China's Progress in Technological Competitiveness

The Need for a New Assessment

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CONTENTS

EXECUTIVE SUMMARY

This report describes 16 recent remarkable achievements in S&T China has reported in 2005, then proposes 20 indicators that should be used to produce a more accurate future assessment of the rate of progress of Chinese S&T. The report also provides summaries of 6 South Korean alarming assessments of China's dramatic progress in Chinese S&T, in 2005. These Korean assessments, even in summary, seem more useful than the data and trends provided in 1999 by the NSF that were biased toward a slow and backward China, said to be facing daunting challenges with little hope of S&T breakthroughs.

The report does not find fault or address why the various NSF indicators were selected. The actual data is relegated to the appendices. It is more important to ask if the 8 South Korean studies are correct to predict that China will soon be major global S&T competitor. Much appears to depend on which indicators will be selected in a new assessment. That is why 20 new indicators are proposed.[1]

Finally, the report quotes from the 2004-2005 Congressional debate on competitiveness and the NSF and other US science budgets, which have been flat or declining for years. There is little mention of any challenge from China or any other nation. At least we cannot accuse the NSF of inflating the threat from foreign S&T in order to save their own declining budget. Other reports on measures to improve US competitiveness – in taxes, science education, basic research, defense technology – rarely raise any concerns about a challenge from China's S&T competitiveness, with some notable exceptions.

Instead, an old paradigm continues to dominate debate in a way that closes off any policy discussion of what to do about a surprisingly competitive China S&T export economy. This old paradigm seems omnipresent. The Economist magazine mistakenly used it in the current April 9, 2005 issue, claiming falsely: "To assess China's future, it is crucial to understand the countryside….where 800 million live on an average income of less than a dollar a day, rural backwardness weighs heavily on the minds of China's leaders as they <u>dream</u> of joining the ranks of the worlds leading economies." Is it really just a <u>dream</u>? The WTO announced last week that China in 2004 surpassed Japan in exports, and that one third was electronic products. Yet, as long as the press portrays China as just a rural poverty case, its leaders merely dreaming of world economics, it will be necessary for reports like this one to over compensate, by showing a bias of stressing China's remarkable achievements and surprising breakthroughs, ignoring rural poverty and other obstacles.

Predictions a decade ago of slow Chinese S&T progress have now proved to be false. A systematic underestimation has occurred. Improved assessments with new analytical techniques will be needed to avoid errors that the "old paradigm" generated. A 1999 National Science Foundation study scored China very low in future S&T prospects, Yet the same indicators are still in use – patent applications, journal articles cited, numbers of new doctorates, and estimates of per centage of GNP allocated to R&D. These do not capture China's progress, and have a bias toward underestimating Chinese competitive progress.

In the past few months, China has announced a new supercomputer that operates at 11 trillion calculation per second, breakthroughs in nanotechnology, manufacture of immunochips to detect staph infection, operation of a mini-space satellite, plans to launch another 100 satellites beyond the 70 already launched, a state of the art new pebble-bed nuclear reactor technology, plans to build 40 nuclear reactors [the US has built none since 1970], a Chinese-designed Pentium-style computer chip, a doubling of factory production of robots, design of a new satellite launch vehicle capable of orbiting 25 tons, successful use of cloning cell technology to produce a buffalo, opening of semiconductor design centers, progress by the

[1] This subject is explored thoroughly in a 550 page book with 24 expert authors. See *Keeping Abreast of Science and Technology*, W. Bradford Ashton and Richard A. Klavans, editors, Battelle Press, Columbus, Ohio, 1997

Institute of High Energy Physics on a electron positron collider, support of a super conducting collider in Germany, partnering with the EU to enable the Galileo global positioning system, and a state of the art planned astronomical observation program . Few if any of these developments would have been forecast a decade ago under the influence of the old paradigm.

Last week, the WTO announced that China has overtaken Japan as the world's third largest exporter, after a 35 per cent jump in the country's overseas sales. Surprisingly, electronic goods now account for a third of Chinese exports. Yet Chinese leaders continue to downplay their achievements in S&T, and demand faster progress.

Without a new assessment, US policy makers will likely be further surprised in the decade ahead as China gradually surpasses the US in technology exports. A similar predictive failure occurred in the early 1950s when Soviet S&T progress was underestimated. The Sputnik shock greatly increased US S&T spending. Alarmed by the decline in US technological competitiveness, the American Electronics Association in February 2005 called for “Sputnik Summit” in 2005 to put forth proposals to improve US competitiveness.

This report quotes many recent Congressional statements of concern from Senators such as Bill Frist, Kit Bond, and Barbara Mikulski, and many Congressmen about the federal S&T budget. Consistent with the influence of the old paradigm and the lack of an adequate assessment, the China challenge has not yet been mentioned in these debates.

The policy deliberations about China by both Congress and the Executive branch have been disadvantaged by mistaken predictions. The “old paradigm” of understanding Chinese S&T emphasized China’s backwardness, its overwhelming obstacles, and predicted a slow pace of Chinese progress. This old paradigm was even encouraged by some Chinese official statements, such as the claim it will take until at least 2049 before China becomes a major power in S&T. The old paradigm promoted a generous, optimistic attitude toward China, even patronizing China’s prospects for S&T growth. The old paradigm did not see China ever becoming a worthy competitor with the American superpower, but as a poor, rural nation of 700,000 villages where per capita income was low. A key part of the old paradigm was the assumption – in spite of Chinese claims – that the Chinese Communist party was headed for a liberal transformation, and that democracy and political liberalization could be expected in a few years. Some who believed in the old paradigm added a twist that some kind of “collapse” in China was likely, but this pathway would also lead to slow growth, and political liberalization. This “collapse” variant seems less likely now.

A new assessment would have to be based on a new paradigm that many are now constructing based on revelations the Chinese have made in the past year of astonishing progress in technological development, combined with extremely firm resistance to any political liberalization.

An up to date assessment of China’s recent remarkable progress would aid Congressional deliberations in three areas: whether to adopt a range of proposals to improve US competitiveness, whether to consider measures to restrict China’s access to advance technology, and whether earlier predictive errors can be corrected.

The NSF deserves praise for recognizing, as early as 2000, the need to fund studies to improve its indicators and its analysis for measuring national progress in S&T. The NSF assessment in 1999 of China’s rank in global competitiveness placed China’s prospects below nine other nations including Malaysia, Taiwan, and South Korea using indicators that need to be supplemented in a new assessment.

SECTION 1
S&T IN CHINA'S GRAND STRATEGY

April 1, 2005, Chinese Premier Wen Jiabao in a formal speech in Beijing asserted that "science and technology are the decisive factors in the competition of comprehensive national strength." This policy dates back 27 years to the policy of Deng Xiaoping on S&T as the "primary" force that helped start China's reform era. Premier Wen added something new: "independent innovations are crucial to the rapid rise of a country. We must introduce and learn from the world's achievements in advanced science and technology, but what is more important is to base ourselves on independent innovations because it is impossible to buy core technology …Independent innovation is the national strategy." Such a goal would surprise anyone who has been reading the conventional assessments of China's slow pace of S&T progress

China has for three decades published its own, more optimistic, assessments of its chances in the future international S&T competition. Beijing claims to use a "scientific" method to predict future power relations among the major nations. Nations are to be measured carefully, especially with respect to indicators of progress in Science and Technology in order to forecast who will be ranked how high in twenty years or more. These formulas have been published in China for the past decade. The Academy of Military Science of the PLA claims to use the formula that Deng Xiaoping himself used in the 1980s. Interestingly enough, S&T is the single most important factor in calculating future national power – after the overall size of the economy of the nation.

Developing national science and technology has not always been China's most important goal, but since the 1978 reforms, it has been. Science and technology has also been called the key link for China's future military power that will be needed in a hostile world.

Chinese ancient statecraft from the Warring States era focused on how a wise leader made strategy according to the power of his state. Sun Zi warned that the outcome of war depends on the correct assessment of power through calculations and estimates of enemy strengths and weaknesses. Consequently, more so than most Western futurists, Chinese authors want to forecast the future international status hierarchy. The means by which they make such strategic assessments is through the measurement and comparison of Comprehensive National Power (CNP), especially the S&T factors. This will lead to wise policy choices, Chinese authors say.

CNP (zonghe guoli) refers to the combined overall conditions and strengths of a country in numerous areas science and technology have become increasingly important in the competition for power and influence in the world. Chinese analysts have developed their own extensive index systems and equations for assessing CNP. It will be seen that their analytical methods are not traditional Marxist-Leninist dogma or Western social science but something unique to China, particularly the stress on the role of S&T as the primary factor that can bring national greatness to China .

Chinese Assessments of S&T Competitiveness in 1995 – Surpassing the US by 2020

Although the phrase "Comprehensive National Power" did not itself come into existence until the 1980s, the concept has ancient cultural roots and "evolved from the concepts of 'power,' 'actual strength', and 'national power.' Western studies, as cited in Princeton Professor Aaron Friedberg's classic book *The Weary Titan*, have warned that errors in assessing power are easy to make, and may even explain why some wars occur. It is extremely difficult to assess power "transitions" accurately, as one great power is surpassed by another. Professor Friedberg cites an almost poetic account of the difficulty in assessing national power transitions, a remark by the great English statesman, Lord Bolingbroke:

"A precise point at which the scales of power turn . . . is imperceptible to common observation . . . they who are in the rising scale do not immediately feel their strength, nor assume that confidence in it which successful experience gives them afterwards. They who are the most concerned to watch the variations of this balance, misjudge often in the same manner and from the same prejudices. They continue to dread a power no longer able to hurt them, or they continue to have no apprehensions of a power that grows daily more formidable.-"

Professor Friedberg's book details how difficult it was for the British to track their gradual loss of international standing to the rising power of Germany and the USA. Officials in London had an impossible time tracking various indicators, with different ministries and politicians using very different indicators. For some, complacency and blissful ignorance ruled while the US rose to surpass Great Britain. Professor Friedberg knowingly asserts, based on this historical case from 1885-1895, that measuring the rise of a challenger to the US today – such as China – may be no easier a task than the effort the British botched a century ago.

The Chinese focus on national competitiveness calculations makes it crucial to them to have good estimates of the future. The idea of measuring and comparing CNP developed during the early 1980s. Military force was no longer the main index for judging a country's strength. Numerous other factors contributed to a country's power and were playing a greater role in warfare, such as science and technology. In order to make more accurate assessments about the future balance of power, country strength had to be evaluated in a variety of areas.

China's "Contribution" to Communist Doctrine: The Primary Role of S&T in National Greatness

Zhu Liangyin and Meng Renzhong, two well known military authors, revealed in 1995 that, "Deng Xiaoping used keen foresight and . . . established the theoretical basis for the emergence and formation of his Comprehensive National Power theory." These two colonels stated that science and technology were determined by Deng and the leadership to be "the guiding force in raising Comprehensive National Power." This is established through Deng's emphasis on the need for scientific and technological research, something new in the early 1980s Deng "developed" the sacred classics of Marxist-Leninism by adding his unique idea of that <u>the "primary" productive role in economic growth</u> is science and technology. Deng's comment was, "Marx talked about science and technology being a productive force and this is very accurate, but perhaps today saying it that way is not sufficient, I think that they are <u>the primary productive force</u>." This quotation from Chairman Deng was to have a great impact.

Science and Technology Capability Rated Highly in the PRC Index

In their predictions of where China would stand in national ranking by 2020 with respect to the US and other nations, the key indicators adopted were similar to those that both the OECD and the US NSF have used. 1] Proportion of research and development in the GDP; 2] number of new scientists and engineers; 3] the ratio of scientists and engineers to the whole population; 4] proportion of machinery and transportation equipment exports in total exports; 5] proportion of high-technology intensive exports in total exports. In later years, however, other indicators were adopted. The main book, *On Comprehensive National Power*, by Colonel Huang Shuofeng, provided a detailed analysis of the major component factors of CNP and their numerous indexes. It added measurement of rates of improvement to the so called "Science and Technology Power Subsystem" such as increasing investment in science and technology (total, proportion of the GNP); "level" of science and technology level, scientific and technological "progress" speed; and progress in contributions, results and applications. The indicators focused on the need above all to improve S&T in China. If this could be done, China would surpass the US by 2020. [2]

[2] I provide these predictive calculations by various Chinese authors in Chapter Six of *China Debates the Future Security Environment*, NDU Press, 2000.

SECTION 2
KOREA'S 6 NEW ASSESSMENTS OF CHINA'S S&T

Before turning to the causes of the mistaken assessments made about China's slow progress in the S&T field, it is useful to contrast how South Koreans see the problem today. They use an innovative approach. They do not track the broad indicators, but attempt instead to examine how many months or years "behind" Korean technology China may be. They do the same measurements for the relative progress of the US, Japan and the European Union. The 6 results cited below suggest one aspect of how a new assessment of Chinese progress could be done – by focusing on the content of the technological products the Chinese produce, and how far "behind" the US these products may be.

KOREAN ASSESSMENT MUCH MORE BULLLISH ON CHINA

A Korean survey predicted that the technology gap between South Korea and China could disappear within three or four years. [3] In a survey of 58 Korean business people in China, the Institute for Global Economics (IGE) found that 36 percent of the respondents believe that the level of technology in China might be on equal footing with Korea within three to four years.

This is one or two years faster than the Ministry of Commerce, Industry and Energy's projection. The ministry estimated that by 2010, China could overtake Korea in core industries, including steel and digital electronics. About 26 percent of those surveyed said it might take five to 10 years for China to catch up with Korea in technology.

TECHNOLOGICAL GAP BETWEEN ROK-CHINA STANDS AT 2.1 YEARS[4]

A second research report shows that the technological gap between Korea and China in the 99 fields designated by the Korean government as core technology, including telecommunication and future energy, has been narrowed to average of 2.1 years. For 10 major growth engine industries, including the next-generation semiconductor, the technological gap between the two countries was shortened to 2.5 years on average.

These new findings were included in a report titled "Comparison of Technological Standard of Core Technologies and the Ten Major Growth Engine Industries," which was written by the Special Committee on Future Strategy under the National Assembly with Chairman Ahn Sang-Soo, and published by the Ministry of Science and Technology on September 29.

The report shows that Korea is technologically ahead of China in some fields that are included among the 99 core technology fields. Korea is still ahead of China by 4.1 years in a field known as "Telecommunication Anytime, Anywhere," and by 4.9 years in "Environmental Innovation for a Comfortable and Healthy Life." However, according to the report, Korea is only a year ahead of China in the field of "The Supply, Demand, and the Industrialization of Efficient and Safe Environmentally-friendly Energy," and trails China by 3.8 years in the field known as "Approaching the Age of Aerospace."

Compared to other countries, Korea is 5.8 years behind the United States on the whole, while trailing the European Union and Japan by 4.0 years and 3.7 years, respectively.

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[3]The Korea Times 6 Apr 05,Seo Jee-yeon : "Technology Gap With China Narrowing Faster"
[4] Seoul Tong-a Ilbo 30 Sep 04 Seung-Heon Lee "Technological Gap between ROK-China Stands at 2.1 Years."

Regarding the 10 major growth engine industries, the technological gap between Korea and China stood at 3.4 years for the digital TV and broadcasting. However, Korea led China by a mere 0.7 year difference in the next-generation power cells. Korea had a 1.6 years' advantage over China in the fields of BT medicines and organs. On the whole, Korea is 4.2 years behind the U.S. and 2.8 years behind Japan, while lagging behind the EU by 2.4 years.

China has embarked on acquisitions of foreign businesses as part of its national strategy for condensed technology growth in the automotive, electronic, and chemical sectors. These industries are all where Korean exports are concentrated. Although the technological power of the Korean automotive industry is eight years ahead of its Chinese counterpart, the gap may be narrowed overnight if Shanghai Automotive's strategy for technology growth succeeds. If China equips itself with technological competitiveness as well as low-wages, major industries of Korea may be threatened

KOREA'S COMPETITIVENESS ON DOWNWARD SPIRAL AGAINST CHINA[5]

A third study shows the competitiveness of South Korea has lost much steam in the global market in the four years since 1999, allowing China to catch up in information technology and light industry sectors over the period. In its report on the international competitiveness of South Korea and China, state-run Korea Development Bank said that South Korea led China in 14 manufacturing sectors out of the total 21, with the gap fast narrowing. Between 1999 and 2003, South Korea dropped 4.4 percentage points in terms of international competitiveness in the manufacturing sector, while China's drop amounted to only 1.9 percentage points.

South Korea led China in semiconductor, automobile, shipbuilding, steelmaking and organic chemical, but it trailed China in coal and crude oil, luxury gems and clothing by a wide margin, the Korean Development Bank report showed. A closer look at the report also showed that South Korea's competitiveness weakened in 13 sectors, such as IT, textile, paper and light industry over the four-year period, while it strengthened in only eight sectors. "To strengthen weakening competitiveness against China, South Korea should make more investment in R&D and facilities in order to expand the base for future growth and expand exports to Brazil, Russia and East European countries," a Korea Development Bank official said.

CHINA RISING AS THREAT TO KOREAN AUTO PARTS[6]

A fourth report on Korean automotive parts makers predicts they will face stiffer competition with Chinese counterparts, as the Chinese contenders are quickly turning to export-oriented strategies, according to a report by Korea's state-run think tank, the Korea Institute for Industrial Economics and Trade. Its recent report warned that Chinese parts makers will soon compete head-on-head with Korean companies not just in developing countries but also in advanced markets such as United States and Europe.

"The Chinese government is now encouraging auto parts makers to sell more products abroad. Though China still lags behind Korea in car manufacture, its auto parts sector is quickly improving in price and quality to challenge Korea's," the report said. Along with the burgeoning car sales, China's auto parts companies have experienced fast growth. The report said General Motor Corp., the world's largest carmaker, will more than triple its parts purchase from China to $10 billion by 2009 from last year's $3 billion.

"The technology gap between China and Korea should be around two years. But the Chinese companies are

[5] Seoul Yonhap 23 Aug 04

[6] The Korea Herald 01 Nov 04

investing huge money in their engineering resources under the government-led campaign. The gap is likely to be narrowed," said Lee Soo-young, executive director of Korea Automotive Technology Institute.

The study also pointed to relentless efforts by the Chinese carmakers moving to export-driven strategies. Despite their little experience in car designing, these companies in a long term will compete with Korean carmakers mainly in developing market such as India or Middle East.

"The centerpiece of Beijing's auto policy is improving the global competitiveness of Chinese cars. Chinese makers should first avoid advanced markets because of their relatively low quality. But they will surely try some Asian market and the Middle East to gain experience in export," the report said.

China has more than 100 carmakers. But only a handful of them, mostly foreign joint ventures, are considered competitive. Shanghai Automotive Industries Corp. is the country's largest carmaker and teams up with two leading foreign carmakers - Volkswagen AG. and General Motors.

Shanghai Automotive drew attention from industry watchers when it signed the final contract to buy Korea's No.4 carmaker Ssangyong Motor Co. The Chinese carmaker is understood to want Ssangyong's technologies on sport utility vehicles to improve its product lineup.

Korea Thwarted China's Industrial Spies Since '98'[7]

A fifth report was a briefing by Korean intelligence that it foiled 96 cases of attempted industrial espionage between 1998 and 2004, preventing losses of W58.2 trillion (US$58 billion), the service said. An official from the National Intelligence Service (NIS)'s Industrial Secrets Protection Center made the claim during a seminar at the Federation of Korean Industries' conference center on preventing leaks of industrial technology secrets. He added the focus of the crackdown was leaks of technological secrets to China.

Aggressive Chinese Strategies Threaten Korean Firms[8]

In a sixth study by Samsung Economic Research Institute (SERI), Chinese companies were reported to be threatening the position of certain Korean enterprises in the global market. China's largest home appliances maker Haier set up a gigantic stand on 660 square meters right next to Samsung Electronics and LG Electronics at the CeBit, the world's largest fair for the information and communication industry, in Hannover, Germany, in mid-March 2005. In attempt to shake its image as a cut-price refrigerator manufacturer, Haier surprised visitors with high-tech products such as third-generation mobile phones and digital TVs.

One Korean businessman said Chinese products, though a little behind in product design, were competitively priced at 50 to 70 percent of Korean products. Chinese products will soon make inroads into the European mobile phone markets, the businessman added. The primary concern for Chinese entrepreneurs is to go out into the world. To narrow the gap between them and their advanced overseas rivals, Chinese companies are aggressively merging with and acquiring foreign companies. The Chinese government also recommends global merger and acquisition strategies to help the country's businesses acquire highly advanced technologies and international distribution networks and brands.

China's largest computer manufacturer, the Lenovo Group, bought the PC division of the IBM last year, turning itself into the third largest computer manufacturer in the world. With that momentum, the Lenovo Group is pursuing ways to penetrate the Korean market this year. TCL, formerly a small Chinese mobile phone maker, acquired both German TV maker Schneider and the television division of France's Thompson in a blow to

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[7] Seoul Chosun Ilbo 24 Mar 05
[8] Chosun Ilbo 24 Mar 05

European pride. Chinese firms are pushing for indiscriminate acquisition of Korean companies like Ssangyong Motor Co. and liquid crystal display maker Hydis.

Samsung Economic Research Institute (SERI) warned that China's global investment is only in its infancy, and that through its massive globalization efforts it will emerge as Korea's strongest rival in the near future.

The size of China's investment in foreign markets has been sharply increasing at the rate of 20 to 30 percent every year since it joined the World Trade Organization in 2001. The number of mergers and acquisitions by the Chinese companies increased by 33 percent compared to 2003, and money involved increased by 320 percent from 2003 to US$1.4 billion.

SERI researcher Chung Sang-eun said China was moving its chief investment from trade and the catering industry to highly advanced fields such as home appliances, information technology and petrochemicals, with the scale of each investment getting larger.

SECTION 3
16 REMARKABLE S&T ACHIEVEMENTS

1. A NEW PLANT DOUBLES PRODUCTION CAPACITY OF ROBOTICS FIRM

Siasun Robot and Automation Co Ltd, China's leading robot producing and engineering firm, will start building a plant in Shenyang, capital of northeastern Liaoning Province, this month.[9]

The new facilities will double the company's annual production capacity to 2,000 units mainly of manufacturing equipment, according to Qu Daokui, president of Siasun.

This marks a crucial step in the firm's efforts to retain its position as China's dominant robot producer, Qu said in an interview with China Daily.

2. SEVEN ASTRONOMICAL PROJECTS TO EXPLORE SPACE MYSTERIES

News from the National Astronomical Observatories (NAOC) says that in order to promote the development of China's astronomical high technologies the NAOC -- dubbed "astronomical carrier", is going all out to push ahead seven astronomical projects. Experts said the construction of them would give full play to the role of astronomy in exploring scientific forefront and developing high technologies, and make important contribution to the demand of national key strategy.[10]

Ai Guoxiang, academician of the CAS (Chinese Academy of Sciences) and director of the NAOC, published an article in the Scientific Development Report 2005, which introduces the seven projects.

1. LAMOST is called a "giant eye" that can simultaneously monitor 4,000 celestial bodies. It will become the telescope that <u>has the highest spectrum acquiring rate in the world.</u>

[9] China Daily 05 Apr 05

[10] Renmin Ribao 17 March 2005

2. SST will be the first spatial telescope that China launches into the space.
All the spatial telescopes currently floating in the space come from the US, Japan and developed countries in Europe. The successful development of SST will bring China into the leading position in international solar space research.

3. FAST is vividly described by scientists as a "heavenly eye" in a valley. Scientists hope it can receive signals sent out by an "extraterrestrial civilization". Radio telescope is different from optical telescopes in that it obtains and analyzes various information through receiving electric wave signals from outer space. Currently, the radio telescope with the largest diameter is a 305-meters telescope built by the Americans. The FAST the Chinese scientists plant to build at Kasite depression in southern Guizhou will be the world's largest radio telescope, so large that it can fill the whole valley with a reception area of one square kilometer.

4-7. According to Ai Guoxiang the other four projects will include an optical telescope installed at Lijiang Gaomei of Yunnan to enhance the capability of observational astrophysics. Second, a 1-meter infrared vacuum solar tower will be built on the northeast bank of Fuxian Lake in Yunnan as one of China's main observational equipments for solar physics. Third, to support the lunar exploration the NAOC will, together with other partners, assume the enacting of scientific objectives, development of payloads, deep space exploration coordination as well as ground application and scientific research system. The fourth project will be to look for a fine site on the Tibet Plateau for the new generation large ground optical, infrared and millimeter-wave telescope.

3. NUCLEAR INDUSTRY [11] - PEBBLE-BED REACTOR TECHNOLOGY[12]

Between 2005 and 2015, China will construct 30 nuclear reactors at the 1m kW level.[13]

The Financial Times reported that China is poised to develop the world's first commercially operated PBMR in the eastern province of Shandong. The "meltdown-proof" PBMR concept, which incorporates uranium-centred graphite spheres the size of billiard balls as a fuel source, was developed in Germany more than 20 years ago. Interest in the technology was revived in the 1990s. Japan, France and the US are known to be working on other fourth-generation nuclear power plant designs. The Financial Times reported the Institute of Nuclear and New Energy Technology at Beijing's Tsinghua University, which operates the world's only test pebble bed reactor in a military zone outside Beijing, was providing the technology for the planned PBMR power station.

An official representing the consortium, which is led by Huaneng, one of China's biggest power producers, was quoted as saying the proposed 195MW gas-cooled power plant could start producing electricity within five years.

4. SHANGHAI SUPERCOMPUTER – 10 TRILLION CALCULATIONS PER SECOND

Chen Liangyu, member of the Political Bureau of the CPC Central Committee and secretary of the Shanghai Municipal CPC Committee, officially started the Dawning 4000A system at the Shanghai Supercomputer Center in October 2004. This is a computer system with a speed of 10 trillion calculations per second. The event marks the official beginning of the operation of a commercial supercomputer system jointly developed by the Institute of Computer Technology of the Chinese Academy of Sciences, Dawning Corporation, and Shanghai Supercomputer Center. The Dawning 4000A system signifies that China has made a breakthrough in the development and application of supercomputers. As a result, China has become the third country that

[11] Beijing Qiushi (Internet Version-WWW) in Chinese 16 Jan 05 no 2.
[12] Johannesburg Business Day (Internet Version-WWW) 9 Feb 05, Dave Marrs, "SA Nuclear Company Claims 'Four-Year Edge' on Chinese Rivals"
[13] Beijing Xinhua in English 25 Mar 05.

is able to manufacture commercial computers with a speed of 10 trillion calculations per second. Moreover, the achievement has enabled Shanghai to go a step further in the information technology construction.

On behalf of the Chinese Academy of Sciences and President Lu Yongxiang of the Chinese Academy of Sciences, Jiang Mianheng extended warm congratulations on the formal operation of the Dawning 4000A system. He said: The Dawning 4000A system represents a major result of the "863" High-Tech Program initiated by the Ministry of Science and Technology. It is a major result of the pilot knowledge innovation project of the Chinese Academy of Sciences. It is also a major result of Shanghai's information technology construction. This is a forward-looking project with strategic significance. He expressed his hope that the Shanghai Supercomputer Center will achieve better scientific and technological results and play a greater role in promoting scientific research and industrial development in Shanghai and eastern China. [CHINA TO SOON BECOME TOP PLAYER IN SUPERCOMPUTING TECHNOLOGY, APPLICATIONS

China will soon be home to a second one of the world's fastest supercomputers, and the nation will hold all intellectual property rights (IPRs) to the system and its relevant applications.[14]

That means China, previously a non-player in the advanced supercomputing that is the core technology to a country's information grid, soon will be among the world's top players in both supercomputing technology and applications, including the United States and Japan.

"We have already developed the world's fastest blade supercomputer," Steve Chen, founder and deputy chairman of Galactic Computing Shenzhen Co Ltd, told China Business Weekly. Chen, a scientist who has dedicated 30 years of his life to the supercomputing technology, is a member of the National Academy of Engineering of the United States and a member of the American Academy of Arts and Sciences. Our third-generation (blade supercomputer) is mature in technology and ready for deployment and development of industrial applications," Chen said.

The company's third-generation supercomputer, launched earlier this year, was reportedly the fastest computer in the world.

With an average calculation speed 1 teraflop (trillion floating-point operations per second), it can be scaled up to more than 50 teraflops at peak speed. US computer giant IBM recently said it is building BlueGene, a 36.01-teraflops supercomputer, in an attempt to recapture its leading position from Japan, which has been ranking No 1 with Earth Simulator, a 35.86-teraflops supercomputer, for three years.

Yet IBM's Japan rival NEC in October 2004 announced a 65-teraflops supercomputer, to date the fastest in the world, leaving Chen's ranking the second.

Dawning Information Industry Co Ltd, a leading Chinese supercomputer vendor, launched, in 2004, a 1-teraflop supercomputer. To date, that is the fastest supercomputer China has made.

However, despite the notable progress, China does not have much IPRs to the computer's core system, which is based on imported technology, Chen said.

Prior to establishing Galactic Computing, Chen had worked in the United States since early 1980s.

He created Supercomputer Systems Inc in 1987, with financial aid from IBM, after he left his post as a vice-president of renowned US supercomputer company Cray Inc.

Users can easily increase the calculation speed of a blade supercomputer by adding "blades," or sets of CPUs (central processing units).

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[14] China Daily 28 Oct 04 "US Expert Drums up Support for Supercomputing"]

5. **CHINA CLAIMS PROPERTY RIGHTS TO PENTIUM-EQUIVALENT COMPUTER CHIP**

China has developed its home-made central processing unit (CPU) chip -- Godson II -- equivalent **to Pentium III**, announced the Institute of Computing Technology of Chinese Academy of Sciences (CAS) April 17, 2005.[15]

Godson II is China's first 64-bit high-performance processor which supports 64-bit Linux operating system and X-window system. It has more advantages and functions than Godson I in terms of operating system supporting, Internet surfing and DVD playing, said Wang Chengwei, academician of Chinese Academy of Engineering.

According to tests, the performance of Godson II is 10 times as much as the performance of Godson I. Its maximum frequency is 500 MHz. Its performance is equivalent to Pentium III.

"The authentication committee concluded that Godson II has reached the international level in 2000 and pioneers China's home- made CPU development," said Wang at the press conference in the Great Hall of the People.

At the press conference, the institute also signed a contract with Jiangsu Menglan Group establishing a industrial base to boost the process of developing, mass producing and marketing of Godson CPU chips.

Godson I, developed on September 28, 2002 by the institute, **was the first CPU chip of which China has proprietary intellectual property rights.**

6. IMMUNOCHIPS FOR THE DETECTION OF STAPHYLOCOCCUS ENTEROTOXINS[16]

An immunochip is a DNA microarray carrying a high density of antigens or antibodies on a solid carrier. It is a novel biochip developed after the emergence of gene chip. Macromolecular Staphylococcus enterotoxins (SEs) are typically detected by the antibody sandwich technique. In this method, SEA, SEB and SEC were added to the reaction pool, and residual free SEs were washed away.

In this experiment, Staphylococcus enterotoxins were detected based on the double antibody sandwich principle. The limit of detection reached the nanogram per milliliter level (ng/ml). Its sensitivity can be further improved if a multiple amplification technique is employed. For instance, Li Chengwen et al at the Academy of Military Medical Sciences developed an amplified fluorescence technique and an amplified ELISA technique[13] to raise the limit of detection of conventional immunofluorescence assay and ELISA from the ng/ml level to the pg/ml level.

7. TAIWAN'S LARGEST SEMICONDUCTOR CO. - DESIGN SERVICE CENTER IN CHINA[17]

Taiwan Semiconductor Manufacturing Co. (TSMC), currently the world's largest supplier of built-to-order chips, will open a design-service center at its mainland Chinese factory, the first of its kind set up abroad by the chipmaker.[18] The mainland factory was opened one and a half years ago

8. CELL CLONING TECHNOLOGY – WORLD’S FIRST BUFFALO CLONED

[15] Xinhua 18 Apr 05 Chinese-Made CPU Chip Equivalent To Pentium III
[16] Zhongguo Shengwu Gongcheng Zazhi Vol 24 No 8 in Chinese 01 Aug 04 pp 99-104 Article by Gao Zhixian, Yang Mingxing and Wang Tao of the Institute of Hygeine and Environmental Medicine, the Academy of Military Medical Sciences, Tianjin 300050 and Wang Shengqi of the Institute of Radiology, the Academy of Military Medical Sciences, Beijing 100850: "Immunochip Technology for the Detection of Stapylococcus Enterotoxins
[17] Taiwan Economic News 23 Mar 05
[18] Taipei, March 23, 2005 CENS

A calf was cloned with ovary cells that were taken from an adult native buffalo and were transplanted into the 12-year-old female buffalo on April 10, 2004, Xinhua announced.

"The birth of the calf proves that our somatic cell clone technology is mature and this technology will greatly promote cattle breeding in China," said the doctor.

9. PLAN TO LAUNCH 100 MORE SATELLITES BY 2020[19]

China plans to launch more than 100 satellites before 2020 to form a global earth observation system with satellites launched by other nations.

The network would monitor water reserves, forests, farmland, city construction and "various activities of society," said Shao Liqin, an official with the Ministry of Science and Technology, at the 18th plenary session of the Committee on Earth Observation Satellites.

The aim is that "we can obtain necessary data on any event through watching the Earth from space, which is vitally helpful for the country's economic and social development," said Shao.

China regularly sends research satellites into orbit. In October 2003, it became the third nation to successfully put a man in space.

Systematic observations of the earth include that of the atmosphere, water, land, mining resources, water resources and ecosystem. No single country or international organization could offer complete observations of all the areas, said experts.

Combining observation platforms of many nations enables all nations to share information. In April 2004, 44 nations and 26 international organizations formally approved the establishment of a global earth observation system.

10. PACKETIZED OPTICAL SWITCHING – 10,000 TIMES MORE DATA

Japan: Fujitsu, PRC University Develop New Optical Communications Technology

TOKYO (Nikkei)--Fujitsu Ltd. and the Beijing University of Posts and Telecommunications have jointly developed a next-generation optical communications technology for broadband networks.

The technology is a variation on packet switching that uses packets holding 1,000 to 10,000 times as much data as regular packets. The result is that large volumes of data can be sent more accurately and reassembled from the packets more easily. In the new technology, the data remains in optical form when it is packetized. Fujitsu aims to have a practical version of the technology ready in 2008.

In addition, the company and its Beijing subsidiary together with the university in Beijing have succeeded in getting development of the technology adopted as a national R&D project in

[19] Xinhua in English 0021 8 Nov 04 "China To Launch More Than 100 Satellites by 2020"
Nikkei Telecom 21 WWW-Text in English 2023 GMT 16 Nov 04

China. **This is reportedly the first time a foreign company has become involved in a national R&D project in the field of optical communications in China.** [20]

11. MAJOR BREAKTHROUGH IN CHINA'S MINI-SATELLITE

"Innovation I", the first mini-satellite of less than 100 kilograms independently developed by Chinese Academy of Science (CAS) has been normally operated for 385 days since launched into the orbit on 21 October 2003. Currently, the satellite is still in good condition and works steadily. As practice proved that the satellite has met the designed standard and the experimental application by the users told satisfactory.

According to experts from "Mini-Satellite Seminar" held in Shanghai Mini-Satellite Research and Development Centre, the success of "Innovation I" has not only made active contribution to China's low orbit communication system, but also enhanced the development and application of China's mega-satellite technology.

Dr. Jiang Mianheng, vice president of CAS and chief scientist with "Innovation I" satellite project gave a report on the working-condition of the satellite at the seminar, saying the space science, space technology and space development were the three pillar technologies. He noted that CAS would step up the research in the fields of space remote sensing, space environment exploration and forecast as well as mini-satellites. Meanwhile, CAS was also expected to participate in the national space projects, closely uniting the users and cooperating with departments of space industries and local government, and contribute to the development of China's space science technology, added Jiang.

12. 3 EXAMPLES OF NANOTECH PROGRESS WITH JAPAN[21]

"Nanotechnology--Itochu Establishes Information Infrastructure for Commercialization"]
With its trans-corporate Leading Edge Technology Strategy Office at the center of its nanotechnology-related endeavors, Itochu Corp. has built strategic partnerships with worldwide research organizations and others and completed the creation of a system for advanced industry creation in areas such as nanomaterials, nanoelectronics, and nanobiotechnology. Because of the collaboration with various functions that Itochu possesses as a general trading company, this will accelerate the commercialization of new products and the materialization of new themes. with China's Tsinghua University

JAPAN'S NICT, CHINA'S QINGHUA UNIVERSITY NANOTECH, WIRELESS COMMUNICATION[22]

The National Institute of Information Communications Technology (NICT) announced November 8th 2004 that it has formed a comprehensive cooperative agreement for joint research in the telecommunications sector with China's Qinghua University. The group will focus on research and development of areas such as next-generation wireless phone technology and nanotechnology essential for semiconductor processing. This move enables NICT to join forces with Qinghua University, one of China most prominent universities as a telecommunications research base, and ensures a dominant position in efforts for international standardization and such of communication standards.

NICT signed an agreement with Qinghua University of Beijing. The contract period is three years during which time the group will be involved in joint research, the mutual exchange of researchers, and such. The use of research results such as intellectual property rights will be discussed as separate contracts.

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[20] Renmin Ribao 12 Nov 04

[21] Tokyo Kagaku Kogyo Nippo (Nikkei Telecom 21 Database Version) 22 Feb 05
[22] Tokyo Nikkei Sangyo Shimbun (Nikkei Telecom 21 Database Version) 9 Nov 04

The joint research themes will include areas such as next-generation wireless phone technology, ultra wideband (UWB) communications, which are faster than optical fibers, and automatic voice translation software for Japanese and Chinese.

Research is advancing to increase the data communication speed of next-generation wireless phones and to enable the reception and transmission of high picture quality in line with that of optical fibers. Studies have begun on a frequency band usable by 2007 with focus on standardization. NICT and Qinghua University will embark on research of fundamental technology with focus on this standardization.

JAPAN: SII NANOTECH ESTABLISHES CHINA-BASED AFFILIATE, INTEGRATED NANOTECH BUSINESS[23]

On 1 November 2004, SII Nanotechnology (SII Nanotech), a subsidiary of Seiko Instruments (SII), established an overseas subsidiary in Shanghai, China, to carry out the development, manufacture, sales, and service of analytical and measurement devices. Up to now they had been exporting finished products from Japan, but in order to meet the growing demand for analytical/measurement devices and devices to support nanotechnology research in China, they have established an end-to-end system which will cover everything from development and manufacture to sales and service.

13. NEW HIGH THRUST ROCKET DESIGN TECHNOLOGY[24]

Luan Enjie, chief commander of China's Lunar Exploration Project, at The Third China Scientists Forum.

China has successfully developed 12 different types of Long March carrier rocket series on its own, and has the capability of launching all sorts of orbiting satellites. However, the transport capacity of the carrier rockets of the United States, Japan, Russia and European Space Agency has all surpassed that of China, the biggest thrust of their rockets has reached 26-27 tons.

China will choose a new vehicle design for two engines and three modules, which is expected to raise the transport capability of the country's launch vehicles to 25 tons.

Luan indicates that the Space Exploration Project represents a breakthrough in China's deep space explorations, implementation of which will further upgrade China's status as a space giant.

14. CHINA, EU SIGN AGREEMENT ON GALILEO SATELLITE NAVIGATION PROJECT[25]

China and the European Union (EU) inked a technological agreement in October 2004 in Beijing to substantially propel forward the Galileo Programme, a European global system of satellite navigation. The agreement ensures China plays a part in the development of the Galileo Programme - from space and ground technology development to application and fund allocation. China and the EU agreed in 2003 to allow China to join the big programme.

"China is the most advanced country of non-EU members to participate in the Galileo Programme," said Loyola de Palacio, vice-chairwoman of the European Commission, at the news conference on Saturday.

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[23] Tokyo Kagaku Kogyo Nippo (Nikkei Telecom 21 Database Version) 4 Nov 04
[24] Renmin Ribao 10 Oct 04 "Expert: Gap Between China & Developed Nations in Carrier Rocket Technology Widens
[25] China Daily 11 Oct 04 Cui Ning “Galileo Project Grows With Accord"
Xinhua in English 0549 GMT 05 Oct 04 "China Makes Strides in Space Technology"

The technological agreement, reached by the Chinese National Remote Sensing Centre (NRSCC) and the Galileo Joint Undertaking (GJU), will make China's industrial circles a partner of GJU, said Rainer Grohe, executive director of GJU.

"Chinese universities, institutes and industries have much experience in space and communication technologies, China's contribution will make the Galileo Programme more successful," he said.

Sources from the Ministry of Science and Technology said that China-EU co-operation on the Galileo Programme is China's largest international scientific co-operative project.

It will help expand China and EU co-operation on satellite radio navigation industries.

15. XINHUA LISTS PRC'S SPACE TECHNOLOGY DEVELOPMENT

On Oct. 15, 2003, China surprised the world by sending its first astronaut Yang Liwei into space aboard a Shenzhou V spacecraft atop a CZ-2 F launch vehicle. The event made China the third country to put a man in space, following the former Soviet Union and the United States.

China has sent about 70 satellites, including those manufactured by foreign companies, into orbit.

Long Lehao, member of the Chinese Academy of Engineering and general commander of the Long March IIIA Rocket Carrier Project, said the success rate of the Long March rocket series exceeded 90 percent, an internationally accepted benchmark for carrier rockets.

The success rates of similar models of rocket, such as the Delta rocket of the United States and those of Europe, stand at around 93 percent, he said.

In the field of satellite research and development, China has developed various types of satellites for telecommunications, meteorology, science, resource exploration, navigation, broadcasting and other purpose.

China is now focusing on more ambitious space programs, including lunar probes and the establishment of space stations.

Sun Laiyan, director of the China National Space Administration, said earlier this year that China is scheduled to launch its second manned spacecraft in 2005, and Chinese astronauts will conduct space experiments during the mission.

Sun announced in February 2004 that China planned to launch a satellite to orbit the moon by 2007 as part of the country's three-stage lunar project. It will be followed by the landing of an unmanned vehicle on the Moon by 2010.

16. PARTICLE ACCELERATOR JOINT RESEARCH[26]

Some of the world's top physicists made a hard yet crucial decision over the technological route of the construction of the largest-ever particle accelerator in history - a step that may help us solve many more secrets of the universe.

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[26] China Daily 25 Aug 04 "Chinese Physicists Help Unravel Life's Mystery"

Chinese Contribution to Particle Research

Chinese scientists, represented by the Institute of High Energy Physics (IHEP) under the Chinese Academy of Sciences, also participated in the international particle research, according to Chen Hesheng, director of the institute. The institute also hosts an electron positron collider that has been running for 15 years.

The International Committee for Future Accelerators (ICFA), meeting during an international physics conference in Beijing last week, endorsed the recommendation of a panel of physicists on the technology choice for a proposed future international particle accelerator. The 12-member International Technology Recommendation Panel (ITRP), chaired by Barry Barish of the California Institute of Technology of the United States, recommended the superconducting technology be adopted for the proposed International Linear Collider.

Accelerators are used in industry as well. Engineers have turned to accelerators to improve the quality of manufactured goods, to sterilize medical equipment and food, to make semiconductors for the computer industry, to refine aircraft engines and artificial hips, to investigate how car engines wear out, to look for contraband in harbours and airports, and to help survey for underground tunnelling.

However, scientists need to go further in their studies of the compelling questions about dark matter, the existence of extra dimensions and the fundamental nature of matter, energy, space and time, and eventually about ourselves.

17. CHINA DEVELOPS WORLD'S FIRST IPV6 ROUTER FOR NEXT GENERATION INTERNET[27]

China has developed the world's first IPV6 router for the next generation of the Internet, Chinese scientists said in August 2004.

A panel of 11 Chinese scientists commissioned by the Ministry of Education said the router, which was developed by Professor Zhang Hongke with Beijing Communications University and his team, is the core part of wireless/mobile IP network technology for the next generation of the Internet.

The scientists, including Chen Junliang, member of the prestigious Chinese Academy , reached the conclusion after their appraisal of the latest product.

The experts said Internet Protocol IPV6, **based on 128-bit Internet address space**, will help create almost unlimited usable IP address space resources to meet increasing demand. Current Internet Protocol is based on 32 bit Internet address space.

According to forecasts by the Ministry of Information Industry**, Internet subscribers will skyrocket to 300 million by 2007 in China.**

The ballooning Internet users and growing application of intelligent electronic devices, such as home appliances and mobile phones, require huge amounts of IP address space, according to the scientists.

The breakthrough could enable China to manufacture and commercialize the IPV6 wireless/mobile router and gain an edge in the next round of international competition for network equipment, thus producing far-reaching impact on the country's competitiveness in the field and national information security.

[27] Xinhua 13 Aug 04 China Develops World's First IPV6 Router for Next Generation Internet"

SECTION 3
20 NEW INDICATORS OF CHINA'S S&T PROGRESS

OVERVIEW- Challenges and Promises of Using New Indicators

The 20 indicators proposed here will pose enormous difficulties for both collection and analysis, but the payoff promises to be greater than the easier to collect, but ultimately much less informative indicators used in traditional assessments of national S&T rates of progress. [28]

1. Indicators of Progress in Organizational Innovation – The Case of the China Electronics Technology Group Corporation

China Electronics Technology Group Corporation (CETC) was founded on March 1, 2002. It is a large state approved national enterprise group. It is also one of the 20 investment agencies authorized by government. Its operations and achievements suggest a whole set of "indicators" would have to be designed to follow its S&T rate of progress. Further background from its brochures and websites is relegated to the appendix.

