cost of modernization is high and funding for S&T will be an important factor in determining the pace of modernization. Government

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Figure 3
Top 10 Cities with Leading Research Facilities



Beijing	15	42	112	169
Changchun	3	5	10	18
Chengde	2	2	6	10
Chengdu	0	6	6	12
Guangzhou	3	7	10	20
Lanzhou	1	6	8	15
Nanjing	7	5	10	22
Shanghai	6	16	47	69
Wuhan	7	10	7	24
Xian	4	3	12	19

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spending for S&T has increased at a slightly greater rate than the expansion of the overall budget. In addition, the central government is encouraging more spending on S&T by local enterprises. At the same time, research institutes will become more independent financially and will offer employees incentives, such as improved housing. But putting research contract reforms into practice will prove difficult because organizations have little experience in treating research and technology as a commodity, and mechanisms to determine their value are not well established. As a result, the cost of research may rise. Also, conflict between central and local interests that characterize bureaucratic politics in China may make implementation of the reforms difficult. Another serious problem will arise when decisionmakers are faced with the issue of how to deal with "unprofitable" research centers. In theory, they should go out of business, but none have been allowed to fail to date.

26. Export trends will also have an important effect on the pace of S&T modernization because China will continue to rely on hard currency holdings to purchase advanced technology. In 1985 our preliminary estimates indicate about an \$8.5 billion trade deficit, causing a significant drop in foreign exchange reserves. This has caused Beijing to slow imports, which could affect S&T modernization because China remains highly dependent on imported technology. Nevertheless, technology imports will retain a high priority for funding.

27. *Assimilation of Science and Technology.* Regardless of the progress within the S&T community, translating research and technology acquisitions into production continues to be a major weakness. Delays in new projects are common, and, once new facilities come on line, productivity often is well below the expected output—primarily due to low labor productivity and poor project management. Quality control problems, poor maintenance, a lack of spare parts, and similar problems are pervasive. Increases in industrial production also will be closely linked to China's ability to narrow the scope of central planning and gradually allow market forces to determine more economic activity. However, the ability to carry out such decentralization without undermining the party's monopoly of power may prove to be the single most vexing problem the leadership will face. These and other difficulties in absorbing new technology have been attributed to a variety of basic conditions that include:

— *Low labor productivity.* Skilled labor is in short supply. Educational standards are low, and work-

ers are unfamiliar with modern technology. Absenteeism is high, and workers are poorly motivated.

- *Poor planning and management.* Managers lack understanding of the market potential for new products. They often lack authority and are not technologically competent.
- *Bureaucratic style.* The locus of authority and responsibility often is unclear, and the bureaucracy tends to overcontrol to the point of stifling initiative.
- *Poor communications and compartmented organizations.* The flow of ideas has been very restricted both on an interpersonal basis and at the societal level. Information sharing between major organizations has been minimal.
- *Inappropriate technologies.* In some cases, technologies have been imported that proved too advanced for China to master.
- *Poor support.* Energy and transportation have been inadequate. Some factories operate only part-time because of electricity shortages. Spare parts and maintenance often are not available.
- *Poor quality control.* Products often are of poor quality. Test and measurement equipment are inadequate, and high standards are not insisted upon by managers.

28. Progress in overcoming the assimilation problem is likely to be slow. In some areas, we expect to see a reduction in the time it takes to apply a new technology to mass production as the quality of the work force and management improves. Progress will be most evident in those industries in which China has long experience with imported plants and equipment, such as petroleum refining and extraction, textiles, aluminum, and chemical fertilizer. Somewhat slower assimilation will characterize developments in the high-technology arena.

29. *The Sum of the Variables.* Trends in the key S&T variables are generally favorable, although progress is likely to be slower than desired. Even though improving at a relatively slow pace, the emerging S&T system probably will gradually become more responsive to a wider range of end user demands, primarily because of more decentralization and less isolation of the research community. The system also will eventually be more agile as information begins to spread more rapidly and research centers are able to react more quickly to promising new developments, espe-

cially with the infusion of computers, modern scientific equipment, and foreign-educated students. Nevertheless, China is likely to become increasingly dependent on foreign technical assistance to sustain positive trends through the end of the century.