What is CETC and how does it use S&T? It is built on a base from 46 electronics research institutions and 26 fully owned or controlling stock high technology enterprises directly under the Ministry of Information Industry. The subsidiaries of the company are distributed in 18 provinces and cities such as Beijing, Shanghai, Tianjin, Guangdong, Sichuan, Shanxi. Its registered capital is 6.35 billion Yuan with total assets of 15.8 billion Yuan and currently has 54 thousand employees and 33 thousand technical professionals, which include 10 China Academy of Engineering academicians, 63 State bestowed outstanding achievement young technical and managerial specialists, 1357 government funded experts, and 6326 senior professional technical staff.

The technology research institutes affiliated with CETC serves as the national team for the information industry. Their research areas cover all special categories of electronic information technology and have multiple areas of technology development and system integration potential from electronic components and entire assembles to total system engineering. Currently the company possesses 14 State level key laboratories, 12 State level and 9 Departmental level quality monitoring agencies, holds several of the nation's first class testing, production, and assembly lines and possesses machining centers and is a complete system able to conduct research, design, testing, production, and experimentation. It has significant advantages in special areas such as integrated circuit technology, software technology, new types of electronic components and electronic information material technology, optoelectronic technology, computer information processing technology, communication and networking technology, audio-visual frequency and multimedia technology, electronic product manufacture technology, information security technology, and Internet application technology.

Long-term services of CETC affiliated divisions in those national economic businesses such as communication, aerospace, finance, energy, transportation have helped to successfully develop integrated information distribution system, navigation system, air traffic control system, railway information integrated processing system, financial networking system, social labor security system, municipal lighting automatic monitoring management system, public security warning Internet integrated system, intelligent architecture administration system, public service information system, intelligent transportation system, automobile electronic system, energy electronic control system and also brought to the market various supplies such as radars, computers, communication network

[28] This subject is explored thoroughly in a 550 page book with 24 expert authors. See *Keeping Abreast of Science and Technology*, W. Bradford Ashton and Richard A. Klavans, editors, Battelle Press, Columbus, Ohio, 1997.

products, digital video products, new type of components, special facility instruments, and fundamental materials.   They all have established very good business records

2. INDICATORS OF PROGRESS IN TECH TRANSFER STRATEGY

In 1998, a Chinese S&T policy journal described the difficulty the PRC is having obtaining state-of-the-art technology from "monopolistic" transnational firms. China's best options reportedly are to pool domestic patents for leverage into cross-licensing agreements with foreign companies and trade access to its markets for advanced foreign technologies. An "independent R&D base" is still a long-term goal.

In the March 1998 issue of Wuhan Keji Jinbu Yu Duice (Science and Technology Progress and Policy), a bimonthly journal of the State Science and Technology Commission (SSTC) covering S&T policy, two researchers affiliated with the Hangzhou Business Institute described the market for intellectual property transfers and suggested specific strategies for securing foreign technology in a difficult environment. Although the article focuses primarily on computers and telecommunications, its authors claim their analysis applies to high-tech industries in general.

The article justifies borrowing technology from advanced nations and "learning lessons" from their experience as the standard practice of technologically developing countries. Transnational companies, however, keep their best proprietary technology "internalized" and transfer it only to fully controlled subsidiaries, relying on their monopoly to maintain a competitive advantage. Even when the technology is ill-suited to a company's line of business, transnational firms will use it as a bargaining chip to obtain useful technology rather than give it away, the article said.

Moreover, since the 1980s foreign companies with monopolies of key technologies have been reluctant to include them in cross-licensing agreements, the article noted. Instead they use the technology to "enter high-level strategic alliances, joint capital cooperative ventures, or make transnational investments of their own." Fees are set high deliberately to "discourage those who would license the technology." Two other recent changes that have made China's situation more difficult, the article noted, are replacement of open-ended cross-licensing agreements with fixed-term agreements and a tendency to treat technologies individually instead of comprehensively by sector as before.

The article conceded that China missed an opportunity to narrow the technology gap earlier when transfers were more easily arranged. Although China's task of building an R&D system "under the leadership of large companies" can be facilitated by participating in cross-licensing agreements, individual Chinese firms are still in no position to negotiate directly with foreign firms on cross-licensing, the article cautioned. Instead China should designate one domestic firm to act as its patents custodian "so the whole nation's strength can be focused on breaking into the oligarchic and monopolistic market for technology."

The article acknowledged that in the present climate general technology is the only sort that can be bought; state-of-the-art technologies needed by China are not for sale. China therefore has no hope of "duplicating Japan's feat of the 1960s and 1970s" of protecting its domestic market while persuading transnational companies to cede key technology. "Using market access in exchange for technology is the only path China can go on at present to develop new high technology industries. But it is not a long-term strategy" and not a substitute for independent, creative R&D, the article concluded.

3. INDICATORS OF NATIONAL S&T PRIORITIES[29]

[29] Xinhua Domestic Service in Chinese 1353 GMT 01 Apr 05
“ National S&T Work Conference, Chen Zhili Stresses That Stepping Up Independent Innovation is Primary Task of China's S&T Work

The 2005 National Science and Technology Work Conference set priorities that can be measured. One priority is “independent innovation.” Progress has been claimed in a number of special projects and in the application of science and technology achievements to industrialized production that have a crucial bearing on economic and social development. It is “ the urgent requirement for improving China's competitive power, and is the primary task of China's science and technology work.”

“It is necessary to take the establishment of a technological innovation system, in which enterprises play a dominant role, as a breakthrough point in stepping up independent innovation,” as was outlined by Xu Guanhua, minister of science and technology.

Can these issues be measured?

Facing a growing ban on core technology transfer to China, State Councilor Chen Zhili urged Chinese scientists and enterprises to become more innovative in building up the nation's research strength.[30] She said the country will “invest more capital to make breakthroughs in key technologies” and offer preferential taxation and financial solutions to help enterprises become involved in the endeavor. "Many lessons have taught us that some countries don't lift barriers when we need technologies to improve people's lives and build up national defense," Chen warned nationwide science officials via a video-conference system.

Chen said the priority of the government's work in science and technology this year is to create an environment that is conducive to innovation, encouraging the nation to “develop more home-grown patents.” Currently, nearly half of all the technologies applied in China originate overseas, a situation that has led to legal disputes between Chinese enterprises and overseas patent-holders. Such disputes are likely to become increasingly common if the country remains heavily dependent on foreign technology. "It's not easy to obtain patent transfers in high-tech fields from developed countries because restrictions are still being enforced," said Chen.

Problems have occurred as a result of China's lack of original inventions and findings, which are critical in the country's modernization drive. The central government's efforts to set up a national mechanism for technological innovation began in 1999.

5. INDICATORS OF PROGRESS TOWARD “MANUFACTURING POWER” GOALS

China plans to sharpen its manufacturing technology to become a world's manufacturing power in 15 years, academician Liu Baicheng said at a forum on China's machine building industry. The senior researcher from the Academy of Engineering of China is one of the writers of "China's Middle and Long Term Program on Science and Technology Development." He specialized in the topical research on "science and technologies for manufacturing industry." According to Liu, the term "manufacturing power" is defined in his report as meaning "having a world-leading manufacturing scale, a cluster of heavyweight conglomerates with innovating and competitive capabilities and a number of world famous and diversified production centers."

Unlike other industrialized powers, Lin said, China's manufacturing industry has been growing at the cost of huge energy consumption and environments pollution. Its products have little added-value while its exports are characterized as labor-intensive and having little "technology content."[31]

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[30] China Daily 2 Apr 05

[31] Xinhua 01 Apr 05

6. RATE OF IMPROVEMENT IN PAPERS CITED, PATENT APPLICATIONS

In 2004, China was fifth in the world in research papers published by journals cited by the Science Citation Index. Patent applications reached 66,000, and 18,000 patents were granted. This represents a startling rate of improvement, which, when projected forward, has dramatic implications. Much depends on the type of papers cited and the nature of the patents, however, not merely the quantity.[32]

7. INDICATORS OF OVERCOMING OBSTACLES TO S&T INDUSTRY

According to Shi Qingqi of the State Development Planning Commission, compared with developed countries, development of China's high-technology industry faces six problems, which suggest types of indicators.[33]

1. The commercialization, industrialization, and economic efficiency of high technology industries are low. Scientific research funds are low, and produce few results. The State Science and Technology Commission conducted a survey of 100 high-technology projects that had received government awards, and the results revealed that the commercialization rate was 10 percent and the industrialization rate was 5 percent.

2. The size of the high-technology industry is small, and the structure is irrational. At present, the gross income of China's high-technology enterprises is less than 5 percent of GDP, but in developed countries it is 40 to 60 percent.

3. The technology is backward, and innovation ability is low. China's high-tech products cannot compete with foreign products in terms of variety, quality and performance. Enterprises rarely develop new technology or new products, and well-known brands are few.
4. There is little investment in research and development. In developed countries, funds are obtained through various channels, such as the stock market, risk investment organizations, etc.

5. There are no mechanisms to develop the high-tech industry.

6. Scientific talent is insufficient, and the loss of scientific talent is serious

Based on the above, Shi Qingqi believes that China must adopt the following overall strategy to develop its high-tech industry: China must strengthen its ability to absorb and improve upon imported technology.

8. INDICATORS OF PROGRESS IN “SHARPENING” COMPETITIVENESS[34]

Researchers say the country's high-tech exports now account for about 30 per cent of the country's total goods sold overseas, up from 10 per cent five years ago. However, closer reading of a report by the Ministry of Commerce will inform you that the bulk of these high-tech exports were generated by foreign companies operating in China. So what is the real picture of China's competitiveness and its ability to provide goods and services with added value?

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[32] Xinhua Domestic Service in Chinese 28 Mar 05
[33] Zhongguo Shichang Jingji Bao (in Chinese) 03 Jun 98 p 1

[34] China Daily 27 Sep 04, "Sharpening Nation's Strategic Competitiveness."

"China is very strong in public use sectors but generally it is still weak in civil technology," said Xie Yibing, chief analyst of IDC (China), an international research agency for technology companies and of markets. China can send an astronaut into space but Chinese companies do not own key technologies in many lucrative industries such as automobiles and personal computers.

However, in some sectors such as life science, Chinese are quietly catching up, he said.

Ma Songde, vice science and technology minister, said that China sees <u>information technology, new material, life science, advanced manufacturing and energy as the most important sectors for competitiveness</u>.

In information technology, Chinese companies are at an apparent disadvantage. China already has big-name IT companies such as Lenovo and Founder. However, apart from a few exceptions such as Huawei, most Chinese IT companies do not possess intellectual property rights for the core technology of their products, Xie said.

Chinese companies are not able to produce the most advanced chips that is the main problem, he said. "Almost all the major Chinese IT producers rely on their management particularly market skills to survive, not technology," Xie said.

In life science, a few Chinese scientists are world leaders in their specialized fields and their scientific achievements have potential for considerable commercial benefits. "It is already very difficult (for China) to catch up in IT, but in life science we have a chance and we cannot afford let the chance slip," said Yang Huanming, director of the Beijing Genomics Institute, which participated in the global endeavor of decoding human gene sequence, the Human Genome Project.

Yang is also head of the Huada Gene Research Centre, which is poised to take the lead in China in commercializing scientific achievements.

Zhao Xinli, a member of **the think tank of the Ministry of Science and Technology**, said although Chinese companies did not have cutting-edge technologies in chip making, they still have big opportunities in the information service industry, which relies heavily on developers' understanding of cultures.
"If a company wants to design a system for selling mooncakes, you need knowledge more than technology," said Zhao, vice director of the Institute of Scientific and Technical Information of China.

"This sounds simple, but things like this constitute a huge market."

In life science, China will benefit from its diversified biological resources, its huge population and its well-preserved biological record of families the charting of "family trees," Zhao said.

In new areas of exploration, Chinese can compete with foreign rivals in nano technology, the most advanced in this sector, Zhao said.

In 1995, funds used for R&D were equivalent to 0.6 per cent of China's gross domestic product. In 2000, it was 1 per cent and last year it stood at 1.3 per cent. The world average has been between 2 to 3 per cent in recent years.

9. **INDICATORS OF NEW DOMESTIC PRIVATE COMPANIES IN S&T INDUSTRY**[35]

[35] Beijing, Oct. 26 (Xinhua) Domestic Private Companies To Become China's Backbone of Science And Technology Industry

These companies have become the backbone of the country's science and technology industry as their numbers and assets increase.

Duan Yongji, president of the association of Chinese private entrepreneurs from the science and technology industry, made the remarks here Tuesday at the second award conference for excellent Chinese entrepreneurs.

Duan said most private scientific and technological companies in China are focusing on the new and high-tech industry. Statistics show that the number of private scientific and technological companies account for more than 80 percent of the total companies in China's 53 state-level high-tech development zones.

In 2003, China's total private scientific and technological companies spent approximately 1.5 billion yuan (about 181 million US dollars) of operation funds on scientific and technological activities, about 40 times the amount spent in 1992, said Duan.

While the technological income of all these private companies reached 171.9 billion yuan (about 22 billion dollars) in 2003, a year-on-year surge of 26 percent, Duan added.

By the end of 2003, there are a total of 120,000 private scientific and technological companies in China, two-thirds of which are scattered in south China's Guangdong province and east China's Zhejiang province.

China's private scientific and technological companies are also expanding in scale. The industry's total assets exceeded 440 million yuan (53 million US dollars) in 2003. Currently, there are 5,175 private companies with their total income of more than 100 million yuan (about 12 million US dollars) each, 545 private companies more than one billion yuan (some 120 million dollars) and more than 100 companies exceeding ten billion yuan (1.2 billion US dollars). \

10. INDICATORS OF EXCELLENCE IN CHINESE PRIVATE S&T CORPORATIONS

THE CASE OF HUAWEI TECHNOLOGIES[36]

Huawei Technologies, China's largest telecommunications equipment maker, is not your average mainland firm. From its slick campus headquarters on the outskirts of Shenzhen and its bevy of pricey Western management consultants to its marching drills, Maoist slogans and collectivist ownership, this is one Chinese company that stands out from the pack.

It has also become a serious international player in a high technology business -- a feat accomplished by very few of its mainland peers. Along the way, though, the company has drawn considerable criticism -- from former employees who decry its "dictatorial" management style to foreign competitors who accuse it of engaging in industrial espionage. None of this has stopped the 100 per cent employee-owned firm from becoming a financial success, according to the limited data the company makes public. Last year it earned US$384 million (HK$3 billion) on sales of US$2.69 billion. With an estimated 60 per cent share of the domestic market and substantial exports, revenues are projected to reach US$5 billion in 2004.

Huawei, which means "China achievement" in Putonghua, is touted by Beijing as a model home-grown multinational. Founded in 1988 by Ren Zhengfei, a laid-off army telecommunications officer, Huawei grew quickly from a Shenzhen start-up into an international powerhouse making switches, routers and mobile phone network equipment. Among its customers are major mainland government agencies, banks, public security bureaus and universities. It exports to more than 40 countries and boasts a blue-chip client list including AT&T,

[36] Hong Kong The Standard 24 Sep 04 Rose Tang: "Hungry Like The Wolf"

British Telecom, France Telecom and Hong Kong's Hutchison Whampoa.

"We have always been profitable," said Huawei spokesman Fu Jun.

Resolutely self-confident, Huawei sees major international telecom firms such as Nokia and Ericsson as its real rivals, not its domestic competitors, which include ZTE and Datang.

Even Chairman Mao doesn't offer sufficient inspiration. Ren encourages employees to learn from the Japanese, the Germans and the Israelis. In a letter to new Huawei recruits in 1994, Ren wrote: "I hope you abandon the mentality of achieving quick results, learn from the Japanese down-to-earth attitude and the Germans' spirit of being scrupulous down to every detail."

The Israelis are also lauded for building their nation "against all odds". Even employees' leisure time falls under the Huawei way. "Don't carry on any inappropriate entertainment," Ren said in one speech. "Mahjong playing undermines one's strength and should be strictly forbidden." Even Huawei's music has a martial tone. It transformed an army marching song dedicated to Chinese soldiers in the Korean War into an anthem for Huawei footsoldiers in the battle for market share:

Cross the Pacific ocean in high spirits and giant stride, to fight in America, Europe and Africa, say the lyrics.

The good sons and daughters of Huawei struggle hard. The Huawei spirit of equality and sincerity inspires the whole globe!

The battlefield imagery is a key to Huawei's success, according to Cheng Dongsheng, a Shenzhen-based journalist who wrote a book entitled The Truth of Huawei. "It's very different from multinationals. Huawei eliminates individualism and promotes collectivism," Cheng said. "It works in a unique Chinese environment."

Cheng has followed the firm for five years and interviewed hundreds of former Huawei employees. "Some other Chinese companies adopt military style in management but they are not as extreme as Huawei," he said.

The company demands total loyalty from its staff, he said, and employees must attend motivational meetings that resemble those held during the Cultural Revolution. Some senior managers have quit in protest against "a lack of respect for individuals despite the high salaries offered to them", he said. Huawei's success rests with its commitment to research and development (R&D), he said. Huawei's glossy company profile states that nearly half of its 22,000 employees are engaged in R&D, on which the company spends 10 per cent of its sales each year.

Huawei, of course, has benefitted immensely from the rapid wiring of China. In 1988, the mainland's phone coverage was less than 1 per cent of the population; now it's 40 per cent.

Fu said Huawei has submitted more than 5,000 patent applications, of which about 1,000 were approved. Recently though Huawei has been accused of industrial espionage. Last month Fujitsu Network Communications's top lawyer wrote to Ren saying a Huawei engineer was caught at a Chicago trade show removing the cover from a US$1 million piece of networking equipment and taking photos of circuitry inside.

11. INDICATORS OF 3 STRATEGIES TO BECOME SCIENTIFIC-TECHNOLOGICAL “GIANT[37]

[37] CPP20041126000072 Beijing Renmin Ribao WWW-Text in English 26 Nov 04
By People's Daily Online: "China aims to be giant in science & technology around 2049";
26 November 2004

Three strategies are needed to ensure the fulfillment of the three-step objective for China's science and technology, said Bai Chunli, vice president of the Chinese Academy of Sciences and China Association of Science and Technology, at the 2004 academic annual meeting held by the association.
The three strategies are:

First, make full use of the global innovation resources, participate widely in bilateral, multilateral and global competition and cooperation and greatly enhance China's capability in innovation and industrialization level in science and technology.

Second, strive to boost the foundation and stamina of science and technology.

Third, exert special efforts to solve some important problems affecting the development of science and technology.

12. INDICATORS OF PROGRESS ON THE 31 KEY STATE RESEARCH PROJECTS[38]

Beijing, Oct. 15 (Xinhua) -- An official with China's Ministry of Science and Technology (MOST) said Friday that the state will support 31 research projects in the next five years.

The projects funded by MOST include genetic research related to crops, genome research on cotton fiber, coal gasification and liquefaction technologies, pollution control and ecological restoration in the Northeast industrial belt, cancer prevention and treatment, membrane protein structure and function, said Zhang Xian'en, director of MOST Department for Basic Research.

Zhang did not specify the total budget of the projects. But, according to statistics released by the Chinese government, the research and development (R&D) expenditure accounted for 1.32 percent of the gross domestic product last year. MOST selected 31 projects out of 263 online applications.

China launched a state project to promote research and development in March 1997. The 973 Program focuses on agriculture, energy, information, natural resources, life sciences and materials research. After five years, the first batch of 15 research projects funded under 973 Program was examined by state expert panels last year. Eleven out of the total will be still financed in the coming five years.

The state mid and long-term research and development strategy will allocate 15 percent of total R&D expenditure from 2010 to 2020 to the state's basic research, or 973 projects." Considering shortage of R&D funds," Vice Minister of Science and Technology Cheng Jinpei said, "we need to gather those funds into key research projects and make wise strategy for development. "

13. INDICATORS OF PROGRESS IN THE MANUFACTURING INDUSTRY

China is "facing serious challenges" because of high energy consumption, low output and production efficiency, low value-added products, heavy pollution and shortage of high technologies, said Vice Chairman of the National Committee of the Chinese People's Political Consultative Conference Xu Kuangdi. [39]

In the government work report delivered by Premier Wen Jiabao during the annual session of the National People's Congress on March 5, Wen said the expenditure on scientific research and experiment would account for 1.5 percent of the nation's GDP this year.

[38] Xinhua 15 Oct 04 China Channels Funds Into 31 Key State Projects in Basic Research"

[39] Beijing, March 23 2005 Xinhua

This is a good signal, experts said.

Feng Fei, director of the economic research department of the State Council Development and Research Center, suggested the government should focus attention on developing industries with growth potential to realize the goal of transforming China from a big manufacturing country to a strong one.

He urged the industry to develop and manufacture home brand and high value-added products instead of processing and assembling products for foreign companies.

I4. INDICATORS OF PROGRESS IN RATE OF GLOBAL PATENT APPLICATIONS[40]

April 8 2005 A research capability analyses report released here said China lags far behind developed countries, such as the United States and Japan in overseas patent applications.

The Chinese Academy of Sciences (CAS) recently sponsored the appraisal on world science development trends and China's influence in scientific research and technological development. Tian Xiaoyang, a senior research librarian, said in an interview with Xinhua that Japan and the United States led others in overseas patent applications and are still keeping good momentum. While China has increased its applications for overseas patents, the rate of increase was only ten percent of that of Japan and 25 percent that of the US, Tian said.

In a list of patent applications made by World Intellectual Property Organization (WIPO) Patent Cooperation Treaty (PCT) members, China applied for 3,935 PCT patents from 1998 to 2002 and was ranked the 16th. The United States ranked first with 180,602 applications over the same period. From 1992 to 2001, China applied for 855 patents from the US Patent and Trademark Office. From 1991 to 2000, China applied for 946 patents from the European Patent Organization, ranked the 24th.

Patent information indicates the research and development capability of a nation, Tian said.

From 1993 to 2002, according to the report, the hot areas of patent application included electronics, information technology, computing technology, bio-technology, organic chemistry, medical technology, transportation technology and new materials. Most of the world's top 15 research powers were those holding the most technological patents, Tian said. China's share in world patents is much smaller than its research papers.

Chinese scientists lag behind their counterparts in developed countries with regard to the innovativeness of their research papers, which leads to a low frequency of citation.[41]

The Chinese Academy of Sciences (CAS) sponsored the appraisal of world science development trends and China's influence in science. Xiao Xiantao, a senior researcher who oversees the project, said in an interview with Xinhua that Chinese scientists performed well in mathematics, material science, chemistry and engineering, while having little influence in agricultural science and life science.

According to the Essential Sciences Indicators (ESI) released by the US Institute for Scientific Information, 253,566 research papers were published by Chinese scientists from 1993 to 2003, ninth most in the world and

[40] Beijing Xinhua in English 8 Apr 05

[41] Beijing Xinhua in English 6 Apr 05

2.63 percent of the world total. The Chinese papers were cited 735,288 times by world publications, 18th most in the world. China also produced 944 of world's top one percent of research papers, ranking 17th.

Among all the global research powers, the United States, which produced 2,799,593 research papers in the ten-year period, was first and followed by the United Kingdom, Japan, Germany and France.

The Chinese papers on material science rose by the largest proportion compared with papers in other fields. Papers on clinical medicine, molecular biology, genetics, neurology and behavioral science, immunology, psychology and agricultural science were much less frequent.

According to the report, most of the world's top 15 research powers were those holding the most technological patents. China's share in world patents is much smaller than its share in research papers. Cao Xiaoye, CAS chief policy designer, said Chinese scientists need to keep cool head in sharpening their edges in scientific innovation.

15. INDICATORS OF PROGRESS IN TARGETING SIGNIFICANT S&T SECTORS

Certain sectors of S&T have an importance all of their own – those capabilities that have the potential to significantly enhance or degrade overall capabilities in the future. They include new and enabling technologies as well as those that can be retrofitted and integrated because of technological advances. DOD's Defense Threat Reduction Agency monitors these areas for defense technology by assigning values and parameters to the relevant technologies. It would have to be done by NSF or OSTP for the civil sector as well. It would cover the worldwide technology spectrum. It would be oriented towards advanced research and development including 1] basic research, 2] applied research and 3] advanced technology development, that would have a cascading effect on other new and enabling technologies.

Case study of Tracking New Indicators: Progress in MANUFACTURING/FABRICATION TECHNOLOGY-

Six Areas of Enabling Technologies With Cascading Effects

1 Advanced Fabrication and Processing
2 Bearings
3 Metrology
4 Non-Destructive Inspection and Evaluation
5 Production Equipment
6 Robotics

Highlights

- The continued development of rapid prototyping and near net-shape manufacturing will result in reduced costs, faster prototyping, and the ability to form a product closer to design (final product tailored to need).
- Higher speed machining capability means less time for the machining operation and, thus, reduced costs.
- The development and implementation of nanotechnology should result in improved military hardware.
- Quieter, longer lasting bearing assemblies will be used in submarines and helicopters.
- As manufactured dimensions become smaller, improved metrology equipment is necessary to maintain quality control and keep costs down.
- As manufactured dimensions become smaller and hardware becomes more expensive, more effective methods of in-process evaluation and non-destructive evaluation (NDE) are necessary to determine the quality of final product.
- Advanced land, sea, and air robots will extend capabilities in several areas.

16. INDICATORS OF NOBEL-WINNER NORTH'S INSTITUTIONAL CRITERIA FOR S& T PROGRESS

How rapidly will China create laws and institutions assuring property right first, and other aspects of North's model for rapid growth? Chinese, Korean and Japanese scholars have written about the significance to S&T strategy of the recent findings of Douglas North, a Nobel Economic Prize winner, has identified a set of indicators of economic growth. Although many economic historians have cited technological innovation as a source of economic growth, Professor North asserts that technological innovation was not a causal reason for growth, but that the more fundamental reason was creation of efficient institutions. He discovered that the nature of government and other institutions was highly significant, since efficient institutions can be found only in societies where property rights were properly defined and exerted, and that such a system can be made possible only by effective government. Additionally, a Korea professor has written that North "regarded creation of ideologies that compelled people to obey social rules in an honest and sincere way as a critical factor," since even the government could not prevent people's tendency to deceive each other, take advantage of others, and act in an opportunistic manner

17. INDICATORS OF PROGRESS IN INTERNATIONAL S&T ASSISTANCE PROGRAMS

China is expanding bilateral and multilateral scientific programmes over the next two years, sources from the Ministry of Science and Technology said. [42] Its main targets include joining international basic research programmes, high-tech projects, space technology and high-energy physics studies.

The country will also nurture some powerful domestic companies, universities and research institutions as backbone international co-operation centres, according to the ministry.

In its latest Five-Year Scientific Plan (2001-05), the ministry for the first time included international scientific co-operation as an important part. Sources from the ministry's Department of International Co-operation said earlier this year that China will kick off several international scientific programmes, including:

Galilei Project, the largest scientific program between China and the European Union (EU) since EU and China established official relations in 1975.   The two sides will collaborate in satellite navigation and industrial manufacturing technology.

Chinese scientists have participated in the global efforts to decode human gene sequence, the Human Genome Project.

An air-to-ground observation program, initiated by Chinese and American scientists.   It should provide a scientific basis for urban planning and disaster forecasts.

The new scientific co-operative plans are built upon China's successful co-operation with other countries over the past two decades, according to the ministry.

China began large-scale bilateral and multilateral co-operation with other countries in 1978 when the country implemented its opening-up policies.

Today, the country has scientific links with 152 countries or regions, and has signed official science and technology agreements with 96 countries.

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[42] China Daily 5 Oct 04

Most programmes in the past offered chances for Chinese scientists to go abroad and to see how their counterparts worked, or to attend science conferences.

Now, channels for co-operation have been widened to include the joint development of new technology, the design of new products and the establishment of institutes or laboratories, sources from the ministry's Department of International Co-operation said.

China and the EU, for example, have carried out 300 joint projects in biology, energy, information technology and environmental science since the two set up science links in 1981, the ministry's incomplete statistics indicate.

The year 1998 marked a milestone in higher-level science co-operation between China and the EU, when they signed an agreement to push collaboration in basic research and high-tech programs. In accordance with the agreement, the EU has opened the Fifth Framework Programme - a high-level scientific plan - to Chinese scientists. To date, several research projects proposed by Chinese scientists have been included in the EU's Fifth Framework Program. China has also begun large-scale scientific collaboration projects with France, covering such areas as water conservation, water disaster prevention, disease control, treatments for hepatitis and leukemia. These new programmes differ from the previous single institute-to-institute collaborations between China and France in that they will be conducted between several top laboratories from the two countries, according to the ministry.

Another big part of China's international scientific co-operation is collaboration between China and the United States.

Sino-US collaboration started in January 1979 under the Science and Technology Co-operation Agreement, signed by the late Chinese leader Deng Xiaoping and former US President Jimmy Carter. The two sides have successfully collaborated in basic science research over the past 20 years, covering the atmosphere, oceans, health, medicine and agriculture.

A typical example is seismology studies. The two countries set up a China Digital Seismology Network in 1983.

Since the network went into operation in 1987, it has supplemented studies into earthquakes in Chinese mainland.

Now China and the United States have started a project to improve Beijing's air quality and environment for the 2008 Olympic Games.

Supported by the US Department of Energy, eight clean energy programmes will be implemented to promote environmentally friendly energy development efforts for the 2008 Games and develop future sustainable energy sources in the capital.

POSSIBLE CASE: ISRAEL SIGNS RESEARCH AND DEVELOPMENT AGREEMENT WITH CHINA

[43]Azi Hamer, Director of International Relations at the Chief Scientists' Office, and Mr. Liu, Deputy Mayor of Shenzhen, have signed the first memo declaring their intention to establish an official research and development cooperative relationship between Shenzhen and Israel.

"China is a major destination for research and development cooperation; my estimation is that we will see

[43] Hamodi'a 25 Oct 04 p 6 "Israel, China Sign Memo To Cooperate in Research and Development"

additional agreements in the near future with China and cooperation agreements with Chinese companies," Hamer said.

The recent visit of Ehud Olmert, Minister of Industry and Commerce, to the area, was the signal for the beginning of the negotiation. Sources at Olmert's office said yesterday that the cue for the launching of a flourishing relationship has been given, and that the memo is a first, significant step in the right direction. Hamer also said that this is a precedent, since this is the first time that Israel has signed an agreement with a municipality.

Shenzhen, one of the fastest-growing cities in China, is a "town" of over 10 million people. It is also the first to be announced as a unique economic-growth zone. The electronics and communications sectors make up a major component of the city's economy and investors. The headquarters of the two largest communications conglomerates in China, Huawei and ZTE, are located in Shenzhen.

The signing ceremony was held when the Israeli delegation arrived for the sixth hi-tech exhibition in China and Shenzhen. The deputy mayor, Mr. Liu, said in the ceremony that Israel and his city have a lot in common. Among other things, he mentioned the fact that they are of a similar size and that both have managed to achieve economic development in a short time.

18. INDICATORS OF QUALITATIVE ACHIEVEMENTS FROM S&T JOURNALS

80 Chinese S&T Journals to Monitor

Chinese media covering missile and space issues can be divided into two basic categories: 1) specialized news magazines, papers, and websites and 2) science and technology journals, both in hardcopy and online. Many media of both categories are sponsored by one of two major state-owned enterprises: China Aerospace Science and Technology Corporation (CASC) and China Aerospace Science and Industry Corporation (CASIC). Other sponsors include industry associations under the China Association for Science and Technology. The specialized news media sometimes carry general reports on developments in China's military but more often dwell on civilian programs, such as the manned space program. All media are controlled by the government and do not stray outside certain political and security bounds..

The following list of publications is limited to those with information on Chinese missiles and space systems. The list is not necessarily exhaustive but represents the majority of openly available media on this topic. A list of 80 journals a survey of their contents is relegated to the appendix.

19. INDICATORS OF SCIENCE PARKS S&T PROGRESS AND FUNDS FROM OVERSEAS MARKET[44]

Zhongguancun Science Park, one of China's pioneering high-tech zones, is striving to help small and medium-sized companies raise funds from the overseas market. Dai Wei, deputy director of the administrative committee of Zhongguancun Science Park, said the government would join with overseas investment and intermediate institutions to provide consulting, designing and agent services for small and medium-sized high-tech enterprises in the park.

"On the one hand, we are targeting attracting more overseas venture capital for high-tech start-ups and returned overseas students' enterprises in our incubators," said Dai.

On the other hand, the government encourages powerful and qualified enterprises to become listed on the

[44] CPP20040802000014 Beijing China Daily (Internet Version-WWW) in English 02 Aug 04

overseas market.

"Overseas investment and intermediary institutions are expected to play active roles, as they have rich experience in overseas fund-raising," said Dai.

Fan Boyuan, Beijing's vice-mayor, said that, to guarantee the smooth implementation of the scheme, the government should make efforts to improve exit of venture capital, information exposure and guarantee systems.

China-Zhongguancun Technology & Equity Exchange was opened in March 2003.

Over 700 high-tech projects were listed at the exchange last year and transaction volume exceeded 3 billion yuan (US$361 million).

This year the exchange and the Beijing Equity & Assets Exchange were restructured into the China Beijing Equity Exchange.

20. INDICATORS OF PROGRESS IN THE BIOTECHNOLOGY S&T SECTOR

China is reshuffling its biotechnology management system and working on a long-term plan to fuel development of the sector, but industry experts say more private involvement is needed if China wants to become a true biotech giant.[45]

The key question for the industry's development is not whether the government has increased public investment, but whether the biotech industry has developed independent and efficient research and development capabilities, said Fang Xingwang, a senior scientist of Austin-based Ambion Inc.

Xu Guanghua, minister of science and technology, announced that the State Council, China's cabinet, has decided to form a top-level leadership committee for national biotech development, which will be headed by a major State Council leader. Xu spoke to the 10th International Symposium of the Society of Chinese Bioscientists in America (SCBA), which was held between last Monday and Friday in Beijing.

Xu said other major measures to boost the biotech sector in China include forming a national industrial association, working out a national development plan outlining the focus and direction of China's biotech sector in the next two decades, as well as working out a biosafety law.

The minister did not give a timetable on when to form the leadership committee or to release the biotech development plan. "The move shows that the top leadership looks at the biotech sector as a kernel area of the national scientific and economic development," Xu said.

Insiders said the committee will be chaired by Chen Zhili, who was promoted to State Councillor from the minister of education in 2003.

In China, leadership committees are very powerful and created only in very crucial sectors. The established ones include Central Leadership Committee of Economic Work, Central Leadership Committee of Laws and Central Leadership Committee of Taiwan Affairs.

"We will continue to increase our investments into basic research, developing research bases and teams, and enhancing national data-sharing mechanism in biotech and life science sectors," Xu said. Since 2001, China

[45] China Daily 29 Jul 04 Jia Hepeng, “Gov't Determined To Develop Biotech"

has tremendously increased the amount of public funds allocated to biotechnology.

The national biotechnology budget in its 10th five-year period (2001-2005) increased 400 per cent from the previous five-year period to reach 10 billion yuan (US$1.2 billion), said Li Yong, vice-minister of science and technology, in a previous speech. Despite the growth in public investment in biotech research, China's biotechnological development is still challenged by the lack of collaboration between different departments, poor corporate support for new biodrug research, as well as lack of intellectual property rights, said Zhang Hongxiang, editor-in-chief of the Journal of Chinese Biotechnology.

The public budget for the biotech sector is distributed by the Ministry of Science and Technology (MOST), the Ministry of Health, as well as universities headed by the Ministry of Education, which may cause red tape and waste resources, Zhang told China Business Weekly.

Sun Qihong, a scientist with the Chinese Academy of Military Medical Sciences, said the lack of co-ordination between different government departments has delayed their work to launch the International Human Liver Proteome Project (HLPP).

HLPP is the first basic international biotech program chaired by Chinese scientists. Sun is the assistant to the HLPP chair. "Our plan and budget of about 200 million yuan (US$24.15 million) have long been endorsed by MOST, but when the budget went to the National Development and Reform Commission (NDRC) for approval, it was stranded for nearly one year because NDRC has to balance the interest of different ministries involved in the programme," Sun told China Business Weekly.

Zhou Yongchun, a senior policy researcher with the Chinese Centre for Science and Technology Promotion, a MOST think-tank, said that the emerging competition from countries like India is another element pushing the Chinese leadership to pay more importance to biotechnology.

Last year, a group of leading overseas Chinese bioscientists wrote a letter to Premier Wen Jiabao calling for China to establish an organ like the US National Institute of Health to steer public investment in the biopharmaceutical field.

"We should not be left laggard behind India this time as we were in information technology last century," Zhou said.

Despite China's ambitious plan to fuel the biotech sector, there are still many institutional barriers in the field, experts say.

SECTION 5
US Congressional Concerns About S&T Issues, 2003-2005

Growing Congressional Concern with S&T Competition in 2004 and 2005[46]

“China … will begin to eat our scientific lunch.”

Last year, both Republicans and Democrats expressed growing concern about US S&T budget trends, China was rarely mentioned. John Porter, former chairman of the House Labor, Health and Human Service, Education Appropriations Subcommittee (R-IL) did state:

Science can, in my judgement, be sold to this Administration and this Congress. I suggest that the best way to do that is to recount to them over and over again. . . that the economic destiny of America lies in science and technology, in science and research. And if we don't invest in research, and we don't inspire our children, and if we don't educate them in Congress, the competition out there, and **China is a good example, but Europe also, will begin to eat our scientific lunch**."

Representative Congressional Comments

"I am very disappointed in the proposed [FY 2005] science budget, and I will be working with the Administration and my congressional colleagues to improve the numbers as we move through the budget process. I understand that we are in a very tight fiscal situation and that the Administration has tried to treat research and development as favorably as possible. But we just have to find a way to do better." - House Science Committee Chairman Sherwood Boehlert (R-NY)

"Two years ago, the Congress sent the President a bill authorizing a doubling of NSF's programs over 5 years. Despite signing that bill to glowing reviews, the President sent us two successive budgets that fall far short of reaching that goal." - Rep. Eddie Bernice Johnson (D-TX)

"...it is going to be a major and perhaps an impossible challenge to find additional funds for NSF for FY 2005. I am committed to NSF, but this year's budget is the most difficult I have seen in years. I want to work with the Administration, but we need to find ways to increase NSF's budget as we move forward, if not this year, next year." - Senate VA, HUD and Independent Agencies Appropriations Subcommittee Chairman Christopher "Kit" Bond (R-MO)

". . . how important it is if we can somehow meet the goal of 3% of defense spending for science and technology and maintain the technological lead that is absolutely essential if we are going to be successful or continue to be successful in the global war on terrorism." - Senate Emerging Threats and Capabilities Subcommittee Chairman Pat Roberts (R-KS)

"This subcommittee bows to no one" in championing NSF, but "doubling [its budget] will be very, very difficult." - House VA, HUD and Independent Agencies Appropriations Subcommittee Chairman James Walsh (R-NY))

[46] http://www.aip.org/fyi

"Grim, in a word. . . very grim." - Bob Palmer, Minority Staff Director for House Science Committee, describing overall science and technology budget outlook.

Growing Concern about Dividing Up The S&T Portfolio: Remarks of Senator Pete Domenici

"The time has come to spend money on basic research, just as we have on medical research" - Senator Pete Domenici

During last week's Senate consideration of the budget resolution, a largely non-binding measure establishing spending levels for various government functions, Senator Pete V. Domenici (R-New Mexico), offered the following remarks on federal science funding:

"Mr. President [of the Senate], I rise to speak for 2 minutes on the fiscal year 2005 budget resolution currently pending before the Senate. In particular, I want to focus for just a little bit on the budgets for scientific research.

"The funding for the National Institutes of Health should be my starting point. In the omnibus bill of 2003, thanks in large part to the leadership of President Bush, we met our commitment; that is, in 2003, we met our commitment to double the funding for NIH .

"Senator [Don] Nickles [R-Oklahoma] remembers that clearly, that a couple of Senators started and everybody followed, and a resolution was adopted that said - it was incredible to many of us, but we did it - let's double the NIH . President Bush helped us, and we did that.

"Allow me to explain these numbers. In 1998, we spent $13.7 billion on the National Institutes of Health for cancer, for all of these various diseases, heart conditions, and mental illness. When the commitment was fulfilled, we spent $27.1 billion for medical research.

Congressional Warnings of Challenges to U.S. Competitiveness

Congressional hearings hosted by Senators Senators Lamar Alexander (R-TN) and Jeff Bingaman (D-NM) included warnings that science and technology play vital the nation's competitiveness. Bingaman commented that the U.S. has not been "as focused" on S&T investment in recent years as have many other countries, and Alexander pointed out that federal funding in many areas of the physical sciences and engineering has been flat or declining for years.

From the President's Council of Advisors on Science and Technology, the American Association for the Advancement of Science's annual Science and Technology Policy Forum, to the recently-issued Electronic Industries Alliance report, the issue of maintaining U.S. leadership in innovation is beginning to attract high-level attention. The Council on Competitiveness (http://www.compete.org) releaseDa policy agenda during the National Innovation Summit in December, 2004.

In related news, data collected by NSF indicate that, between 2001 and 2002, the U.S. investment in industrial R&D declined $7.7 billion, or 3.9 percent. According to NSF, this represents "the largest single-year absolute and percentage reduction in the current-dollar cost of industrial R&D performance since the survey's inception in 1953." When the data are adjusted for inflation, NSF states, the decline still represents the largest single-year reduction of the years surveyed and the second largest percentage reduction; the largest constant-dollar percentage reduction occurred between 1969 and 1970. It adds that contributions to industrial R&D from company funds, federal funds, and other non-federal sources all declined between 2001 and 2002. The information is provided in an NSF "InfoBrief" released in May; see InfoBrief NSF04-320 at www.nsf.gov/sbe/srs/infbrief/ib.htm.

Need for Better Metrics – Competitiveness Council Tells Congressional Hearing

NSF has been the sole authority of foreign S&T competiveness. NSF indicates that other countries, especially many Asian countries, are succeeding in efforts to increase their S&T and innovation capacity.

While the U.S. is still the world leader in high-tech industries and has the greatest number of international technology alliances, he said, some Asian nations have nearly doubled their share in global high-tech markets over the past several decades and have almost tripled their share of high-tech exports. The U.S. share of total articles in science and engineering publications has been declining since 1988, while that of many countries is growing, and indicators of bachelors-degree production in the natural sciences and engineering show the U.S. far behind many other nations. NSF in 2000 requested proposals to improve the indicators it follows for assessing S&T trends.

What is needed for the U.S. to stay on top, the Competitiveness Council's Deborah Wince-Smith has suggested, is to restore emphasis on the sciences that drive innovation, develop better metrics for the results of innovation, and transition away from disciplinary "stovepipes" in education and research to a multi-disciplinary, cross-sector model. Policymakers must also recognize the importance of tax and fiscal policies, she said, and deals with the deficit and entitlement spending, high corporate tax rates, and intellectual property and piracy issues.

March 1, 2005 - Senate NSF Appropriators Senators Kit Bond and Barbara Mikulski

"We have fallen off the path for doubling NSF's budget, but we must not give up," warned Senate Independent Agencies Appropriations Subcommittee Chairman Christopher Bond.

Senators with jurisdiction over the National Science Foundation have voiced support for the agency. VA, HUD, and Independent Agencies Appropriations Subcommittee Chairman Christopher "Kit" Bond (R-MO) and Ranking Minority Member Barbara Mikulski (D-MD) have made very positive statements about NSF at the annual budget request hearings.

In 2004, Chairman Bond's words left no doubt about his high regard for the foundation, and his support for physical sciences: "As many of you know, I have been, and will continue to be a strong supporter of NSF and a robust budget for NSF as well. My support for the work done at NSF has not, and will not diminish." He continued, "Unfortunately, the Federal government has not adequately supported NSF and the physical sciences. I strongly believe that the funding disparity between the life sciences and the physical sciences has grown too large. This funding imbalance is alarming because it directly jeopardizes our Nation's ability to lead the world in scientific innovation. Further, we are jeopardizing the work of the National Institutes of Health because we are undermining the physical sciences, which provide the underpinning for medical technological advances."

Senator Mikulski was equally critical: "This barely keeps pace with inflation. Most disturbing is the cut to education programs. This budget actually cuts education programs by 12%. Research is increased by just over 2% - which barely keeps pace with inflation. Yet, salaries and expenses rise by 22%, and major equipment goes up by 44%. I do not doubt the value, need or resources devoted to major equipment. But when every other part of the NSF budget is starved for resources, a huge increase like that stands out."

Senator Mikulski's views on NSF funding align closely with those of Chairman Bond, cited their mutual effort to double the NSF's budget. She stated, "Senator Bond and I are committed to doubling the NSF budget over five years. We have increased NSF's budget by an average of 10% over the President's budget for the last several years. But this Administration has broken its promise to NSF. In 2002, the President signed the NSF

Authorization into law. It authorized a doubling of the NSF budget between 2002 and 2007. In 2006, NSF is authorized to be funded at $8.5 billion. Yet the President's 2006 budget funds NSF at $5.6 billion - 34% below where it should be."