30. Inevitably, some setbacks will occur in S&T modernization. In some cases, imported technology will be inappropriate for China's labor force or energy resources, in others, raised public expectations about modernization will be dashed. But such problems have already been anticipated. Articles have appeared cautioning people not to expect a smooth transition to high

technology. In one example, a "bathtub curve" is described in which high failure rates are to be expected both during the early stages of a process, when new technologies are introduced, and during later stages, as equipment wears out and the technology becomes obsolescent. In between, though, should lie a sustained period in which failure rates are low. The intended message is: "Don't change policy prematurely because of early failures."

31. Over the next several years, selected indicators will suggest whether the pace of S&T modernization is likely to be sustained (see inset).

Positive Indicators

- Greater leadership role for younger, better educated scientists and technicians.
- Continued emphasis on education and training for all people.
- Increased openness to foreign technology, including management techniques.
- Continued top-level public endorsement of S&T reforms.
- Sustained economic growth.
- Return to China of a high percentage of students sent abroad.
- Freer flow of foreign and Chinese S&T personnel within China.
- Improvements in economic productivity attributable to technological innovation.

Negative Indicators

- Greater role of party in S&T affairs.
- Resurgence of ill treatment of intellectuals.
- A swing back to more centralized planning.
- Increased charges of corruption.
- Decline in foreign exchange reserves.
- Restrictions on students abroad and drop in number sent abroad.
- Continued resistance to the mobility of S&T personnel.
- Reduced foreign investment.

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Prospects for S&T Achievements

Scientific Frontiers

32. China's emphasis on applied research and development work threatens to hinder advancements in science. The leadership is aware of this and is increasing funds for basic research. But basic research in China includes that which may be quickly applied to national needs. Thus, in general, fewer resources will be available for theoretical work, and experimental research—which already accounts for a very low share of scientific work—probably will fall even further behind Western standards. Thus the results are more likely to be evolutionary advances, rather than revolutionary breakthroughs. Nevertheless, the scale of research in China, involving about

9,000 facilities, probably will produce some significant scientific results. However, we cannot predict in which fields these are most likely to occur.

33. Although the quality of science in China has in general not been on a par with the West, a few Chinese scholars have gained international prominence. Particularly strong research fields in China include magnetic materials, mathematics, high explosives, medicine, plant genetics, and virology. Similarly, the top research institutes in China are doing work in a few high-priority areas that compares favorably with that of research facilities in the West. Several of China's top research centers are noted in the inset below and undoubtedly there are more.

Leading Centers of Research in China

Centers	Areas of Excellence
Fudan University.	Lasers, optics, electronics.
Qinghua University.	Microelectronics.
Shanghai Jiaotong University.	Computers, telecommunications.
Hefei Institute of Plasma Physics.	Physics.
Beijing Institute of Physics.	Molecular beam research.
Xian Institute of Optics and Precision Mechanics.	Lasers, high-speed photography.
Software Technology Institute.	Computer software.
Shanghai Institute of Biochemistry.	Biotechnology.
Beijing Institute of Genetics.	Plant genetics.
National Defense S&T University.	Supercomputers, software.
Shanghai Institute of Metallurgy.	Semiconductors.
Shanghai Institute of Ceramics	Silicon crystal growth

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Technological Advances

34. Although China is at a very early stage of development and is faced with substantial obstacles, concerted efforts to focus the best talent and sufficient resources, along with the introduction of foreign technology, should increase the levels of technology available in China in several areas (see annex A). China's efforts to close the technology gap with the West, however, are hampered by such factors as the low

level of indigenous R&D and continued technological advances in the West. Among the priority technologies, we expect China to narrow the gap in shipbuilding and air transport, energy, special structural materials, and biotechnology. We believe the gap will widen, however, in microelectronics, computers, telecommunications, automated manufacturing, and road transport. The general outlook for progress in high-priority areas is summarized in the inset and discussed in more detail in annex A.