NSF Director Arden Bement explained the Administration's request for NSF as follows: "In light of the tight fiscal times, NSF fared relatively well. For the coming fiscal year, NSF requests $5.6 billion, an increase of $132 million, or 2.4%, over last year's appropriated level. At a time when many agencies are looking at budget cuts, an increase in our budget underscores the Administration's support of NSF's science and engineering programs, and reflects the agency's excellent management and program results." Bement's words were reinforced by National Science Board Chairman Warren Washington who also testified at this hearing, who stated that the requested increase was "a significant investment in NSF programs in a time of National fiscal austerity."

Bond and Mikulski's statements reinforced their opening written remarks. Senator Bond told the Administration's witnesses that "I am unhappy," and looking at John Marburger, the chairman said of his efforts to significantly boost NSF funding, "I can't do it if OMB undercuts us." Senator Bond was also unhappy with House appropriators, who have reshuffled subcommittee jurisdictions that are now out of alignment with those in the Senate. Bond called the House's actions "hasty and ill-advised," saying that it will force an Omnibus appropriations bill late this year. Under such a scenario, Bond predicted, basic research will be cut, as it was in the last omnibus. In any case, Bond said, it will be a "major challenge to find funds for NSF in 2006."

Senator Bond was also unhappy with the proposed "disturbing" cuts in NSF's education programs, asking what the Administration could have been thinking. He contended that this would damage efforts to attract minority students into science, and said the United States could not continue to rely on foreign students. Senator Mikulski later had similar comments. Also noted by Bond was his unhappiness with NSF's management of large facilities, calling its reform efforts too slow (later saying that the foundation's lagging pace "drives us nuts," and adding that the subcommittee "will hold the foundation accountable.") Bond also told NSB Chairman Washington that the Board needed to develop a strategic plan for the foundation.

Chairman Bond also had words for the research community. Describing efforts to double the foundation's budget as one of the nation's "highest priorities," he said, "This must mean a greater effort by the research and high-tech sector in advocating and ‘selling' the virtues of NSF to the general public." To do this he added, "Come out of your labs, out of your think tanks, and let people know how important this funding is."

House Science Committee Chairman Sherwood Boehlert (R-NY) has also expressed concern. His committee's Views and Estimates can be accessed at: http://www.house.gov/science/committeeinfo/06Views.pdf

The 26-page publication states **"The Committee believes the proposed funding for basic research is insufficient**. Funding short-term development at the expense of longer-term basic and applied research is not advisable, and neglects those portions of R&D where government support is most crucial. The Committee also believes that the budget must fully consider appropriate balances between defense and non-defense R&D spending and between biomedical and non-biomedical spending. At $71 and $29 billion, respectively, the R&D budgets of DOD and the National Institutes of Health (NIH) account for more than 75 percent of the total R&D budget." Later in the document the committee characterized the FY 2006 request for the DOE Office of Science as "inadequate" that will do little to bring physical sciences funding into parity with life sciences funding.

The House Science Committee "strongly supports" the budget request for NIST core laboratory programs and facilities, but was "disappointed" in the recommendations for the Advanced Technology Program and the Manufacturing Extension Partnership. Regarding the National Science Foundation, the committee called the overall budget request "inadequate," saying it was "especially disturbed" by the proposed cuts in NSF's Education and Human Resources Directorate.

March 10, 2005 Call for Higher Defense S&T Spending

The American Institute of Physics and several of its Member Societies belong to the Coalition for National Security Research. The coalition advocates for defense science and technology spending, and annually prepares a recommendation on total funding for the 6.1 (basic research), 6.2 (applied research), and 6.3 (advanced technology development) programs.

In its FY 2006 budget submission to Congress, the Bush Administration requested a 21.1% cut in overall funding for these three programs as compared to current spending. Under this request, funding would decline from $13,329 million to $10,522 million (see http://www.aip.org/fyi/2005/018.html .)

The last Quadrennial Defense Review, drawing on a recommendation of the Defense Science Board, recommended that 3.0% of the total Defense Department budget be allocated for the three S&T programs. Currently, the level is 2.6%; under the proposed budget that figure would drop to 2.5%.

AIP, the American Physical Society, and the Optical Society of America (two of AIP's Member Societies) have endorsed the FY 2006 Coalition for National Security Research funding statement which calls for 3.0% of the Defense Department budget to be allocated to these three S&T programs. This statement follows:

"The Coalition for National Security Research (CNSR) strongly urges the Administration and Congress to provide a robust and stable investment in the Science and Technology (S&T) programs of the Department of Defense. These programs play a crucial role in protecting and equipping America's future fighting force.

"CNSR urges a renewed commitment to the Department's basic science program. The coalition recommends an increase in funding to not less than three percent of total DoD spending for the department's competitively awarded merit-reviewed S&T programs in FY 2006. Further, CNSR encourages Congress and the Administration to endeavor to begin efforts to increase the portion of the portfolio dedicated to basic research to return it to the level that served it well during past conflicts, 20% of total S&T spending.

"CNSR's funding recommendation embraces the recommendation of the Quadrennial Defense Review (QDR), and is based upon the President's Fiscal Year 2006 request for the Department of Defense. The QDR states: "To provide the basic research for these capabilities [technological superiority], the QDR calls for a significant increase in funding for S&T programs to a level of three percent of DOD spending per year."

"The defense S&T program consists of three accounts: basic (6.1), applied (6.2) and advanced technology development (6.3). These accounts have provided, and will continue to provide, transformational capabilities to ensure our national security and protect our homeland while educating the future defense science and engineering workforce. As our armed services fight the Global War on Terrorism, they increasingly rely on technology to help defeat the asymmetric threats posed by the terrorists. The technologies that address these threats - such as rapid multilingual support devices, laser-guided munitions, global positioning systems, and the thermobaric bomb - share a provenance in pioneering defense research.

Unfortunately, the accounts that fund these programs have remained essentially flat in constant dollars over the last few decades. National security challenges posed by unforeseen and unpredictable threats demand continued innovation, requiring a consistently strong investment in S&T programs.

DoD's need for personnel in these areas makes support of undergraduate and graduate education critical. The threat posed by a lack of students pursuing S&T careers is compounded by the fact that 57% of the civilian defense S&T workforce will be eligible for early or regular retirement in the next five years**.**

February 25, 2005 DOE FY06 Office of Science Funding Request

In February 2005, the day President Bush's FY 2006 budget request was released, DOE Office of Science Director Ray Orbach discussed the request for his Office, its impacts, and some of the justifications behind the budget numbers. He acknowledged several times that the tightness of the budget required priority-setting, and explained that his choices were determined by the goal of maintaining U.S. leadership in science. He warned that the budget constraints "are not going to go away in 2007 [and] it's going to be a difficult four years."

The request would cut Office of Science funding by 3.8 percent from the current year, to $3,462.7 million. This is below both FY 2004 and FY 2005 levels (see http://www.aip.org/fyi/2005/016.html). While Basic Energy Science and Fusion Energy Sciences would be increased, the High Energy and Nuclear Physics programs would both be reduced below FY 2004 and FY 2005 levels. Biological and Environmental Research, Advanced Scientific Computing Research, Scientific Laboratory Infrastructure, and Workforce Development for Teachers and Scientists would experience reductions from FY 2005 levels.

Given that FY 2006 would be "a difficult budget year for us, for the U.S.," Orbach thought that his office had been "very well treated." In the scheme of things, he said, "we're doing just fine." If the congressionally-directed earmarked projects from the FY 2005 budget are removed for purposes of comparison, he noted, the FY 2006 request is only 1.6 percent less than FY 2005 funding.

Orbach explained that the budget priorities were chosen to keep the U.S. "at the forefront across the spectrum of science" that his office supports. He pointed out that a significant amount of funding would go to starting operations at several new facilities, including the Spallation Neutron Source (SNS), the Linac Coherent Light source, and four of five planned Nanoscale Science Research Centers. These centers, he said, "are unique," and would give U.S. scientists an edge over any in the world. It would be "thrilling," he added, to "start to see them operate."

Regarding the SNS, Orbach called it "a magnificent new machine" that would be an order of magnitude more intense than any neutron source in the world, and would provide two decades of capability that "no one else has."

Orbach also highlighted research in climate change, the Genomes to Life program, and advanced computing, stating that he believed "computation can become the third leg of scientific discovery." Orbach said that the FY 2006 request includes funding for a leadership class machine that could simulate a supernova collapse.

In the High Energy Physics program, Orbach noted that the BTeV program would not be continued. Instead, he said, the lab's future might lie in either neutrino research or a linear collider, although he could not predict "whether the linear collider will be built." Right now, he said, he wanted to run Fermilab "till it's a smoking ruin" to get as much science out of it as possible. While he expected the Large Hadron Collider (LHC) in Europe to start operations in 2008, Orbach declared, "there's still a lot of life left at Fermilab; it won't just disappear when the LHC turns on."

Bush Administration Requests Dramatic Cuts in DOD S&T Program Funding

The Bush Administration has requested a 21.1% cut in overall funding for Department of Defense Science and Technology Programs in FY 2006 as compared to current spending. With proposed cuts ranging almost as high as 50% in some categories, the Administration's request would make double-digit cuts in all but two accounts.

There was no written or oral explanation for the proposed cuts in materials released by the Department of Defense or the Office of Science and Technology Policy. Under the president's request, DOD's total funding would increase 4.8%.

Many of the below figures were provided by the Coalition for National Security Research, to which AIP and several of its Member Societies belong.

Detailed figures are in RDT&E PROGRAMS (R-1)document at
http://www.defenselink.mil/comptroller/defbudget/fy2006/fy2006_r1.pdf

The Defense Science Board and the Quadrennial Defense Review recommended that total funding for the 6.1, 6.2 and 6.3 programs be 3.0% of the total Defense Department budget. This year, the level was 2.6%; under the proposed budget that figure would drop to 2.5%.

Under the Administration's proposal, total federal R&D funding would increase by 1% or $733 million, which Marburger said "maintains that strength, we are not going backward." Under the Administration's proposal, non-defense R&D spending would increase 0.75% over this year's budget.

Marburger briefly described those budgets which would increase next year, including an 8% increase in NIST's core research activities, a 2.4% increase for NSF, a 2.4% increase for NASA, a 1% increase for NIH, and an increase in S&T funding for the Department of Homeland Security. Total funding for DOE's Office of Science would decline, as would Defense 6.1 and 6.2 program spending. USGS funding would be flat. The Advanced Technology Program would be eliminated. Future issues of FYI will examine physics and astronomy budget requests more closely.

ASSESSING THE 2006 R&D REQUEST- No Mention of a Challenge from China

There are several ways to assess the FY 2006 R&D request. The Office of Management and Budget has a series of tables in a document entitled "Analytical Perspectives" that review all federal R&D spending. It shows an overall FY 2006 increase of +1% over the current year. Basic research would decline -1%. Applied research would remain approximately level. Development funding would increase +2%, while Facilities and Equipment spending would fall -4%.

A different categorization is the Federal Science and Technology Budget which OMB says "highlights the creation of new knowledge and technologies more consistently and accurately than the traditional R&D data collection. The FS&T budget emphasizes research, does not count funding for defense development, testing and evaluation, and totals less than half of Federal R&D spending." Under the Administration's FY 2006 request, this funding would decline -1%.

The two senior members of the House Science Committee issued statements in reaction to the Administration's request. Committee Chairman Sherwood Boehlert (R-NY) said, "As everyone knows, this is a very tight budget, with an overall cut to non-defense domestic discretionary spending. Given that context, the science programs fared relatively well. I was especially pleased to see the significant increase proposed for the laboratories at the National Institute of Standards and Technology. **That said, I would certainly like to see more robust increases in the science budget, particularly for the National Science Foundation (NSF) and the Department of Energy Office of Science. And I am especially troubled by the proposed cuts in the education programs at NSF.** . . . As for NASA, the budget appears to be reasonable and balanced overall. But we must review the details of the budget and also think carefully about how NASA should fare relative to other science agencies."

The Ranking Minority Member of the Science Committee**, Bart Gordon (D-TN) was more critical, saying, "This budget ignores our future economic needs and will cause irreparable harm to our country's ability to compete in the increasingly sophisticated and competitive global market place. In the current fiscal crisis we must prioritize. However, when we fail to put job creation, life-saving technologies and students' studies near the top of our list we send the wrong message to the world. The priorities in this budget are not merely harmful, they push this country on a downward slide to losing our global**

science and technological edge. Make no mistake, this is a race. Having a lead in science and technology will not last for the U.S. if we allow ourselves to slow down or, as this budget suggests, stop running. If we stop running at the top speed we can manage, we will lose."

January 2005 Report – General Larry Welch Assesses Defense Basic Research

"No significant quantities of 6.1 funds (basic research) have been directed toward projects that are typical of research funded under categories 6.2 or 6.3." This statement will probably be the most discussed finding of a just-released study by the "Committee on Department of Defense Basic Research" of the National Research Council of the National Academies.

When Congress passed the FY 2004 National Defense Authorization Act it included report language mandating an NAS study "to assess the basic research portfolio of the [armed] services and the Defense Advanced Research Projects Agency (DARPA). This assessment should review the basic research portfolio in order to determine if the programs are consistent with the definitions of basic research in DoD regulation."

The 16-member NAS committee was chaired by Larry Welch, U.S. Air Force (retired), now with the Institute for Defense Analyses. Other committee members have backgrounds in academia, industry, and government. The study began in March 2004, and involved two meetings in which the committee heard from private and governmental experts. In addition, numerous visits or interviews were conducted at universities and site visits were made to defense facilities. The committee reported its findings in a 33-page document, with additional appendixes. It may be ordered or read on line at http://books.nap.edu/catalog/11177.html

The motivation for the congressional mandate was concern expressed by universities and defense laboratories over the last six years that the conduct of DOD basic research was changing. Specifically, there was concern that some 6.1 basic research money is being used to fund other research. In addition, DOD grant and contract reporting requirements are cumbersome and constraining. Finally, the services use basic research funds differently, making tracking and monitoring difficult.

The committee questioned the appropriateness of only a "small percentage" of work classified as 6.1 research, and that some of this uncertainty may revolve around the definition of basic research. "There is no evidence of significant misapplication of basic research funding," the committee stated. It urged that the definition of basic research be refined to include that it "has the potential for broad, rather than specific, application," and "may lead to: . . . the discovery of new knowledge that may later lead to more focused advances." Rejecting the traditional linear process view of 6.1, 6.2 and 6.3 research, the committee advised that "DOD should view basic research, applied research, and development as continuing activities occurring in parallel, with numerous supporting connections throughout the process."

While the committee may not have found 6.1 funding be used inappropriately, it did find reduced attention to basic research: "there has been a trend within DOD for reduced attention to unfettered exploration in its basic research program. Near-term DOD needs are producing significant pressure to focus basic research in support of those needs. DOD needs to realign the balance of its basic research effort more in favor of unfettered exploration."

SECTION 6
POLICY OPTIONS AND A NEW ASSESSMENT

Predictions a decade ago of slow Chinese S&T progress have now proved to be false. A systematic underestimation has occurred. Improved assessments with new analytical techniques will be needed to avoid errors that the "old paradigm" generated. A 1999 National Science Foundation study scored China very low in future S&T prospects, yet the same indicators are still in use – patent applications, journal articles cited, numbers of new doctorates, and estimates of per cent age of GNP allocated to R&D. These do not capture China's progress, and have a bias toward underestimating Chinese competitive progress.

Anecdotal evidence can be misleading, too. However, in past few months, China has announced a new supercomputer that operates at 11 trillion calculation per second, breakthroughs in nanotechnology, manufacture of immunochips to detect staph infection, operation of a mini-space satellite, plans to launch another 100 satellites beyond the 70 already launched, a state of the art new pebble-bed nuclear reactor technology, plans to build 40 nuclear reactors [the US has build none since 1970], a Chinese-designed Pentium-style computer chip, a doubling of factory production of robots, design of a new satellite launch vehicle capable of orbiting 25 tons, successful use of cloning cell technology to produce a buffalo, opening of semiconductor design centers, progress by the Institute of High Energy Physics on a electron positron collider, support of a super conducting collider in Germany, partnering with the EU to enable the Galileo global positioning system, and a new astronomical observation program .

Few if any of these developments would have been forecast a decade ago under the influence of the old paradigm.

Last week, the WTO announced that China has overtaken Japan as the world's third largest exporter, after a 35 per cent jump in the country's overseas sales. Surprisingly, electronic goods now account for a third of Chinese exports.

Chinese leaders continue to downplay their achievements in S&T, and demand faster progress.

Without a new assessment, US policy makers will likely be further surprised in the decade ahead as China gradually surpasses the US in technology exports. A similar predictive failure occurred in the early 1950s when Soviet S&T progress was underestimated. The Sputnik shock greatly increased US S&T spending. Alarmed by the decline in US technological competitiveness, the American Electronics Association in February 2005 called for "Sputnik Summit" in 2005 to put forth proposals to improve US competitiveness.

Any mention of competition from China is missing from recent Congressional statements of concern from Senators such as Bill Frist, Kit Bond, and Barbara Mikulski, and many Congressmen about the federal S&T budget. Consistent with the influence of the old paradigm and the lack of an adequate assessment, the China challenge has not yet been mentioned in these debates.

The policy deliberations about China by both Congress and the Executive branch have been disadvantaged by mistaken predictions. The "old paradigm" of understanding Chinese S&T emphasized China's backwardness, its overwhelming obstacles, and predicted a slow pace of Chinese progress. This old paradigm was even encouraged by some Chinese official statements, such as the claim it will take until at least 2049 before China becomes a major power in S&T. The old paradigm promoted a generous, optimistic attitude toward China, even patronizing China's prospects for S&T growth. The old paradigm did not see China ever becoming a worthy competitor with the American superpower, but as a poor, rural nation of 700,000 villages where per capita income was low. A key part of the old paradigm was the assumption – in spite of Chinese claims – that the Chinese Communist party was headed for a liberal transformation, and that democracy and political liberalization could be expected in a few years. Some who believed in the old paradigm added a twist that

some kind of “collapse” in China was likely, but this pathway would also lead to slow growth, and political liberalization. This “collapse” variant seems less likely now.
A new assessment would have to be based on a new paradigm that many are now constructing based on revelations the Chinese have made in the past year of astonishing progress in technological development, combined with extremely firm resistance to any political liberalization.

An up to date assessment of China’s recent remarkable progress would aid Congressional deliberations in three areas: whether to adopt a range of proposals to improve US competitiveness, whether to consider measures to restrict China’s access to advance technology, and whether earlier predictive errors can be corrected.

The NSF deserves praise for recognizing, as early as 2000, the need to spend $400,000 for studies of how to improve its indicators and analysis for measuring national progress in S&T. The NSF assessment in 1999 of China’s rank in global competitiveness placed China below nine other nations including Malaysia, Taiwan, and South Korea using indicators that need to be supplemented in a new assessment.

APPENDIX ONE
Chinese Innovation Centers

China Electronics Technology Group Corporation

Overview

China Electronics Technology Group Corporation (CETC) was founded on March 1, 2002. It is a large state approved national enterprise group. It is also one of the 20 investment agencies authorized by government.

CETC is built on a base from 46 electronics research institutions and 26 fully owned or controlling stock high technology enterprises directly under the Ministry of Information Industry. The subsidiaries of the company are distributed in 18 provinces and cities such as Beijing, Shanghai, Tianjing, Guangdong, Sichuan, and Shanxi. Its registered capital is 6.35 billion Yuan with total assets of 15.8 billion Yuan and currently has 54 thousand employees and 33 thousand technical professionals, which include 10 China Academy of Engineering academicians, 63 State bestowed outstanding achievement young technical and managerial specialists, 1357 government funded experts, and 6326 senior professional technical staff.

The technology research institutes affiliated with CETC serves as the national team for the information industry. Their research areas cover all special categories of electronic information technology and have multiple areas of technology development and system integration potential from electronic components and entire assembles to total system engineering. Currently the company possesses 14 State level key laboratories, 12 State level and 9 Departmental level quality monitoring agencies, holds several of the nation's first class testing, production, and assembly lines and possesses machining centers and is a complete system able to conduct research, design, testing, production, and experimentation. It has significant advantages in special areas such as integrated circuit technology, software technology, new types of electronic components and electronic information material technology, optoelectronic technology, computer information processing technology, communication and networking technology, audio-visual frequency and multimedia technology, electronic product manufacture technology, information security technology, and Internet application technology.

Long-term services of CETC affiliated divisions in those national economic businesses such as communication, aerospace, finance, energy, transportation have helped to successfully develop integrated information distribution system, navigation system, air traffic control system, railway information integrated processing system, financial networking system, social labor security system, municipal lighting automatic monitoring management system, public security warning Internet integrated system, intelligent architecture administration system, public service information system, intelligent transportation system, automobile electronic system, energy electronic control system and also brought to the market various supplies such as radars, computers, communication network products, digital video products, new type of components, special facility instruments, and fundamental materials. They all have established very good business records.

CETC Second Research Institute

Founded in 1962, the CETC Second Research Institute is the only integrated technology research institution in China's electronics industry. It currently has 655 employees, among them, 465 are technical professionals.

The Second Research Institute deals with technology research and product development in areas such as automation technology, precision machinery processes, heat treatment processing techniques and equipment, electronic assembly techniques and equipment, powder metallurgy techniques, electro-chemical techniques, surface treatment techniques, liquid crystal production techniques and equipment, electronic cleaning techniques and equipment, and chip component production equipment.

The Ministry of Information Industry's prominent periodical "Electronic Technology", complied by the institute and published worldwide, is a comprehensive technical journal introducing electronic industry's production, techniques, extensions, and related information. The institute is also associated with industry and academy groups such as a chapter of the China Electronics Society Production Technology Society, Electronics Industry Technique Standardization Technical Committee, Electronic Industry Technique Working Network, and Electronic Industry Technique Information Bulletin.

Institute's major products are:

- LCD display screen production equipment.
- LCD glass cutters, slicing machine, vacuum liquid crystal fluid injector, LCD assembling sealers, ultraviolet light solidification ovens, cluster crashers, ultrasonic cleaners, polarized beam panel cutter, polarized beam panel bonding machines, liquid crystal bubble eliminators, cleaning ovens, PIN automatic assemblers, coating machines, optical cleaners, grinders, liquid crystal cleaner sets.
- Vacuum brazing welder and heat treatment process equipment.
- Vacuum brazing welding oven, gas quenching oven, vacuum heat treatment oven, etc.
- Panel type component production and fabrication equipment.
- High precision optical sensing multiple printers, automatic dual function screen printers, high speed ribbon makers, automatic ribbon material weaving machine, ribbon alignment machine, semi-automatic ribbon maker, chip slicing machine, and terminal seamer.
- Electrical plating equipment.
- Powder metallurgical products.

CETC 8th Research Institute

CETC Second Research Institute is a specialized research institute mainly dealing with optical fiber and cable transmission technology and currently has 555 employers with 276 various types of technical professions and 154 middle and senior level or higher staff. The institute primarily engages in research and production of optical fiber and cable technology, optical fiber sensors and its systems, special optical fiber communication network and optical terminals, special equipment for optical fibers and cables. After more than 30 years of development effort, 8th Institute has become one of China optical communication research and development bases.

Since the founding of the institute, it has accomplished close to 200 scientific, research, testing, and production projects and has been honored with over 80 State and Provincial/Ministerial scientific technology achievement award. 8th institute is nation's first organization engaged in optical fiber and cable research and production, development, exploration, and application. Its scientific research and products are the front runner or advanced level of the nation. China's first optical fiber drawing machine, first optical fiber cable maker, first set of practical optical fiber based transmission system, first practical shallow water optical cable, nation's first stage optical fiber communication test site demonstration engineering project, which have already been widely developed and utilized, are all the 8th Institute scientific research

CETC 9th Research Institute

CETC 9th Research Institute was founded in 1967 after relocating from Beijing to Mianyang. It is the nation's only integrated applied magnetism research institution. It currently has 8 research laboratories, 6 testing production lines, three companies, as well as a branch office in Zhuhai.

Institute's major products are:

- Micro-wave ferrite isolators, circulars.

- YIG modulated frequency filter/oscillators.
- Power distributors, switches, artificial loads.
- EMI filters.
- EMI suppression magnetic cores.
- Magnetic materials and devices.

CETC 10th Research Institute
First Division
Crystal Division

CETC 10th Research Institute was established as the first comprehensive electronics high technology research institute after the founding of new China

CETC 11th Research Institute

Founded in 1956, CETC 11th Research Institute is a China's earliest comprehensive research institution engaging in integrating laser and infrared technology and putting materials, components, and whole devices into assembled systems. The institute has over 900 employees with more than 500 engineering technical professionals and 120 senior engineers and higher level staff.

Currently, the institute has large scale research and production capability in the areas of laser crystal, pulse Xenon lamps, continuous Krypton lamps, laser power supplies, solid laser devices, laser range finders, laser processing equipment, infrared crystal materials, indium antimonide infrared detector components, telluride cadmium mercury infrared focal plate components, infrared thermal imaging equipment, and infrared temperature gauges etc. The production lines and manufacture techniques are well established for the domestic industry. Some technologies have already reached or exceeded the international level of similar products.

The 11th institute's key products are: laser crystal material, pulsed Xenon lamps and continuous Krypton lamps, solid state laser devices, laser range finders, laser processing equipment, infrared crystal material, indium antimonide, telluride cadmium mercury infrared detector components, infrared thermal imaging equipment and infrared optical mirrors, infrared temperature gauges and medical thermal imagers.

CETC 12th Research Institute

Founded in 1957, CETC 12th Research Institute mainly engages in research on vacuum electronics and laser technology. It is located at the center of Beijing's electronics city and has about 1100 employees, more than half of them are engineering technology staff.

12th institute mainly deals with microwave tubes, but at the same time also pursues applied research and fundamental technology. Its major products are various velocity modulation tubes, traveling wave tubes, magnetrons, microwave triodes, tetrodes, ionization gas switches, thyratrons, inigitrons, gas lasers, monitor components, vacuum positive polarized lamps, vacuum regulation tubes, accelerators and various special equipment, and power supplies. The institute has achieved many research accomplishments in the areas of technological application of electronic ceramics, magnetic materials, precision processing and microwave energy, electronic beams, ion beams, and laser beams.

The major products of 12th institute have been widely adopted in radar, communication, navigation, television transmitting, microwave electronic medical treatment, plasma heating, and testing equipment, etc. They have also provided important impact in science and technology frontiers of launching the man-made satellites, payload operation of missiles, manned space ships

Currently, the institute provides various electronic instrument equipment such as vacuum electronic beam welders, X-ray non-destruction tester, laser processing equipment, display tube production equipment, on-line testing equipment, microwave dryer equipment, microwave medical treatment equipment, and coronary heart disease treatment instrument. The institute meanwhile explores new ideas and enhances professional experience for strengthening its industry base.

CETC 13th Research institute

CETC 13th Research Institute was originally founded in Beijing in 1956 and moved to Shijiazhuang in 1963. It is the earliest established large scale, strong technical potential, and specially equipped comprehensive semiconductor research institution. Currently, there are over 1400 employees in the organization, where 1000 are engineering technical personnel.

The 13th institute's major products are microwave semi-conductor components, optoelectronic components, micromechanical electronics systems, quantum components, vacuum micro-electronics components, field controlled power electronics components, special highly reliable components, arsenide gallium integrated circuits, microwave hybrid package integrated circuits, microwave modules and sets, semiconductor materials, semiconductor packages and semiconductor technical equipment. The institute's manufacturing company's products include serial communication power supplies, high frequency heating power supplies, super bright diode light lamps, communication signal lamps, optical communication equipment, microwave communication equipment, intelligent monitoring systems, networks, intelligent taxing fuel pump etc.

CETC 16th Research Institute

CETC 16th Research Institute found in 1986 is national special research institute particularly engaged in the development of low temperature electronics technology research and applications. It has unique professional advantage and strong research and development abilities. The institute mainly deals with application and development research on low temperature cooling technology, super conductive electronics technology, and microwave millimeter technology. They are mutually independent scientific technologies, and each has its own merits and development prospects.

16th institute has 11 research laboratories, of which 4 engage in low temperature cooling research, 3 engage in microwave millimeter technology research, one engages in super conductor technology research; two affiliated factories engage respectively in mechanical reprocessing and automobile air condition production. The institute has a total of 691 employees with over 300 various types of technical personnel.

The 16th institute's major products are: small and micro scale Stirling type refrigerators, G-M type refrigerators, Sullivan type refrigerators, throttling type refrigerators, and pulsating tube type refrigerators; various types of bore size low temperature vacuum pumps, middle and small scale helium liquefier, low temperature container series (those series products have been widely used as storage for liquefied nitrogen and helium, low temperature physical experiments, particularly the long term storage for high Tc super conductor experiments and long term storage of frozen biological specimen.), petroleum deep well testing thermal bottles, super conductive materials, thin film components, super conductor frequency mixers, resonance cavities, super conductor active and passive components, microwave millimeter wave receiver front stage components, low noise amplifiers and power amplifiers, transmitting frequency synthesizers and mixers, microwave and millimeter wave frequency mixers, amplitude limiters, attenuators, filters, oscillators and VCO, power distributors and detectors, up and down frequency converters and their components.

CETC 18th Research Institute

Found in 1958, CETC 18th Research Institute is China largest and the first established comprehensive research institution engaged in chemical and physical power supply technology research and product development production and applications. Currently it has 1300 employees with more than 600 engineering technical staff, where over 20 are professor rank senior engineers and 220 are senior engineers

In recent years, 18th institute has successively developed cadmium nickel batteries, metal nickel hydrogen batteries, sealed lead acid batteries, temperature difference electric refrigerator components, high ratio energy lithium ion batteries, and related technology as well as a series of products for implementing many production techniques and equipment transfers. One of the largest projects is to cooperate with several Tianjing companies jointly found a Tianjing Lishen Battery Company, Ltd. Its newly formed automatic production line for manufacturing cylindrical and square type high quality lithium ion batteries has an annual production reaching to 50 million sets, which has become an endorsed supplier for the Motorola Company. The power supply products from 18th institute have been widely used in the areas of aerospace, communication, transportation, and small appliances.

18th institute is broad directorship agency of China Chemical and Physical Power Supply Industry Association, the Chemical and Physical Power Supply Technology Chapter of China Electronic Society, Battery Special Committee of the China Electrical Engineering Technology Society, Hydrogen Energy Electric Generation Device Special Committee, Space Energy Special Committee of the China Aerospace Association, National Alkali Storage Battery and Fiber Optics Standardization Technical Committee national professional academic and standardization organizations sponsoring agency

CETC 21st Research Institute

Founded in 1963, CETC 21st Research Institute mainly engages in research, development, testing, and manufacture of small specialized electric motors, components, and mechanic-electric integrated products. The institute has so far developed 1800 sorts of products and 500 Ministerial/City approval projects
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The 21st institute is located in the Caohejing High-tech Development Zone, Shanghai, and has over 700 workers, among them, 360 are engineering technical staff. Various types of small specialized electric motors and components manufactured by the 21th institute are: electromagnetic rotating transformers, synchros, two-channel rotational converters, AC/DC servo motors, AC/DC velocity sensing generators, synchronous motors, DC torque motors, stepping motors, brushless DC motors, DC torque speed sensing motor components, DC servo speed sensing motor components, permanent magnetic AC synchronous servo motors, axial angular coders, electromagnetic brakes, and magnetic powder clutches. Currently, in addition to perfecting continuously the general industry use of permanent magnet brushless electric motor series, the institute has paid great attention to development of the electric car motor and the automobile micro electric motors as well as the market share expansion for the electrical bicycle brushless electric motors and controllers. Moreover, it also develops production for specialized equipment for electronics products such as small specialized electric motors and anti-interference power supplies.

21st institute is the directorship agency for the Small Specialized Motors and Components Industry Association, chairs the China Electrical Technology Society Small Specialized Motor Trade Committee, serves as the webmaster of nation's micro electric motor information net, a leading member firm of nation's Micro Motor Standardization Technical Committee and its Quality Control and Test Center.

CETC 23rd Research Institute

Founded in 1963, CETC 23rd Research Institute mainly engages in technical application research, product development, and large quantity production of information transmission components. Currently it has about 600 employees and 300 professional staff with about 129 senior engineers. Major research areas are communication cables, connectors, wave guides, optical fibers, optical cables, optical devices, and optical fiber transmission systems.

Its major products are:

- Coaxial cable with imbedded foam insulation corrugated tubing.
- Various frequency adaptive low loss axial electric cables and special electric cables.
- Various radiation and high temperature resistant hookup wires.
- Various axial connectors/adapters and their accessories matching with all kinds of cables. Various types of electric cable parts.
- Various types of optic fibers, optical cables, and optical passive devices.
- Transmitter feed line and receiver electric cable used in broadcasting, television, radar, satellite, and mobile phone.
- Coaxial electric cables and their accessories used in the blind areas for the subway and tunnels.
- Communication elliptic wave guide and integrated flexible wave guide for microwave applications.

CETC 24th Research Institute

CETC 24th Research Institute located at the Nanping Economic Technology Development Zone of Chongqing City is one of the earliest founded semi-conductor integrated circuit special research institutions. Currently, it has 777 employees, where 50 percent are professional technical staff. It mainly engages in the development and production of analog integrated circuits, hybrid integrated circuits, micro electronic circuit modular broads, and electronics components. With years of research and development experiences, the institute has established itself as a representative of advanced level in the arena of high quality analog IC in China's integrated circuit technology at various development stages.

CETC 26th Research Institute

The CETC 26th Research Institute is a research institution engaged specially in piezoelectric and acousto-optic technology research and their corresponding product development. Currently it employees 844 workers and 478 technical staff, where 6 are professor ranked senior engineers and 118 are senior engineers. Its main technical disciplines are: inertia vibration technology, acoustic surface wave technology, solid bulk wave and microwave technology, piezoelectric ceramic technology, oxide single crystal growth technology, and acousto-optic technology. In 2001 the institute passed ISO 9001 Quality System Certificate.

The CETC 26th Research Institute manufactures several hundred types of products such as: various series of surface wave filters, resonators, vibrators, storage/correlation circular integrators, frequency synthesizers, components for multiple signal channel filters, parts for signal conditioning and pulse compression. While bulk acoustic wave (BAW) microwave component development fulfills China's needs in this technology areas, various linear accelerators, angular velocity and position gyros, fabricated inertia state sensors, inclinometers, compasses, GPS ground navigation instruments, and other vibration inertia devices and their derived instruments have contributed to a manufacturing capacity of an annual production line of 100 thousand accelerators and 10 thousand sets of various types of gyros

CETC 33rd Research Institute Component Division

The CETC 33rd Research Institute was found in 1958. Its research directions are electromagnetic information leakage technology and products, information security equipment exploration, anti-destruction technology and products, information censorship and recording technology and products, computer system engineering application and intelligent measurement and detection equipment studies, and high quality magnetic material development and manufacture. It oversees 11 research laboratories, one machine shop, one information center, three foreign and domestic joint investment enterprises, and some high technology industries. Currently it has over 1000 worker and 700 technical staff, about 70 percent of the total employees, and 300 senior and middle level science and technical personnel

The institute's major products are:

- Screen shielded ventilation panel.
- Metal mesh net screen shield pad.
- Screen shielded glass window.
- Screen shielded connector/transfer and screen shielded electrical cable.
- Electromagnetic screen shielded rubber panel.
- Screen shielded finger spring liner pad.
- Electromagnetic heat shrinkable tubing.
- EMI absorber.
- High quality precision neodymium ferro-boron.
- High quality aluminum cobalt magnetic metal net.
- High quality iron nitrogen samarium adhering magnet.
-

CETC 40th Research Institute

The CETC 40th Research Institute was officially restructured in 1984, located at the provincial new high technology development zone in Bangbu City of Anhui Province. Currently it employs 543 workers with 245 in various categories of professional staff, 45 percent of total employees

The 40th institute has four centers, "Electronic Industry Connector Relay Quality Control and Testing Center", "Electric Connector Component Industry Association Quality Administration Center", "Controlled Relay Industry Association Technology Exchange Center", and "Connector Component Industry Association Personnel Exchange Center", where the "Electronic Industry Connector Relay Quality Control and Testing Center" is the State's Certified Measurement Administrator (CMA). In 1999, the 40th research institute was awarded as a new high technology enterprise in Anhui Province.

CETC 43rd Research Institute

CETC 43rd Research Institute is the earliest research institution engaged in hybrid microelectronics technology production, research and development. Currently, the institute has 800 workers and 420 various types of professional technical staff, 14 are research level senior engineers, 110 are senior engineers.

The institute's major products are:

- DC/DC converter series. Use hybrid integration and surface pasting process for fabrication. Systematized production and modularized inventory supply.

- Axial angular -- digital rotation converter series. Selsyn or rotation transformer -- digital converter, digital -- selsyn or rotation transformer, arbitrary speed ratio dual velocity processor, various signal driving sources, and power amplifier.
- Various specifically designed electric circuits. Electric current/voltage reference sources and stable voltage sources, AC source electric circuits, power driving electric circuits, amplifier circuits, signal and digital process electric circuits, oscillator circuits, filter circuits, I/F converter circuits.
- Multiple Chip Member (MCM) components. Use low temperature baking, multi-layer based, hybrid multi-layer linear base boards, thick coated multi-layer linear distributed base boards, large area aluminum nitride base boards, and pitted reversed welding development techniques to fabricate various circuitry.
- Seal casting. Shallow cavity type casting series, flat bottom type casting series, power casting series, and aluminum nitride casting series etc.

CETC 44th Research Institute

The CETC 44th Research Institute is a specialty research institution engaged in semiconductor opto-electric devices and technical research on their application. It was found in 1969 and currently has 1019 workers and 457 technical staff, where 6 are researchers, 436 are middle and senior level technical staff. It administrates 8 research laboratories as well as three information, measurement, and package centers with advanced facilities and strong technology potential. It holds the nation's first class large area super cleaning manufacture space The 44th research institute mainly deals with opto-electric system research and development in fields of charge coupling devices (CCD), infrared focus plane devices, semiconductor light emitters, semiconductor light detecting and measurement devices, opto-electric coupling devices, integrated optical devices, optical fiber transmission components and cameras, infrared thermal imagers. Its products have been widely used in the areas of optical fiber transmission, laser range measurement, navigation, ignition, automatic control, aviation and space imaging remote sensors, precision size measurement, computer figure and character recognition, information storage and process, laser and infrared night vision. Based on its new high technology opto-electric capability and broad international technology exchange networking, the institute works actively to engage in research and development tasks to develop domestic and foreign new types of opto-electric products and engineering projects.

The 44th institute accomplished approximately over 700 research project in total and about 450 projects are commended with science and technology achievements, where more than 30 projects are near or exceed international advanced level, more than 200 projects are domestic front runners and accomplishments from more than 100 projects received State and Ministerial level achievement awards. The institute has been established as the important base for China's semiconductor opto-electric device and their application technology research and development.

The 44th institute has developed multi-lateral economic technological cooperation with such countries and regions as the US, Russia, Japan, France, and Taiwan and Hong Kong to strengthen the research and development capability and technology level.

CETC 45th Research Institute

The CETC 45th Research Institute is a comprehensive research institution engaged in electronics industry special equipment research, development, manufacture, and related manufacture technique research.

The products of 45th institute are sold to many of the nation's research institutes, universities and colleges as well as factories. Slicing machines, electronic material processing equipment, and aluminum electrolytic capacitor production equipment are shipped as far away as the US, Jordan, Indonesia, Korea etc. Quartz crystals are exported 100 percent. Applications of the institute's products cover many areas in electronics, aerospace, aviation, and materials.

The institute's major products are:

- Stepping projection optical engraver. The major technical indicator of 0.5 □m stepping projection optical engraver has already reached the level of the international standard of the mid-90s. It is China's first self-developed I -- line stepping projection optical engraver equipment of 0.5 □ m level.
- Contact/close type optical engraver. 2", 3", 4", 5", and 6" 5th generation contact/close type optical engraving equipment are widely used for discrete devices, specialized new types of components research and development and manufacture. Meantime, it also provides support to domestic silicon controlled rectifiers, transducers, especially for support of MEMS research and development.
- In line testing equipment. 15 models and 5 series of probe detectors for using in line testing platform, TZ-107 type probe detectors, and TZ-109 type fully automatic probe detection platform able to measure a 6" diameter plate.
- Package sealing equipment. Primarily carrying out research and development for IC package sealing equipment such as wafer slicing, patching, bonding, plating, character printing, pattern cutting, and ribbon weaving. They already being used in IC and discreet component production lines.
- Material processing equipment and slicing tools. The six series for processing board diameters from 2" -- 6" and 11 types of slicing machines are sold as far as away as Singapore and Korea.
- Electronic part manufacture equipment. 12 kinds of production equipment from aluminum electrolytic capacitor key manufacturing equipment, solid core resistor key manufacturing equipment, glass axial potentiometer key manufacturing equipment, sheet type tantalum electric capacitor key manufacture equipment, and ceramic filter key manufacturing equipment are sold.
- Precision screen mesh printing equipment.
- Image and letter processing equipment.

CETC 46th Research Institute

The CETC 46th Research Institute is one of the nation's forerunners engaged in the research and development of semiconductor materials and optical fibers. It has 704 employees, of which 408 are professional technical staff, 299 are middle and senior rank professional technical staff. Since its founding over four decades ago, the institute has become a comprehensive electronic materials research institution dealing with semiconductor germanium arsenate materials, semiconductor silicon materials, semiconductor silicon carbide materials, optical fiber research development and manufacture, industry instrumentation development and production, micro processor software development application, and electronic material characterization and evaluation. It has a strong technical capability and top grade technical equipment
.

The majority of electronic products developed at the 46th institute are: WT series intelligent display instruments, SFG/K isolated transducers, SMY-GP series general hydraulic transmitters, SMT- L series static pressure type fluid level transmitters, SWT-1151 series pressure difference/pressure transducers, SWT-1151 series remote pressure difference/pressure transmitters, MM 2000 series surface quality analyzers, metallic surface label systems, and thermal energy consuming meters etc.

CETC 47th Research Institute

CETC 47th Research Institute located in Shenyang City of Liaoning Province is one the earliest semiconductor devices and integrated circuits research, development, and manufacture research institutions. Currently it has about 700 employees, where 20 are research staff and 100 are senior engineers. The institute mainly engages in micro-electronic technology research and development dealing with micro-control/micro-processor and their connection circuitry, special integrated circuits, storage circuits, thick layer hybrid integrated circuit research and development, and application oriented computer development

.

The institute's major products are:

- Micro-processor/micro-controllers.
- 16 bit micro-processor series electric circuits.
- General digital series electric circuits.
- Digital terminal electric circuits.
- Memory and buffer electric circuits.
- Anti-radiation electric circuit.
- Digital only electric circuit.
- LED large screen manufacture.

CETC 48th Research Institute

The CETC 48th Research Institute is a "three beams" [laser, ion, and electron beams] centered comprehensive research institution for semiconductor micro processing equipment research and development. It has a strong development capability in special electronics equipment with a very outstanding science and technology research, manufacture, and management team. Various professional staff in fields such as mechanics, electronics, optics, physics, and computers count for more than 50 percent of institute's workers, of which 10 are research class senior engineers, 71 are senior engineers, 18 are specialist subsidized with State Government financial support
The successful research and development effort of 48th institute's ion injector contributes to many product ion series: LC1, and LC2 type ion injector, which is used in the production of integrated circuit and independent components, and provides an effective mixing technique; LC3 and LC4 type high energy ion injectors; LC6 type metallic material property alteration injector; and the newest developed automatic LC15 large beam flow ion injector which can fill the 6 inch 0.5 micron process production line requirement.

In the area of electronic beam exposure technology, the 48th institute's newly developed D88 type electronic exposure system can manufacture a characteristic line width less than 0.3 microns, which is the first time in this country that direct printing can be implemented for meeting actual application needs.

The 48th institute successively developed 3 inch, 4 inch, and 6 inch processing diffusion system. In order to perfect diffusion technology demands, it also developed a source diffusion system for solid and liquid states of potassium and boron, and the dual temperature zone buried diffusion series equipment for zinc. In order to adapt the technology to advance oxidation techniques, the newly developed external combustion type hydrogen and oxygen synthesis oxidation system has been made a production series..

CETC 49th Research Institute

The CETC 49th Research Institute is a specialty research institution particularly focusing on transducer technology research and development. It is located in the famous northern city of Harbin, and currently has over 600 employees, where more than 400 are engineering technical staff, over 80 are senior engineers, and over 20 are research class senior engineers. Its products have been widely used in the areas of aerospace, shipping, petroleum, chemical engineering, electrical power, light industry, medicine, and environmental protection
Major products of the institute are:

- Temperature sensor.
- Pressure sensor.
- Humidity sensor.
- Accelerometer sensor.

- Vapor sensor.
- Electro-chemical sensor.
- Magnetic sensing transducer.

CETC 55th Research Institute

Founded 1958 and located at Nanjing, Jiangsu, CETC 55th Research Institute mainly engages in research and development on micro-electronics, opto-electronics, vacuum electronics, and related technology and their associated tube sealing and packaging, materials, and special manufacturing equipment. Since the found of the institute more than 40 years ago, it has received a total over 1300 scientific research achievements, where over 60 are State class awards and over 300 are Provincial/Ministerial level awards.

The 55th institute currently has employees 1731, where 1230 are scientific technical staff (about 72 percent) 300 senior engineers (including professor class senior engineers), and 500 engineers

The institute's major products are:

- GaAs, InP, GaN, SiC based field effect, high electronic mobility rate, and diode type microwave devices.
- Si based microwave power components.
- GaAS, InP based microwave single broad integrated circuits.
- Multiple Chip Microwave (MCM) modular electric circuits.
- Microwave receiver/transmitter components and subsystems.
- GaAs, InP, GaN, SiC, Si based VPE, MBE, MOCVD microstructure function thin film materials.
- Compound semiconductor single crystal materials.
- Microwave packaging.
- Acoustic surface wave filter.
- Silicon epitaxy materials.
- Liquid crystal display devices.
- Electro-illumination display devices.
- Plasma display devices.
- Special vacuum device (micro-channel plate opto-electric multiplier, image multiplier, night vision instrument etc.).

CETC 58th Research Institute

The CETC 58th Research Institute is a specialty research institute geared toward digital and analog integrated circuits based on ASIC, DSP, and CPU. It currently has over 500 employees, where over 400 are scientific technical staff, one is an academician of the Chinese Academy of Engineering, over 140 are professor class senior engineers and senior engineers, more than 130 are engineers. The institute has established eight research laboratories and one film coating board manufacture center.

The institute's major products are:

- Special digtal integrated circuit.
- Memory circuit.
- 80 thousand gate series array gate mother-board.
- E2PROM general application circuitry.
- 400 million bits MASK ROM.
- 32 bit high-speed digital signal processor.

- 200 thousand gate array gate mother-board.
- 16 bit system microprocessor.
- 32 bit system microprocessor.

Dalian Institute of Chemical Physics
National Key Laboratory of Short Wavelength Chemical Lasers

The Dalian Institute of Chemical Physics National Key Laboratory of Short Wavelength Chemical Lasers located in Liaoning undertakes the 863 plan's short wavelength chemical laser research. As stated on its website (www.dicp.ac.cn), its goal is to reach and surpass international levels in chemical laser technology. Since 1972 the lab has carried out research in the areas of CO2 lasers, HF/DF lasers, and COIL lasers, with most research now being devoted to COIL

Patents:

- An Unstable Ring Resonator with 90 Degree Laser Beam Rotation
- A Small Form, Highly Efficient Energy Saving Bubble Iodine Steam Generator
- A Complex Iodine Steam Generator
- A Type of Slide Valve Vacuum Pump Fuel Tank.
- Internally Externally Heated, Dynamically Balanced Iodine Steam
- GeneratorEquipment for Optical Two-Dimensional Scanning Test.
- Equipment Measuring Absolute Concentration of Emitted Photons
- Equipment Using Measured Spontaneous Raman Scattering Technology to Measure Gas Component Concentration.

APPENDIX TWO
Chinese S&T Journals to Monitor

Chinese media covering missile and space issues can be divided into two basic categories: 1) specialized news magazines, papers, and websites and 2) science and technology journals, both in hardcopy and online. Many media of both categories are sponsored by one of two major state-owned enterprises: China Aerospace Science and Technology Corporation (CASC) and China Aerospace Science and Industry Corporation (CASIC). Other sponsors include industry associations under the China Association for Science and Technology.

The specialized news media sometimes carry general reports on developments in China's military but more often dwell on civilian programs, such as the manned space program. All media are controlled by the government and do not stray outside certain political and security bounds..

The following list of publications is limited to those with information on Chinese missiles and space systems. The list is not necessarily exhaustive but represents the majority of openly available media on this topic.

Specialized News Media

1. **China Space News**

Zhongguo Hangtian Bao started publication on 1 January 1986. Sponsored jointly by the China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation (CASIC), it is one of the major national newspapers in China. It carries news on aerospace events, popular astronautic science knowledge, anecdotes of famous aerospace individuals, space exploration, and hot spots in society so on. It is published biweekly, with its front page designated for Important News, second page for Comprehensive News, third page for Economics Hot Line, fourth page for Popular Science Salon, and so on. Its online version can be found at www.china-spacenews.com.

2. **Aerospace China**
www.spacechina.com

Zhongguo Hangtian started publication in 1987. It is sponsored by CASC's China National Aerospace Information Center with the aim of becoming a bridge and link of exchange between aerospace circles at home and abroad. The main contents of the journal are as follows: China Report, Aerospace Industry and National Economy, Aerospace Policy and Management, Aerospace Systems and Technology, Space Exploration, Missiles and Other Weapon Systems, and so on.

3. Aerospace Knowledge

Hangkong Zhishi is a monthly magazine sponsored by the Chinese Society of Aeronautics and Astronautics and managed by the China Association of Science and Technology. The magazine reports on a wide variety of aerospace topics, including domestic and international, civilian and military, air and space.

4. **Space International**

Guoji Taikong started publication in 1979 and is sponsored by Beijing Space Scientific and Technological Information Institute to introduce the newest accomplishment in China's aerospace sector and report the new trends in aerospace activities both at home and abroad. The main contents of the journal are as follows: China Space, Popular and Focal Topics, Space Tour, Star Interview, Manned Space Flight, Flight Malfunction, Space Exploration, Space File, and so on. The Internet address of the journal is www.cast.com.cn.

5. **Space exploration**
Taikong Tansuo, a monthly originally known as Aerospace, started publication in 1981 and is sponsored by the China Aerospace Society. Issued both at home and abroad, it claims it is the only authoritative periodical for popular space science in China, integrating knowledge, readability, practicability, and interest. The journal aims to popularize space knowledge, publicize China aerospace, and explore the secrets of outer space. It has special columns of Hot and Focal Spot, New Routes to Space, Universe Secrets, Most Advanced Weapons, Manned Space Flight, and so on.

6. **Aerospace World**

Shijie Hangkong Hangtian Bolan is a large-scale semimonthly military journal. It started publication in 1998 and is sponsored by CASC's China National Aerospace Information Center. The journal has an exclusive use license for the Hong Kong based journal entitled Junshi Jia [Militarist] in Mainland China. The main contents of Shijie Hangkong Hangtian Bolan A (published in the first half of each month) are as follows: World Military News, Militarist Observatory, Insider's Information on Military and Weapon Equipment, Foreign Commentary, Taiwan Military Trends, Aeronautic and Astronautic Shows, Famous Weapon Museums, and so on. The main contents of Shijie Hangkong Hangtian Bolan B (published in the second half of each month) are as follows: Military Report, China's Military Strength, Elite Strategy, Weapon Ranking, Green Club, and so on. Its Internet address is www.spacechina.com.

7. **China National Space Administration**
www.cnsa.gov.cn/index.asp

The website of the China National Space Administration has a news section called Comprehensive Reports, carrying domestic and international aerospace news reposted from other news sites. It has special columns on Aerospace and Politics, Space Commercialization, Space Station, Space Weapons, Space Shuttles, Outer Space, International Cooperation, Delivery and Propulsion Technology, Satellites and Application, Aerospace Programs, and Launch Activities.

8. **Commission of Science Technology and Industry for National Defense**
www.costind.gov.cn/htm/kjcg/zhuanhua.asp

The website of the Commission of Science Technology and Industry for National Defense has the section Scientific Accomplishments and Exchange. Within this section, there is a special column entitled Aerospace Scientific Accomplishments. The column provides a list of aerospace technological accomplishments that can be commercialized for the national economic development.

9. **Newsletter of the Ministry of S&T**
www.most.gov.cn/English/newletter/newsletter2004.htm

The website of the Chinese Ministry of Science and Technology has the special section S&T Newsletter that carries news on the development of science and technology in China, including aerospace events. The first article in issue No. 357 dated 10 February 2004, for example, is entitled Asia-Pacific Space Cooperation.

10. **China Aerospace Science & Technology Corporation**
www.spacechina.com/espace/

The website of the China Aerospace Science and Technology Corporation, hosted by the National Aerospace Information Center, has the section News & Information that carries articles on domestic aerospace events reposted from other news sites. There is also a section called Products, which carries news on the company's products, such as launch vehicles, man-made satellites and so on. Another section called Launch

Record provides a list of the company's launch activities.

11. **Chinese Academy of Space Technology (CAST)**
www.cast.cn/

The website of the Chinese Academy of Space Technology has a News section, which is further divided into the three subsections of National News, Industry News, and International News, reporting domestic and international aerospace events reposted from other news sites. It also has other sections called Products, Research Fields, International Cooperation, and so on.

12. **China Academy of Launch Vehicle Technology (CALT)**
www.calt.com/news/

The website of the China Academy of Launch Vehicle Technology (CALT) has a news section, mostly articles on domestic and international aerospace events reposted from other news sites. There is also a section carrying news on events within the academy.

13. **China Great Wall Industry Corp.**
www.cgwic.com.cn/chinese/application/index.html

According to its website, the China Great Wall Industry Corp. has been acting as the tie and bridge between the Chinese and global space community. Its website has special sections for What's New, Launch Services, Satellites and Application, and Trade and Services.

14. **Shanghai Academy of Spaceflight Technology**
www.sast.org/default1.htm

The website of the Shanghai Academy of Spaceflight Technology has three news sections called Shanghai Aerospace, China Aerospace, and International Aerospace containing mostly articles on domestic and international aerospace events reposted from other news sites. There is also a section called Shanghai Aerospace Newsflash carrying news updates on aerospace events within China and worldwide.

Science and Technology Journals

CASC Journals

15. **Satellite Applications**

Weixing Yingyong started publication in June 1993. Jointly sponsored by the Commission of Science Technology and Industry for National Defense, the PLA General Armament Department (GAD), and CASC, it is a quarterly journal with restricted distribution. As an interdisciplinary and comprehensive publication, the journal extensively covers research work, practical accomplishments, technological progress, system development, and so on in the field of satellite applications. It also carries the current international accomplishments and development trends in satellite applications.

16. **Infrared and Laser Engineering**

17. Hongwai yu Jiguang Gongcheng, a bimonthly Chinese edition with English abstracts, is sponsored by CASC. As a key journal in the fields of telecommunications and radio engineering, the journal advertises itself as the best way to know IR & Laser technology progress in the China aerospace industry. It focuses on applications of infrared and laser technology in space science, especially in the research and design of

satellites and missile weapon systems. New methods and the results of experiments, new techniques and materials, and new achievements in applications of infrared and laser technology in civil industry are also introduced in its technical reports and research papers. With the latest updates on theories and practices, the journal shows the current status and development of infrared and laser technology in China.

Aerospace Technology & Civilian Products

18. Hangtian Jishu yu Minpin, a monthly, is sponsored by CASC's Institute for Astronautics Information. It is a comprehensive and informative technical magazine circulated to readers at home and abroad. It mainly covers the results of space R&D, civilian products, bidding projects, management experiences, technical innovations made by domestic and foreign related organizations, related policies and regulations, projects of technical transfer, and new technologies and products. It also makes analyses on the technical market and gives suggestions on countermeasures. The journal aims to serve those who are engaged in technical research, product development, and management.

19. **Computer Engineering and Design**

Jisuanji Gongcheng yu Sheji, a bimonthly, is sponsored by the Beijing Computer Technology and Applications Institute, under CASC. It is a scientific journal carrying articles on various kinds of computers and computer systems, including reports, surveys and reviews on researching, analyzing, designing, and developing computers and applications. The journal is helpful to those who are engaged in the work of scientific research, teaching, development, application, consultant services, and information processing.

20. **Aerospace Control**

Hangtian Kongzhi started publication in 1983 and is sponsored by the Beijing Aeropace Automatic Control Institute. It is a technical journal covering the technological development standard at home and abroad in the fields of both navigation guidance and control. The journal has the following major special columns: Missiles, Launch Vehicle Guidance and Control Technology, Spacecraft Navigation Guidance, Navigation and Control Technology, Simulation Technology, and so on. The Internet address of the journal is htkz.chinajournal.net.cn.

21. **Journal of Astronautic Metrology and Measurement**

Yuhang Jice Jishu started publication in 1981 and is sponsored jointly by CASC's 102 Institute and 203 Institute. It mainly covers the design of measurement standards for length, heat, mechanics, radio, time frequency, electromagnetics, chemistry, and optics. It also covers development and manufacturing, measurement test technology, diagnostic maintenance technology of both instruments and meters, error analysis, data processing technology, and so on.

22. **Journal of Propulsion Technology**

Tuijin Jishu, a bimonthly, first published in 1980 and has been available abroad since 1988. Sponsored by Beijing Power Generating Machinery Institute and CASC, it is one of the key scientific journals in China and reflects the research and development status of the propulsion systems for missiles and space vehicles in China. It mainly carries thesis, research papers, and reports on design, test, manufacture, and applications of propulsion systems for missiles, launch vehicles, and spacecraft. It also covers the related spin-offs of propulsion technology. The journal aims to serve scientists, engineers, teachers, students, and decision makers engaged in the research and development of missiles and space vehicle propulsion. It is a window through which China exchanges space propulsion technology information with the rest of the world.

Computer Simulation

23. Jisuanji Fangzhen is a comprehensive quarterly journal, managed by CASC, sponsored by the Editorial Office of Computer Simulation, and under the editing and publishing control of Beijing KW System Integrated Co., Ltd. The journal provides information on advanced technology and methodology in the field of computer simulation in China. Topics in the journal include modeling, algorithms, experimental methods, virtual reality, artificial intelligence, and so on.

China Astronautics and Missilery Abstracts

24. Zhongguo Daodan yu Hangtian Wenzhai is a bimonthly and bilingual (Chinese/English) journal sponsored by CASC's Institute for Astronautics Information. As the only reference journal on aerospace and rockets in China, it exhaustively cites the latest aerospace, missile, and defense related documents produced in China. A CD-ROM version of China Aerospace Database is also available. The CD-ROM contains more than 250,000 records dating back to 1985 (Chinese edition) or 15,000 records dating back to 1994 (English edition).

China Military and Civilian Use Technology and Products

25. Junmin Liangyong Jishu yu Chanpin started publication in 1988. It is sponsored by CASC's China National Aerospace Information Center to track and report trends in both developments and markets in the fields of military and civilian technologies. The main contents of the journal are as follows: Special Report, Industrial Trends, Astronautics and Aeronautics, Ships, Automobiles and Vehicles, Computers and Networks, Communications, Industrial Interview, and Classic Case. Its Internet address is www.chinatoptech.com.

Aerospace Industry Management

26. Hangtian Gongye Guanli started publication in 1983. It is sponsored by CASC's China National Aerospace Information Center to introduce and review experiences, lessons, problems, and the corresponding solutions relating to R&D, production, and management in the field of national defense industry both at home and abroad. The main contents of the journal are as follows: Study and Discussion, Management and Practice, Industrial Trends, Industrial Informatization, Industrial Culture, Management Review, Lesson, and Case Analysis.

Scientific Policy Decision

27. Kexue Juece started publication in 1994. It is sponsored jointly by China Social Economic Systems Analysis Research Association, CASC's 710 Institute, and the International Information Institute of China. The main contents of the journal are as follows: Development Forum, Exclusive Interview, Finance and Bonds, International Observation, Regional Economy, Commodity Market, High Education, Typical Case, International Security, Science and Technology, Industrial Culture, Decision Debate, and so on.

Aerospace Standardization

28. Hangtian Biaozhunhua is a comprehensive scientific and technological periodical covering both space high-tech accomplishments and the related application standardization. The journal started publication in 1983 and is sponsored by CASC's China Institute of Space Standardization. The main contents of the journal are as follows: Policy, Goals and Tasks, Study and Discussion, Standard Introduction and Implementation, Standardization in Model Research, Industrial Standardization, Foreign Standardization, and so on. The Internet address of the journal is htbh.chinajournal.net.cn.

Quality and Reliability

29. hiliang yu Kekaoxing is a comprehensive scientific and technological periodical integrating guidance,

academics, practicability, popularity, and interest. It started publication in 1986 and is sponsored jointly by China Quality Society of Space and CASC's 708 Institute. The main contents of the journal are as follows: Policy and Strategy, Theory and Method, Exclusive Interview, Quality Culture, Practical Experience, Software Engineering, Foreign Space Information, and so on. The Internet address of the journal is www.ht708.com.cn.

Chinese Space Science and Technology

30. Zhongguo Kongjian Kexue Jishu started publication in 1981 and is sponsored by China Academy of Space Technology. It covers various aspects in the field of space science and technology of China such as the corresponding research accomplishments, technological accomplishments, and academic knowledge. The main contents of the journal are as follows: Research and Exploration, Special Subject Discussion, and Technology Exchange. The Internet address of the journal is zgkj.chinajournal.net.cn.

Journal of Telemetry, Tracking, and Command

31. Yaoce Yaokong started publication in 1976 and is sponsored by CASC's 704 Institute. It covers new development results in the field of remote measurement and control technologies and reports theoretical and applied research results of the same field as well as research results on both related systems and products. The main contents of the journal are as follows: Scientific Paper and Technical Report, Comprehensive Review and Commentary, Scientific Discussion, New Technology Introduction, Promising Small Technology Introduction, Scientific and Technological Trend, Special Topic Lecture and Book Review.

Cryogenic Engineering

32. Diwen Gongcheng started publication in 1979. It is sponsored by CASC's 101 Institute and covers mainly scientific papers and research reports in the following areas: Cryogenic Technology, Gas Liquidation and Separation Technology, Liquefied Gas Storage Technology, Cryogenic Isolation Technology, Cryogenic Sealing and Related Materials, Cryogenic Parameter Measurement Technology, Cryogenic Safety Technology, Application of Cryogenic Technology in Aerospace Engineering Research, and so on.

Vacuum and Cryogenics

33. Zhenkong Diwen started publication in 1982, and is sponsored by CASC's 510 Institute. The journal introduces and deals with development trends, new equipment, new processes, new materials, and new approaches. It also reflects applications and developments in both modern vacuum and cryogenic sciences and technologies. The journal has the following major columns: Comprehensive Review, Research Report, Knowledge and Advancement, Market Information, and so on.

Space Electronic Technology

34. Kongjian Dianzi Jishu started publication in 1971 and is sponsored by the Xi'an Space Radio Technology Institute. It aims to exchange space electronic technology, train young technical personnel, refresh the academic research environment, and promote aerospace development. The journal has the following major columns: Review and Research, Technical Report, Design and Measurement, New Technology and Process, Information and Trends, and so on.

Microelectronics and Computers

35. Weidianzixue yu Jisuanji started publication in 1972 and is sponsored by CASC's 771 Institute. It is a Chinese language multidisciplinary, comprehensive, vocational core scientific and technological periodical in China. The journal mainly publishes papers in the following areas: Microelectronic Process and Device, Computer Theory and Application, Networks and Communications, Software and Algorithms, and so on.

Missiles and Space Vehicles

36. Daodan yu Hangtian Yunzai Jishu started publication in 1972 and is sponsored by China Academy of Launch Vehicle Technology. It claims it is the only technical journal in China that comprehensively reports on both high-tech missiles and space launch vehicles. The journal has the following major special columns: Expert Forum, Review and Commentary, Launch Vehicle Overall and Separation System Technologies, Research Paper and Technical Report, Research Briefing, Foreign Development, High-tech Window, and so on.

37. **Guidance and Fuse**

Zhidao yu Yinxin started publication in 1979 and is sponsored by CASC's 802 Institute. It mainly covers papers dealing with missile systems, navigation guidance and detonation, airborne radar, short-distance radar, antennas, antenna blister, and so on. The journal has the following major special columns: Navigation Guidance and Detonation Technology, Antenna Technology, Electronic Jamming Technology, Electronic Environmental Technology, Microwave Technology, Measurement Technology, Reliability Technology, Computer Technology, and so on.

Journal of Solid Rocket Technology

38. Guti Huojian Jishu started publication in 1979. It is sponsored jointly by China Fourth Academy and the Solid Propulsion Committee of China Society of Astronautics. It claims to be the only specialized journal in the world focused specifically on the solid rocket propulsion field. The journal has the following major special columns: Engines, Propellant, Materials Processing, Measurement Technology, and so on. The Internet address of the journal is gthj.chinajournal.net.cn.

Spacecraft Recovery & Remote Sensing

39. Hangtian Fanhui yu Yaogan started publication in 1980. It is sponsored by CASC's 508 Institute and introduces scientific accomplishments and developments in the areas of return spacecraft, manned space launch, space remote sensing, and so on, at home and abroad, to stimulate scientific research activities. The journal has the following major special columns: Space Return and Manned Spacecraft, Remote Sensing Technology, New Processes and Materials, Space Technology, and Space News Brief.

Chinese Journal of Aerospace Medicine

40. Zhongguo Hangtian Yiyao Zazhi started publication in 1999 and is sponsored by the general hospital of CASC. It is a comprehensive medical journal covering both the most advanced development standards and the newest trends in medical science in aerospace systems. The journal has the following major special columns: Scientific Paper, Emergency Experience, Review, Lecture, Lesson, Technological Exchange, Clinic Pathological (Case) Discussion, R&D Trends at Home and Abroad, and so on.

Structure & Environment Engineering

41. Qiangdu yu Huanjing started publication in 1973 and is sponsored by CASC's 702 Institute. The journal mainly covers engineering applications but also deals with theoretical analysis. It has the following major special columns: Structural Strength, Fatigue, Rupture, Reliability, Reliability Engineering, Environment Engineering, Measurement, Disposal, Equipment, Measurement and Testing Technology, Engineering Management, and so on.

Aerospace Shanghai

42. Shanghai Hangtian, a bimonthly, started publication in 1984. It is a comprehensive journal managed by the CASC and sponsored by the Shanghai Academy of Spaceflight Technology. Issued both at home and abroad, the journal mainly carries academic and technical papers, research reports, technical reports, and special reviews that are related to satellite application, carrier rockets, and air defense missile systems and research, experiments, and applications for their subsystems.

Aerospace Techniques

43. Hangtian Gongyi, a bimonthly, is managed by CASC and sponsored by the Capital Aerospace Mechanical Co. It is the only technical journal among the aerospace companies and organizations, mainly carrying scientific and technical papers and technological management articles on manufacturing technology for aerospace and civil products. Its content covers welding, cold-heat-treatment processes, assembly techniques, and measuring technology.

CASIC Journals

Systems Engineering and Electronics

44. Xitong Gongcheng yu Dianzi Jishu started publication in 1979. It is managed by the China Aerospace Science and Industry Corporation (CASIC) and jointly sponsored by the 2nd Research Institute of CASIC, the China Aerospace Society, and the China Systems Engineering Society. It is a key, interdisciplinary journal that focuses on hi-tech development and application. It aims to introduce new technology, promote academic exchange, and reflect the latest accomplishments in the two major areas of systems engineering and electronic technology. The journal has special columns of Electronic Technology, Aerospace System Analysis, Defensive Electronic Technology, and so on.

Winged Missiles Journal

45. Feihang Daodan started publication in 1971. It is managed by CASIC and sponsored by the 3rd Research Institute of CASIC. It is a monthly journal of the 3rd Research Institute, mainly carrying research programs, developments, experiments, and practice of winged missiles in foreign countries and introducing various types of new technology, new materials, and new techniques in winged missiles development. The journal aims to report in a timely fashion international news related to winged missiles and to boost winged missile programs to develop rapidly in China. The journal has as main columns Missiles Survey, Information Exchange, Weapon System, Propulsion Technology, Control and Navigation Guidance, Unmanned Vehicle, and Process and Materials.

Aerospace Electronic Warfare

46. Hangtian Dianzi Duikang, a bimonthly, started publication in 1985; it is managed by CASIC and sponsored by the 8511 Research Institute of CASIC. It covers scientific and technological research, production, management, and teaching and learning in the field of electronic warfare and the research results and activity news of user companies and organizations.

Aeronautical Manufacturing Technology

47. Hangtian Zhizao Jishu started publication in 1983 and is sponsored by Beijing Aerospace Machinery Corporation. It is a comprehensive technological journal covering various areas such as modern advanced manufacturing technology, new product R&D, product design innovation, technology management, production organization, and new aerospace manufacturing trends both at home and abroad in the development and manufacturing of the corresponding aeronautic and astronautic aircraft, manned spacecraft, and satellites.

Control Technology of Tactical Missiles

48. Zhanshu Daodan Kongzhi Jishu, a quarterly, started publication in 1980; it is managed by CASIC and sponsored by the Beijing Institute of Automatic Control Equipment. As one of the key journals in China, it mainly covers autopilot-navigators, navigation guidance and control, accelerometers, and so on.

Journal of System Simulation

49. Xitong Fangzhen Xuebao started publication in 1989; it is managed by CASIC and sponsored by the China System Simulation Society. It is a monthly academic journal of the Society. The main contents of the journal are Analog Set Up and Simulation, Simulation Computers and Simulation Software, Simulation Devices in Training, Research and System Operations, Simulation Algorithms, Artificial Intelligence in Simulation, Simulation Technology of Concurrent Distribution and Interaction, and Analog Set Up and Simulation in Advanced Manufacturing.

Other Journals

Chinese Journal of Space Science

50. Kongjian Kexue Xuebao is jointly sponsored by the Center for Space Science and Applied Research of the Chinese Academy of Sciences and the China Space Science Society. It claims to be an influential and comprehensive publication focusing on space research accomplishments and basic research related to the space environment. The major branch disciplines covered in the journal include space astronomy, space physics, space chemistry, space geology, space life science, space materiel science, space earth science, and so on. The journal has main columns such as Theory and Research, Exploring and Experiment, Review and Briefing,

Remote Sensing Technology and Application

51. Yaogan Jishu yu Yingyong, a bimonthly, started publication in 1986 and is jointly sponsored by the Chinese Academy of Sciences Remote Sensing Joint Center and the Chinese Academy of Sciences Resources and Environmental Science Information Center. It is a comprehensive remote sensing academic journal mainly reporting new theories, new technology, new methods, new accomplishments, and development trends in the research and application of remote sensing technology at home and abroad. The journal has special columns of Research and Application, Development Trends, Geographic Information Systems, Image Processing, and Review,

Advanced Display

52. Xiandai Xianshi is a quarterly periodical on display technology. The Advanced Display Systems of U.S.A is its sponsor and financial supporter. It is also sponsored by the Beijing Research Institute of Telemetry. The content of the periodical covers the features, principles, structure, material, manufacturing techniques, applied technology, development trends, and marketplace of display technology. Its readers are engineers, teachers and students, and related government officials.

Spacecraft Engineering

53. Hangtianqi Gongcheng is a quarterly journal with strict restricted distribution. The main columns of the journal are Research and Design, Management and Practice, and Others.

Space Medicine & Medical Engineering

54. Hangtian Yixue yu Yixue Gongcheng, a bimonthly, started publication in 1988. It is jointly sponsored by the Headquarters Office of the PLA General Armament Department (GAD) and the Aerospace Medical Engineering Research Institute of the GAD. Issued at home and abroad, the journal mainly carries new theories, new accomplishments, new technology, and new trends in aeronautic and astronautic medicine, biological medical engineering, and research related to ergonomic engineering in China and foreign countries. Being one of the key journals in the areas of manned space flight and life science in China, it has special columns on Academic Books and Papers, Special Topic Commentary, Literature Review, Research Newsflash, News and Trends, and so on.

Chinese Journal of Aerospace Medicine

55. Zhonghua Hangkong Hangtian Yixue Zazhi, originally known as Zhonghua Hangkong Yixue Zazhi, started publication in 1990. It is sponsored by the Chinese Medical Association and published quarterly in Chinese or English by the Press of the Chinese Journal of Aerospace Medicine. The journal has special columns of Original Articles, Clinical Research, Review Articles, Aeromedical Practice, Case Reports, News and Notes, and so on. Articles in this journal provide the latest available information on aviation medicine, space medicine, history of aerospace medicine, aerospace physiology, aerospace neurophysiology/vision, fatigue/circadian rhythms, acceleration/escape/impact, aerospace human factors, flight safety/accident investigation, performance/psychology/psychophysiology, air medical transport, hyperbaric medicine, and other related areas. The journal aims to serve and support all those who explore, travel, work, or live in hazardous environments of aerospace.

Aerospace Medicine

56. Hangkong Hangtian Yiyao, a quarterly, started publication in 1990. It is managed by the Office of Heilongjiang S&T for National Defense and sponsored by the Harbin 242 Hospital of China Aviation Industry Co. The publication focuses on practical applicability and innovation. The main columns of the journal are Experiment and Research, Aeronautic and Astronautic Medicine Clinical Books and Papers, Clinical Experience, Case Report, Prevention Medicine, Medical Information, and so on.

Experiments and Measurements in Fluid Mechanics

57. Liuti Lixue Shiyan yu Celiang, a quarterly, started publication in 1987 and is jointly sponsored by the China Aerodynamic Society and the China Aerodynamic Research and Development Center. It is a state-level, comprehensive academic and technical publication with unrestricted distribution. It is also a key journal on aviation and aerospace, mainly carrying new theories, new accomplishments, and new trends in fluid mechanics, especially in every aspect of testing and measurement of aerodynamics.

Acta Aerodynamica Sinica

58. Kongqi Donglixue Xuebao, a quarterly, started publication in 1980 and is jointly sponsored by the China Aerodynamic Society and the China Aerodynamic Research and Development Center. It is a state-level, academic publication issued both at home and abroad. As an important key journal in China, it mainly carries research papers and briefings on creative theory, experiment, and application in the field of aerodynamics.

Journal of Beijing University of Aeronautics and Astronautics

59. Beijing Hangkong Hangtian Daxue Xuebao, a monthly, started publication in 1956. It is managed by the Commission of Science, Technology, and Industry for National Defense and sponsored by the University. It is a comprehensive academic journal focusing on aeronautic and astronautic science and technology. The journal aims to introduce the University's R&D results and trends, promote academic exchange, educate

creative professionals, and boost the transformation of R&D results into productive power. It mainly carries research papers on material science and engineering, fluid mechanics and dynamic engineering, computer and application technology, and reliability and fault analysis in aeronautic and astronautic science and technology.

Journal of Nanjing University of Aeronautics & Astronautics

50. Nanjing Hangkong Hangtian Daxue Xuebao, a bimonthly, started publication in 1957. It is managed by the Commission of Science, Technology, and Industry for National Defense and sponsored by the University. It is a comprehensive academic journal reflecting scientific and technological accomplishments in the areas of aeronautic and astronautic technology. It carries research papers, reviews, and ademic trend reports on dynamic engineering, automatic control, electronic engineering, manufacturing engineering, material science and technology, combustion theory, and so on.

Journal of Vibration Measurement & Diagnosis

61. Zhendong Ceshi yu Zhenduan, a quarterly, started publication in 1980. It is managed by the Commission of Science, Technology, and Industry for National Defense and jointly sponsored by the Universities Research Association of Mechanical Engineering Testing Technology and the Nanjing University of Aeronautics & Astronautics. It is a technical publication reflecting R&D results as well as the applications of these results in the areas of vibration, dynamic measurement, and fault diagnosis. The journal introduces domestic and international technical papers, special reports, and academic trends in the study and application of dynamic measurement theory, method, and approach, including testing technology, testing instruments development, system configuration, signal analysis, data processing, parametric recognition, and so on.

Journal of North China Institute of Astronautic Engineering

62. Huabei Hangtian Gongye Xueyuan Xuebao, a quarterly, started publication in 1989. It is managed by the Education Department of Hebei Province and sponsored by the Institute. It is a technical journal carrying academic papers and research reports in the areas of engineering technology application, natural science, social science, and so on.

Journal of National University of Defense Technology

63. Guofang Keji Daxue Xuebao, a bimonthly, started publication in 1956 and is sponsored by the University. Issued both at home and abroad, it is a comprehensive academic journal on engineering technology and natural science, reporting the latest R&D accomplishments and promoting academic exchange and personnel training. It mainly carries academic papers with ideas on innovation, reports on creative and practical technical accomplishments, reviews on important academic issues, and so on from within the University. It also includes and publishes those leading edge research papers from other universities based on projects sponsored by national and provincial funds.

Journal of Remote Sensing

64. Yaogan Xuebao, a bimonthly, started publication in 1997 and is sponsored by the Environmental Remote Sensing Association, the Geographical Society of China, and the Institute of Remote Sensing Application, Chinese Academy of Sciences. It is a professional academic journal reflecting scientific and technological research accomplishments and technical applications in the field of remote sensing, including these comprehensive application areas of aviation and aerospace, agricultural and forest resources development, geographic information systems, remote sensing, spatialization systems, and so on.

Journal of Projectiles, Rockets, Missiles, and Guidance

65. Danjian yu Zhidao Xuebao, a quarterly, started publication in 1980. It is managed by the China Association for Science and Technology and sponsored by the China Ordnance Society. The journal aims to publish academic papers on missiles, rockets, ammunition, guided weapons, and so on, highlighting new hi-tech accomplishments in this sector, introducing the latest application accomplishments in scientific research, production, teaching-learning, and practice, and serving the modernization of China's national defense.

Journal of Vibration and Shock

66. Zhendong yu Chongji, a quarterly, started publication in 1982. It is managed by the China Association for Science and Technology and jointly sponsored by the Chinese Society for Vibration Engineering, the Shanghai Jiaotong University, and the Shanghai Vibration Engineering Society. It is a comprehensive, key academic journal introducing accomplishments and experience concerning vibration, ballistics, and noise in the fields of aviation, aerospace, shipbuilding, marine engineering, and environmental protection. The content of the journal includes structural dynamic analysis, model analysis, parametric recognition, and so on.

Vacuum Electronics

67. Zhenkong Dianzi Jishu, a bimonthly, started publication in 1959. It is managed by the Chinese Ministry of Information Industry and sponsored by the Beijing Institute of Vacuum Electronic Technology. Issued at home and abroad, the journal is the only comprehensive technical publication in the field of vacuum electronic technology in China. It is also the journal of the Vacuum Electronic Professional Society, mainly carrying articles on vacuum microwave devices, vacuum electronic devices, vacuum pumping, measurement and control, and so on. The journal has special columns of Expert Forum, Research Report, Study and Design, New Technology Exchange, Techniques and Application, and Review.

Vacuum

68. Zhenkong, a bimonthly, started publication in 1994. It is managed by the Chinese Ministry of Machine-Building Industry and sponsored by the Shengyang Institute of Vacuum Technology and the China Mechanized Equipment Group Co. It is one of the major vacuum journals in China, with special columns on Expert Focus, Innovation Products, Solar Energy Utilization, Experience Exchange, Series of Lectures on Vacuum Technology and Application, and so on.

Vacuum Science and Technology

69. Zhenkong Kexue yu Jishu, a bimonthly, started publication in 1981. It is managed by the China Association for Science and Technology and sponsored by the Chinese Vacuum Society. It mainly covers vacuum technology, surface analysis, electronic materials, and so on. The journal has special columns of Academic Papers, Summary Review, Technology Exchange, Scientific Research Trends, and so on.

Vacuum Communication

70. Zhenkong Tongxun, a bimonthly, started publication in 1973 and is jointly sponsored by the China General Mechanical Vacuum Equipment Association, the Mechanical Industry Vacuum S&T Information Net, the Zibo Vacuum Equipment Plant Co, Ltd, and Zhejiang Vacuum Equipment Group Co, Ltd. The journal mainly covers practical problems in the application of vacuum technology and introduces development trends in this field.

Sichuan Vacuum

71. Sichuan Zhenkong, a semiannual, is jointly sponsored by the Sichuan Vacuum Society and the Guotou

Nanguang Co, Ltd, introducing research accomplishments and development application of vacuum science and technology in Sichuan Province.

Shanghai Vacuum News

73. Shanghai Zhenkong Bao, a quarterly, started publication in 1990. It is sponsored by the Shanghai Vacuum Society and Shanghai Five-Steel Special Metallurgy Co. The paper aims to enhance the exchange between the Shanghai Vacuum Association and its members and to promote communication between the Association and vacuum circles at home and abroad.

Acta Materiae Compositae Sinica

74. Fuhe Cailiao Xuebao, a bimonthly, started publication in 1984 and is sponsored by the Chinese Complex Materials Society. As an academic journal, it mainly carries scientific and technical papers and special reports written by well-known scientists and experts and reflects domestic and international innovative, high-level, significant research accomplishments and the latest research trends in complex materials' basic and application research. The journal is of great reference value.

Journal of Engineering Thermophysics

75. Kongcheng Rewuli Xuebao, a bimonthly, started publication in 1980. It is managed by the Chinese Academy of Sciences and jointly sponsored by the Chinese Engineering Thermophysics Society and the Engineering Thermophysics Institute of the Chinese Academy of Sciences. It mainly carries scientific papers, research briefings, and important academic trends in engineering thermodynamics and power gear, theory of combustion, comprehensive utilization of energy, and so on.

Aerospace Materials and Technology

76. Yuhang Cailiao Gongyi started publication in 1971. It is sponsored by the China Institute of Aerospace Materials and Processes and reports mainly scientific and technological advancements, R&D results, and engineering practice relating to aerospace materials and processes in China in the forms of scientific papers, research reports, review, and special discussion on new materials, new processes, and new products. This journal was included in the list of China's one hundred key journals in the second national journal competition.

Journal of Astronautics

77. www.caaspace.org.cn/C_cbkw/C_cbkw.htm.

Yuhang Xuebao started publication in 1980. It is sponsored by the China Society of Astronautics and reports research and development results in the field of aerospace in China, reflecting the hot, focal, and bright spots of China's aerospace research and development. The journal has two main sections: Treatises and Research Notes.

Remote Sensing Information

78. Yaogan Xinxi, a quarterly, started publication in 1986. It is managed by the Chinese State Bureau of Surveying and Mapping (CSBSM) and sponsored by the National S&T Department Remote Sensing Center of the CSBSM. The main columns of the journal include Forum, Theory and Study, Application Technology, Scientific Accomplishments, Translated Text, International Trend, Knowledge Window, and Remote Sensing Technical Equipment.

Journal of Flight Vehicle Measurement and Control

79. Feixingqi Cekong Xuebao, a quarterly, started publication in 1982 and issponsored by the Beijing Institute of Tracking and Communication Technology. The journal won the third S&T Progress Award conferred by the Commission of Science, Technology, and Industry for National Defense in 1986, received the third Military S&T Journal Award in 1991, and won the title of "Excellent National Defense S&T Journal" in 1996. Its main columns include General Measurement and Control, Data Processing, Radio Measurement and Control, Computer Technology, GPS Application, Newsflash, and so on.

Journal of Science Technology and Industry for National Defense

80. Guofang Keji Gongye, a monthly publication issued both at home and abroad, is sponsored by the Commission of Science, Technology, and Industry for National Defense. It is the only journal that reports news for the overall national defense science and technology industry in China. Integrating guidance, academics, comprehensiveness, and expertise, it is an authoritative publication covering China's nuclear technology, aerospace, aviation, shipbuilding, weapons, military electronics, and other related industries.

Flight Dynamics

81. Feixing Lixue, a quarterly, started publication in 1983. It is managed by the China Aviation Industry Corporation I and sponsored by the China Flight Testing Research Institute. It is a key, comprehensive academic journal focusing on aviation, aerospace, and flight dynamics. The journal aims to introduce flight dynamics related theories on airplanes, helicopters, missiles, and other flight vehicles, to report domestic and international development trends, to exchange domestic theories and research accomplishments, and to promote academic exchange and the development of flight dynamics. The journal has special columns on Review and Prospect, Theory and Analysis, Testing and Application, Flight Field, and Related Disciplines.

Aerospace Literature Newsflash
www.space.cetin.net.cn

82. The website of the China Engineering Technology Space Information Net (Zhongguo Gongcheng Jishu Hangtian Xinxiwang) has a special section of Aerospace Literature Newsflash, with special reports and publications with abstracts written and compiled by aerospace experts or companies at home and abroad. These publications, some with translated versions, cover many aspects of the domestic and international aerospace industry.

A Glance at China Aerospace Literature
www.space.cetin.net.cn/

83. The website of the China Engineering Technology Space Information Net (Zhongguo Gongcheng Jishu Hangtian Xinxiwang) has a special section called A Glance at China Aerospace Literature.

APPENDIX THREE
Revising the U.S.-PRC Joint S&T Commission

Beijing, April 25-26, 2002

Xu Guanhua, Minister of Science and Technology of the People's Republic of China, and John Marburger, Director of the Office of Science and Technology Policy in the Executive Office of the President of the United States of America, co-chaired the 10th meeting of the U.S.-PRC Joint Commission on Scientific and Technological Cooperation (hereinafter referred to as the JCM) April 25-26 in Beijing. The Joint Commission was established by the Agreement Between the Government of the United States of America and the Government of the People's Republic of China on Cooperation in Science and Technology, signed at Washington, D.C., on January 31, 1979, to plan, coordinate, monitor and facilitate bilateral cooperation in science and technology.

Participants included high-ranking officials with strong scientific credentials from the U.S. and Chinese governments. Discussions focused on the following topics: (1) Energy and Physical Sciences; (2) Ecosystem and Environmental Sciences; (3) Life and Health Sciences; (4) Agricultural and Food Sciences; and (5) Science Education and Public Outreach; and (6) Cooperation Mechanisms and Methods. In each of these areas, participants briefly reviewed ongoing cooperation activities, indentified issues of mutual interest and explored possible areas for future cooperation. Name lists of delegations and agenda are attached to these minutes as appendices. The meeting was conducted in a pragmatic style, in the spirit of seeking common ground.

Overview

Minister Xu welcomed Dr. Marburger and the U.S. delegation to Beijing and noted the tremendous potential for U.S.-China cooperation in science and technology. He referred to the common understanding reached by President George Bush and President Jiang Zemin in February to strengthen cooperation and exchanges in areas such as economy and trade, energy, science and technology, and HIV/AIDS prevention and treatment. Minister Xu said U.S.-China S&T cooperation had developed smoothly since 1979, achieving some good results and contributing to mutual understanding, as well as to social and economic development. He said there was huge potential to expand cooperation and called for increased exchanges among U.S. and Chinese S&T leaders, renowned scientists and young scientists. He said China's entry into the World Trade Organization would enhance Chinese participation in global scientific efforts and create possibilities for cooperation in broader areas.
Dr. Marburger noted that science and technology formed the basis for human prosperity and a more secure world, and invited JCM participants to identify projects for joint investigation that would have significant impacts on both societies, stressing the importance of inter-agency cooperation.

Energy and Physical Sciences

Both sides expressed satisfaction with ongoing cooperation in areas such as fossil energy, energy efficiency and renewable energy, high energy physics and other basic scientific research and hoped to strengthen cooperation in those areas. It was agreed that, as the world's two largest energy consumers, both relying on imported petroleum, China and the United States shared a strong interest in developing cleaner energy sources to meet their development needs while protecting the environment and the global climate. There was strong interest expressed on both sides in cooperating on nanotechnology, nuclear fusion, plasma physics, genomics, catalysis, quantum computation and controls, photonics and treatment of nuclear waste. A policy discussion on creating the infrastructure for a hydrogen energy economy was also proposed. Other potential areas mentioned for expanded cooperation included electric and fuel-cell vehicles, new materials, science and technology policy and clean coal technology.

Ecosystem and Environmental Sciences

Experts from both sides agreed that coping with global environmental problems required international and multi-disciplinary collaboration on research, monitoring, evaluation and control strategies. The U.S. side described its expanded inter-agency climate research program, intended to enhance the strong scientific basis underpinning its climate change policy. China was invited to participate in future expansions of U.S. global climate observation systems. The Chinese side reported on ongoing efforts in climate, ocean and ecosystem monitoring, with emphasis on natural disaster prediction and mitigation, pollution monitoring and control, strengthening environmental management, protecting water resources, forests, wetlands and wildlife, preventing soil erosion and sustainably developing China's Western regions. There was additional discussion of cooperation on microbial genomics as it applies to ecosystem studies. China was invited to participate in U.S.-led global data-gathering networks, such as the National Ecological Observation Network (NEON) and the International Long-Term Ecological Research (ILTER) program, using the successful bilateral cooperation on earthquake studies as a model. It was noted that the human dimension and bio-complexity needed to be factored into environmental modeling. The Chinese side expressed interest in building on areas identified for further cooperation at previous meetings on climate science.

Life and Health Sciences

The two sides discussed ongoing and expanding cooperation on HIV/AIDS and other public health problems of mutual concern. It was agreed that recent advances in genomics provided new tools making it possible to conduct systematic research on Chinese traditional medicine, and there was mutual interest in expanding work in that area. China proposed establishing a Joint Program on Genomic Science, to focus not just on gene sequencing but also bio-informatics and functional analysis. It was agreed that this area had enormous potential as the genomics revolution turns toward proteomics and new product development. China referred to the China Integrated Project on AIDS Research, proposed to the U.S. National Institutes of Health last July, on which there is ongoing dialogue, and reported on its efforts to improve HIV/AIDS monitoring, epidemiology, education, blood safety and community care. Cooperation on studies relating health to environmental change and economic development was also discussed. Both sides noted the importance of establishing a firm ethical basis for human research and mechanisms to protect research subjects.

Agricultural and Food Sciences

Both sides expressed interest in cooperating on water conservation, dairy technology, food safety, food processing and environmental protection in agriculture, although the U.S. side said that due to limited funding it could not promise to cooperate on all of them. It was noted that the two sides would inaugurate a Joint Center of Excellence on Soil Erosion and Environmental Protection in Yanglin, Shaanxi Province, in May. China sought U.S. cooperation on reducing the environmental impact of fertilizer and pesticide use, as well as on irrigation technology and management of agricultural water use. The U.S. side observed that genetically modified crops could reduce the requirements for water, pesticides and fertilizers. The Chinese side responded that its research on GMOs was continuing. It was agreed that China's Ministry of Science and Technology would coordinate U.S.-China cooperation with the 13 Chinese ministries and agencies involved in agricultural and food sciences, and MOST will pursue a memorandum of understanding with USDA.