China's Technology Gap

Microelectronics	Nine to 12 years behind now. Making progress but much slower than the West. Gap will widen.
Computers	
Microcomputers	Approximately five years behind now, using imported components. Gap will widen.
Minis & Mainframes	More than 10 years behind. Gap will widen.
Supercomputers	Five to 10 years behind, using imported components. Gap will widen.
Telecommunications	
Switching	Domestic systems 20 to 25 years behind, imported systems three to five years behind. Gap will remain.
Fiber Optics	Research three to five years behind, production five to seven years behind. Imported technology will allow progress but slower than West. Gap will remain or widen.
Satellites	Five to 15 years behind on communications satellites, using some imported components. Gap will narrow as China progresses in C & Ku band, then widen as West moves to higher frequencies.
Automated Manufacturing	Gap likely to persist.
Transportation	
Rail	More than 10 years behind. Gap will remain fairly uniform.
Shipping	Gap narrow and getting narrower.
Road	More than 10 years behind. Gap will widen.
Air	Five to 10 years behind. Gap will remain fairly uniform or narrow slightly.
Energy	
Coal mining	Five to 10 years behind. Gap will narrow.
Petroleum exploration and production	More than 10 years behind. Gap will narrow.
Hydroelectric	Five to 10 years behind. Gap will narrow.
Nuclear	10 to 15 years behind. Gap will probably narrow slightly.
Special Structural Materials	Five to 10 years behind. Gap may narrow.
Biotechnology	Three to 5 years behind. Gap will narrow.

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35. The extent to which the technology gap will be narrowed also is related to the success of economic reforms. While we view the prospects for the economic reforms as positive, on balance, it is also plausible—though less likely—that the reforms will unravel. Such an outcome would likely lead to setbacks across the board in economic, scientific, and technical cooperation with the West and may also contribute to a widening of the technological gap with the West.

36. Progress relative to the Soviet Union should be notable, particularly in computers and biotechnology. This is because China enjoys better access to foreign technology than the Soviet Union and stands to benefit considerably from sending large numbers of students abroad. China also has undertaken more sweeping reforms than Moscow in the organization and management of science and technology. Relative to other developing countries, China will also make substantial gains. Yet, on balance, China will be a net importer of high technology from the West.

Consequences of S&T Modernization

37. The main consequences of S&T modernization efforts will be in the technological transformation of industrial enterprises in China. Traditional industries will increasingly benefit from a wide variety of new technologies. For example, microelectronic sensors in boilers will facilitate more efficient use of energy resources, while computers will assist scheduling, testing, and inventory control. The net result will be increasing productivity in some areas, which is the primary objective of S&T modernization.

38. In addition to gaining from increased industrial productivity, the military sector will also both drive and benefit from the acquisition of foreign technology and the enhancement of domestic research capabilities. Military R&D programs already in progress are likely to be accelerated (see inset).^{*} Foreign technological assistance probably will reduce by several years the time it takes to solve critical problems, such as have been encountered in jet engine manufacturing. Thus, access to foreign technology probably will be the most important single factor in the modernization of China's military inventory.

^{*}The Director of the Bureau of Intelligence and Research, Department of State, believes that the linkages among research, technology requisition, assimilation, and production by China's defense industries are not made sufficiently clear to judge the resulting effects on military modernization.