Science Education and Public Outreach

Both sides referred to the problem of declining numbers of young students going into science and engineering fields. It was agreed that getting children interested in science at a young age was critical to maintaining an adequate S&T workforce. The impact of globalization and changing economic and social conditions on international mobility of S&T workers was also discussed. The U.S. side proposed a study group regarding

S&T workforce issues. In connection with this issue, U.S. NIH reported it has a program to provide "re-entry grants" to foreign students, which allow them to maintain ties to U.S. institutions after returning to their home countries.

Mechanisms and Methods for U.S.-China S&T Cooperation

The two sides agreed that it would be useful to hold science-based meetings or forums during the interim between JCMs to discuss key topics of mutual interest and provide feedback and recommendations to the JCM. The two sides also agreed to explore mechanisms for giving researchers from each side increased access to research funding from the other side. China proposed concluding an agreement to facilitate science-based youth exchanges, and the U.S. side proposed a separate meeting to develop that idea. U.S. NSF expressed willingness to extend its existing exchange programs for young scholars to China.

Both sides noted the importance of public-private cooperation on research and development. The Chinese side described its science park project with the University of Maryland as an example of such cooperation. The U.S. side suggested further exploring such models and policies for involving the business sector in funding S&T research and development and technology transfer. However, the focus of the JCM should be on science.

Conclusions

The two sides agreed that the following should be priority areas for future S&T cooperation: (1) Agricultural Science and Technology; (2) Clean Energy; (3) Nanotechnology; (4) Global Change; (5) Genomics; (6) Science Education; and (7) Information Technology. Each side will designate points of contact for each of these areas. At the same time, both sides underlined the importance of inter-agency cooperation in all of these areas.

Both sides agreed that the Executive Secretariat Meeting should convene soon to translate the principles and framework suggested at the JCM into concrete cooperation, leading the China-US science and technology cooperation into a more practical direction.
These Minutes were approved and signed in Chinese and English, both versions being equally authentic, by the leaders of the two delegations at the conclusion of the JCM at Beijing on April 26, 2002.

For the United States of America:
John H. Marburger III
President’s Science Advisor

Xu Guanhua
Director, Minister of Science and Technology

APPENDIX FOUR
PRC Science Goals for 2005

A resolution on strengthening S&T innovation capacity building was adopted at a meeting recently held by the Chinese Academy of Sciences (CAS). According to the resolution, CAS will concentrate its efforts on strengthening S&T innovation capacity building, and realize a leaping and sustainable development through the phase III of the so-called knowledge innovation demonstrations, in a move to render new contributions to the socioeconomic development, national security, and to the improvement of people's life.

It is pointed out at the meeting that the phase III activities of the knowledge innovation demonstrations shall enhance original innovations, proprietary key technology innovations, major system integration, knowledge innovations, and technology support capacity, striving to raise the capacity of addressing current and future major S&T issues concerning the socioeconomic development, striving to raise the capacity of providing knowledge bases and technology support for realizing scientific development concepts, striving to raise the capacity of safeguarding the national security and responding to new changes in the military world, striving to climb up the world's scientific peaks, and striving to build CAS into a scientific research base of an internationally advanced level , a base for training of high caliber S&T personnel, and a base for promoting high tech industrialization in the country.

The Chinese Academy of Engineering (CAE) also adopted a resolution, at a meeting held recently, in a move to take further advantage of the roles played by academicians. The resolution placed the priorities in the year on three major activities, including strengthening the construction of an academician contingent, strengthening decision making related consultation, and improving the quality of academic exchange activities.

To further strengthen the construction of the academician contingent, CAE will stick to the prescribed standards and qualifications in selecting academicians in 2005, a year for selection of additional academicians, with an emphasis on candidate's scientific ethics. Attention will also be paid to discovering and selecting qualified young scientists, and optimizing the composition of the academician contingent.

To strengthen decision making related consultation activities, CAE, in the new year, will be an active part of China' long and medium term S&T development planning process, in addition to its major missions in the fields of oil and gas resources, mineral resources, water resources, and information process. At the same time, CAE will widen international cooperation channels, and take effective use of overseas resources. In addition, CAE will organize innovation tours for academicians, allowing them to bring the latest technology and S&T knowledge to the localities.

To unify the management of academic activities, integrate resources and improve the quality of academic exchanges activities, CAE will build a multi-tiered platform for academic explorations and exchanges, especially for cutting edge issues and priorities concerning engineering development. CAE will continue to host series of academic activities, including the Xiangshan Meeting, engineering forums, and popular science activities. It encourages academic activities initiated by disciplinary departments, in an attempt to promote the development of the engineering contingent. The meeting also called for the establishment of an academic committee for post-graduate education at industrial research institutes, so as to spur up the development of engineering education at a higher level.

Special Programs Solved Key Technologies

Since putting in place in 2002 twelve major S&T special programs with a budget of more than RMB 20 billion, China has harvested phase progresses from these programs. For examples, the food safety special program makes breakthroughs in a line of key technologies, including food safety testing technology and control technology. 54 testing processes are created for quarantine examination of pesticides, vet drugs, and contaminated food sources. The program rolled out 18 equipment or instruments for testing pesticides, vet drugs and biological toxicants, and established the nation's first import & export monitoring, pre-warning, risk analyzing and control system. A special program for new drugs and accelerating the modernization of Chinese traditional medicines has resulted in the establishment of technical platforms for new drug screening, safety evaluation, and scalable preparation of biological drugs. A special program created for the dairy industry has worked out solutions to address key technologies relating to fetus transplanting, which has produced more than 50% of the quality cow fetus needed in the nation, and laid a ground for establishing a technical support system for the industry.

Other special programs also made their harvests. For examples, the electric automobile special program applauds for important progresses made in key unit technologies, system integration and whole-car technologies. More than 500 patents, obtained either domestically or internationally, have effectively raised the competitiveness of China's electric automobiles, a core product that will bring out a new industry. In the field of information technology, Chinese scientists have developed a preliminary research and development capacity in the core computer technology. A special biotechnology program cloned out functional genes of mice with broad application perspectives, marking China's internationally advanced level in crop gene studies.

While raising China's proprietary innovation capacity, special programs also brought about remarkable socioeconomic benefits. For example, a special program for deep processing of agricultural produces resulted in more than 100 new technologies and techniques, created a comprehensive economic return over RMB 10 billion. China's technical development in water efficiency, through the implementation of a water efficiency special program, witnesses a narrowed gap with the internationally advanced level from 20 years to 15 years.

161 National Key Labs

Covering a wide range of basic research fields, China's 161 national key labs have produced numerous S&T findings or results of an internationally advanced level. The Chengjiang animal colony, for example, discovered by the National Key Lab for Paleontology and Stratigraphy is deemed "one of the most astonishing discoveries made in the 20th century". The lab's investigation of the Chengjiang animal colony makes China a leader in studying the earlier life evolution process on earth. The National Key Lab for Medical Genetics has successfully cloned the genes causing high frequency nerve deafness, making a breakthrough from ground zero in cloning the genes causing local genetic diseases. The geometric calculation process for the Hamiltonian system, worked out by the National Key Lab for Science and Engineering Computation, creates a new approach to know the system. The new process has found broad applications in orbit calculation for celestial mechanics, and particle mechanics calculation for the particle accelerator.

Other national key labs also produced eye-catching achievements. While addressing national strategic needs, national key labs also provide powerful S&T support for the construction of major projects at the national level. For example, a national key lab serving for frozen earth projects worked out solid findings on frozen earth engineering process, which becomes a firm scientific basis for the construction of the Qinghai-Tibet railway system. The lab also provides technical support for the roadbed design and construction of the Qinghai-Tibet railway system, which saved over RMB 100 million for the project. A national key lab for disaster prevention oriented civil engineering developed wind and earthquake resistant technologies for more than 200 major national infrastructure projects.

More Progress for Technology Standardization

Study of Major Technology Standards, a major S&T initiative jointly organized and implemented by the Ministry of Science and Technology, the General Administration of Quality Supervision, Inspection and Quarantine and the National Committee for Standards in the 10th Five-year period(2001-2005), has achieved phased results in the two-year implementation.

According to a briefing, in the past 2 years, more than 70 central government agencies and sectors, 19 pilot cities, and 22 demonstration enterprises were mobilized to address technology standards. More than 2,100 experts from 650 research institutes participated in 61 topic oriented research activities. Up to date, about a hundred national and industrial standards have been formulated. Researches on China's technology standard development strategies, and on the construction of a national technology standard system, have resulted in a draft plan for technology trade measures, strategies and pre-warning system. Four mandatory national standards are developed for air-conditioning units and refrigerators, which will result in a saving of 50 billion kWh within 5 years, and become an important supporting tool for China's energy efficiency activities. A research project on key information processing technologies rolled out 12 national standards, which raised China's position in international competition for information technology. In developing the techniques for testing food, Chinese traditional medicine, and effective elements in natural herbs, Chinese scientists worked out an analyzing system and standards that are in line with international norms. The system and standards have been used in market and industrial testings. Other major progresses are also seen in numerous aspects, including setting up standards for environmental markers, textile products safety, wireless local network, wireless broadband IP network, and city mapping system.

APPENDIX FIVE
Export Controls Issue — Early Warning on Manufacturing

DEFENSE THREAT REDUCTION AGENCY

The Developing Science and Technologies List (DSTL) is a product of the Militarily Critical Technologies Program (MCTP) process. This process provides a systematic, ongoing assessment and analysis of a wide spectrum of technologies of potential interest to the Department of Defense. The DSTL focuses on worldwide government and commercial scientific and technological capabilities that have the potential to significantly enhance or degrade US military capabilities in the future. It includes new and enabling technologies as well as those that can be retrofitted and integrated because of technological advances. It assigns values and parameters to the technologies and covers the worldwide technology spectrum. The DSTL is oriented towards advanced research and development including science and technology. It is developed to be a reference for international cooperative technology programs. S&T includes basic research, applied research and advanced technology development.

MANUFACTURING AND FABRICATION TECHNOLOGY- 5 Sectors of Concern

Scope

1 Advanced Fabrication and Processing
2 Bearings
3 Metrology
4 Non-Destructive Inspection and Evaluation
5 Production Equipment
6 Robotics

Highlights

- The continued development of rapid prototyping and near net-shape manufacturing will result in reduced costs, faster prototyping, and the ability to form a product closer to design (final product tailored to need).
- Higher speed machining capability means less time for the machining operation and, thus, reduced costs.
- The development and implementation of nanotechnology should result in improved military hardware.
- Quieter, longer lasting bearing assemblies will be used in submarines and helicopters.
- As manufactured dimensions become smaller, improved metrology equipment is necessary to maintain quality control and keep costs down.
- As manufactured dimensions become smaller and hardware becomes more expensive, more effective methods of in-process evaluation and non-destructive evaluation (NDE) are necessary to determine the quality of final product.
- Advanced land, sea, and air military robots will extend military capabilities in several areas, including reconnaissance and mine detection.

Overview

This section describes selected developing critical technologies for the production of U.S. military hardware. Such technology is important if the U.S. military is either to produce increasingly superior military performance or reduce the costs of existing hardware. In most cases, the technologies, the equipment, and the know-how are dual use and impact civil applications, where considerations of costs, agility, flexibility, competitiveness, and so forth have also become major concerns. All technologically advanced countries are pursuing similar programs if only to maintain a commercial advantage.

Several technologies included which are rather mature, and are included as affordability issues. Affordability usually is considered in the context of a life-cycle allocation of resources. Major considerations for affordability include the following: (1) meets the consumer's performance parameters; (2) has resources available; (3) is available when the consumer requires it; (4) can be maintained through its life cycle with or without hostilities and without undue shortages at projected budget levels; (5) has importance established compared with other requirements; and (6) reduces cost of operation; and (7) increases reliability, effectiveness, or efficiency.

The technologies addressed in this section either allow prototypes to be produced in a fraction of the time required by conventional methods or, in some cases, actually produce one-of-a kind parts, in a first-time-right concept, without the need of expensive stocks of spare parts. Other technologies (e.g., nanotechnology and several coating technologies) are aimed at effecting significant improvement in military hardware. Bearings address the development of three new types of bearings. In two of the technologies, the new bearings would be critical parts of the improved (high-speed) spindles used in machine tools. The remaining bearing development has potential application in electric power generation.

Developing technologies address techniques either to inspect dimensionally (metrology) the final product or test the final product for latent failures. Continued development of these technologies will result in more accurately produced and reliable products. Technologies listed include both affordability issues (high-speed spindles, machine tool monitoring, and so forth) and technologies that might improve the overall capability of military hardware [hexapods, precision grinders, micromachines/microelectromechanical systems (MEMS), and so forth].

In short, the items addressed in this section address two critical points: Can we make it better and can we make it more affordable?

Background

For years, manufacturing and fabrication equipment has been a mainstay of industrial societies. This equipment was instrumental in bringing about the Industrial Revolution in the 18th century, the continued development of a wider range of machines in the 19th century, and the development of the concept of automation in the early 20th century. The mid-to-late 20th century witnessed a rapid expansion, with the introduction of automatic control of the machining axes and the incorporation of additional axes of motion. Indeed, one can trace the development of our present industrial society, as well as the sophistication of military hardware, to the development of manufacturing and fabrication equipment.

While rudimentary machines have been used throughout history, machines, as we know them today, were first developed in England and the United States. In England in 1775, J. Wilkinson invented a precision horizontal-boring machine to bore out cylinders for the newly invented steam engine. In the United States in 1798, Eli Whitney, invented machinery to produce interchangeable parts for the assembly of army muskets. The 19th century saw the development of milling machines and turning machines (for rifle stocks), gear-cutting machines, sewing machines, harvesters, grinding machines, and automatic screw machines.

The early 20th century witnessed the development of automation. This, coupled with the existing machines, opened the world to mass production. Products could now be manufactured in higher volume and at much lower cost, and the world experienced the mass-market appeal of automobiles and numerous other consumer products. Consumer products became affordable to a much wider range of the populations. At the same time, the military used this capability during World War II to produce tanks, planes, and ships in unprecedented numbers and at costs previously unheard of. Such machines were critical for the manufacture of engine parts and nuclear weapons.

However, automation alone was not sufficient to meet some of the post-World War II military needs, as more sophisticated weapons were developed. Production of these weapons required not only high accuracy, but also high repeatability. From this need came the development, in 1952, of a three-axis machine with the rudiments of numerical control (tape instructions). Development continued, with the introduction of automatic tool changing, four- and five-axes machines, and computer numerical controllers. Most subsequent improvements involved materials, better cutting tools, more accurate raceways, and faster and more stable spindle assemblies.

At the same time that these later developments were being introduced, composite materials were developed. To make best use of these new materials, new machines—tape-laying and filament-winding machines—were developed. This revolutionized the production of a wide range of commercial and military products (e.g., strong and lighter aircraft assemblies and automobile and tank parts).

Along with these continued improvements in manufacturing technology came continued requirements to perform both dimensional inspection and non-destructive inspection (NDI) of the final product.

The technology for coating various substrates has also experienced rapid growth and development during the 20th century. In earlier centuries, coatings were mainly applied for surface protection, and the most common media were paints or similar coatings. The perfection of equipment to produce vacuum environments increased rapidly the range of coating materials and technologies. Technologies moved from simple vacuum evaporation to chemical vapor deposition, plasma spraying, sputter deposition, ion implanting, and so forth. The refinement of these various technologies resulted in faster, more reliable jet aircraft (improved gas turbine engines); improved canopies for aircraft; longer-life bearings for applications in jet engines, machine tools, drive trains of automobiles, trucks, and tanks; specially designed dielectric layers and wear coatings for optical systems and sensors; and coatings to reduce observability of weapon systems.

Other products addressed in this section, bearings and robotics, have experienced similar developments. While bearings, in their simplest concept, have been used for many years, it was not until the 19th century, with the introduction of machine tools, that they were recognized as individual, important components. In the mid 20th century, the development of tapered bearings, high-speed bearings, and miniature bearings were instrumental in improving automotive drive trains; high-speed machine tool spindles; and navigation systems and gyroscopes, respectively. Robots, as they are known today, have developed as a direct result of the invention of computers. They have matured from interesting playthings to important production tools in most state-of-the-art factories, whether as robotic welders or material delivery tools. In more sophisticated applications, they are used in nuclear facilities and are being developed as a battlefield replacement for soldiers in some dangerous environments.

ADVANCED FABRICATION AND PROCESSING

Highlights

- Rapid prototyping and near net-shape manufacturing will result in reduced cost of producing prototypes and end products.
- More accurate grinding machines will result in reduced cost and improved engine performance.
- Breakthroughs in nanotechnology will result in significant improvements in electronics, chemistry, and materials, with widespread military applications.
- Continued advances in coating technologies will result in improved hardness capability of various military hardware surfaces and improved performance in multiple domains.

Overview

This section covers two groups of technologies. The first includes equipment for fabricating structures using a wide range of different equipment, ranging from various thermal furnaces and equipment for bending, stretching, or rolling material to form-desired shapes to scanning tunneling microscopes (STMs). The second group includes the development, refinement, and production of nonorganic coatings on non-electronic substrates. Such substrates include ceramics, low-thermal-expansion glass, metals, polymers, and so forth. Coating materials include ceramics, metals, dielectric layers, abradable materials, and so forth. The coating procedures include chemical vapor deposition (CVD), various techniques of physical vapor deposition (PVD), sputter deposition, plasma spraying, and ion implantation. Many of the developing technologies associated with the fabrication equipment involve new and continuing procedures to produce what is needed accurately and affordably. While manufacturing most products, prototypes have to be produced. An ongoing program, rapid (virtual) prototyping allows for a quick three-dimensional (3–D) fabrication of the prototype so that a design can be evaluated before production is initiated. This technology consists of:

- A computer-aided design (CAD)-generated virtual-reality model of the design, which can be analyzed and altered, as necessary.
- The ability to perform virtual machining (manufacturing) of the virtual part, followed by a computer comparison of the virtual part with the original digital design.
- The capability to produce a model from the pattern in a fraction of the time required to produce a model using conventional model-shop procedures.

Additional effort is being aimed toward extending this procedure to produce not only prototypes, but also final products, thus significantly reducing the time/cost of production.

Rapid prototyping is an integral part of the product realization cycle. It permits the fabrication of complex parts in a fraction of the time required by traditional prototyping techniques and, thus, will play a significant role in making products more affordable. Rapid prototyping can be categorized into two areas: virtual and physical. In the former, the computer system (CAD) is used to generate a 3–D image that can be analyzed before final manufacture. In the latter, the CAD program is fed directly to the manufacturing tool that produces either a final product (most often made of ceramic, wax, or plastic) or a mold to produce a metal object. Much effort is being expended to produce high-quality metal objects without the need of a mold.

Another ongoing developing technology included in this subsection is near net-shape. Near net-shape is an ongoing program with the goal of lowering the costs of manufactured products by reducing the amount of raw material used (less waste) and by producing a product so close to the design shape that only a minimum amount of subsequent machining is required to achieve the desired final shape. Casting is an example of a technology in which much effort is being expended in near net-shape. The traditional trial-and-error approach of selecting an optimum combination of design and process parameters results in long lead times and excessive material waste. To circumvent this approach, computer simulation of the casting process is being used and evaluated as a means to ensure that defect-free castings are produced in the first attempt.

Generally, items manufactured using techniques such as casting, injection molding, hot isostatic pressing, and so forth result in a final shape different from the shape of the container. As a result, historically, many products were manufactured using several steps until the proper shape of the container could be determined. Near net-shape technology uses CAD programs to calculate the resultant changes in shape that occur during cooling of the product so that the final product is "near the designed shape." This is of particular importance when fabricating ceramic parts because such items are very hard and subsequent finishing steps can be quite time consuming and expensive. Near net-shape is an approach similar to the philosophy of "first-time-right" manufacturing.

Ausforming is another developing near net-shape technology to manufacture superior spur and helical gears at less cost. It involves contour austenization of case-hardened gear teeth and quenching to metastable austenite, followed by plastic deformation of the gear tooth surface layers to final dimensions and then quenching to marstenite. The potential advantage of this procedure is that it forms the final shape of the gear without damaging the hard surface. It eliminates the need for gear tooth grinding while improving surface durability and fatigue behavior and reducing overall processing time and costs. The objective of the research program is to produce gears of better than 12 American Gear Manufacturing Association (AGMA) quality.

Semi-solid metalworking (SSM) is another example of near net-shape manufacturing, incorporating elements of casting and forming. In this process, the raw material is melted and allowed to cool to form a “mush” of liquid/solid material. This slush is then forced into a die, forming a final product that has higher structural integrity than castings but can be produced at lower cost than forgings. Parts produced with SSM enjoy several advantages:

- Have higher structural integrity than castings, yet can be produced at lower cost than forgings.
- Are less porous than parts produced with conventional high-pressure die casting
- Have equivalent properties to parts produced by either forging or conventional machining but require fewer steps.

To date, SSM has been demonstrated with aluminum, titanium, and copper; however, its implementation in either civil or military applications has been hindered by lack of process specifications, process models, training, and experience.

The most radical technology in this subsection deals with nanotechnology, defined as an anticipated manufacturing technology giving thorough, inexpensive control of the structure of matter (i.e., the ability to design and manufacture devices that are only tens or hundreds of atoms across). Nanotechnology is still an emerging technology. Significant advances have been made (e.g., buckyballs and fullerenes), but there has been little commercial activity. The development of “supersensitive coating to improve detection of dangerous materials” has been evaporated. Some use has been made of conducting fullerton as a filler material in plastics to make the plastic conductive. However, nanotechnology holds promise of an industrial revolution, as witnessed by the organizations—both government and industry—that are active in research.

Most of the research technology areas include materials, electronics, and medical devices. In materials, the bulk behavior of materials can be dramatically altered when constituted from nanoscale building blocks, the hardness and strength of nanophase metals can be greatly increased, and nanophase fillers in composite materials yield unique properties. Buckyballs and fullerenes (sometimes called buckytubes) are examples of nanophase materials. They are specific forms of carbon that are one-fourth the weight of steel and greater than 100 times stronger. Such capabilities hold great promise not only for use as improved cables, but as filler material for composite materials. Other potential applications include metal-doped buckytubes that theoretically would be 50 times more conductive than copper. Such tubes would bring about a revolution in power transmission.

Such a capability holds great promise in biology, electronics, chemical catalysis, and materials. This technology requires the capability to manipulate microscopic atoms, molecules, and so forth to form the desired structures. The procedures used in nanobiotechnology might be significantly different from those used in nonbiological applications. In the former, researchers are studying the molecular behavior of nucleic acids and proteins. In the latter, researchers are actively studying ways to use “buckyballs” and “buckytubes” (nanotubes) to produce usable end-items. Some military applications of this technology include biosensors, stronger ceramics and composites, superior coatings, abrasion-resistant materials, and so forth.

Buckyball structures are extremely malleable, can be compressed to less than half their original volume, and can be joined readily to other atoms, creating new capabilities. Although there have been no practical applications, as yet, for buckyballs, possible applications include superior armor, superconductor applications, ferromagnetic applications, superior lubricants, and medical applications.

Another fallout from buckyballs, and possibly more promising, are buckytubes (or nanotubes). These nanotubes are similar to buckyballs, but, instead of a sphere, the carbon atoms are linked together in a chicken-wire pattern. In certain cases (controllable), the carbon sheets roll together, and the edges join seamlessly, forming a nanotube. In some arrangements, the tube is a conductor. In other arrangements, the tube is a semiconductor. If two such tubes are joined to form a single molecule, the junction acts like a diode. Other possibilities for nanotubes include use as ultrastrong, thin cable and as a means of delivering medicine internally. Presently, conductive nanotubes are used in plastics to make the plastic conductive.

Coating technologies include several programs of developing technologies. Research has been conducted for several years on the technology for the deposition of diamond coatings. While some success has been achieved, the widespread application of the technology is still 5–10 years away. Nanophase coatings and cubic boron nitride coatings are more recent research programs, and both offer potential in the same technology area as diamond coatings—extremely hard, durable coatings. All these technologies have wide potential applications in military and civil applications. Of the three, nanophase coatings (related to nanophase materials) is probably the most esoteric.

Items fabricated from nanophase materials have superior characteristics. For example, nanophase copper and palladium have hardness and yield strengths 500 percent greater than conventionally produced metal, and nanophase ceramic material can be manufactured with much greater ductility than conventionally manufactured ceramics. These same bulk-nanophase characteristics result in similar improvements in the characteristics of nanophase coatings, particularly in applications requiring improved wear-resistant surfaces and increased thermal protection.

More recent studies have focused on the use of multilaser sources to heat the surface of a substrate selectively—resulting in extremely hard, graded surfaces. The technology can be modified by adding specific constituents to the plasma around the surface, altering the surface layer of the substrate and resulting in an extremely hard surface alloy.

1. RAPID PROTOTYPING MANUFACTURING (RPM)

Developing Critical Technology Parameter

Some early users of this technology report time reductions of 5–1 and cost reductions of 10–1. This is an ongoing program in a wide range of civil and military facilities.

Critical Materials

The materials depends on the RPM procedure used, including materials such as photopolymer epoxy resins, acrylates, polycarbonates, nylon, elastomers, certain metals, thermoplastics, polyester, ceramic powder, and so forth.

Unique Test, Production, Inspection Equipment

Laser stereolithography, laser sintering equipment, polymer extrusion equipment, and computers (for CAD).

Unique Software

CAD programs.

Major Commercial Applications

Aerospace products that are produced in small volume and molds for items produced in large volume (e.g., automotive).

Affordability

1. Allows quick fabrication of 3–D prototypes to evaluate of the design before beginning production.
2. Allows rapid production of small-volume products, spare parts, and so forth.

2. IMPROVED NEAR NET-SHAPE

Developing Critical Technology Parameter

This is a continuing, ongoing program, encompassing several different manufacturing technologies. Near net-shape manufacturing is a manufacturing process aimed at producing a final product that closely approximates the final design shape. Advanced simulation software is an important element is most of the processes.

As an example, “Ausforming,” a technique being developed for gear manufacture, minimizes manufacturing steps, preserves the hard surface of the gear, and imparts compressive residual stress into the gear. The technical objective is to produce gears of that are greater than 12 AGMA quality. The goals of near net-shape manufacturing are cost reduction (less final machining to reach the final design shape and less waste) and improved technical characteristics of the final product.

Critical Materials

Depends on the process used. Fine powder technologies (metal and ceramic).

Unique Test, Production, Inspection Equipment

Hot isostatic press, powder press, casting equipment, injection molding equipment, X-ray machines, electron microscopes, metallography, forming press, and so forth.

Unique Software

CAD for process simulations. To incorporate algorithms to initiate changes in component form because of compensation for shrinkage, warpage, or other process and material conditions.

Major Commercial Applications

Aerospace engines; automotive transmission cases and engine blocks; marine engine blocks and motor mounts; bearings made from powder metallurgy; home appliances (e.g., washers, dryers, and mixers); and office equipment (e.g., printer heads and disc drives); and so forth.

Affordability

If items can be cast, or prepared, closer to their final shape, fewer machining operations are required to reach the design shape, thus reducing cost.

3. SEMI-SOLID METALWORKING (SSM)

Developing Critical Technology Parameter

Initial studies indicate that parts manufactured using SSM have higher structural integrity than castings and are less expensive than forgings.

Critical Materials

The base materials used in the manufacture of end product.

Unique Test, Production, Inspection Equipment

Casting and forming equipment, X-ray machines, electron microscopes, metallography, and so forth.

Unique Software
CAD and process simulation software.

Major Commercial Applications

Aerospace engines; automotive transmission cases and engine blocks; marine engine blocks and motor mounts; home appliances (e.g., washers, dryers, and mixers); and office equipment (e.g., printer heads and disc drives); and so forth.

Affordability
Estimates from pilot work indicate that cost savings per valve will be in the $1K–$10K range. If this technology allows conversion to titanium valves, savings could reach $13,000,000 per ship, over a 40-year life.

Background
SSM technology is a near net-shape approach to manufacturing wherein the metal, in a semi-solid state (i.e., at a temperature between its solid and liquid states) is formed, using pressure, in dies. This combination of slush and pressure results in a final product with less voids. More conventional processing uses either molten metal (casting) or solid metal (forming). Parts produced by SSM have higher structural integrity than castings and can be produced at lower costs than forgings. The process is capable of producing parts that are essentially free of the porosity associated with conventional high-pressure die casting. At the present time, SSM is being used with titanium and aluminum.

4. TECHNOLOGY FOR MOLECULAR MANUFACTURING (NANOTECHNOLOGY)

Developing Critical Technology Parameter

The manufacture of items using extremely small and/or extremely strong building materials [e.g., buckyballs (fullerenes), buckytubes (nanotubes), and so forth]. Nanophase materials and nanocomposites are characterized by ultra-fine grain size.

Critical Materials

The base materials used in the manufacture of end product. Buckyballs and nanotubes are made of carbon. Many potential applications of buckyballs and nanotubes would require the addition of other elements to the carbon structure. This could include hydrogen or fluorine atoms to form “fuzzy” balls, potassium to form a superconducting material, and so forth.

Unique Test, Production, Inspection Equipment

Scanning tunneling microscopes (STMs) for the manipulation of atoms and furnaces to form buckyballs and nanotubes.

Unique Software

None identified.

Major Commercial Applications

Applications could include very small, highly sophisticated, low-power electronic systems; stronger, lighter structural members; multifunctional surfaces; small, accurate antennas; and so forth.

Affordability

Not an issue.

Background

Nanotechnology was defined by Drexler as “the knowledge and means for designing, fabricating, and employing molecular scale devices by the manipulation and placement of individual atoms and molecules with precision on the atomic scale.” This so-called “bottom-up” approach to manufacture contrasts sharply with the conventional “top-down” approach, where a bulk material is machined down to meet the designed shape. Research on specific characteristics of buckyballs and nanotubes have demonstrated that:

- They are unaffected by collisions at speeds of up to 15,000 mph.
- When compressed, they are harder than diamonds.
- Their internal cavity is large enough to hold any known element, thus having the possibility of being a carrier for medicines or radioactive materials.
- The addition of hydrogen or fluorine atoms to each of the carbon atoms (“fuzzy balls”) should result in films with very low coefficient of friction.
- The addition of potassium atoms can result in either a superconducting material or an insulator, depending on the number of potassium atoms.
- Nanotubes could be used as fibers in composite materials, resulting in materials superior to carbon-carbon composite materials.

5. TECHNOLOGY FOR DIAMOND COATINGS

Developing Critical Technology Parameter

Extremely hard, durable coatings. Characteristics should approach the following properties of diamond:

- Hardness of 80–90 GPa
- Coefficient of thermal expansion (at room temperature) of 0.8 ×10–6 K
- Coefficients of 0.005
- Thermal conductivity (at room temperature) of 2 ×103 W/m/K
- Very resistant to chemical corrosion
- Biologically compatible.

Critical Materials

Carbon deposition source.

Unique Test, Production, Inspection Equipment

Chemical vapor-deposition equipment, sputtering, ion beam and direct current (DC) plasma deposition equipment, multi-laser system.
Scanning electron microscopes (SEMs) and various optical equipment to analyze the surface.

Unique Software

None identified.

Major Commercial Applications

Wide application in materials requiring surface protection from erosion.

Affordability

Not an issue.

Background

Diamond coatings offer extremely hard, durable, transparent coatings for a wide variety of applications. Extensive research is being conducted worldwide, and progress is continuing. Some applications have entered the commercial marketplace [e.g., coating of cutting tools (not applicable for machining ferrous materials) and heat sinks].

6. TECHNOLOGY FOR NANOPHASE COATINGS

Developing Critical Technology Parameter

Extremely hard, durable coatings and thermal barrier coatings produced from the deposition of particles whose size is in the nanometer range (10–9 m).

Critical Materials

Many different materials are being studied (e.g., n-WC/Co, MnO_2 , yttria-stabilized zirconia, SiC, BN, and so forth).

Unique Test, Production, Inspection Equipment

Thermal spray equipment, CVD equipment, DC plasma deposition equipment, PVD equipment, and equipment to analyze the surface coating.

Unique Software

None identified.

Major Commercial Applications

Wide application in materials requiring surface protection from erosion or high temperatures. Applications would extend to cutting tools, engines, sensor windows, and so forth.

Affordability
Not an issue.

7. TECHNOLOGY FOR MULTI-LASER SURFACE MODIFICATION/COATING

Developing Critical Technology Parameter

Produces either a super-hard outer layer of the base material or a super-hard graded coating made up of the base material and an added constituent.

Critical Materials

Dependent on the coating to be deposited. The technique has had success with diamond, diamond-like carbon, and titanium carbide, among other sources.

Unique Test, Production, Inspection Equipment

Excimer, yttrium-aluminum garnet, and carbon-dioxide lasers. Other laser types might be substituted for these lasers.

Unique Software

Programs to control the multiplexing of the three lasers, the furnace temperature, and the gas mixtures.

Major Commercial Applications

Wide application in materials requiring an extremely hard surface layer. Preliminary results on steel punches, golf club heads, and fuel-injector nozzles.
Affordability

Not an issue.

Background

Surface modification/coating offers extremely hard coatings for a wide range of applications and does so with only surface heating. At the present time, the patented procedure can deposit diamond, diamond-like carbon, and titanium carbide films.

8. TECHNOLOGY FOR CUBIC BORON NITRIDE COATINGS

Developing Critical Technology Parameter

Extremely hard, durable coatings, with a hardness of 5,000 knoop (second only to diamond), a thermal conductivity of 13 (W/cm)(K) and a heat resistance of 1,000 °C. “Knoop” hardness is a method of measuring a material’s hardness by its resistance to indentation.

Critical Materials

Boron and nitrogen compounds

Unique Test, Production, Inspection Equipment

CVD equipment, sputter equipment, PVD equipment for deposition, and IR spectroscopy to characterize films.

Unique Software

None identified.

Major Commercial Applications

Wide application in materials requiring surface protection from erosion. Also, should have wide application in the production of superior cutting tools, dies, and molds.

Affordability

Not an issue.

CATEGORY 2: BEARINGS

Highlights

Development of magnetic bearings using high-temperature superconductors will result in

- Improved compressors for space cryocoolers
- Frictionless bearings for use in high-speed machining
- Magnetic bearings for use in electric vehicles and magnetic guns

Overview

Bearings are not only key elements in military equipment that use rotating elements, but they are essential for the operation of precision machine tools and metrology equipment used to manufacture military equipment. For many years, steel roller and tapered bearings were used almost exclusively in advanced military hardware and precision machine tools. In recent years, considerable effort has been expended in developing self-lubricating ceramic bearings. These bearings have longer life, less friction, and lower density than similar steel bearings. More recent effort has been focused on aerostatic and hydrostatic bearings. These bearings use air and liquid to maintain a separation between the surfaces during their sliding or rotating motion. Their potential in high-/low-speed, high-precision equipment is unquestioned. They also operate quietly, thus offering the possibility of improved quiet propellers. Aerostatic and hydrostatic bearings approaches possess the following advantages:

- No wear of either surface
- High precision
- Operation at both very low and very high speeds

- High stiffness (hydrostatic bearings only).

Research on high-temperature superconductor, magnetic bearings is still in an early stage. Much of this program's success is related to continued research on high-temperature superconductors. Several potential applications have been discussed. The use of these bearings in space cryocoolers would avoid the problem of heat generation that occurs with the present gas bearings. Other possible applications include the support for the shaft of high-speed motors, the levitation force for high-speed locomotives, and energy storage. The concept of energy storage involves using the bearings with flywheels, where the flywheels rotate at very high speeds. The flywheel concept holds great promise for both off-peak energy storage of power plants and use a power source for vehicles, whether civil or military. A major problem has been related to concerns of flywheel breakage and the requirements to surround the system with heavy production shrouds. Another possibility is application in high-energy weapons.

9. TECHNOLOGY FOR SUPERCONDUCTING MAGNETIC BEARINGS

Developing Critical Technology Parameter

Offer promise for the mounting frame of flywheel energy storage systems (with application in electric vehicles and electric utilities) and spacecraft gyroscopes.

Critical Materials

High critical temperature superconductive material.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

CAD programs for design of structure.

Major Commercial Applications

Electric automobiles, electric utility companies, superior coolers, and the superconductive magnetic levitated (MAGLEV) railway systems.

Affordability

Not an issue.

Background

Superconducting magnetic bearings are directly dependent on the advances in the development of superconducting materials. Materials have been developed with transition temperatures (Tc) in the 135 K range, considerably higher than the temperature of liquid nitrogen (77 K). Research on superconducting bearings is proceeding at a rapid pace throughout the world.

CATEGORY 3: METROLOGY

Highlights

- As critical dimensions of hardware become smaller, the positioning of the machining tool and the ability to measure that position become more important.
- The accuracy to which gears can be machined has a direct bearing on the noise and heat generated by the gears. Efforts to extend the metrology capability of gears to the 100-nm range should result in quieter and more efficient gear trains.
- The ability to operate high-quality coordinate measuring machines (CMMs) in the shop environment would result in a cost saving because the necessity of taking the part to a centrally located measuring room for high-precision dimensional measurements is very time consuming.

Overview

Metrology, in some form, has been used since the beginning of civilization. It took on additional importance during the Industrial Revolution when parts were no longer manufactured as one-of-a-kind. During the intervening years, metrology has advanced from measuring angles and lengths in inches and degrees to measurements in fractions of microns and arc-seconds. Modern metrology equipment includes gauge blocks, surface profilers, angular measuring equipment, laser-based measuring systems, coordinate measuring machines, and so forth. Present developing technology can be separated into two parts: increased measurement capability and the use of advanced equipment in the shop working area (as opposed to operation only in controlled environments). This subsection addresses two technologies in the first part and one in the second. The following programs to increase measurement capability are listed: (1) to produce gear-measuring equipment that is not only faster than conventional equipment but will have measurement accuracies less than 1 μm and (2) to improve the capability of more accurately measuring the position of the spindle of a machine tool. Work is also being carried out to produce highquality coordinate measuring machines that can withstand the environment of the shop floor and, thus, carry out inspections next to the production machines.

10. MACHINE TOOL METROLOGY

Developing Critical Technology Parameter

There are no quantitative parameters for this technology. Studies are being conducted on techniques to measure the position of the spindle more accurately. Techniques include laser triangulation and IR technology. Time frame: 5–10 years.

Critical Materials

Sensors to measure displacement, velocity, acceleration and deceleration, force and strain, pressure, or temperature.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

Software algorithm to analyze input from sensors.

Major Commercial Applications

Broad application in most machining operations used in the manufacture of commercial hardware.

Affordability

Increased metrology capability and reduced time for measurements reduces overall costs for gears.

11. GEAR METROLOGY

Developing Critical Technology Parameter

Measure gear parameters 102 to 103 times faster than CMMs (3–4 gears per second), with submicrometer accuracies.

Critical Materials

Sensors.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

Software algorithm to analyze input from sensors.

Major Commercial Applications

Application in the manufacture of a range of gears that require very accurate tolerances (e.g., helicopter gear sets and jet engines).

Affordability

Increased metrology capability and reduced time for measurements reduces overall costs for gears.

12. FACTORY-FLOOR-CAPABLE COORDINATE MEASURING MACHINES (CMMs)

Developing Critical Technology Parameter

The design and manufacture of CMMs so that the critical operating parts are not affected by the shop environment. The goal is to produce CMMs with accuracies in the 3.5 μm = L/200, where L is the linear distance being measured, in a temperature from 10–35 °C. Time frame: 5–10 years.

Critical Materials

None identified.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

Software algorithm to analyze input from sensors.

Major Commercial Applications

Broad application in most machining operations used in the manufacture of commercial hardware.

Affordability

Having the CMMs on the shop floor, near the machining centers, would result in reduced costs of performing product inspections.

CATEGORY 4: NON-DESTRUCTIVE INSPECTION AND EVALUATION

Highlights

- The use of shearographic techniques should increase the technical capabilities for the detection of flaws.
- Smart materials could revolutionize the inspection and evaluation of hardware by incorporating within the hardware sensors that could detect flaws.
- The application of data fusion technology to NDE should reduce the time/cost to perform more advanced analyses.

Overview

NDE encompasses a wide range of disciplines, including eddy current, magnetic testing, penetrant testing, radiographic testing, and ultrasonic testing. Each of these techniques is used in several different applications; however, they all have one thing in common: They are used for the detection of defects after an item or structure has been manufactured and requires periodic inspection. All these techniques have been used for quite a few years, and only minor changes have been incorporated into the procedures. Most changes have resulted from improvements in detection equipment. In this subsection, we describe three new NDE techniques: digital shearography, the use of smart materials, and data fusion.

Shearography is more traditional. It is a technique that is used to analyze finished product. In its simpler sense, shearography is an existing technology; however, it has several drawbacks. Digital shearography is an approach aimed at improving the technique. In short, shearography is a nonscanning, laser-based interferometry system used to detect areas of stress concentration caused by anomalies in materials. Digital shearography combines these techniques with charged-coupled device (CCD) cameras and computers to improve the image and allow analyses of the results. Digital shearography can examine substances as large as one ft square and is portable so inspection need not to be place in a laboratory.

Shearography has a major advantage over conventional non-destructive test (NDT) techniques (e.g., dye penetrant, magnetic particles, and radiography) used to detect flaws. The conventional techniques detect all visible flaws, but shearography, by examining not the flaws but the flaw-induced strain, provides more information on the criticality of the flaw. Potential military applications include the detection of subsurface flaws in aircraft panels and the detection of voids in composite materials.

The use of smart materials is a more radical approach because the sensors used to detect flaws in the structure are built into the structure and can be used to monitor quality/reliability either during manufacture or after the product is completed. The concept of smart materials is also an emerging technology in materials technology. In that application, the sensors detect some “designed-for” parameter and respond with a counteraction (e.g., damping engine vibrations, silencing refrigerators and aircraft cabin noise, and so forth).

Smart materials include technologies such as piezoelectric materials, shape memory alloys, and magnetostrictive fluids. The field of piezoelectric materials is the most advanced, and some commercial applications have been developed. However, widespread use of these technologies is still in the future. Potential civil and military applications abound, with civil applications including sensor determination of aging in building, bridges, and so forth; determination of maintenance requirements for engines, aircraft, and so forth; and chromogenic applications (e.g., self-dimming rear-view mirrors, architectural windows, and so forth).

Data fusion is a technique that uses data from a group of NDE sensors rather than using data from a single sensor. It has potential application in a wide range of disciplines. In essence, data fusion is a technique in which data from multiple—and perhaps diverse—sensors are correlated into digitally formatted products. These products provide a user with complex information in a user-friendly format so that decisions can be made quickly and accurately.

13. NON-DESTRUCTIVE INSPECTION AND EVALUATION- DIGITAL SHEAROGRAPHY

Developing Critical Technology Parameter

Provides a large-area, quantitative analysis of stress concentrations resulting from either the vibration of a structure or existing in composite materials in aging aircraft. Inspection speed of an order of magnitude higher than conventional ultrasonic techniques. Time frame: 5–10 years.

Critical Materials
Lasers, CCD cameras, and so forth.

Unique Test, Production, Inspection Equipment

Laser system, CCD camera, and image processor.

Unique Software

Software algorithm to process information.

Major Commercial Applications

Useful in a wide range of commercial hardware, particularly aging aircraft.

Affordability

Improved shearography would result in reduced costs for performing some NDI tests.

CATEGORY 5: PRODUCTION EQUIPMENT

Highlights

- The development of spindles capable of operating at higher speeds and power would reduce the cost of machining.

- Improved grinding machines would result in more powerful jet and diesel engines and more accurate guidance systems.
- The continued development of parallel kinematic machine tools may result in improved machining capabilities and reduced cost of the machining operation.
- The use of MEMS technologies to improve military hardware and to reduce costs may be one of the most significant advances in developing superior and less expensive military hardware.
- Improved monitoring of machines and tools should reduce the cost of military hardware.

Overview

This subsection addresses various developing production technologies including the following:
- Improved grinding machines
- Machine tools based on the parallel kinematic concept (e.g., Stewart platform or hexapod)
- Extremely small machine tools (micromachines)
- MEMS, a revolutionary technology or manufacturing miniature hardware that combines both electronic and mechanical on a monolithic substrate.

Hexapods are based on the Stewart platform. Companies in numerous countries are investigating the use of hexapods as machine tools. Indeed, initial designs have been manufactured and are in the process of being evaluated. While some limited use has been found for the equipment, sufficient problems still limit their use at the present time. The main problem is that the positioning accuracies are on the order of five times worse than that of the best milling machines (although comparable to many existing machines). Such equipment might find a niche in the manufacture of micro- or nano-scale products.

Tetrahedral tripods are a third class of parallel kinematic machines. Efforts are still in the research stage, but such equipment may avoid some of the problems inherent in Stewart-platform-based equipment.

Micromachines are being pursued to manufacture minute items, such as invasive medical micromachines and maintenance systems for power plants. The technology, although different from MEMs, has the same general goals as the MEMS concept.

MEMS uses the techniques developed for the manufacture of integrated circuits to fabricate devices that incorporate, on a semiconductor substrate, not only integrated circuits, but also mechanical structures that can be used for a range of applications. MEMS technology includes three important characteristics: miniaturization, multiplicity, and microelectronics. By using semiconductor device manufacturing technology, these packaged MEMS-based systems are very small (ranging from 1 mm to 2 cm in size), can be manufactured in quantity using conventional pholithographic techniques, and incorporate complex electronic circuitry.

Until the advent of MEMS, miniaturization was a concept most often associated with electronics. The continual miniaturization of electronic systems has been one of the pillars of the advanced technologies used in military and civil hardware. The decrease in size, coupled with the increase in processing power, of computers is a prime example of the advances in electronic technology. In MEMS technology, actuators, sensors, and medical devices incorporating mechanical structures (e.g., levers, springs, motion sensors, and so forth) and integrated circuits are manufactured on semiconductor substrates, thus using the miniaturization capabilities of integrated circuit technology. The use of semiconductor manufacturing technology also results in the batch processing inherent in photolithographic-based semiconductor processing and makes it possible to fabricate thousands of components as easily as a single component. As a result, the cost of the components is reduced significantly, thus extending the use of the products to a wider range of applications. The incorporation of these mechanical structures either into microcircuit chips or on associated substrates (hybrid device) provides the intelligence to the devices that allow their use without the cumbersome external components that were often required to interconnect discrete components.
Technologies that may result in decreased costs include:

- Tool monitoring and sensing, which may result in more cost effective technique for determining tool life
- Machine degradation monitoring, which may result in a more cost-effective technique for determining machine tool maintenance
- High-speed spindles, which will decrease the time required to machine many parts, thus reducing the final cost
- First-part-correct programs, which would reduce the cost of having to make two or three items before the design/manufacturing process was corrected to produce a product that met design specifications.

14. HIGH-SPEED, HIGH-POWER SPINDLES WITH HIGH-FEED RATE

Developing Critical Technology Parameter

The requirement is to obtain spindles that have not only high-speed capability, but can operate at that speed with both high force and feed rates. The overall goal is to develop spindles with the following capabilities: 100,000 rpm @ 100 kW and with a feed rate of 3,000 in. per minute.

Critical Materials

Bearings, motors, seals, cooling, and lubrication.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

Software algorithms to handle high-speed machining/grinding.

Major Commercial Applications

Large-scale manufacturing: aerospace, automotive.

Affordability

The use of higher speed spindles would allow the fabrication of many critical parts in much less time.

15. CUBIC BORON NITRIDE (cBN) GRINDING WHEELS FOR HARDENED STEEL GEARS AND BEARINGS

Developing Critical Technology Parameter

Important for grinding steel gears (diamond-coated wheels are of limited value in grinding hardened steel) to improve power density of gearbox.

Critical Materials

cBN.

Unique Test, Production, Inspection Equipment

None identified.

Unique Software

None identified.

Major Commercial Applications

Helicopters, engines, and so forth.

Affordability

cBN-coated wheels will last much longer than conventional wheels.

16. PRECISION PROFILE GRINDERS

Developing Critical Technology Parameter

A work head run-out <0.1 microns and a wheel surface speed >100 m/second @ 50 kW grinding power help achieve 6-sigma quality for ground parts.

Critical Materials

None identified.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

None identified.

Major Commercial Applications

Large-scale manufacturing: aerospace, automotive.

Affordability

Not an issue.

17. PARALLEL KINEMATIC MACHINE TOOLS (STEWART PLATFORM, HEXAPOD, PARALLEL LINKAGE STRUCTURES, AND SO FORTH)

Developing Critical Technology Parameter

Parallel kinematic machine tools are a new concept in machine tool design. Existing developmental models have several drawbacks, and considerable research is being done to overcome these problems. If such machines can be improved to possess positioning accuracies of < 10 microns, velocity of 1 m/second, and spindle speeds in the 50,000-rpm range, they would find a definite niche among machine tools.

Critical Materials

None identified.

Unique Test, Production, Inspection Equipment

Standard machine tools.

Unique Software

Unique algorithms to control six axes (for the Stewart platform and hexapod) and three axes (for the tetrahedral tripod).

Major Commercial Applications

Applications would include machining of small, complex parts or for use in pick-andplace systems.

Affordability

Not an issue.

18. MONITORING AND SENSING OF CUTTING TOOLS AND MACHINE TOOLS

Developing Critical Technology Parameter

No quantitative parameters are available; a continuing, ongoing program. Thin film sensors (coated with a hard protective layer) can be deposited onto the cutting tool and used to measure the condition of the tool. In machine tools, the sensors are mounted within the mass of the machine tool and measure parameters such as temperature, vibration, and so forth.

Critical Materials

Capacitance gauging, lasers, sensors, and so forth.

Unique Test, Production, Inspection Equipment

Computers and sensors.

Unique Software

Unique algorithms to monitor cutting tool or machine tool condition.

Major Commercial Applications

General machine tool operation.

Affordability

Cutting time is the criterion used by most manufacturers for tool life. With sensors mounted on, or in, the tools to measure parameters such as force (radial and thrust) and torque, a more accurate determination of tool life and condition is possible.

Background

The normal operation of a machine tool generates heat and vibration within the mass of the machine tool. Both can affect the positioning accuracy and cut of the tool. Accurate monitoring of these parameters, coupled with a feedback mechanism, can minimize most of the heat and vibration effects.

19. MICROMACHINES

Developing Critical Technology Parameter

No quantitative parameters are available. However, the general concept is to build extremely small machines (using miniaturized machine tools) that can perform the same tasks, albeit on a miniature scale, as conventional machines.

Critical Materials

Material of end product.

Unique Test, Production, Inspection Equipment

Machine tools or lasers capable of producing the micromachines.

Unique Software

None identified.

Major Commercial Applications

Overall applications are unknown. Initial interest includes invasive medical devices and very small items, such as mini-gyroscopes, micromotors, pumps, and robots.

Affordability

Not an issue.

Background

Micromachines are extremely small and comprise minute (millimeter range) functional elements that are highly sophisticated and are capable of performing complicated tasks. The concept of micromachines is similar to that of MEMS technology (i.e., manufacture devices that are extremely small, allowing continued miniaturization of hardware, with the many benefits associated with miniaturization).

20. MICROELECTROMECHNICAL SYSTEMS (MEMS)

Developing Critical Technology Parameter

No quantitative parameters are available. However, the general concept is to build extremely small machines (devices) that can perform the same tasks, albeit on a miniature scale, as conventional machines. In short, MEMS devices should be smaller, less expensive, and more reliable than more conventional devices.

Critical Materials

Silicon wafers; other materials used in microelectronics fabrication industry.

Unique Test, Production, Inspection Equipment
Standard semiconductor manufacturing equipment, including photolithographic equipment, dry etchers, deposition equipment, and systems for reactive ion etching, LIGA, wafer-to-wafer bonding, and so forth.

Unique Software

None identified.

Major Commercial Applications

Unlimited applications. Present uses include accelerometers for airbag deployment in automobiles; micropressure sensors, medical microfluidic systems; micromirrors for projectors; nozzles for inkjet printers; and fluid flow sensors.

Affordability

MEMS fabrication is less costly than the fabrication of traditional components. MEMSbased systems often have improved performance or reduced size and weight, which leads to further savings.

Background

MEMS are micron-scale devices that integrate novel sensing and actuation functions with traditional microelectronics-based data processing and control systems. MEMS are unique because they combine mechanical or structural elements, such as accelerometers and micromirrors, with electronic elements, such as microprocessors and radio frequency transmitters

21. FIRST PART CORRECT (OR VALID)

Developing Critical Technology Parameter

Ability to take complicated engineering designs from design to manufacturing and have the end product meet all specifications the first time.

Critical Materials

None identified.

Unique Test, Production, Inspection Equipment

Computers and normal manufacturing equipment.
Unique Software

Computer-aided design/computer-aided manufacturing/computer-aided engineering (CAD/CAM/CAE) programs.

Major Commercial Applications

All manufacturing operations; however, the most important area would be for items manufactured in small volumes.

Affordability

In small-volume applications, each part that does not meet specification is a significant part of the overall cost.

ROBOTICS

Highlights

- Advanced sea, air, and land robots will carry out a wide range of military operations, ranging from chemical and biological warfare (CBW) detection and reconnaissance to mine detection.
- The development of fractal, self-duplicating, self-repairing robots would be a significant breakthrough in the design of military hardware.

Overview

This subsection covers the developing technology for advanced battlefield robots, encompassing robots for land, sea, and air. Possible robots include:

- **Ground robots.** Although these robots could be designed for many different applications, early planning has addressed the fields of cameras, sensors, or equipment for gathering and disseminating information.
- **Seaborne robots that resemble jet skis.** These robots can be equipped with a various types of equipment, including underwater cameras, laser scanners, night vision equipment, radar, and so forth.
- **Micro and mini air vehicles (MAVs).** Proposed designs of these pilotless machines vary from micro (smaller than 6 in.) to extremely small (8- to 10-in. size) to moderate (on the order of 3- to 5-ft size). Initial plans would be for the craft to carry some type of sensor, although they could also carry small amounts of explosives.
- **Fractal shape-changing robots.** These robots can, theoretically, change shape, replicate, self-repair, and perform a wide variety of military tasks.

The fractal shape-changing robots are a form of nanotechnology and are still in the conceptual stage. However, interest has been increasing since the inventor was awarded the 1996 European Invention Competition of Monaco. The concept of replication is a basic tenet of nanotechnology, whether one considers classic nanotechnology or molecular nanotechnology. The goals of nanotechnology are low cost, molecular precision, and flexibility. Some authors believe these can only be reached with the development of self-replicating objects.

APPENDIX SIX
PRC International S&T Agreements

New Organization for Japan-China S&T Cooperation

Yomiuri Shimbun 26 Jan 98 (VIA Internet)

The Japan-China Science and Industrial Technology Exchange Organization (direct translation from Japanese) was established on 26 January. The Chairman, Minoru Nagaoka, a former Administrative Vice-Minister of the Ministry of Finance, has been named its head. Members of the board of directors include officials of NEC Corporation, Nippon Steel Corporation, Toyota Motor Corporation, and Toray Industries, Inc. Eventually a total of over 200 major Japanese companies are expected to join the organization.
The organization will carry out technological exchanges and joint research in the science and industrial fields to help create mutual business opportunities.
The organization will begin operations with sponsorship of various symposiums in both countries, creation of a data bank on engineers who belong to research organizations and companies in China, and training of researchers. They are expected eventually to conduct joint research on subjects such as telecommunications, power generation technology, and environmental issues, areas in which China has particular interest, as well as agriculture and medicine.

The American-Oceania Division
China Science and Technology Exchange Center
The American-Oceania Division Tel: 010-68511822
Brief Introduction to the Division
The American -Oceania Division, one of divisions of China Science and Technology Exchange Center, is responsible for organizing and conducting various training courses both at home and abroad, and offering quality services for scientific and technological cooperation and exchanges with foreign countries. The business scope of AOD is as the following:

- Organizing and conducting all training courses held abroad and some other domestic training courses for the Ministry of Science and Technology (MOST).
- Carrying out the projects for scientific and technological cooperation and exchange which are entrusted by relevant departments of MOST, particularly by the Department of International Cooperation.
- Developing international exchange and cooperation with circles of science and technology and industries in the American and Oceania region.
- Providing consulting services for international scientific and technical cooperation for enterprises, with special attention to small-and-medium sized scientific and technical enterprises.

Training Courses

China Science and Technology Exchange Center, one of the semi-governmental agencies affiliated to the Ministry of Science and Technology (MOST), has been the only organization authorized to conduct the training courses abroad for the Ministry. In the past years , the American-Oceania Division was a major one in the center for organizing training courses, and then, since the reform of the center's readjustment of organizational structure, the division has becomes the unique division to conduct all training courses abroad and some domestic training courses for the Ministry, for the purpose of improving the quality of the training courses and developing various training programs to meet the increasing personnel training needs of the Ministry. These training courses include:

1. Short-term Training Courses Abroad
2. Medium,-and-long-term Training Courses Abroad
3. Key Training Program for Technological Innovations
4. Domestic Training Courses

Short-Term Training Course

For year 2001, The State Bureau of Foreign Experts, a governmental agency responsible for introducing intellects from abroad, approved 3 financial-aided training courses , 50 person-times, for MOST; While the Department of International Cooperation of MOST approved 10 self-funded training courses, 217 person-times. The courses are:

1. Management of incubators for hi-tech enterprises in university science and technology zone;
2. Management of investment and fund raising of small-and-medium sized S & T enterprises;
3. Protection of agricultural water and soil resources and ecological environment;
4. Establishment of legislations and capability of regional sustainable development;
5. Scientific and technical consultancy and technological innovation of enterprises;
6. Sustainable Technologies and development model for tropical agricultural resources;
7. Management of stock market of hi-tech enterprises;
8. Methods of analysis and research on hi-tech quota system;
9. Desert control and ecological environment protection;
10. Management of human heredity resource;
11. Technique and management of scientific and technical consulting.

Medium-and-long-term Training Courses Abroad

This courses, supported by the Bureau of Foreign Experts and Ministry of Science and Technology, and initiated at the beginning of this year, is mainly designed to provide chances for governmental officials for advanced study abroad. Two officials from MOST have already been in the United States for their one-year advanced study as visiting scholars, and ten more will be dispatched this year, according to the course plan.

Key Training Program for Technological Innovation

This is brand new long-term training program initiated by the Ministry of Science and Technology. The Bureau of Foreign Experts showed their great interest, and will give a powerful support to carry out the program.

Just as its name implies, in accordance with the program, yearly in the coming five years, four courses for 100 trainees will be carried out, and 10 officials will be selected to have their special training courses abroad, and at the same time, two domestic training courses for 200 person-times will be held. All the courses will concentrate on different aspects dealing with technological innovation, to which the Chinese government paid tremendous attention.

Domestic Training Courses

With China's forthcoming entry to WTO, China will be more open to the outside world , therefore, more and more Chinese enterprises and other organizations will irrevocably face with challenges of how to professionally handle business with their foreign partners. In order to provide a practical knowledge for these people, Our center is entrusted to conduct some domestic training courses focusing on practice of international science and technology cooperation and exchanges. In 2001 two such courses have been scheduled as pre-training courses for the courses abroad.

Newsletters

The Center Won the First Place to Organize Training Courses Abroad

On December 25, 2000,the State Bureau of Foreign Experts convened a meeting in Beijing to legalize agencies for organizing the training courses abroad. Having examined the works in the past years done by the 33 agencies and organizations who were qualified to organize training courses abroad before the meeting, the Bureau decided to give qualifications legalization to 20 units. Thanks to the concern of the Bureau and consistent support from the Ministry of Science and Technology, particularly from the Department of International Cooperation of MOST, our center honorably got the certificate and possessed the first place on a list of the successful candidates.

Our Trainees

The American Concerning with Politics

Mr. Xu Jing, Director of Energy Division, Department of Hi-tech Development, MOST, has been in the United States for about two months. Since he arrived in America January 25 , this year, we have received 6 "Newsletters" from him by E-mail (in Chinese), titled "Training Diary_ Xu Jing in the United States". The following is one of the E-mails, " The American Caring about Politics" (translated by Mr. Zhang Zhixinag).

The American Caring about Politics

Ministry of Science and Technology of the People´s
Republic of China
15B, Fuxing Road, Beijing, 100862, P.R. China
Sponsor: Executive office of MOST
Support: Information Centre of MOST

Affiliated Agencies

No.	Name	Principal	Telephone
1	Logistics Services Center, MOST	MA Lianfang	58881260
2	Office for National Science and Technology Awards	CHEN Chuanhong	68521383
3	Institute of Scientific and Technical Information of China	ZOU Dating	68514037 58882582
4	National Research Center for Science and Technology for Development	WANG Yuan	68252487 68252488
5	China Science and Technology Exchange Center (Sino-Japanese Technology Cooperation Center)	HUANG Xing	68511829
6	China Rural Technology Development Center	WU Yuanbin	68511848
7	Torch High Tech Industrial Development Center, MOST	WU Yingjian	68511133
8	China Technology Market Management and Promotion Center	ZHANG Xuguo	68575704

9	China National Center for Biotechnology Development	WANG Hongguang	62111948
10	Administrative Center for China's Agenda 21	WANG Weizhong	82636297
11	High Tech Research and Development Center, MOST	ZHAO Yuhai	68313388
12	Information Center, MOST	BAO Hong	68573525
13	National Remote Sensing Center of China	ZHANG Guocheng	68570820
14	Evaluation Center, MOST	ZHANG Xiaoyuan	

APPENDIX SEVEN
US Congressional Concerns S&T Competitive Issues 2003-2005

July 2004 Speakers Warn of Challenges to U.S. Competitiveness

Speakers at a June 24 congressional briefing sounded a wake-up call that increasing competition from the rest of the world threatens America's preeminence in innovation. The speakers reported that the U.S. science and innovation system is seen as a model; many countries are investing significant amounts to imitate it, and are making strides in scientific advances, developing scientific talent, and attracting outside business and investment.

The briefing was kicked off by Senators Lamar Alexander (R-TN) and Jeff Bingaman (D-NM), who have both demonstrated recognition of the role that science and technology play in the nation's competitiveness. Bingaman commented that the U.S. has not been "as focused" on S&T investment in recent years as have many other countries, and Alexander pointed out that federal funding in many areas of the physical sciences and engineering has been flat or declining for years.

Council on Competitiveness President Deborah Wince-Smith defined innovation as the ability to keep productivity growing by creating new knowledge and quickly turning it into products.

Alan Rapoport of NSF cited statistics indicating that other countries, especially many Asian countries, are succeeding in efforts to increase their S&T and innovation capacity. While the U.S. is still the world leader in high-tech industries and has the greatest number of international technology alliances, he said, some Asian nations have nearly doubled their share in global high-tech markets over the past several decades and have almost tripled their share of high-tech exports. The U.S. share of total articles in science and engineering publications has been declining since 1988, while that of many countries is growing, and indicators of bachelors-degree production in the natural sciences and engineering show the U.S. far behind many other nations.

What is needed for the U.S. to stay on top, Wince-Smith suggested, is to restore emphasis on the sciences that drive innovation, develop better metrics for the results of innovation, and transition away from disciplinary "stovepipes" in education and research to a multi-disciplinary, cross-sector model. Policymakers must also recognize the importance of tax and fiscal policies, she said, and deal with the deficit and entitlement spending, high corporate tax rates, and intellectual property and piracy issues.

From the President's Council of Advisors on Science and Technology, the American Association for the Advancement of Science's annual Science and Technology Policy Forum, to the recently-issued Electronic Industries Alliance report, the issue of maintaining U.S. leadership in innovation is beginning to attract high-level attention. The Council on Competitiveness (http://www.compete.org) releaseDa policy agenda during the National Innovation Summit in December, 2004.

In related news, data collected by NSF indicate that, between 2001 and 2002, the U.S. investment in industrial R&D declined $7.7 billion, or 3.9 percent. According to NSF, this represents "the largest single-year absolute and percentage reduction in the current-dollar cost of industrial R&D performance since the survey's inception in 1953." When the data are adjusted for inflation, NSF states, the decline still represents the largest single-year reduction of the years surveyed and the second largest percentage reduction; the largest constant-dollar percentage reduction occurred between 1969 and 1970. It adds that contributions to industrial R&D from company funds, federal funds, and other non-federal sources all declined between 2001 and 2002. The information is provided in an NSF "InfoBrief" released in May; see InfoBrief NSF04-320 at www.nsf.gov/sbe/srs/infbrief/ib.htm.

March 1, 2005 Senate NSF Appropriators Senator Kit Bond and Barbara Mikulski

"We have fallen off the path for doubling NSF's budget, but we must not give up."

- Senate VA, HUD, and Independent Agencies Appropriations Subcommittee Chairman Christopher Bond

The hearing only lasted about one hour, but that was more than enough time for the two key senators with jurisdiction over the National Science Foundation to voice their strong support for the agency. Both VA, HUD, and Independent Agencies Appropriations Subcommittee Chairman Christopher "Kit" Bond (R-MO) and Ranking Minority Member Barbara Mikulski (D-MD) made very positive statements about NSF at the February 17 hearing on its budget request.

Chairman Bond's words left no doubt about his high regard for the foundation, and his support for physical sciences: "As many of you know, I have been, and will continue to be a strong supporter of NSF and a robust budget for NSF as well. My support for the work done at NSF has not, and will not diminish." He continued, "Unfortunately, the Federal government has not adequately supported NSF and the physical sciences. I strongly believe that the funding disparity between the life sciences and the physical sciences has grown too large. This funding imbalance is alarming because it directly jeopardizes our Nation's ability to lead the world in scientific innovation. Further, we are jeopardizing the work of the National Institutes of Health because we are undermining the physical sciences, which provide the underpinning for medical technological advances."

Under the Bush Administration's request, NSF funding would increase 2.4% in FY 2006 over the current year. Bond voiced his disapproval: "Sadly, the budget request for NSF does not provide it with adequate resources to meet its mission. While Dr. Marburger [who was a witness at this hearing] and our friends at OMB will state that NSF's budget is one of the few increases in the federal budget, it does not give me any solace. This is especially disappointing given the efforts of myself, Senator Mikulski, and many of my other colleagues to double the funding of NSF. We have fallen off the path for doubling NSF's budget, but we must not give up."

Mikulski was as critical: "This barely keeps pace with inflation. Most disturbing is the cut to education programs. This budget actually cuts education programs by 12%. Research is increased by just over 2% - which barely keeps pace with inflation. Yet, salaries and expenses rise by 22%, and major equipment goes up by 44%. I do not doubt the value, need or resources devoted to major equipment. But when every other part of the NSF budget is starved for resources, a huge increase like that stands out." Mikulski, whose sentiments on NSF funding align closely with those of Bond, also cited their mutual effort to double the foundation's budget. She stated, "Senator Bond and I are committed to doubling the NSF budget over five years. We have increased NSF's budget by an average of 10% over the President's budget for the last several years. But this Administration has broken its promise to NSF. In 2002, the President signed the NSF Authorization into law. It authorized a doubling of the NSF budget between 2002 and 2007. In 2006, NSF is authorized to be funded at $8.5 billion. Yet the President's 2006 budget funds NSF at $5.6 billion - 34% below where it should be."

NSF Director Arden Bement explained the Administration's request for NSF as follows: "In light of the tight fiscal times, NSF fared relatively well. For the coming fiscal year, NSF requests $5.6 billion, an increase of $132 million, or 2.4%, over last year's appropriated level. At a time when many agencies are looking at budget cuts, an increase in our budget underscores the Administration's support of NSF's science and engineering programs, and reflects the agency's excellent management and program results." Bement's words were reinforced by National Science Board Chairman Warren Washington who also testified at this hearing, who stated that the requested increase was "a significant investment in NSF programs in a time of National fiscal austerity."

Bond and Mikulski's statements reinforced their opening written remarks. Senator Bond told the Administration's witnesses that "I am unhappy," and looking at John Marburger, the chairman said of his efforts to significantly boost NSF funding, "I can't do it if OMB undercuts us." Senator Bond was also unhappy with House appropriators, who have reshuffled subcommittee jurisdictions that are now out of alignment with those in the Senate. Bond called the House's actions "hasty and ill-advised," saying that it will force an Omnibus appropriations bill late this year. Under such a scenario, Bond predicted, basic research will be cut, as it was in the last omnibus. In any case, Bond said, it will be a "major challenge to find funds for NSF in 2006."

Senator Bond was also unhappy with the proposed "disturbing" cuts in NSF's education programs (http://www.aip.org/fyi/2005/022.html), asking what the Administration could have been thinking. He contended that this would damage efforts to attract minority students into science, and said the United States could not continue to rely on foreign students. Senator Mikulski later had similar comments. Also noted by Bond was his unhappiness with NSF's management of large facilities, calling its reform efforts too slow (later saying that the foundation's lagging pace "drives us nuts," and adding that the subcommittee "will hold the foundation accountable.") Bond also told NSB Chairman Washington that the Board needed to develop a strategic plan for the foundation.

Chairman Bond also had words for the research community. Describing efforts to double the foundation's budget as one of the nation's "highest priorities," he said, "This must mean a greater effort by the research and high-tech sector in advocating and ‘selling' the virtues of NSF to the general public." To do this he added, "come out of your labs, out of your think tanks, and let people know how important this funding is."

House Science Committee Chairman Sherwood Boehlert (R-NY) The committee's Views and Estimates can be accessed at: http://www.house.gov/science/committeeinfo/06Views.pdf

The 26-page publication states **"The Committee believes the proposed funding for basic research is insufficient**. Funding short-term development at the expense of longer-term basic and applied research is not advisable, and neglects those portions of R&D where government support is most crucial. The Committee also believes that the budget must fully consider appropriate balances between defense and non-defense R&D spending and between biomedical and non-biomedical spending. At $71 and $29 billion, respectively, the R&D budgets of DOD and the National Institutes of Health (NIH) account for more than 75 percent of the total R&D budget." Later in the document the committee characterized the FY 2006 request for the DOE Office of Science as "inadequate" that will do little to bring physical sciences funding into parity with life sciences funding. The committee "strongly supports" the budget request for NIST core laboratory programs and facilities, but was "disappointed" in the recommendations for the Advanced Technology Program and the Manufacturing Extension Partnership. Regarding the National Science Foundation, the committee called the overall budget request "inadequate," saying it was "especially disturbed" by the proposed cuts in NSF's Education and Human Resources Directorate. There was a range of opinion regarding the Administration's request for NASA, the document stating: "The Committee is divided over the NASA budget request as of now even though there is broad support for the basic thrust of the Space Exploration Vision outlined by the President on January 14, 2004. Key questions include the relative priority of NASA funding as compared to that of other science agencies; the adequacy of funding for science and aeronautics within NASA; and the future of the NASA workforce."

March 10, 2005 AIP Endorses Statement Calling for Higher Defense S&T Spending

The American Institute of Physics and several of its Member Societies belong to the Coalition for National Security Research. The coalition advocates for defense science and technology spending, and annually prepares a recommendation on total funding for the 6.1 (basic research), 6.2 (applied research), and 6.3

(advanced technology development) programs.

In its FY 2006 budget submission to Congress, the Bush Administration requested a 21.1% cut in overall funding for these three programs as compared to current spending. Under this request, funding would decline from $13,329 million to $10,522 million (see http://www.aip.org/fyi/2005/018.html .)

The last Quadrennial Defense Review, drawing on a recommendation of the Defense Science Board, recommended that 3.0% of the total Defense Department budget be allocated for the three S&T programs. Currently, the level is 2.6%; under the proposed budget that figure would drop to 2.5%.

AIP, the American Physical Society, and the Optical Society of America (two of AIP's Member Societies) have endorsed the FY 2006 Coalition for National Security Research funding statement which calls for 3.0% of the Defense Department budget to be allocated to these three S&T programs. This statement follows:

"The Coalition for National Security Research (CNSR) strongly urges the Administration and Congress to provide a robust and stable investment in the Science and Technology (S&T) programs of the Department of Defense. These programs play a crucial role in protecting and equipping America's future fighting force.

"CNSR urges a renewed commitment to the Department's basic science program. The coalition recommends an increase in funding to not less than three percent of total DoD spending for the department's competitively awarded merit-reviewed S&T programs in FY 2006. Further, CNSR encourages Congress and the Administration to endeavor to begin efforts to increase the portion of the portfolio dedicated to basic research to return it to the level that served it well during past conflicts, 20% of total S&T spending.

"CNSR's funding recommendation embraces the recommendation of the Quadrennial Defense Review (QDR), and is based upon the President's Fiscal Year 2006 request for the Department of Defense. The QDR states: "To provide the basic research for these capabilities [technological superiority], the QDR calls for a significant increase in funding for S&T programs to a level of three percent of DOD spending per year."

"The defense S&T program consists of three accounts: basic (6.1), applied (6.2) and advanced technology development (6.3). These accounts have provided, and will continue to provide, transformational capabilities to ensure our national security and protect our homeland while educating the future defense science and engineering workforce. As our armed services fight the Global War on Terrorism, they increasingly rely on technology to help defeat the asymmetric threats posed by the terrorists. The technologies that address these threats - such as rapid multilingual support devices, laser-guided munitions, global positioning systems, and the thermobaric bomb - share a provenance in pioneering defense research**. Unfortunately, the accounts that fund these programs have remained essentially flat in constant dollars over the last few decades**. National security challenges posed by unforeseen and unpredictable threats demand continued innovation, requiring a consistently strong investment in S&T programs.

DoD's need for personnel in these areas makes support of undergraduate and graduate education critical. The threat posed by a lack of students pursuing S&T careers is compounded by the fact that 57% of the civilian defense S&T workforce will be eligible for early or regular retirement in the next five years**.**

February 25, 2005 DOE FY06 Office of Science Funding Request

On February 7, the day President Bush's FY 2006 budget request was released, DOE Office of Science Director Ray Orbach discussed the request for his Office, its impacts, and some of the justifications behind the budget numbers. He acknowledged several times that the tightness of the budget required priority-setting, and explained that his choices were determined by the goal of maintaining U.S. leadership in science. He warned that the budget constraints "are not going to go away in 2007 [and] it's going to be a difficult four years."

The request would cut Office of Science funding by 3.8 percent from the current year, to $3,462.7 million. This is below both FY 2004 and FY 2005 levels (see http://www.aip.org/fyi/2005/016.html). While Basic Energy Science and Fusion Energy Sciences would be increased, the High Energy and Nuclear Physics programs would both be reduced below FY 2004 and FY 2005 levels. Biological and Environmental Research, Advanced Scientific Computing Research, Scientific Laboratory Infrastructure, and Workforce Development for Teachers and Scientists would experience reductions from FY 2005 levels.

Given that FY 2006 would be "a difficult budget year for us, for the U.S.," Orbach thought that his office had been "very well treated." In the scheme of things, he said, "we're doing just fine." If the congressionally-directed earmarked projects from the FY 2005 budget are removed for purposes of comparison, he noted, the FY 2006 request is only 1.6 percent less than FY 2005 funding.

Orbach explained that the budget priorities were chosen to keep the U.S. "at the forefront across the spectrum of science" that his office supports. He pointed out that a significant amount of funding would go to starting operations at several new facilities, including the Spallation Neutron Source (SNS), the Linac Coherent Light source, and four of five planned Nanoscale Science Research Centers. These centers, he said, "are unique," and would give U.S. scientists an edge over any in the world. It would be "thrilling," he added, to "start to see them operate."

Regarding the SNS, Orbach called it "a magnificent new machine" that would be an order of magnitude more intense than any neutron source in the world, and would provide two decades of capability that "no one else has."

Orbach also highlighted research in climate change, the Genomes to Life program, and advanced computing, stating that he believed "computation can become the third leg of scientific discovery." Orbach said that the FY 2006 request includes funding for a leadership class machine that could simulate a supernova collapse.

In the High Energy Physics program, Orbach noted that the BTeV program would not be continued. Instead, he said, the lab's future might lie in either neutrino research or a linear collider, although he could not predict "whether the linear collider will be built." Right now, he said, he wanted to run Fermilab "till it's a smoking ruin" to get as much science out of it as possible. While he expected the Large Hadron Collider (LHC) in Europe to start operations in 2008, Orbach declared, "there's still a lot of life left at Fermilab; it won't just disappear when the LHC turns on."

When asked about R&D funding for the Rare Isotope Accelerator (RIA), Orbach said that "the situation is complicated." He remarked that continuing budget pressures would make building the RIA in the next few years "a cute trick." He noted that the Nuclear Sciences Advisory Committee had supported the construction of RIA if it did not have an impact on other nuclear programs. Stating that "I don't think isolation is feasible in the current budget climate," Orbach said he hoped to go back to the advisory committee and ask for further prioritization, possibly by May or June. At this time, he has elected not to go forward with a request for proposal for RIA. It is "frozen till we have a better sense of the landscape," he said.

february 9, 2005
Bush Administration Requests Dramatic Cuts in DOD S&T Program Funding

The Bush Administration has requested a 21.1% cut in overall funding for Department of Defense Science and Technology Programs in FY 2006 as compared to current spending. With proposed cuts ranging almost as high as 50% in some categories, the Administration's request would make double-digit cuts in all but two accounts.

There was no written or oral explanation for the proposed cuts in materials released by the Department of Defense or the Office of Science and Technology Policy. Under the president's request, DOD's total funding would increase 4.8%.

Many of the below figures were provided by the Coalition for National Security Research, to which AIP and several of its Member Societies belong. Readers wishing detailed figures should consult the RDT&E PROGRAMS (R-1)document at http://www.defenselink.mil/comptroller/defbudget/fy2006/fy2006_r1.pdf

The Defense Science Board and the Quadrennial Defense Review recommended that total funding for the 6.1, 6.2 and 6.3 programs be 3.0% of the total Defense Department budget. This year, the level was 2.6%; under the proposed budget that figure would drop to 2.5%.

The direction the Administration has taken in the FY 2006 request is contrary to that which Congress took in approving the current appropriation. In the bill passed last July, all but two of the below budgets increased (see http://www.aip.org/fyi/2004/097.html).

February 9, 2005 Administration Seeks 2.4% Increase in NSF Budget

National Science Foundation Director Arden Bement described the FY 2006 budget request as follows: "For FY 2006, the National Science Foundation is requesting $5.605 billion. That's $132 million, or 2.4 percent, more than in FY 2005. This modest increase allows us to assume new responsibilities, meet our ongoing commitments, and employ more staff – with little room for growth in research and education programs. This means we'll all have to keep working to leverage resources and work more productively."

NSF was one of the few S&T agencies that would see a budget increase in FY 2006 under the request that the Bush Administration submitted this week. Following in the wake of Congress' decision to cut NSF's budget this year, the Administration's request would restore some, but not all of the agency's budget to its former level. The numbers spell this out: in FY 2004 the NSF budget was $5,652.0 million. The current budget is $5,472.8 million. The request for next year is $5,605.00 million

February 8, 2005 Almost Flat FY 2006 R&D Funding

"The budget is not flat, but pretty close," OSTP Director John Marburger said yesterday at a White House briefing on the FY 2006 research and development budget request. The request is somewhat like viewing a glass that is half-empty/half-full. Characterizing the overall request and its components very much depends upon the perspective employed, with the caveat, as Marburger said, that "the devil is sometimes in the detail."

Federal program expenditures can be categorized as discretionary and non-discretionary. Non-discretionary spending is mandated by law, and includes programs such as Social Security. Unless the underlying law is changed, as is now being proposed for Social Security, spending is largely automatic. Discretionary spending varies, and depends on the will of the Congress as expressed through the appropriations bills. R&D funding falls into this category, so that the annual budgets for NSF or DOE, for instance, will vary.

Under the Administration's proposal, total federal R&D funding would increase by 1% or $733 million, which Marburger said "maintains that strength, we are not going backward." Under the Administration's proposal, non-defense R&D spending would increase 0.75% over this year's budget.

Marburger briefly described those budgets which would increase next year, including an 8% increase in NIST's core research activities, a 2.4% increase for NSF, a 2.4% increase for NASA, a 1% increase for NIH, and an increase in S&T funding for the Department of Homeland Security. Total funding for DOE's Office of Science would decline, as would Defense 6.1 and 6.2 program spending. USGS funding would be flat. The Advanced

Technology Program would be eliminated. Future issues of FYI will examine physics and astronomy budget requests more closely.

There are several ways to assess the FY 2006 R&D request. The Office of Management and Budget has a series of tables in a document entitled "Analytical Perspectives" that review all federal R&D spending. It shows an overall FY 2006 increase of +1% over the current year. Basic research would decline -1%. Applied research would remain approximately level. Development funding would increase +2%, while Facilities and Equipment spending would fall -4%.

A different categorization is the Federal Science and Technology Budget which OMB says "highlights the creation of new knowledge and technologies more consistently and accurately than the traditional R&D data collection. The FS&T budget emphasizes research, does not count funding for defense development, testing and evaluation, and totals less than half of Federal R&D spending." Under the Administration's FY 2006 request, this funding would decline -1%.

The two senior members of the House Science Committee issued statements in reaction to the Administration's request. Committee Chairman Sherwood Boehlert (R-NY) said, "As everyone knows, this is a very tight budget, with an overall cut to non-defense domestic discretionary spending. Given that context, the science programs fared relatively well. I was especially pleased to see the significant increase proposed for the laboratories at the National Institute of Standards and Technology. **That said, I would certainly like to see more robust increases in the science budget, particularly for the National Science Foundation (NSF) and the Department of Energy Office of Science. And I am especially troubled by the proposed cuts in the education programs at NSF.** . . . As for NASA, the budget appears to be reasonable and balanced overall. But we must review the details of the budget and also think carefully about how NASA should fare relative to other science agencies."

The Ranking Minority Member of the Science Committee**, Bart Gordon (D-TN) was more critical, saying, "This budget ignores our future economic needs and will cause irreparable harm to our country's ability to compete in the increasingly sophisticated and competitive global market place. In the current fiscal crisis we must prioritize. However, when we fail to put job creation, life-saving technologies and students' studies near the top of our list we send the wrong message to the world. The priorities in this budget are not merely harmful, they push this country on a downward slide to losing our global science and technological edge. Make no mistake, this is a race. Having a lead in science and technology will not last for the U.S. if we allow ourselves to slow down or, as this budget suggests, stop running. If we stop running at the top speed we can manage, we will lose."**

January 20, 2005
New Report Assesses Defense Basic Research

"No significant quantities of 6.1 funds (basic research) have been directed toward projects that are typical of research funded under categories 6.2 or 6.3." This statement will probably be the most discussed finding of a just-released study by the "Committee on Department of Defense Basic Research" of the National Research Council of the National Academies.

When Congress passed the FY 2004 National Defense Authorization Act it included report language mandating an NAS study "to assess the basic research portfolio of the [armed] services and the Defense Advanced Research Projects Agency (DARPA). This assessment should review the basic research portfolio in order to determine if the programs are consistent with the definitions of basic research in DoD regulation."

The 16-member NAS committee was chaired by Larry Welch, U.S. Air Force (retired), now with the Institute for Defense Analyses. Other committee members have backgrounds in academia, industry, and government. The study began in March 2004, and involved two meetings in which the committee heard from private and governmental experts. In addition, numerous visits or interviews were conducted at universities and site visits were made to defense facilities. The committee reported its findings in a 33-page document, with additional appendixes. It may be ordered or read on line at http://books.nap.edu/catalog/11177.html

The motivation for the congressional mandate was concern expressed by universities and defense laboratories over the last six years that the conduct of DOD basic research was changing. Specifically, there was concern that some 6.1 basic research money is being used to fund other research. In addition, DOD grant and contract reporting requirements are cumbersome and constraining. Finally, the services use basic research funds differently, making tracking and monitoring difficult.

The committee questioned the appropriateness of only a "small percentage" of work classified as 6.1 research, and that some of this uncertainty may revolve around the definition of basic research. "There is no evidence of significant misapplication of basic research funding," the committee stated. It urged that the definition of basic research be refined to include that it "has the potential for broad, rather than specific, application," and "may lead to: . . . the discovery of new knowledge that may later lead to more focused advances." Rejecting the traditional linear process view of 6.1, 6.2 and 6.3 research, the committee advised that "DOD should view basic research, applied research, and development as continuing activities occurring in parallel, with numerous supporting connections throughout the process."

While the committee may not have found 6.1 funding be used inappropriately, it did find reduced attention to basic research: "there has been a trend within DOD for reduced attention to unfettered exploration in its basic research program. Near-term DOD needs are producing significant pressure to focus basic research in support of those needs. DOD needs to realign the balance of its basic research effort more in favor of unfettered exploration."

January 5, 2005 S&T Policy Quotations of 2004

http://www.aip.org/fyi/2004 to see the issue.

"I am very disappointed in the proposed [FY 2005] science budget, and I will be working with the Administration and my congressional colleagues to improve the numbers as we move through the budget process. I understand that we are in a very tight fiscal situation and that the Administration has tried to treat research and development as favorably as possible. But we just have to find a way to do better." - House Science Committee Chairman Sherwood Boehlert (R-NY)

"Two years ago, the Congress sent the President a bill authorizing a doubling of NSF's programs over 5 years. Despite signing that bill to glowing reviews, the President sent us two successive budgets that fall far short of reaching that goal." - Rep. Eddie Bernice Johnson (D-TX)

"...it is going to be a major and perhaps an impossible challenge to find additional funds for NSF for FY 2005. I am committed to NSF, but this year's budget is the most difficult I have seen in years. I want to work with the Administration, but we need to find ways to increase NSF's budget as we move forward, if not this year, next year." - Senate VA, HUD and Independent Agencies Appropriations Subcommittee Chairman Christopher "Kit" Bond (R-MO)

". . . how important it is if we can somehow meet the goal of 3% of defense spending for science and technology and maintain the technological lead that is absolutely essential if we are going to be successful or continue to be successful in the global war on terrorism." - Senate Emerging Threats and Capabilities Subcommittee Chairman Pat Roberts (R-KS)

"This subcommittee bows to no one" in championing NSF, but "doubling [its budget] will be very, very difficult." - House VA, HUD and Independent Agencies Appropriations Subcommittee Chairman James Walsh (R-NY))

"Now, more than ever, American science must enlighten American statecraft." - Secretary of State Colin Powell

"Nanoscience will make the physical sciences as sexy as the life sciences were in the last ten years." - Rep. Zach Wamp (R-TN) at DOE NanoSummit

"Grim, in a word. . . very grim." - Bob Palmer, Minority Staff Director for House Science Committee, describing overall science and technology budget outlook.

Science can, in my judgement, be sold to this Administration and this Congress. I suggest that the best way to do that is to recount to them over and over again. . . that the economic destiny of America lies in science and technology, in science and research. And if we don't invest in research, and we don't inspire our children, and if we don't educate them in Congress, the competition out there, and **China is a good example, but Europe also, will begin to eat our scientific lunch**." - John Porter, former chairman of the House Labor, Health and Human Service, Education Appropriations Subcommittee (R-IL)

March 18, 2004 Dividing Up The S&T Portfolio: Remarks of Senator Domenici

"The time has come to spend money on basic research, just as we have on medical research" - Senator Pete Domenici

During last week's Senate consideration of the budget resolution, a largely non-binding measure establishing spending levels for various government functions, Senator Pete V. Domenici (R-New Mexico), offered the following remarks on federal science funding:

"Mr. President [of the Senate], I rise to speak for 2 minutes on the fiscal year 2005 budget resolution currently pending before the Senate. In particular, I want to focus for just a little bit on the budgets for scientific research.

"The funding for the National Institutes of Health should be my starting point. In the omnibus bill of 2003, thanks in large part to the leadership of President Bush, we met our commitment; that is, in 2003, we met our commitment to double the funding for NIH .

"Senator [Don] Nickles [R-Oklahoma] remembers that clearly, that a couple of Senators started and everybody followed, and a resolution was adopted that said - it was incredible to many of us, but we did it - let's double the NIH . President Bush helped us, and we did that.

"Allow me to explain these numbers. In 1998, we spent $13.7 billion on the National Institutes of Health for cancer, for all of these various diseases, heart conditions, and mental illness. When the commitment was fulfilled, we spent $27.1 billion for medical research.

"We need not stop there, however. Last year, we further increased it to $27.9 billion. This means we have spent $145.9 billion in the last 7 years on the National Institutes of Health -- a 109-percent increase. This year we are planning on further increasing the budget of NIH to $28.7 billion."

After criticizing lobbying efforts seeking higher funding for NIH, saying "Enough is enough," Domenici continued:

"The NIH is doing amazing work in developing techniques to detect, diagnose, and treat many of the most devastating diseases humans face, such as cancer, diabetes, and Alzheimer's disease. I hope that we can continue to fund this important agency at these record levels.

"I am concerned, though, that we have collectively failed to be as aggressive when it comes to funding basic scientific research in other agencies.

"Basic research is defined as systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

"The technologies transitioned from basic research are the foundation of applied programs and eventually fielded systems.

"Put another way, basic research is the engine that makes our national defense, homeland security, and economic superiority possible.

<u>"However, basic scientific research is not funded in a single place as with medical research at NIH .</u>

"The correlative type research to NIH is something we call in America basic research--physics, computer science, chemistry, engineering, et cetera. We have no central focus point for that in America. I am not sure we should or should not. It is just a fact.

"In 2004, the sum total of expenditures for that was $11 billion, and that included the Veterans' Administration - we assume some of what they do is science - Interior, EPA, NASA, DOE. This is compared to $8.8 billion for these programs in 1998.

<u>"In the same period of time these programs have increased 35 percent, while NIH increased by over 100 percent. I do not think America can continue to dominate the world, invent the products, maintain our standard of living with that kind of disparity for too much longer. The time has come to spend money on basic research, just as we have on medical research.</u>

"It is important to note much of our scientific research is done at our universities. They have plenty of research in medical science and medical science problems. But I guarantee you, Mr. President and fellow Senators, they are very short on research for the basic sciences.

February 18, 2004
Science Committee Weighs Administration's FY 2005 S&T Request

"It's impossible to seriously view this as a good budget for science," House Science Committee Chairman Sherwood Boehlert (R-NY) declared at a February 11 hearing on the Administration's FY 2005 S&T request. Boehlert's comments aptly summarize the sentiments of his colleagues on the committee, regardless of what side of the aisle they sit on.

<u>Senate Majority Leader Bill Frist: A Friend of Science</u>

Senator Bill Frist (R-TN has long been involved in science budget and policy issues, and is well-known as a friend of science.

The senator graduated from Princeton University's Woodrow Wilson School of Public and International Affairs, specializing in health care policy. In 1978, Frist graduated from Harvard Medical School. Before coming to Washington, he was known internationally for his practice at Vanderbilt University Medical Center, specializing in heart and lung transplants.