Military and Space Programs That Could Benefit From S&T Modernization

Space

- New heavy-lift launch vehicle
- New navigation and geodetic satellites
- New meteorological satellite
- New warning and ocean surveillance satellites
- Improved photo and ELINT reconnaissance satellites, communications satellites

Ballistic Missile Forces

- New solid-propellant ICBM
- New multiple reentry vehicle capability
- Improved warheads, guidance systems

General Purpose Forces

- New main battle tank
- New armored personnel carrier infantry fighting vehicle
- New antitank guided missile
- New low altitude surface-to-air missile
- New truck
- Improved munitions
- Improved logistics system

Naval Forces

- New class frigate/destroyer
- New cruise missile
- New shipboard surface-to-air missile
- Improved antisubmarine warfare, electronic warfare, and shipboard command and control systems

Air Forces

- New fighter-bomber
- New air-to-air missile
- Improved radar, fire control, armaments, engines, and fuselages

* For a more detailed description of China's developmental military programs, see DIA's Defense Intelligence Projections for Planning: The PRC Military Forces. (U)

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39. While the developmental process will be speeded up in many areas, the production of new weapons and equipment by China is not likely to substantially alter the Sino-Soviet military balance. Soviet ground, naval, and air forces in the Far East already possess weapons more sophisticated than those currently being fielded by China, and Moscow's continuing modernization of its forces in the Far East make it highly

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unlikely that Beijing will erode Soviet military superiority. The balance of forces with other potential adversaries in East Asia is also unlikely to change dramatically over the next 10 years. Despite China's development of new weapons based on foreign technology or purchase of some Western arms, it is unlikely that China can either absorb the technology or field sufficient numbers of more advanced weapons before the late 1990s. []

40. Although the pace of modernization will be slow, successful use of technology will create additional demands for research and development. Increasing demands on S&T will lead Beijing to intensify efforts to acquire foreign technology, while attempting to avoid becoming overly dependent on any particular foreign source. China has generally found technology more accessible in the United States than anywhere else. Thus, S&T ties to the United States will gain a momentum that will be difficult for Beijing to change. []

41. In addition to pressing for better access to technology, Beijing will seek help to encourage Chinese students to return home. The leadership has expressed increasing concern about the percentage of the over 40,000 students who have gone abroad for study since 1978 and have not returned to China. Some have remained in the West, particularly in the United States, and accepted high-paying, technical jobs. While a few may be engaged in some form of industrial espionage, most have simply been attracted by US prosperity and freedom. These trends have caused Chinese officials to become seriously concerned about a "brain drain" that they can ill afford. []

42. For the USSR, S&T modernization in China poses some risks and opportunities. Not only is Beijing clearly moving away from the Soviet model, it is establishing some S&T relations with Eastern Europe that may trouble Moscow. Should Beijing's reform efforts be even relatively successful, the Soviet model would be further discredited in the eyes of the Third World. On the other hand, Moscow can use China's

desire for technology to improve relations through S&T exchanges. Some Chinese students may even go to study in the USSR where Beijing can be assured that few are likely to remain. In addition, some Chinese enterprises are anxious to expand trade relations with the USSR because it is much easier to compete in the Soviet market. Their products sell for three to four times the value that they can command in the Western market. In addition, they can save hard currency by countertrade arrangements. But improvements in Sino-Soviet S&T relations are likely to be limited because the West provides a much better source of advanced technology. []

43. For the rest of the world, China's S&T modernization—to the extent that it contributes to significant industrial advances—suggests that Beijing may play a larger role in the world market, both as a consumer and as a competitor. China's ability to export both raw materials and products involving low to medium levels of technology, such as machine tools, will be strengthened by technological improvements. As Chinese goods improve in quality, they will become increasingly competitive on the world market. []

44. Beyond these economic and military possibilities, S&T modernization may also have unintended social and political consequences in China. S&T is at the leading edge of reform and has contributed in large measure to the increased openness noted in China. Scientists and engineers in particular have been granted exceptional opportunities for travel and study abroad. This broad exposure encourages freedom of thought and could increase pressure for social and political changes in China. It also may raise expectations that similar opportunities and freedoms should be made available to other groups. While such developments are not likely to undermine the fundamental control exercised by the Communist Party, such openness will contribute to the broader problems Beijing's leaders will face: how to open China—for economic and technological reasons—without seriously undercutting the party's monopoly of power. []

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