Frist has long served on Senate committees with oversight on science and technology issues. He was also one of the founders of the Senate Science and Technology Caucus. Senator Frist has been active politically, serving as the head of the National Republican Senatorial Committee which works to elect and reelect Republicans to the Senate. He has a strong relationship with President Bush.

In January 1999, Frist reintroduced his doubling bill in the new Congress. On the floor, he stated, "if we are to dedicate ourselves to advancement of biotechnology and all the benefits that it will afford, we must support it with solid funding for the basic sciences. One truly depends upon the other." In another few weeks, following the release of President Clinton's budget request, Frist outlined his support for the civilian R&D numbers, but criticized the defense numbers as too low. He also expressed concern about how defense testing and similar programs were now being included in long-term R&D budget projections. In late July, the Senate approved the doubling bill.

IN 2003, Frist was one of 38 senators to sign a letter to the Senate's leadership advocating a five year doubling of the NSF budget. He was also one of 36 senators who sent a letter to the Senate leadership in support of a substantial increase in funding for the Department of Energy's Office of Science. A similar letter was sent to the President that autumn stressing the importance of DOE's Office of Science's research in the physical sciences. Finally, that fall there was a somewhat unusual publicized exchange of rather sharp letters between Frist and House Science Committee Chairman James Sensenbrenner (R-WI) regarding Sensenbrenner's refusal to move the doubling bill through the House.

In 2001, Frist was one of seven cosponsors of an amendment, during the Senate's consideration of the budget resolution, that would increase the overall amount of money available for science funding. Last year, the senator was one of five original cosponsors of legislation to award competitive grants to academic institutions with programs to increase the number of students in S&T fields. Late last year, with the strong leadership of the new chairman of the House Science Committee, Sherwood Boehlert (R-NY), and his colleagues, a bill was passed that realized, in part, the goal first set forth in 1997 with the introduction of the first doubling bill. This legislation, now signed into law by President Bush, authorizes a doubling of the budget for the National Science Foundation.

The National Science Foundation (NSF) is under new jurisdiction after both the House of Representatives and Senate announced major restructuring of their respective appropriations committees for the 109th Congress.

On Feb. 9, 2005, Chairman Jerry Lewis (R-CA) announced a reorganization of the House Appropriations Committee that reduces the number of individual subcommittees from 13 to 10. The changes place NSF, NASA and the Office of Science and Technology Policy under the jurisdiction of the Subcommittee on Science, State, Justice, and Commerce, chaired by Frank R. Wolf (R-VA). The now defunct VA-HUD and Independent Agencies Subcommittee previously handled all three organizations.

On March 2, 2005, Chairman Thad Cochran (R-MS) announced a slightly different structure for the Senate Appropriations Committee. The programs and accounts previously handled by the VA-HUD and Independent Agencies Subcommittee were redistributed, reducing the number of subcommittees from 13 to 12. The Commerce, Justice and Science Subcommittee absorbed NSF, NASA and the Office of Science and Technology Policy. A member roster is not yet available.

APPENDIX EIGHT
The Latest NSF Study

NSF 04-306 | February 2004
U.S.-China R&D Linkages: Direct Investment and Industrial Alliances in the 1990s
by Francisco Moris

Foreign direct investment (FDI) and research and development (R&D)-related activity by U.S.-owned companies in mainland China (henceforth China) expanded substantially during the 1990s, especially in the information technology sector.[1] U.S. affiliates in China were among the most R&D-intensive overseas affiliates in 2000, making China the eleventh largest host of U.S. R&D expenditures overseas, up from the number 30 spot in 1994. Investment by U.S. companies through majority-owned affiliates grew, while the frequency of new industrial R&D alliances dropped. However, U.S. companies and other organizations still participate in more industrial R&D alliances with Chinese partners than do entities from other investing countries.

During the 1990s China initiated a number of economic and science and technology policies designed to foster economic growth, including steps for attracting foreign investment (OECD 2002; UNCTAD 2001). In the same period, multinational corporations (MNCs) from advanced economies began increasing technology-related activities abroad in a number of emerging markets, including China, to exploit local capabilities, adapt technology for local markets or regulations, and reduce costs and risks through collaboration with international research and development (R&D) partners.
China became the eleventh largest host of U.S. R&D expenditures overseas in 2000, up from the number 30 spot in 1994, after U.S. affiliates in that country more than doubled.

This report analyzes trends in R&D-related FDI and alliance activity by U.S. MNCs in China. It uses FDI data from the U.S. Bureau of Economic Analysis (BEA) and data on industrial alliances from the Joint Ventures/Alliances database of Thompson Financial (SDC Platinum). Two major types of FDI data are used in this report: (1) direct investment position and related capital outflows, and (2) operations data (e.g., gross product, employment, R&D expenditures) of affiliates or subsidiaries. Operations data in this report are for majority-owned affiliates of U.S. parent companies.[2] Industrial or business alliances involve for-profit partners and may or may not include nonprofit organizations, such as universities or government units. Industrial R&D alliances target research or technology objectives, along with other business goals.[3]

U.S. Direct Investment and R&D Activities in China
From 1994 to 2001, the direct investment position, or cumulative investments, of U.S. MNCs in China more than quadrupled, from $2.6 billion to $10.5 billion (table 1). After adjusting for inflation, cumulative investments grew at an average annual rate of 20.1 percent, about twice the average inflation-adjusted annual growth rate of total overseas investments by U.S. companies during the same period. U.S. investments in China appear to be highly targeted: in 2001 China represented 7.6 percent of the global U.S. FDI position in electronic and other electrical equipment but only 0.9 percent of global U.S. investments in all industries (BEA 2003).

TABLE 1. U.S. foreign direct investment in China: 1994–2001

Year	Direct investment position	Direct investment capital outflows	Gross product (value added)	R&D expenditures	R&D/GP ratio (percent)	Number of affiliates
	Billions of current U.S. dollars					
1994	2.557	1.232	0.678	0.007	1.0	172
1995	2.765	0.261	1.092	0.013	1.2	183
1996	3.848	0.933	2.073	0.025	1.2	223
1997	5.150	1.250	3.194	0.035	1.1	274
1998	6.350	1.497	3.004	0.052	1.7	330
1999	7.951	1.947	3.945	0.319	8.1	456
2000	9.861	1.817	5.516	0.506	9.2	454
2001	10.526	1.225	NA	NA	NA	NA

NA = Not available.
GP = Gross product.

NOTES: Data for 2000 and 2001 are preliminary. The U.S. Bureau of Economic Analysis (BEA) defines direct investment as ownership or control of 10 percent or more of the voting securities of a business in another country. Direct investment capital outflows consist of net equity capital outflows, reinvested earnings, and intercompany debt outflows from U.S. parent companies to their foreign affiliates. Direct investment position is a cumulative measure of the financing provided by U.S. parents to their foreign affiliates in the form of equity and debt, recorded at historical cost (net book value). Data for gross product, R&D expenditures, and number of affiliates are for majority-owned affiliates of U.S. parent companies. Majority-owned affiliates of U.S. parent companies are those affiliates in which the combined ownership of all U.S. parents is more than 50 percent.

SOURCE: U.S. Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad, Washington, DC, annual series. Available at www.bea.gov/bea/di/di1usdop.htm.

Investment growth by U.S. companies in China was fueled by annual capital investment flows exceeding one billion dollars for most years since 1994 (table 1). The number of majority-owned, U.S.-owned affiliates in China reached 454 in 2000, more than double the number in 1994, representing just over 2 percent of all majority-owned U.S. affiliates overseas.

In 2000 these affiliates had a gross product (value added) of $5.5 billion, sales of $26.0 billion, and employed 240,400 workers (BEA 2003). The largest industry in terms of gross product was computer and electronic products at $2.0 billion, about 5 percent of the $41.9 billion in U.S.-owned overseas gross product by this industry. This level of activity made China the eighth-largest worldwide location for U.S.-owned computer and electronic products subsidiaries in 2000 and the third largest in the Asia-Pacific region after Singapore ($5.6 billion) and Japan ($3.0 billion). The second largest sector of U.S.-owned gross product in China was chemicals manufacturing, with $899 million.

Even though China's R&D spending relative to gross domestic product was below 1 percent during the 1990s, reaching 1 percent only in 2000,**[4]** a substantial number of MNCs from advanced economies have established R&D or technical centers in China in recent years, either as stand-alone facilities or integrated with manufacturing or services operations. These facilities support activities in the country or in the Asia-Pacific region through a combination of wholly owned subsidiaries, joint ventures, and contractual agreements in key industrial sectors, such as telecommunications, electronics, chemicals, and auto manufacturing. U.S. companies with major R&D activities or facilities in China include DuPont, Ford, General Electric, General Motors, IBM, Intel, Lucent Technologies, Microsoft, Motorola, and Rohm and Haas.**[5]**

Majority-owned affiliates of U.S. parent companies in China performed $506 million in R&D spending in 2000, compared with only $7 million as recently as 1994 (table 1). The level of R&D expenditures by U.S.-owned companies in China in 2000 represented 2.6 percent of total overseas R&D by U.S. companies, compared with less than one-half of 1 percent earlier in the decade. The vigorous investment activity over the late 1990s propelled China as a location of U.S.-owned R&D spending from a rank of 30 in 1994 to 11 in 2000. Furthermore, U.S. affiliates in China invest relatively more in R&D compared with U.S. affiliates in other countries, as measured by the ratio of R&D spending to gross product. In 2000 this ratio was 9.2 percent for U.S. affiliates in China, compared with 3.3 percent for the aggregate of U.S. affiliates in all host countries.

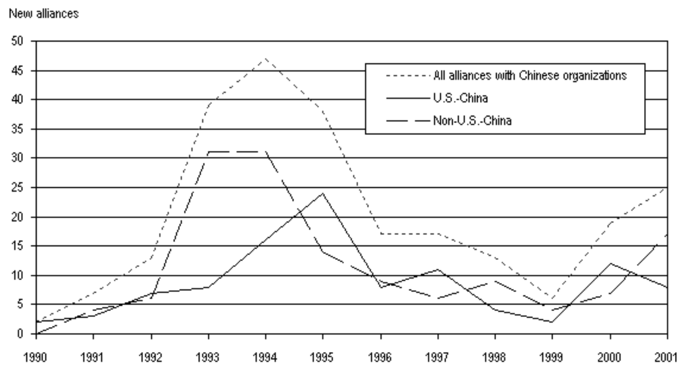
In 2000, R&D spending by U.S. affiliates in China was concentrated in the manufacturing sector ($491 million);**[6]** another $15 million in R&D spending was performed in the professional, scientific, and technical services industry, which includes computer system designs and R&D services.

Trends in U.S.-China Industrial R&D Alliances
Industrial R&D alliances are separate business organizations that collaborate to achieve specific research or technology development objectives. Some include nonprofit partners, such as universities or government

agencies. An alliance can be organized as a legally distinct business entity (joint venture or equity-based alliance) or as a short-term contractual or nonequity alliance. Joint ventures are a common entry vehicle for foreign investors in emerging markets, such as China. Contractual alliances focus on shorter-term projects and are more likely to have nonprofit members. China has encouraged collaboration in scientific research as a policy goal since 1985 and reaffirmed this policy in 1995 (IDRC 1997).

According to the Thomson Financial Joint Ventures/Alliances database, U.S. and Chinese-owned companies and other organizations formed 105 new business alliances with a large R&D component (U.S.-China R&D alliances) from 1990 to 2001. The highest annual frequency of partnerships was reached in the mid-1990s (figure 1). A slowdown after this peak coincided with an increase in majority-owned affiliates of U.S. companies in China (table 1) and may reflect a shift to wholly owned R&D facilities by companies with an established presence in the country.[7] Still, U.S. entities formed more business R&D alliances than did other countries' organizations in China from 1990 to 2001. Over the same period, Japan had the second largest number of R&D partnerships with Chinese organizations (26), followed by Germany (15), the United Kingdom (14), Singapore (12), and Canada (11).

FIGURE 1. Industrial R&D alliances with Chinese-owned private and public organizations: 1990–2001



SOURCE: Thomson Financial Joint Ventures/Alliances database.

Alliance Location and Partners

Ninety percent (94 of 105) of U.S.-China R&D alliances had activities in China. Of these, 79 had activities exclusively in China, 12 had activities in both the United States and China, and 3 had activities in China and elsewhere. The other 11 partnerships performed activities either exclusively in the United States or in other locations outside China, including Singapore and South Korea. Information on the location of alliances within China was not available for many entries of the database; however, most of the identified sites were in Beijing and Shanghai. Other cities hosting several R&D alliances were Tianjin, Guangzhou, and Shenzhen.

Eighty-one percent of the alliances had two members and the rest had either three or four members. A sizable proportion, at least 19 percent, had Chinese public or nonprofit participants, such as universities, R&D institutes, or government ministries. All but six of these partnerships were exclusively between U.S. and Chinese organizations. Likewise, most R&D alliances involving Chinese organizations and companies from Japan, Germany, the United Kingdom, Canada, and Singapore were organized as bilateral partnerships. This pattern is consistent with activities performed jointly with domestic companies aimed at adapting products or technologies to local markets and regulations—a common objective at early stages of foreign-based R&D activities.

Organizational Forms

Although U.S.-China R&D alliances were equally divided between joint ventures and contractual alliances over the 12-year period from 1990–2001, most have been structured as contractual or nonequity alliances since 1996 (table 2). This increasing preference toward nonequity alliances matches overall trends in worldwide alliances by companies from advanced economies (NSF/SRS forthcoming). The trend toward nonequity arrangements in U.S.-China R&D alliances appears to be stronger in nonmanufacturing alliances.

TABLE 2. U.S.-China industrial R&D alliances by organizational form, industry sector, and selected industry: 1990–2001

Alliance category	1990–2001	1990–1995	1996–2001
Total industrial R&D alliances	105	60	45
Organizational form			
Joint ventures	53	41	12
Contractual alliances	52	19	33
Industry sector			
Manufacturing	46	35	11
Services	45	16	29
Trade/finance	6	4	2
Telecommunications	5	4	1
Primary resources[1]	3	1	2
Selected industry			
R&D services	25	1	24
Computer programming, data processing services	17	14	3
Pharmaceuticals	10	5	5
Instruments	8	8	0
Motor vehicles	6	3	3
Communications equipment	5	5	0
Computer manufacturing	4	4	0

[1]Agricultural products and oil and gas extraction.

NOTE: Data are the sum of new annual industrial R&D alliances involving at least one U.S. and one Chinese company or organization over the indicated years.

SOURCE: Thomson Financial Joint Ventures/Alliances database.

Industrial Sectors and Activities

About 75 percent of U.S.-China R&D alliances between 1990 and 2001 were classified in seven industries: R&D services, computer programming and data processing services, pharmaceuticals, instruments, motor vehicles, communications equipment, and computer manufacturing (table 2).[8] In the late 1990s, the distribution of these alliances shifted from manufacturing to service industries. Two-thirds of the alliances in the services sector (29 of 45) were formed in 1996–2001, whereas only one-fourth of alliances in the manufacturing sector (11 of 46) were formed during the same period.

Alliances classified primarily in services, however, included manufacturing companies with complementary activities. For example, all but 4 of the 17 R&D alliances in computer programming and data processing services between 1990 and 2001 (table 2) involved computers, electronic components, or communications equipment manufacturers. Likewise, two-thirds of the alliances in R&D services were effectively information technology (IT) alliances, bringing together IT equipment manufacturers with specialized services companies. About one-fourth of R&D-services alliances involved pharmaceutical companies, most of which were established in 2000 or 2001.

A different profile of these partnerships is obtained by examining their major activities, regardless of industrial classification (table 3). About 30 percent performed only R&D. The rest combined R&D and other activities, such as marketing, manufacturing, technology transfer, and specialized services. R&D-only alliances were more frequent in the second half of the 1990s, whereas alliances combining R&D with marketing, manufacturing, or technology transfer were more frequent in the early 1990s.

TABLE 3. U.S.-China industrial R&D alliances by type of activity: 1990–2001

Alliance activity	1990–2001	1990–1995	1996–2001
Total industrial R&D alliances	105	60	45
R&D and marketing	34	25	9
R&D only	31	11	20
R&D and manufacturing	29	21	8
R&D and technology transfer	19	18	1
R&D and specialized services[1]	13	4	9

[1]Specialized services include consulting, telecommunications, and educational services.

NOTE: Data are the sum of new annual industrial R&D alliances involving at least one U.S. and one Chinese company or organization over the indicated years. Details by alliance activity exceed total industrial R&D alliances because some R&D alliances conduct more than two major activities.

SOURCE: Thomson Financial Joint Ventures/Alliances database.

Conclusion

Activities by U.S. MNCs in China expanded substantially during the 1990s using two different investment modes: direct investment and nonequity business alliances. As part of this investment drive, U.S. affiliates in China became among the most R&D-intensive overseas affiliates in 2000.

The frequency of new U.S.-China industrial R&D alliances, especially equity alliances, declined after the mid-1990s in contrast with an increase in U.S. majority-owned affiliates and R&D expenditures in China. U.S.-owned entities, however, still represent the largest block of foreign-based participants in these alliances among all investing countries in China. R&D alliances in the service industries—especially in the IT sector—are likely complementing a growing technology-intensive manufacturing base by U.S. MNCs in China.

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Footnotes

[1] FDI is the ownership of productive assets outside the home country by multinational corporations. Data for Hong Kong and Taiwan are not included in this report.

[2] Majority-owned affiliates of U.S. parent companies are those affiliates in which the combined ownership of all U.S. parents is more than 50 percent.

[3] Data are primarily from English-language news sources and public documents. Agreements involving small firms or less publicized industrial sectors are likely to be underrepresented.

[4] By comparison, the average ratio of R&D relative to gross domestic product for all Organisation for Economic Co-operation and Development (OECD) countries for the same period exceeded two percent from 1991 to 2000 (OECD 2002, table 9.1, figure 9.3).

[5] Source: Individual company Web sites. Accessed September 2003.

[6] No further details for the manufacturing sector were available due to disclosure limitations.

[7] For a discussion of policy changes in China in the late 1990s and their effects on foreign technology investments in that country see Walsh (2003:79, 89).

[8] Industry classifications are from the Standard Industrial Classification System (SIC).

Report Overview

APPENDIX NINE
NSF Indicators of Competition

Suggested Citation
This report was prepared by Lawrence M. Rausch, Senior Analyst, Science & Engineering Indicators Program, Division of Science Resources Studies (SRS), National Science Foundation (NSF). Guidance and review were provided by Jennifer Bond, Director of the Science & Engineering Indicators Program and by Kenneth M. Brown, Director of SRS.

NSF extends sincere appreciation to the outside expert review provided by Dr. Donald Dalton, U.S. Department of Commerce, Drs. J. David Roessner and Alan L. Porter, Georgia Institute of Technology, and Dr. Richard P. Suttmeier, Director, Center for Asian & Pacific Studies, University of Oregon.

The report was made more readable and its presentation more pleasing through the efforts of Nita Congress (editor) and David Saia, SRS's Publications Manager.

The author also wishes to thank Vellamo M. Lahti

Decades of market success in general manufactures gave Japan the revenues and rationale for even larger investments in education and in research and development (R&D). These investments, in turn, propelled that country's entry into technology areas previously dominated by the West. Today, several other Asian economies are exhibiting similar patterns of industrialization (see Balk 1991). Once considered a locus for labor-intensive, low-skilled manufacturing, Asia now boasts several economies that are active, if not prominent, suppliers of a growing number of high-technology products in the global marketplace.

Which of these economies will be full-fledged participants in the technology development efforts of the future? Which will be the competitors in tomorrow's high-tech product market? To provide a basis for answering these questions, this report profiles nine economies linked by an Asian identity, yet marked by great economic and technological disparity.

Japan stands alone as the most advanced industrialized country in the region, on a par with the world's leading industrialized nations. It is included here as a benchmark to compare and contrast technology-related activity in the other eight Asian economies.

A group of four - Hong Kong, Singapore, South Korea, and Taiwan - often referred to as the "four tigers" or as newly industrialized economies (NIEs) have made dramatic leaps forward in the global economy over the past decade. Still, they do not yet measure up technologically to Japan.

The remaining four countries, China, India, Indonesia, and Malaysia, lag far behind Japan and the NIEs in terms of economic and technological development. Yet each of these four countries has exhibited tremendous growth on both these fronts. Recent commitments voiced by the governments of these countries to pursue technology-based economic growth might mean that one or more of these countries could be the next "tiger" of Asia. These four countries are herein collectively referred to as the emerging Asian economies (EAEs).

Findings

Based on the various indicators of technological activity and competitiveness presented in this report, several Asian economies stand out, apparently headed toward greater prominence as developers of technology and as more visible competitors in high-tech product markets.

Taiwan and South Korea seem best positioned to move closer to Japan's technological stature.

Among the group of Asian NIEs, Taiwan and South Korea are likely to increase their competitiveness in technology-related fields and product markets. This conclusion is based on both economies' strong patent activity in the United States in electronics and telecommunications, data showing both economies increasing their licensing of U.S. technological know-how, and data showing both economies' rapidly rising imports of U.S. products that incorporate advanced technologies. Other indicators highlight the technological infrastructure (defined by the existence of a system of intellectual property rights, R&D activities closely connected to industrial applications, large number of qualified scientists and engineers, etc.) in place in both economies that should serve to support further growth in high-tech industries.

The other two Asian NIEs, Singapore and Hong Kong, also show strong signs of technological strength and scored impressively on many of the indicators. However, both seem to be functioning on a somewhat narrower technology foundation than either Taiwan or South Korea. Singapore and Hong Kong have not shown the same level of patent activity or the same presence in global technology markets as have the other two NIEs. Their comparatively small populations will limit their ability to make a major impact across any broad spectrum of technology areas. In addition, the pace of Hong Kong's technological development will soon be altered by its integration with China in 1997: the extent and direction of this alteration is difficult to predict with any certainty. However, the prospect of a "greater China" - a China that is not limited by geographical boundaries, but rather is formed around networks of expatriate Chinese peoples and resources spread throughout Asia - also looms in the background. Hong Kong's considerable capital and technology resources will be highly valued in either scenario.

Malaysia is the single emerging Asian economy that, on the basis of these indicators, could likely develop into the next Asian "tiger" - that is, move closer in technological mastery and high-tech production to the more developed NIEs.
Malaysia is purchasing increasing amounts of U.S. high-tech products and has attracted large amounts of foreign investment, much of it in the form of high-tech manufacturing facilities. Even if these facilities are mostly platform (assembly) operations today, Malaysia's strong national orientation (defined by the existence of national technology strategies and an accepting environment for foreign investment), socioeconomic structure (evidence of functioning capital markets and rising levels of foreign investment and investments in education), and productive capacity (future capacity suggested through assessments of current level of high-tech production combined with evidence of skilled labor and innovative management) suggest that as it gains technological capabilities, more complex processing will likely follow. While it still has a long way to go before joining the ranks of the NIEs, Malaysia shows many signs of developing the resources it will need to compete in global technology markets.

India shows considerable strengths in certain of the indicators, but also shows weaknesses. India has a long tradition of educating highly qualified scientists and engineers and of excellence in basic research, yet it harbors one of the highest illiteracy rates in the region. This anomaly produced one of the lowest scores among the eight economies for the socioeconomic infrastructure indicator. Uneven acceptance of foreign products and investment have inhibited internal competition that otherwise may have motivated India to better capitalize on its engineering strengths. Now, evidence of change underway in India's regulations and policies opening the economy to more foreign investment and goods may allow the country to leverage its many science and technology (S&T) strengths, such as in software development.

China and Indonesia show many mixed signs in these indicators of technology development and competitiveness. On the positive side, both countries have enjoyed tremendous economic growth and have attracted large amounts of foreign investment. Both have large populations that could support a large domestic market, abundant natural resources, and a central Government that has placed a high priority on technical training and development. But many challenges remain. China will face many difficulties in the years ahead as it continues to transform its centrally planned economy to one directed by market forces. These difficulties should not be underestimated. Indonesia's challenge is different. A continuity in leadership for over 30 years has produced a certain stability but may have also masked growing social and ethnic discontent among the peoples of Indonesia. With a change in the presidency expected soon, many wonder whether the economic and technological progress achieved over the past decade will continue. Consequently, political and social uncertainties for both countries prevent any direct projection of their technological future based on their recent technological achievements.

Acknowledgments

Suggested Citation

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III. Performance Measures

GPRA concepts. For purposes of annual performance reporting, GPRA seeks information about program outputs and outcomes. The immediately observable products of program activity such as publications or graduates are termed **outputs**. Intermediate and longer-term results for which the program is designed, such as producing knowledge or enabling improved health or national security, are referred to as **outcomes**.

Outputs and outcomes should be distinguished from **inputs**, such as researchers' knowledge and time, use of equipment, instruments, facilities, and supplies [1] Further, OMB guidance differentiates between outputs (e.g., graduates) and production **activities** (e.g., teaching). The text of GPRA does not specify a distinction between outputs and activities, but one purpose of the Act is to focus attention beyond an effort or activity in order to assess outputs and outcomes.

The OMB guidance for implementation of GPRA also discusses program impacts. These are the total long-run direct or indirect effects or consequences of the program. These effects may be intended or unintended, and may be positive or negative. Although information about impacts is useful for understanding the eventual effects of government programs, it is not required under the GPRA legislation.

In principle, it should be easy to distinguish among indicators for inputs, outputs, intermediate outcomes, and end outcomes. In practice, these four concepts represent a continuum for which indicators can blend one into another. A simplified description of the process of training in science and engineering illustrates the point. High school graduates represent a final output from secondary schools and an input to colleges and universities (as well as an input to employers who hire high school graduates directly). Baccalaureate recipients represent a final output from colleges and universities when they move directly into science and engineering employment. Baccalaureate recipients represent an intermediate output when they move on to graduate training. Individuals who complete doctoral or post doctoral programs represent outputs of those programs and inputs to renew the scientific work force's human resource base. Meanwhile, maintenance of a top quality science and engineering work force, appropriately employed, represents an outcome that enables continued conduct of world-class science, training of the next generation of scientists and engineers, and deployment of scientific expertise throughout the many sectors of the economy to assure development and application of new knowledge and techniques. And all of these, in combination with other factors, enable attainment of the Federal over-arching national goals of improved health, environment, prosperity, national security, and quality of life.

Whether a particular product or result is an output or intermediate or end outcome depends upon the mission and goals of the agency which produced it and upon whether it is viewed from the perspective of that agency's individual plan or from the perspective of over-arching national goals. Program-specific information about goals, institutional setting, and overall context is needed before definitions of outputs, intermediate outcomes, and end outcomes can be tailored to program reporting and before indicators can be identified. Appendix C provides an example from the Department of Agriculture that illustrates how overall agency goals and specific program goals can be used to derive performance indicators.

Pre-existing measures. Because pre-existing measures of research results were developed primarily for other purposes, they have not yet been adapted for use in reporting at the agency level. Pre-existing measures capture only a subset of the spectrum of research outputs and outcomes. Unfortunately, they do not map neatly or cleanly onto GPRA concepts. Although there are many measures of potential applicability to the science enterprise, most track inputs or levels of research activity. Some could be used as a starting point for examination of output. A few could be considered to capture selected aspects of outcomes. Thus far, comprehensive efforts to determine impacts appear to be rare. Consequently, pre-existing measures can serve only as a starting point for agency thinking about how to design the most effective assessment methods. Some well-known pre-existing measures are discussed below.

Publication counts. Publication counts have been used in non-GPRA contexts as measures of the quantity of knowledge produced by a research program. Publication itself is a tangible indictor of the transfer of research findings to the public domain, and publication in a peer reviewed journal is an indicator of a positive scientific evaluation of the information. Although publication counts provide useful information when **combined** with a larger richer set of indicators and analyses, their use alone or without sufficient information about other aspects of performance and the circumstances of the research can produce an incomplete, if not inaccurate, picture. For example, differences in publication rates between scientific disciplines may reflect differences in propensity to publish, in the definition of the smallest publishable unit, and in patterns of collaboration rather than differences in productivity. Also, the mere introduction of the counting of publications as a performance indicator, depending on how it is done, can influence publication patterns or publication rates--setting up incentives that focus on the production of more articles, rather than on the discovery of new knowledge.

Patent counts. Counts of patents, new devices, computer programs, and other inventions do not say much about whether a program is conducting world-class science at the frontier of knowledge; but, some mission agencies may use them to gain insight about connections between their program and the agency mission. If such counts are used in the assessment of a fundamental science program, they should be used **in combination** with other sources of information as part of a richer, more detailed assessment. Further, any use made of such counts should be undertaken only with full awareness of their limitations. In particular, patent counts and other indicators of inventive activity tend to be low for basic research programs. The statistical instability of the variability in small numbers from year to year suggests that inclusion of measures of inventive activity among a few summary indicators in a short program report would be a risky strategy for a fundamental science program; however, it should be possible to handle the problem of high variability in small numbers by using, for example, a rolling three-year average.

Citation counts. In the program evaluation literature, citation counts are sometimes described as an unobtrusive form of wide-scale scientific review. As with publication counts, their use and interpretation should be undertaken with certain caveats: in a few cases, high numbers of citations may indicate a negative evaluation (e.g., the disputed cold fusion results); possible citation "clubs" or "spirals" do not say much about the underlying science; citation rates vary among fields; in many fields, experimental work tends to be cited more frequently than theoretical, and occasional methods papers achieve extremely high levels of perfunctory citation with the consequence that citation counts, in general, may under-value advances in understanding and over-value sheer experimental activity; and, in fields for which the writing of a book is a major publication outlet (e.g., some social sciences), citation counts are an unfair assessment of value, since Science Citation Index, on which such counts are based, only includes references from journals.

Since prior experience with program evaluation suggests that retrospective scientific review and citation counts seem to provide complementary perspectives, evaluators generally advocate using the two together for detailed program evaluation. For example, a scientific review panel's judgments may be sharpened when it is required to evaluate and respond to literature-based data regarding the program being evaluated. A perception seems to be emerging that citation counts could be usefully **combined** with other descriptive information in summary reports of overall performance.

Contributions to other goals. A program may also contribute to other Federal goals, and such contributions are relevant aspects of program performance whether or not they are listed among specific program objectives. Such contributions can be included in program reports (and can be added to program objectives). Measures have been attempted for other aspects of research programs such as the development of human resources and physical infrastructure, the building of cross-disciplinary and cross-sectoral partnerships, or the numbers of undergraduates involved in a research program or in informal science education activities.

Output indicators for some activities might be available from published reports. Others could be collected from principal investigators at the completion of research projects and aggregated at the agency level. If data are collected from individual investigators and program managers, it should be made clear that such data will be aggregated and reported at the agency level. It should also be made clear that not all projects or programs need to contribute to all of an agency's goals. This makes good management sense, and communicating the point should help assure researchers that they have the flexibility that they need for creative work.

Some experimental efforts at the National Science Foundation to develop new sets of indicators are reported in Appendix C.

Rate-of-return and other measures developed by economists. Economists have developed a number of techniques intended to estimate the benefits of, or returns to, research. These generally involve efforts to link, directly or indirectly, the knowledge produced by research to the benefits eventually produced by use of the knowledge in practical applications. Basic approaches include efforts to (1) compute the benefits associated with the results of a research program or aggregation of programs, (2) compare the benefits of the research to the costs of conducting the research by constructing a benefit-cost ratio, and (3) compare benefits to costs by computing the implicit rate of return.

The findings of the "Assessment Process" (the Process is described in Appendix A) and of other sources (e.g., American Enterprise Institute et al. 1994) indicate that existing economic methods and data are sufficient to measure only a subset of important dimensions of the outcomes and impacts of fundamental science. Sufficiency varies among Federal programs--economic methods are perhaps best suited to assessing programs in some mission agencies and least suited to assessing programs not directly aimed at specific applications. When methods and data permit, economic techniques can be used to communicate the size and significance of the benefits of research. Two examples of the computation of economic benefits of research are given in Appendix C. One discusses the estimation of the cost savings flowing from biomedical research at the National Institutes of Health; the other, the economic impacts of research in metrology at the National Institute of Standards and Technology.

Economists have also developed substantive information about the determinants of the level and pattern of investments in research and the adoption and diffusion of new products and processes. However, there are complexities among the ever-changing pattern of innovative activities that are not well understood and for which the limitations of the data preclude study. In particular, what economists cannot now do is estimate (1) the benefit compared to the cost **"at the margin"** regarding the start of one more research program in comparison to something else, or (2) the benefit compared to the cost **"at the margin"** for an additional research program in one field or application as compared to another [2]. Since economists require information about benefits and costs **"at the margin"** to make decisions about resource allocation, many suggest that existing economic methods and data do not provide useful criteria for allocating resources among potential areas for future research. Of course, to the extent that existing data permit computations of benefits or returns "on average" (rather than "at the margin"), economic methods can be used to gain retrospective insight about past performance.

Future benefits. Decision makers and policy makers sometimes seek information about what can be expected in the future if investments are made in one line of research or another. There are no measures (in the conventional sense of the word) of what the **future** benefits of research will be, at least in part because the future pattern and course of research impacts cannot be known. The "Assessment Process" did not attempt to develop measures of **future** benefits. Nor did it attempt to develop methods for setting priorities for future spending [3].

Other approaches. Performance reports need not and should not rely on quantitative measurement alone. Annual performance reports might, for example, document progress toward enabling goals over a rolling historical period of, say, the last twenty years; they might present examples of outstanding or more typical research accomplishments; or they might build descriptive case studies of how the accretion of knowledge through research eventually leads to long-run applications which contribute to over-arching national goals.

Merit review with peer evaluations. The insufficiency of measures per se is one reason why merit review with peer evaluations of past performance provide important information for retrospective performance assessment. The focus of such assessments for responding to GPRA would be at the program level. Since agencies are just now developing their approaches for assessment under GPRA, it is not yet clear how the expert assessments would be structured. Individual assessment panels might focus on key agency programs or groups of related agency programs (covering each such program or group of related programs every five years or so).

It should be recalled that a program under GPRA is an activity or project listed in the Federal budget; however, GPRA gives agencies the option to aggregate or dis-aggregate activities for GPRA reporting, as long as it does not omit or minimize the significance of any major function or operation of the agency. In practice, the definition of a program for reporting under GPRA seems to be evolving to include a major function or operation of an agency or a major mission-directed goal that cuts across agency components or organizations.

The credibility and effectiveness of scientific review for retrospective assessment is critically dependent on how it is organized and on the types of participants. A review panel clearly must have competencies that are a good match to the program content; it must have reviewers who are respected and objective (for example, not likely to be influenced by concerns that the panel's conclusions will influence future funding for their own work). Only then will a review be credible.

An assessment panel should consider whether research performance has been at the frontiers of scientific knowledge. In addition, program managers may seek expert assessment of the program's contributions to other enabling goals--for example, contributions to maintaining a high quality scientific work force appropriately employed or to ensuring that facilities and instrumentation are maintained to support work at the cutting edge.

Program managers may also seek expert insight about whether the program has made contributions to the knowledge base for specific mission goals as well as over-arching national goals. Intended users of the results of the program could provide information about the relevance or importance of the program's results. Their perspectives could be tapped by including them in the review panels. For "mission agencies," intended users might be those expected to apply the results of the science program (e.g., industry, agriculture, or users within the agency). For "non-mission agencies" such as the National Science Foundation, users might be researchers in areas for which the program's work is claimed to have impact. For agencies that support general knowledge development and scientific training, it might be appropriate to include stakeholders for the general pools of knowledge and talent to which the agency contributes.

To assure objective judgments from expert panel members, input should in principle be sought from researchers who were not among those supported by the program or involved in selecting projects funded by the program.
An example of the use of assessment panels at the National Institute of Standards and Technology is given in Appendix C.

International standing. Maintaining leadership across the frontiers of scientific knowledge is a critical element in our investment strategy for science. As noted above, for an individual agency, the evaluation criterion is whether the agency's research is conducted at the frontiers of scientific knowledge. For evaluation from an NSTC or national perspective, information isneeded about United States standing internationally. The findings of the "Assessment Process" indicate that, although some data and methods exist for international comparisons of a nation's research activity and some aspects of overall research output, the methods for international comparison are still in their infancy. Further work is needed to develop cost-effective strategies for assessing American standing on the world stage. An inter-agency group, such as the Committee on Fundamental Science, might consider how this can best be accomplished. We stress that leadership evaluation does not entail simplistic numerical ranking of national programs. Our national interest in leadership rests in having our research and educational programs perform at the cutting edge--sometimes in competition, but often in explicit collaboration, with scientists from other nations.

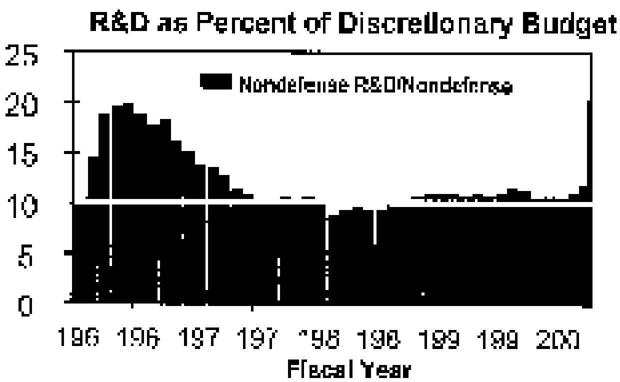
[1] Services from a resource base (e.g., staff expertise and time) are defined as inputs to a program. Increments to a resource base (e.g., newly trained personnel) are defined as outputs or outcomes. (A program output or outcome could be negative; for example, net depletion of a resource base).
[2] A benefit "at the margin" refers to the benefit associated with starting one more unit or increment of research (or other investment), as opposed to the "average" benefit for all research (or other investment). Similarly, cost "at the margin" refers to the cost of starting one more unit or increment of research (or other investment), as opposed to the average cost for all research (or other investment)
[3] At the request of Congress, an exploration of methods for setting priorities among research fields or applications was undertaken by the National Academy of Sciences. Their findings are reported in National Academy of Sciences Committee on Criteria for Federal Support of Research and Development 1995.

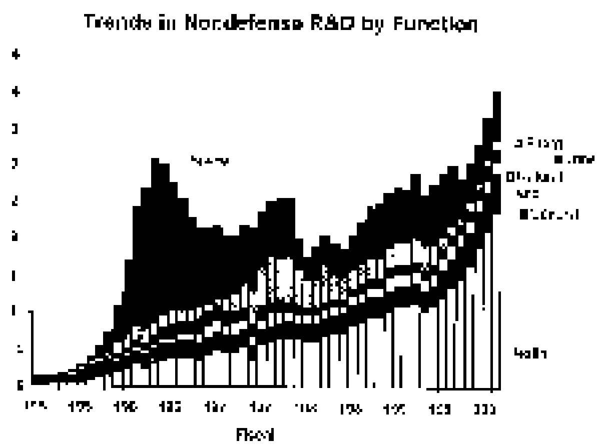
"Policy, Politics, and Science in the White House: Conversations with Presidential Science Advisors"
University of Colorado at Boulder
Boulder, Colorado
February 14, 2005

John Marburger
Director, Office of Science and Technology Policy
Executive Office of the President

. A popular graph compiled by The American Association for the Advancement of Science from OMB historical data and available at www.aaas.org (Trends in Non-Defense R&D by Function, FY 1953–2005) shows the three major trends that have defined postwar science: the 15 year Apollo hump starting in about 1960, the post Arab Oil Embargo energy research bulge in the mid 1970's, and the inexorable rise in the NIH budget, culminating in the five year doubling period ending in 2003

 it is clear from the mega-trends that the policy is impelled by societal issues external to science. [Figure 4 shows the now famous AAAS graph.]





APPENDIX TEN
NSF Indicators in 2002

Science & Engineering Indicators – 2002 _ A6-51
Appendix table 6-8. [Data from 1999]

Leading indicators of technological competitiveness: 1999

Region or country/ economy	National orientation	Socio-economic orientation	Technolo–gical infrastructure ture	Productive capacity
South Korea	74.9	73.5	44.6	48.8
Taiwan	90.7	74.2	43.6	53.7
Malaysia	69.5	58.9	31.9	44.1
China	65.3	52.4	46.4	41.9
Philippines	60.9	63.7	24.4	42.6
Thailand	50.7	46.5	20.5	30.6
India	67.7	48.4	46.8	51.3
Indonesia	53.9	43.8	19.2	23.7
Mexico	41.8	40.4	21.8	24.8
Brazil	61.5	49.1	40.4	39.6
Argentina	41.3	53.3	27.5	31.0
Venezuela	39.8	49.4	21.3	24.3
Hungary	73.7	60.9	43.0	42.2
Poland	69.6	58.4	38.2	44.3
Czech Republic	68.2	58.9	41.5	44.6
Ireland	92.2	75.6	48.0	55.9
Israel	92.0	74.1	58.2	50.6

NOTES: For score and indicator calculations, raw data were transformed into scales of 0–100 for each indicator component and then averaged to generate comparable indicators with a 0–100 range. For survey items, 100 represents the highest response category for each question; for statistical data, 100 typically represents the value attained by the country with the largest value among the 30 countries included in the study. In the indicator formulations cited below, each term carries equal weight.

National orientation (NO) provides evidence that a nation is taking directed action to achieve technological competitiveness. These
actions could take place in the business, government, or cultural sector or any combination of the three.
Indicator formulation: NO = [Q1 + (Q2 + Q3)/2 + Q4 + F1V99]/4.
Data used: Published data from the PRS Group, Political and Economic Forecast Table, "Political Risk Letter" for 1999 rating each country's investment risk (F1V99); and survey data assessing each country's national strategy to promote high-technology development (Q1), social influences favoring technological change (Q2 and Q3), and entrepreneurial spirit (Q4).

Socioeconomic infrastructure (SE) assesses the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation.
Indicator formulation: SE = (Q5 + Q10 + HMHS99)/3.
Data used: Published data on the percentage of students enrolled in secondary and tertiary education (HMHS99) from the Harbison-
Myers Skills Index for 1999, table 2.10, 1999 World Development Indicators, World Bank, 1999; and survey data assessing each country's ef forts to attract foreign investment (Q10) and the mobility of capital (Q5).

Technological infrastructure (TI) assesses the institutions and resources that contribute to a nation's capacity to develop, produce, and market new technology.
Indicator formulation: TI = [(Q7 + Q8)/2 + Q9 + Q11 + EDP99 + S&E96]/5.
Data used: Published data from Statistical Yearbook 1998, UNESCO, 1998, on the number of scientists and engineers involved in research in 1996 (S&E 96), national purchases of electronic data processing equipment (EDP99) from Reed Electronics Research, Yearbook of World Electronics Data 1999/2000, Reed Business Information Ltd., England, 1999; and survey data assessing linkages of R&D to industry (Q9), output of indigenous academic science and engineering (Q7 and Q8), and the ability to make effective use of technological knowledge (Q11).

Productive capacity (PC) assesses the physical and human resources devoted to manufacturing products and the efficiency with which those resources are employed.
Indicator formulation: PC = (Q6 + Q12 + Q13 + A2699)/4.
Data used: Published data on electronics production (A2696) from Reed Electronics Research, Yearbook of World Electronics Data 1999/2000, Reed Business Information Ltd., England, 1999; and survey data assessing the supply and quality of skilled labor (Q6),
capability of the indigenous management (Q13), and the existence of indigenous suppliers of components for technology-intensive products

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SOURCE: Alan L. Porter, J. David Roessner, Nils Newman, and Xiao-Yin Jin, Indicators of Technology-Based Competitiveness of Nations, Summary Report, report to the National Science Foundation under purchase order no. B04841X-00-0 (Atlanta: Georgia Institute of Technology, 2000).

International Comparisons of National R&D Trends

Absolute levels of R&D expenditures are indicators of the breadth and scope of a nation's S&T activities and are a harbinger of future growth and productivity. Indeed, investments in the R&D enterprise strengthen the technological base on which economic prosperity increasingly depends worldwide. The relative strength of a particular country's current and future economy and the specific scientific and technological areas in which a country excels, are further revealed through comparison with other major R&D-performing countries. This section provides comparisons of international R&D spending patterns.**[47]** It examines absolute and relative expenditure trends, contrasts performer and source structural patterns, reviews the foci of R&D activities within sectors, and looks at government research-related priorities. Although R&D performance patterns by sector are broadly similar across countries, national sources of support differ considerably. In nearly all OECD countries, government has provided a declining share of all R&D funding during the past decade, whereas the industrial share of the funding total has increased considerably. The relative emphasis of industrial R&D efforts, however, differ across countries, as do governmental R&D priorities and academic S&E field research emphases. Reflecting an overall pattern of R&D internationalization, foreign sources of R&D funding have been increasing in many countries.

Absolute Levels of Total R&D Expenditures

The worldwide distribution of R&D performance is concentrated in relatively few industrialized nations. Of the $518 billion in estimated 1998 R&D expenditures for the 30 OECD countries, fully 85 percent is expended in only 7 countries (Organisation for Economic Co-operation and Development 2000a).**[48]** These estimates are based on reported R&D investments (for defense and civilian projects) converted to U.S. dollars with purchasing power parity (PPP) exchange rates.**[49]** See sidebar, "Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data."

The United States accounts for roughly 44 percent of all OECD member countries' combined R&D investments; U.S. R&D investments continue to outdistance by 150 percent R&D investments made in Japan, the second largest R&D-performing country. The United States not only spent more money on R&D activities in 1999 than any other country but also spent as much by itself as the rest of the G-7 countries (Canada, France, Germany, Italy, Japan, and the United Kingdom) combined. (See figure 4-26 and appendix table 4-40 for inflation-adjusted PPP R&D totals for OECD and G-7 countries.) In terms of other large R&D performers, only South Korea accounts for a substantial share of the OECD total (a remarkable 3.8 percent in 1998, which is higher than the amounts expended in either Canada or Italy). In only four other countries (the Netherlands, Australia, Sweden, and Spain) do R&D expenditures exceed 1 percent of the OECD R&D total (OECD 2000a).**[50]**

In terms of relative shares, U.S. R&D spending in 1985 reached historical highs of 53 percent of the G-7 total and 48 percent of all OECD R&D.**[51]** As a proportion of the G-7 total, U.S. R&D expenditures declined steadily to a low of 49 percent in 1992. Since then, U.S. R&D has climbed to its 1999 level, a 53 percent G-7 share. (See figure 4-26 for actual expenditure totals.) Conversely, R&D spending in the United States was equivalent to 112 percent of spending in non-U.S. G-7 countries and to approximately 80 percent of all other OECD countries' R&D expenditures in 1999.

Initially, most of the U.S. improvement since 1993 relative to the other G-7 countries resulted from a worldwide slowing in R&D performance that was more pronounced in other countries. Although U.S. R&D spending stagnated or declined for several years in the early to mid-1990s, the reduction in real R&D spending in most of the other large R&D-performing countries was more striking. In Japan, Germany, and Italy, inflation-adjusted R&D spending fell for three consecutive years (1992, 1993, and 1994) at a rate of decline that exceeded similarly falling R&D spending in the United States.**[52]** In fact, large and small industrialized countries worldwide experienced substantially reduced R&D spending in the early 1990s (OECD 2000a). For most of these countries, economic recessions and general budgetary constraints slowed both industrial and government sources of R&D support. More recently, R&D spending has rebounded in several G-7 countries, as has R&D spending in the United States. Yet since annual R&D growth generally has been stronger in the United States than elsewhere and has even slowed to a standstill in Japan according to the most recently available statistics (see figure 4-27), the difference between the United States and the other G-7 countries' combined R&D spending has continued to widen.

Concurrent with the latest years' increase in the U.S. share of the G-7 countries' R&D performance, a similar increase has been seen in the U.S. share of all OECD countries' R&D spendiing. In 1985, the United States accounted for 48 percent of the R&D reported by OECD countries; by 1995, the U.S. share had dropped to 42 percent of the OECD R&D total. Part of this share reduction (perhaps up to 2 percentage points) resulted from the addition of several countries to OECD membership (thereby increasing the OECD R&D totals); worldwide growth in R&D activities, however, was a greater contributing factor to the loss of R&D share experienced by the United States. Since then, the U.S. share has climbed back to 44 percent of the OECD total in 1999, more a result of robust R&D growth in the United States than a result of the significant changes under way in the other OECD countries.

Trends in Total R&D/GDP Ratios

One of the first (Steelman 1947) and now most widely used indicators of a country's commitment to growth in scientific knowledge and technology development is the ratio of R&D spending to GDP. (See figure 4-28.) For most of the G-8 countries (that is, the G-7 countries plus the Russian Federation), the latest R&D/GDP ratio is no higher now than it was at the start of the 1990s, which ushered in a period of slow growth or decline in their overall R&D efforts. The ways in which different countries have reached their current ratios vary considerably, however.**[53]** The United States and Japan reached 2.7 and 2.8 percent, respectively, in 1990–91. As a result of reduced or level spending by industry and government in both countries, the R&D/GDP ratios declined several tenths of a percentage point, to 2.4 and 2.6, respectively, in 1994 before rising again to 2.6 and 3.0 percent. Growth in industrial R&D accounted for much of the recovery in each of these countries. Electrical equipment, telecommunications, and computer services companies have reported some of the strongest R&D growth since 1995 in the United States. Growth in pharmaceutical R&D also has been substantial. In Japan, spending increases were highest in the electronics, machinery, and automotive sectors and appear to be associated mainly with a wave of new digital technologies (Industrial Research Institute 1999). However, the steady increase in Japan's R&D/GDP ratio since 1994 is also partially a result of anemic economic conditions overall: GDP fell in both 1998 and 1999, so that even level R&D spending resulted in a slight increase in its R&D ratio (OECD 2000a).

Among the remaining six G-8 countries, two (Germany and Russia) display recent increases in their economies' R&D intensity, and four (the United Kingdom, France, Italy, and Canada) report an R&D/GDP ratio that has remained stagnant or continues to decline. In Germany, the R&D/GDP ratio fell from 2.9 percent at the end of the 1980s, before reunification, to 2.3 percent in 1993 before rising to its current level of 2.4 percent. By comparison, this macro-R&D indicator continues to slip slightly in France and the United Kingdom to their current levels of 2.2 and 1.9 percent, respectively, and has fluctuated narrowly at 1.0 and 1.6 percent in Italy and Canada, respectively, for the past five years or longer. The end of the cold war and collapse of the Soviet Union had a drastic effect on Russia's R&D enterprise. R&D spending in Russia was estimated at 2.0 percent of GDP in 1990; that figure plummeted to 1.4 percent in 1991 and then tumbled further to 0.7 percent in 1992. Moreover, the severity of this R&D decline is masked somewhat: although the R&D share was falling, it also was a declining share of a declining GDP. By 1999, the R&D/GDP ratio in Russia had inched back to about 1.0 percent, although the country continues to experience severe reductions in its R&D spending.

Overall, the United States ranked fifth among OECD countries in terms of reported R&D/GDP ratios for the 1996–99 period. (See text table 4-13.) Sweden leads all countries with 3.7 percent of its GDP devoted to R&D, followed by Japan (3.0 percent), Finland (2.9 percent), and Switzerland (2.7 percent). In general, nations in Southern and Eastern Europe tend to have R&D/GDP ratios below 1.5 percent, whereas Nordic nations and those in Western Europe report R&D spending shares greater than 1.5 percent. In a broad sense, the reason for such patterns has much to do with overall funding patterns and macroeconomic structures. In practically all OECD countries, the business sector finances most of the R&D. However, OECD countries with relatively low R&D/GDP ratios tend to be relatively low-income countries, and government funding tends to provide a larger proportion of the R&D support than it provides in the high R&D/GDP ratio countries. Furthermore, the private sector in such low-income countries often consists of low-technology industries, resulting in low overall R&D spending and, therefore, low R&D/GDP ratios. Indeed, a strong link exists between countries with high incomes that emphasize the production of high-technology goods and services and those that invest heavily in R&D activities (OECD 2000e).**[54]**

Outside the European region, R&D spending has intensified considerably since the early 1990s. Several Asian countries, most notably South Korea and China, have been particularly aggressive in expanding their support for R&D and S&T-based development. In Latin America and the Pacific region, other non-OECD countries also have attempted to increase R&D investments substantially during the past several years. Even with recent gains, however, most non-European (non-OECD) countries invest a smaller share of their economic output on R&D than do OECD members (with the exception of Israel, whose reported 2.5 percent nondefense R&D/GDP ratio ranks seventh in the world). With the apparent exception of Costa Rica, all Latin American countries for which such data are available report R&D/GDP ratios below 1 percent. (See text table 4-13.) This distribution is consistent with broader indicators of economic growth and wealth. However, many of these countries also report additional S&T-related expenditures on human resources training and S&T infrastructure development that are not captured in R&D and R&D/GDP data (Red Iberomericana de Indicadores de Ciencia y Tecnologia 2001).

Nondefense R&D Expenditures and R&D/GDP Ratios

As a result of concerns related to national scientific progress, standard-of-living improvements, economic competitiveness, and commercialization of research results, attention has shifted from nations' total R&D activities to nondefense R&D expenditures as indicators of scientific and technological strength. Indeed, conclusions about a country's relative standing may differ dramatically, depending on whether total R&D expenditures are considered or defense-related expenditures are excluded from the totals; for some countries, the relative emphasis has shifted over time. Among G-8 countries, the inclusion of defense R&D has little impact on R&D totals for Japan, Germany, Italy, and Canada, where defense R&D represents 5 percent or less of the national total. In other countries, defense has accounted for a more significant, although since the end of the cold war declining, proportion of the national R&D effort. Between 1988 and 1998, the defense share of the R&D total:

- has fallen from 31 to 15 percent in the United States,
- has fallen from 21 to 7 percent in France,
- has fallen from 17 to 12 percent in the United Kingdom, and
- accounts for approximately 25 percent of the 1998 Russian R&D total.

Consequently, if current trends persist, the distinction between defense and nondefense R&D expenditures in international comparisons may become less important. In absolute dollar terms, the U.S. nondefense R&D spending is still considerably larger than that of its foreign counterparts. In 1998 (the latest year for which comparable international R&D data are available from most OECD countries), U.S. nondefense R&D was more than twice that of Japan and was equivalent to 94 percent of the non-U.S. G-7 countries' combined nondefense R&D total. (See appendix table 4-41.)

In terms of R&D/GDP ratios, the relative position of the United States is somewhat less favorable for this nondefense metric compared with those ratios for all R&D combined. Japan's nondefense R&D/GDP ratio (3.0 percent) exceeded that of the United States (2.2 percent) in 1998, as it has for years. (See figure 4-28 and appendix table 4-41.) The nondefense R&D ratio of Germany (2.3 percent in 1999) slightly exceeded that of the United States (again, in contrast to total R&D). The 1998 nondefense ratio for France (2.0 percent) was slightly below the U.S. ratio; ratios for the United Kingdom and Canada (each at 1.6 percent) and for Italy (1.0 percent) were considerably lower. The nondefense R&D/GDP ratio for Russia was nearly one-third (0.7 percent) the U.S. ratio.

International R&D by Performer, Source, and Character of Work

Broad Sector Patterns

Although marked differences are observed in the financing and performance of R&D among both OECD and non-OECD countries, similarities also are observed in R&D patterns for the G-8 countries. Government and industry account for roughly 80 percent or more of the R&D funding in each of these eight countries, although the respective contributions vary substantially across countries.**[55]** The industrial sector provided more than 70 percent of R&D funds in Japan, 67 percent in the United States, 64 percent in Germany, 54 percent in France; and between 44 and 49 percent in the United Kingdom, Italy, and Canada. (See figure 4-29.) In

Russia, industry provided approximately 35 percent of the nation's R&D funding. Government provided the largest share (54 percent) of Russia's R&D total, as it did in Italy (at 51 percent of the national R&D effort). In the remaining six countries, government was the second largest source of R&D funding, ranging between 19 percent (in Japan) and 37 percent (in France) of the total. In each of these eight countries, government provided the largest share of the funds used for academic R&D performance. (See appendix table 4-42.)

The industrial sector dominates R&D performance in each of the G-8 countries. (See figure 4-29.) Industry performance shares for the 1998–99 period ranged from a little more than 70 percent in the United States and Japan to less than 54 percent in Italy. Industry's share was between 62 and 69 percent in France, Canada, the United Kingdom, Germany, and Russia. Most of the industrial R&D performance in these countries was funded by industry. Government's share of funding for industry R&D performance ranged from as little as 2 percent in Japan to 43 percent in Russia. (See appendix table 4-42.) In the other G-8 countries, the government funding share of industrial R&D ranged narrowly between 5 and 13 percent.

In most of these countries, the academic sector was the next largest R&D performer (at about 12 to 25 percent of the performance total in each country).**[56]** Academia often is the primary location of research (as opposed to R&D) activities, however. Government was the second largest R&D performing sector in France (which included spending in some sizable government laboratories), as it was in Russia (accounting for 26 percent of that nation's R&D effort).

Character of R&D Effort

Not all of the G-8 countries categorize their R&D expenditures into basic research, applied research, or development categories, and for several countries that do use this taxonomy, the data are somewhat dated (OECD 2000b). In fact, only 6 of the 30 OECD members (and Russia) have reported their countries' character of work shares for 1998 or later. R&D classification by character of work probably involves a greater element of subjective assessment than other R&D indicators. See sidebar, "Choice of the 'Right' R&D Taxonomy Is a Historical Concern." Rather than resulting from surveys, the data often are estimated in large part by national authorities.**[57]** Nonetheless, where these data exist, they indicate the relative emphasis that a country places on supporting fundamental scientific activities—the seed corn of economic growth and technological advancement.

The United States expends approximately 18 percent of its R&D on activities that performers classify as basic research. (See figure 4-30.) About one-half of this research is funded by the Federal Government and performed in the academic sector. The largest share of this basic research effort is conducted in support of life sciences. Basic research accounts for comparatively smaller amounts of the national R&D performance efforts in the Russian Federation (16 percent); South Korea (14 percent), which is currently the sixth largest R&D-performing member of OECD; and Japan (12 percent). Compared with patterns in the United States, however, a considerably greater share is funded for engineering research activities in each of these three countries. Conversely, basic research accounts for more than 20 percent of total R&D performance reported in Italy, France, and Australia.**[58]**

In contrast to spending patterns reported for most countries, spending on applied research activities accounts for the largest proportion (43 percent) of Italy's R&D total. In each of the other countries shown here, development accounted for the largest share of national totals (approximately 60 percent but as little as 40 percent of total in Australia), with most of the experimental development work under way in their respective industrial sectors.

Higher Education Sector

Source of Funds. In many OECD countries, the academic sector is a distant second to industry in terms of the national R&D performance effort. Among G-8 countries, universities account for as little as 5 percent of Russia's R&D total to upward of a 25 percent share in Italy.**[59]** For most of these countries, the government is now, and historically has been, the largest source of academic research funding. However, in each of these countries for which historical data exist (the exception being Russia), the government financing share has declined during the past 20 years, and industry as a source of university R&D funding has increased. Specifically, the government share, including both direct government support for academic R&D and the R&D component of block grants to universities,**[60]** has fallen by 8 percentage points or more in six of the G-7 countries since 1981 (the exception being Italy, in which the government share has dipped from 96 to 94 percent of the academic R&D total). By comparison, and as an indication of an overall pattern of increased university-firm interactions (often intending to promote the commercialization of university research), the funding proportion from industry sources for these seven countries combined climbed from 2.5 percent of the academic R&D total in 1981, to 5.4 percent in 1990, to 6.4 percent in 1998. In Germany and Canada, almost 11 percent of university research is now funded by industry. (See text table 4-14.)

S&E Fields. As noted in the discussion on the character of the R&D effort, the national emphases in particular S&E fields differ across countries. Where they are collected at all, most of the internationally comparable data on field-specific R&D are reported for the higher education sector. Although difficult to generalize, it would appear that most countries supporting a substantial level of academic R&D (defined at $1 billion PPPs in 1998) devote a relatively larger proportion of their R&D for engineering, social sciences, and humanities than does the United States. (See text table 4-15.) Conversely, the U.S. academic R&D effort emphasizes the medical sciences and natural sciences relatively more than do many other OECD countries.**[61]** The latter observation is consistent with the overall U.S. relative R&D emphases in health and biomedical sciences for which NIH and U.S. pharmaceutical companies are known.

Industry Sector

Sector Focus. Industrial firms account for the largest share of the total R&D performance in each of the G-8 countries. However, the purposes to which the R&D is applied differ somewhat, depending on the overall industrial composition of the economy. Furthermore, the structure of industrial activity can itself be a major determinant of the level and change in a country's industrial R&D spending. Variations in such spending can result from differences in absolute output, industrial structure, and R&D intensity. Countries with the same size economy could have vastly different R&D expenditure levels (and R&D/GDP ratios). Differences might depend on the share of industrial output in the economy, on whether the industries that account for the industrial output are traditional sites of R&D activity (e.g., food processing firms generally conduct less R&D than pharmaceutical firms), and on whether individual firms in the same industries devote substantial resources to R&D or emphasize other activities (i.e., firm-specific intensities). Text table 4-16 provides the distribution of industrial R&D performance in the G-8 countries and in Sweden and Finland, which have the first and third highest R&D/GDP ratios in the world, respectively.**[62]**

The level of industrial R&D in the United States far exceeds the level reported for any and all other of these countries, and therefore, the data are reported as shares of countries' industrial R&D totals. Most of these countries perform R&D in support of a large number of industry sectors. The sector distribution of the U.S. industrial R&D effort, however, is among the most widespread and diverse. This perhaps indicates a national inclination and ability to invest in becoming globally competitive in numerous industries rather than specializing in just a few industries or niche technologies. No U.S. industry sector accounts for more than 13 percent of the industry R&D total (the electrical equipment industry representing the highest level), and only two others (office machinery, including computers, and aerospace) account for 10 percent or more of the industry total. By comparison, most of the other countries display somewhat higher sector concentrations, including 20 percent or higher industry R&D shares for electrical equipment firms in Finland (at 44 percent of its industry total), Canada, Italy, and Sweden. Indeed, the electrical equipment sector is among the largest performers of the industrial R&D effort in 8 of the 10 countries shown (exceptions are the United Kingdom and Russia). Among other manufacturing sectors, 20 percent or higher shares are reported for motor vehicles in Germany and for pharmaceuticals in the United Kingdom, which is consistent with general economic production patterns.**[63]**

As indicated earlier, one of the more significant trends in U.S. industrial R&D activity has been the growth of the R&D effort within the nonmanufacturing sector. According to the internationally harmonized data in text table 4-16, such growth accounted for 20 percent of the U.S. 1997 industry R&D total, with computer services, R&D services, and trade each accounting for the largest individual shares (about 5 percent). A number of other countries also report substantial increases in their service sector R&D expenditures during the past 25 years.

Among G-7 countries, nonmanufacturing R&D shares have increased by about 5 percentage points in France and Italy and by 13 percentage points in Absolute Levels of Total R&D Expenditures:

Trends in Total R&D/GDP Ratios
Nondefense R&D Expenditures and R&D/GDP Ratios
International R&D by Performer, Source, and Character of Work
the United States, United Kingdom, and Canada since the early 1980s (Jankowski 2001b). In each of these three English-speaking countries, computer and related services account for a substantial share of the service R&D totals. Furthermore, R&D services appear to be an important locus of industry activity in several countries, reflecting in part the growth in outsourcing and greater reliance on contract R&D in lieu of in-house performance, as well as intramural R&D in these industries.

According to the national statistics, only in Germany and Japan do the nonmanufacturing sectors currently account for less than 10 percent of the industry R&D performance total. Among the countries listed in text table 4-16, services R&D shares range from as little as 4 percent in Japan to 59 percent in Russia. The latter figure, however, primarily occurs because specialized industrial research institutes perform a large portion of Russia's industry and federal government R&D and are classified under the "research and development" sector within the service sector. Apart from these institutes, the manufacturing-nonmanufacturing split in Russia's industrial R&D would be similar to ratios in the United States (American Association for the Advancement of Science (AAAS) and Centre for Science Research and Statistics (CSRS) 2001).

Source of Funds. Most of the industrial R&D in each of these eight countries is provided by industry itself. As is the situation for OECD countries overall, government financing accounts for a small and declining share of the industry R&D performance total within G-7 countries. See "Government Sector" for further discussion. Government financing shares range from as little as 2 percent of the industry R&D in Japan to 13 percent of Italy's industry R&D effort. (See appendix table 4-42.) (For recent historical reasons, Russia is the exception to this pattern among the G-8 countries, with government accounting for 43 percent of its industry total.) In the United States, the Federal Government currently provides about 11 percent of the R&D funds used by industry, and the majority of that funding is obtained through contracts from DOD.

As shown in figure 4-31, funds from abroad accounted for as little as 0.4 percent of Japan's R&D expenditure total to almost 22 percent of total R&D expenditures in the United Kingdom. Foreign funding, predominantly from industry for R&D performed by industry but also including some small amounts of foreign funding provided to other nonindustry sectors, is an important and growing funding source in several countries. Growth in this funding source primarily reflects the increasing globalization of industrial R&D activities overall. For European countries, however, the growth in foreign sources of R&D funds may also reflect the expansion of coordinated European Community (EC) efforts to foster cooperative shared-cost research through its European Framework Programs.**[64]** Although the growth pattern of foreign funding has seldom been smooth, it now accounts for more than 20 percent of industry's domestic performance totals in Canada and the United Kingdom and approximately 10 percent of industry R&D performed in Italy, France, and Russia. (See figure 4-31.) Such funding takes on even greater importance in many of the smaller OECD countries as well as in less industrialized countries (OECD 1999b).

In the United States, approximately 13 percent of funds spent on industry R&D performance in 1998 are estimated to have come from majority-owned affiliates of foreign firms investing domestically. This amount was considerably more than the 3 percent funding share provided by foreign firms in 1980 and their 8 percent share reported as recently as 1991.**[65]**

Government Sector

Government R&D Funding Totals. In most countries, the government sector makes its strongest impact on the R&D enterprise not by conducting R&D but, rather, by financing R&D. The government sector accounts for only 11 percent of OECD members' combined R&D performance in 1998 (OECD 2000a) and for 26 percent or (usually much) less in each of the G-8 countries. (See appendix table 4-42.) Government accounted for 13 percent of the OECD performance total as recently as 1995.

The decline in governments' share of the R&D performance totals, however, pales in comparison with their shrinking share of the R&D financing total. Indeed, the most significant trend among the G-7 and other OECD countries has been the relative decline in government R&D funding in the 1990s. In 1998, less than one-third of all R&D funds were derived from government sources, down considerably from the 45 percent share reported 16 years earlier. (See figure 4-32.) Among all OECD countries, government accounts for the highest funding share in Portugal (68 percent of its 1997 R&D total) and the lowest share in Japan (19 percent in 1998). Part of the relative decline reflects the effects of budgetary constraints, economic pressures, and changing priorities in government funding (especially the relative reduction in defense R&D in several of the major R&D-performing countries, notably France, the United Kingdom, and the United States). Another part reflects the absolute growth in industrial R&D funding as a response to increasing international competitive pressures in the marketplace, irrespective of government R&D spending patterns, thereby increasing the relative share of industry's funding as compared with government's funding. Both of these considerations are reflected in funding patterns for industrial R&D performance alone. In 1982, government provided 23 percent of the funds used by industry in conducting R&D within OECD countries, whereas by 1998 government's share of the industry R&D total had fallen by more than half, to 10 percent of the total. In most OECD countries (as in the United States), government support for business R&D is skewed toward large firms.

Government R&D Priorities. A breakdown of public expenditures by major socioeconomic objectives provides insight into government priorities that as a group have changed over time and that individually differ considerably across countries.**[66]** Within OECD, the defense share of governments' R&D financing total has declined annually since the mid-1980s. Accounting for 44 percent of the government total in 1986, defense-related activities now garner a much smaller 31 percent share. (See text table 4-17.) Much of this decline is driven by the U.S. experience: 53 percent of the U.S. Government's $78 billion R&D investment during 1999 was devoted to national defense, down from its 69 percent share in 1986. Nonetheless, defense still accounts for a relatively larger government R&D share in the United States than elsewhere. This share compares with the 35 percent defense share in the United Kingdom (of a $9 billion government total), 30 percent in Russia (of $4 billion), 23 percent in France (of $13 billion), and less than 10 percent each in Germany, Italy, Canada, and Japan. (See figure 4-33 and appendix table 4-43.) As in the United States, these recent figures represent substantial cutbacks in defense R&D in the United Kingdom and France, where defense accounted for 44 and 40 percent, respectively, of government R&D funding in 1990. However, defense-related R&D also seems particularly difficult to account for in many countries' national statistics. See sidebar, "Tracking R&D: Gap Between Performer- and Source-Reported Expenditures."

Concurrent with the changes in overall defense/nondefense R&D shares, notable shifts have occurred in the composition of OECD countries' governmental nondefense R&D support during the past two decades. In terms of the broad socioeconomic objectives to which government programs are classified in various international reports (OECD 1999a, 2000f), government R&D shares have increased most for health and the environment and for various nondirected R&D activities (identified in text table 4-17 as "other purposes").**[67]** Growth in health-related R&D financing has been particularly strong in the United States, whereas many of the other OECD countries have reported relatively greater growth for environmental research programs. Indeed, as is indicated from a variety of R&D metrics, the emphasis on health-related research is much more pronounced in the United States than in other countries, although the importance of tracking the R&D contribution to improving human health has become widely accepted (OECD 2001). In 1999, the Federal Government devoted 21 percent of its R&D investment to health-related R&D, making such activities second only to defense. (Direct comparisons between health and defense R&D are complicated because most of the health-related R&D is research, and about 90 percent of defense R&D is development.)

The relative shift in emphasizing nondirected R&D reflects government priority setting during a period of fiscal austerity and constraint. With fewer discretionary funds available to support R&D, governments have tended to conduct activities that are traditionally in the government sphere of responsibility and for which private funding is less likely to be available. For example, basic research projects are inextricably linked to higher education.**[68]** Conversely, the relative share of government R&D support provided for economic development programs has declined considerably, from 38 percent of total in 1981 to 23 percent in 1999. Economic development programs include the promotion of agriculture, fisheries and forestry, industry, infrastructure, and energy, all activities for which privately financed R&D is more likely to be provided without public support, although the focus of such private and public support would undoubtedly differ somewhat.

Different activities are emphasized in individual countries' governmental R&D support statistics. Japan committed 19 percent of its total governmental R&D support ($20 billion) to energy-related activities, reflecting the country's historical concern about its high dependence on foreign sources of energy. (See appendix table 4-43.) In Canada, 11 percent of the government's $4 billion in R&D funding was directed toward agriculture. Space R&D received considerable support in the United States and France (11 percent of the total in each country), while industrial development accounted for 8 percent or more of governmental R&D funding in Canada, Germany, Italy, and Russia. In fact, industrial development is the leading socioeconomic objective for R&D in Russia, accounting for 23 percent of all government R&D, funding for which is primarily oriented toward the development of science-intensive industries and is aimed at increasing economic efficiency and technological capabilities (AAAS and CSRS 2001).**[69]** Industrial development programs accounted for 7 percent of the Japanese total but for less than 1 percent of U.S. R&D. (See figure 4-33.) The latter figure, which includes mostly R&D funding by NIST of the U.S. Department of Commerce, is understated relative to most other countries as a result of data compilation differences. In part, the low U.S. industrial development share reflects the expectation that firms will finance industrial R&D activities with their own funds; in part, government R&D that may be indirectly useful to industry is often funded with other purposes in mind such as defense and space (and is therefore classified under other socioeconomic objectives).

Japanese, German, and Italian government R&D appropriations in 1998–99 were invested relatively heavily in advancement of knowledge (50 percent or more of the $20 billion total for Japan, 55 percent of Germany's $16 billion total, and 59 percent of the $7 billion total in Italy). "Advancement of knowledge" is the combined support for advancement of research and GUF.**[70]** Indeed, the GUF component of advancement of knowledge, for which there is no comparable counterpart in the United States, represents the largest part of government R&D expenditure in most OECD countries.

R&D Tax Policies. In many OECD countries, government not only provides direct financial support for R&D activities but also uses indirect mechanisms such as tax relief to promote national investment in S&T. Indeed, tax treatment of R&D in OECD countries is broadly similar, with some variations in the use of R&D tax credits (OECD 1996, 1999a). The main features of the R&D tax instruments are as follows:

- Almost all OECD countries (including the United States) allow 100 percent of industry R&D expenditures to be deducted from taxable income in the year they are incurred.
- About one-half of OECD countries (including the United States) provide some type of additional R&D tax credit or incentive with a trend toward using incremental credits. A few countries also use more targeted approaches, such as those favoring basic research.
- Several OECD countries have special provisions that favor R&D in small and medium-size enterprises. (In the United States, credit provisions do not vary by firm size, but direct Federal R&D support is provided through grants to small firms.)

A growing number of R&D tax incentives are being offered in OECD countries at the subnational (provincial and state) levels, including in the United States. See Poterba (1997) for a discussion of international elements of corporate R&D tax policies.

Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data

Comparisons of international R&D statistics are hampered because each country's R&D expenditures are denominated in its home currency. Two approaches are commonly used to normalize the data and facilitate aggregate R&D comparisons: dividing R&D by gross domestic product, which results in indicators of relative effort according to total economic activity and circumvents the problem of currency conversion, and converting all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation that permits only gross national comparisons. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D investments, but it entails choosing an appropriate currency conversion series.

Market Exchange Rates Versus Purchasing Power Parity Rates

Because (for all practical purposes) no widely accepted R&D-specific exchange rates exist, the choice is between market exchange rates (MERs) (International Monetary Fund 1999) and purchasing power parities (PPPs) (OECD 2000a). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

Market Exchange Rates—At their best, MERs represent the relative value of currencies for goods and services that are traded across borders; that is, MERs measure a currency's relative international buying power. Sizable portions of most countries' economies do not engage in international activity, however, and major fluctuations in MERs greatly reduce their statistical utility. MERs also are vulnerable to a number of distortions, including currency speculation, political events such as wars or boycotts, and official currency intervention, which have little or nothing to do with changes in the relative prices of internationally traded goods.

Purchasing Power Parity Rates—Because of the MER shortcomings described above, the alternative currency conversion series of PPPs has been developed (Ward 1985). PPPs take into account the cost differences across countries of buying a similar basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is, therefore, representative of total GDP across countries. When the PPP formula is applied to current R&D expenditures of other major performers, such as Japan and Germany, the result is a substantially lower estimate of total R&D spending than that given by MERs. (See figure 4-25 .) For example, Japan's R&D in 1998 totaled $92 billion based on PPPs and $115 billion based on MERs, and the German R&D expenditure was $44 billion on PPPs and $50 billion on MERs. (By comparison, the U.S. R&D expenditure was $227 billion in 1998.)

PPPs are the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official OECD R&D tabulations. Unfortunately, they are not available for all countries and currencies. They are available for all OECD countries, however, and are therefore used in this report.

Exchange Rate Movement Effects

Although the difference is considerable between what is included in GDP-based PPP items and R&D expenditure items, the major components of R&D costs, fixed assets and the wages of scientists, engineers, and support personnel, are more suitable to a domestic converter than to one based on foreign trade flows. Exchange rate movements bear little relationship to changes in the cost of domestically performed R&D. (See figure 4-25.) When annual changes in Japan's and Germany's R&D expenditures are converted to U.S. dollars with PPPs, they move in tandem with such funding denominated in their home currencies. Changes in dollar-denominated R&D expenditures converted with MERs exhibit wild fluctuations that are unrelated to the R&D purchasing power of those investments. MER calculations indicate that, between 1988 and 1998, German and Japanese R&D expenditures each increased twice by 15 percent or more. In reality, nominal R&D growth was only one-fourth to one-third those rates in either country during this period. PPP conversions generally mirror the R&D changes denominated in these countries' home currencies.

Choice of the "Right" R&D Taxonomy is a Historical Concern

With the following words, written more than 50 years ago, Vannevar Bush (1945) laid the basis in his seminal report, Science—The Endless Frontier, for what eventually became known (and perhaps was unfairly derided) as the linear model of innovation:

"Scientific research may be divided into the following broad categories: (1) pure research, (2) background research, and (3) applied research and development. The boundaries between these categories are by no means clear-cut and it is frequently difficult to assign a given investigation to any single category. On the other hand, typical instances are easily recognized, and study reveals that each category requires different institutional arrangements for maximum development." (p. 81.)… "Basic research…creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science." (p. 19.)

Bush's model somewhat simplistically depicts innovation as a three-step process whereby (1) scientific breakthroughs from the performance of basic research (2) lead to applied research, which (3) leads to the development or application of applied research to commercial products, processes, and services. Although it is quite unlikely that either scientific or statistical experts ever really believed that such a model captured the complex relationships between science, technology, and innovation, it did (and still does) lend itself to the collection and analysis of data for policymaking purposes.

Most of the criticism surrounding the inappropriateness of the basic research, applied research, and development categories that are used in practically all R&D data collection efforts (see sidebar, "Definitions of Research and Development," at the beginning of this chapter) focus on the lack of clear boundaries between basic research and applied research.[*] This debate took form ever since Bush first differentiated "basic research" (a term he used interchangeably with "pure research") as that which is performed without thought of specific practical ends from applied research, the function of which is to provide "complete answers" to practical problems. A number of proposals have arisen over the years to replace, or supplement, the basic/applied research taxonomic categories, including fundamental versus strategic research, exploratory versus programmatic research, curiosity-driven versus mission-oriented research—to name just a few.**[†]** Indeed, in the last published version (OECD 1994) of the Frascati Manual (international standards and guidelines for conducting R&D surveys), the option of collecting separate data on "pure basic research" and "oriented basic research" was introduced. To date, few countries have chosen to collect research expenditure data with these, or similar, reporting refinements. More generally, none of the proposed alternatives has gained a consensus in either the scientific, political, or statistical communities; each proposed alternative suffers from its own shortcomings which are as least as problematic as the taxonomic categories that would be replaced. On a more historical note, Bush himself was not particularly concerned about the precision of the definitions he used. Rather, he simply wanted to establish a framework that offered the best chance for basic research to receive special protection and, more important, ensured government financial support.

It is just as likely, however, that the distinctions between applied research and development and between development and related (for example, routine testing and evaluation) and downstream (for example, preproduction) activities are subject to their own reporting complexities.

[†] One of the more recent well-known alternative taxonomy paradigms was developed by the late David Stokes (1997) and depicted in Pasteur's Quadrant: Basic Science and Technological Innovation. Stokes suggested multiple research categories: pure basic research (work inspired by the quest for basic understanding but not by potential use), purely applied research (work motivated only by potential use), and strategic research (work inspired by both potential use and fundamental understanding). Stokes characterized Louis Pasteur's research on the microbiological process of disease in the late 19th century as strategic research.

Tracking R&D: Gap Between Performer- and Source-Reported Expenditures

In many OECD countries, including the United States, total government R&D support figures reported by government agencies differ substantially from those reported by performers of R&D work. Consistent with international guidance and standards (OECD 1994), however, most countries' national R&D expenditure totals and time series are based primarily on data reported by performers. This convention is preferred because performers are in the best position to indicate how much they spent in the actual conduct of R&D in a given year and to identify the source of their funds. Although funding and performing series may be expected to differ for many reasons such as different bases used for reporting government obligations (fiscal year) and performance expenditures (calendar year), the gap between the two R&D series has widened during the past several years. Additionally, the divergence in the series is most pronounced in countries with relatively large defense R&D expenditures (National Science Board (NSB) 1998).

Data Gap Trends

For the United States, the reporting gap has become particularly acute over the past several years. In the mid-1980s, performer-reported Federal R&D exceeded Federal reports by $3 to $4 billion annually (5–10 percent of the government total). This pattern reversed itself toward the end of the decade; in 1989, the government-reported R&D total exceeded performer reports by $1 billion. The gap has since grown to about $8 billion. In other words, approximately 10 percent of the government total in 1999 is unaccounted for in performer surveys. (See figure 4-34.) The difference in Federal R&D totals is primarily in Department of Defense (DOD) development funding of industry (principally aircraft and missile firms). For 1999, Federal agencies reported $31.9 billion in total R&D obligations provided to industrial performers compared with an estimated $20.2 billion in Federal funding reported by industrial performers. (DOD reports industry R&D funding of $24.6 billion, whereas industry reports using $11.7 billion of DOD's R&D funds.) Overall, industrywide estimates equal a 37 percent paper "loss" of federally reported 1999 R&D support. (See figure 4-34.)

Reasons for Data Gaps

Interviews with industry representatives have helped the National Science Foundation (NSF) identify possible reasons that performer-reported R&D totals might differ from funding agency-reported totals. Generally, since the end of the cold war, numerous changes have occurred in the defense contracting environment and DOD's budgeting process. These have been accompanied by major shifts in the composition of R&D, test, and evaluation contracts, which may account for some of the statistical discrepancies. In ways unknown a decade earlier, new types of defense contractors and nontraditional forms of R&D expenditures apparently play a major role in complicating the collection of R&D data. (A complete summary of the NSF study appeared in NSB 2000.)

More recently, however, Federal agencies and representatives from firms and universities (recipients of Federal R&D funding) gathered at a Congressional Research Service (CRS) workshop to discuss these R&D data issues. Not surprisingly, participants were unable to reach a consensus on the reasons for the growing data gaps. According to the CRS summary (Davey and Rowberg 2000), participants generally agreed that agency downsizing in recent years has left fewer resources to collect, process, and report R&D data to NSF. Because agencies do not place a high priority on such data reporting, those who report data are likely to be the early victims of downsizing. Nonetheless, the agencies with the largest discrepancy between their reported R&D obligations and the R&D expenditures reported by industry performers receiving those funds (DOD, Department of Energy, and National Aeronautics and Space Administration) believe that the source of the discrepancy lies almost exclusively with the performers. Those agencies have reviewed their data collection and reporting methods and contend that they have been stable and consistent over the period during which the discrepancies have grown.

On the other hand, the U.S. Bureau of the Census, which collects the industry R&D data for NSF, stated that it has not seen any significant shifts in the character of that data since at least 1992. In particular, no significant changes have appeared that could correlate with the rise in mergers and acquisitions among the surveyed firms. Industry participants questioned why agencies were not solely responsible for reporting these Federal R&D funding data to NSF rather than sharing the burden with industry. And according to an even more recent U.S. General Accounting Office (2001a) investigation, "Because the gap is the result of comparing two dissimilar types of financial data [Federal obligations and performer expenditures], it does not necessarily reflect poor quality data, nor does it reflect whether performers are receiving or spending all the Federal R&D funds obligated to them. Thus, even if the data collection and re-porting issues were addressed, a gap would still exist." In summary, users should expect no quick resolution to the issue of why performer-reported R&D data differ from the data reported by the funding Federal agencies, nor perhaps should they be overly concerned about the discrepancy.

Footnotes

[47] Most of the R&D data presented here are from reports to OECD, the most reliable source of such international comparisons. A high degree of consistency characterizes the R&D data reported by OECD, with differences in reporting practices among countries affecting their R&D/GDP ratios by no more than an estimated 0.1 percentage point (International Science Policy Foundation 1993). Nonetheless, an increasing number of non-OECD countries and organizations now collect and publish internationally comparable R&D statistics, which are reported at various points in this chapter.

[48] Current OECD members are Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

[49] Although PPPs technically are not equivalent to R&D exchange rates, they better reflect differences in countries' research costs than do market exchange rates.

[50] Although countries other than members of the OECD also fund and perform R&D, with the exception of just a handful, most of these national R&D efforts are comparatively small. For example, in 1997 total R&D expenditures in China and Russia were $24.7 billion and $10.3 billion (PPP dollars) and nondefense R&D in Israel totaled $2.5 billion PPP (OECD 2000c). Among non-OECD members of Red Iberomericana de Indicadores de Ciencia y Tecnologia (RICYT), the largest R&D expenditures are reported for Brazil ($9.2 billion U.S. at market exchange rates), Argentina ($1.1 billion), Chile ($0.5 billion), and Colombia ($0.4 billion) (RICYT 2001). The combined R&D expenditures of these seven countries (approximately $50 billion) would raise the

OECD world total by about 10 percent, and about one-half would be derived from China alone.

[51] OECD maintains R&D expenditure data that can be divided into three quality; (2) 1973 to 1980, which are probably of reasonable quality, for which some metadata are available; and (3) 1963 to 1972, about which there are serious doubts for most OECD countries (with notable exceptions of the United States and Japan), many of which launched their first serious R&D surveys in the mid-1960s. The analyses in this chapter are limited to data for 1981 and later years.

[52] The United Kingdom similarly experienced three years of declining real R&D expenditures, but its slump took place in 1995, 1996, and 1997. The falling R&D totals in Germany were partly a result of specific and intentional policies to eliminate redundant and inefficient R&D activities and to integrate the R&D efforts of the former East Germany and West Germany into a united German system.

[53] A country's R&D spending and therefore its R&D/GDP ratio is a function of several factors in addition to its commitment to supporting the R&D enterprise. Especially because the majority of R&D is performed by industry in each of these countries, the structure of industrial activity can be a major determinant of a country's R&D/GDP ratio. For example, economies with high concentrations in manufacturing (which traditionally have been more R&D intensive than nonmanufacturing or agricultural economies) have different patterns of R&D spending. See "Industry Sector" for further discussion of such considerations.

[54] See OECD (1999b) for further discussion of these and other broad R&D indicators for OECD countries.

[55] In accordance with international standards, sources of funding are attributed to the following sectors: all levels of government combined, business enterprises, higher education, private nonprofit organizations, and funds from abroad. The taxonomy used in presenting U.S. R&D expenditures elsewhere in this chapter differs somewhat.

[56] The national totals for Europe, Canada, and Japan include the research component of general university fund (GUF) block grants (not to be confused with basic research) provided by all levels of government to the academic sector. Therefore, at least conceptually, the totals includeperiods: (1) 1981 to the present, which are properly annotated and of good academia's separately budgeted research and research undertaken as part of university departmental R&D activities. In the United States, the Federal Government generally does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. On the other hand, a fair amount of state government funding probably does support departmental research at public universities in the United States. Data on departmental research, considered an integral part of instructional programs, generally are not maintained by universities. U.S. totals are most certainly underestimated relative to the R&D effort reported for other countries.

[57] The magnitude of the amounts estimated as basic research also is affected by how R&D expenditures are themselves estimated by national authorities. International R&D survey standards recommend that both capital and current expenditures be included in the R&D estimates, including amounts expended on basic research. Each of the non-U.S. countries displayed in figure 4-30 includes capital expenditures on fixed assets at the time they took place (OECD 1999b). All U.S. R&D data reported in the figure include depreciation charges instead of capital expenditures. U.S. R&D plant data (not shown in the figure) are distinct from current fund expenditures on R&D.

[58] The most current character of work data available from OECD sources for Germany are for 1993. The United Kingdom compiles such data only for the industry and government sectors, not for higher education or its nonprofit sector, the traditional locus of basic research activities.

[59] Country data are for 1998 or 1999. (See appendix table 4-42.)

[60] Whereas GUF block grants are reported separately for Japan, Canada, and European countries, the United States does not have an equivalent GUF category. In the U.S., funds to the university sector are distributed to address the objectives of the Federal agencies that provide the R&D funds. Nor is GUF equivalent to basic research. The treatment of GUF is one of the major areas of difficulty in making international R&D comparisons. In many countries, governments support academic research primarily through largeblock grants that are used at the discretion of each individual higher education institution to cover administrative, teaching, and research costs. Only the R&D component of GUF is included in national R&D statistics, but problems arise in identifying the amount of the R&D component and the objective of the research. Government GUF support is in addition to support provided in the form of earmarked, directed, or project-specific grants and contracts (funds for which can be assigned to specific socioeconomic categories). In the United States, the Federal Government (although not necessarily state governments) is much more directly involved in choosing which academic research projects are supported than are national governments in Europe and elsewhere. In each of the European G-7 countries, GUF accounts for 50 percent or more of total government R&D to universities and for roughly 40 percent of the Canadian government academic R&D support. Thus, these data indicate not only relative international funding priorities but also funding mechanisms and philosophies regarding the best methods for financing research.

[61] In international S&E field compilations, the natural sciences comprise math and computer sciences, physical sciences, environmental sciences, and all life sciences other than medical and agricultural sciences. Also note that the U.S. academic R&D effort is considerably larger than in any other country and the U.S. total ($25 billion PPP) is comparable with the combined R&D total ($29 billion PPP) of the other seven countries listed in text table 4-15.

[62] Similar industrial R&D details for Switzerland and South Korea (which report the fourth and sixth highest R&D/GDP ratios in the world, respectively) were not available from OECD harmonized databases (OECD 2000a).

[63] See OECD (1999a) for a harmonized historical series on industry R&D expenditures in several OECD countries.

[64] Since the mid-1980s, EC funding of R&D has become increasingly concentrated in its multinational Framework Programmes for Research and Technological Development (RTD), which were intended to strengthen the scientific and technological bases of community industry and to encourage it to become more internationally competitive. EC funds distributed to member countries' firms and universities have grown considerably. The EC budget for RTD activities has grown steadily from 3.7 billion European Currency Units (ECU) in the First Framework Programme (1984–87) to an estimated 15 billion ECU for the Fifth Framework Programme that runs from 1998 to 2002. The institutional recipients of these would tend to report the source as "foreign" or " funds from abroad" (Eurostat 2001).

[65] Unlike for other countries, there are no data on foreign sources of U.S. R&D performance. The figures used here to approximate foreign involvement are derived from the estimated percentage of U.S. industrial performance undertaken by majority-owned (i.e., 50 percent or more) nonbank U.S. affiliates of foreign companies. In short, the U.S. foreign R&D totals represent industry funding based on foreign ownership regardless of originating source, whereas the foreign totals for other countries represent flows of foreign funds from outside the country to any of its domestic performers. See the extensive coverage of industrial foreign R&D investments in the following sections of this chapter.

[66] Data on the socioeconomic objectives of R&D funding are rarely obtained by special surveys; they are generally extracted in some way from national budgets. Because those budgets already have their own methodology and terminology, these R&D funding data are subject to comparability constraints not placed on other types of international R&D data sets. Notably, although each country adheres to the same criteria for distributing their R&D by objective as outlined in OECD's Frascati Manual (OECD 1994), the actual

classification may differ among countries because of differences in the primary objective of the various funding agents. Note also that these data reflect government R&D funds only, which account for widely divergent shares and absolute amounts of each country's R&D total.

[67] Health and environment programs include human health, social development, protection of the environment, and exploration and exploitation of the Earth and its atmosphere. R&D for "other purposes" in text table 4-17 includes nonoriented programs, advancement of research, and primarily GUF (e.g., the estimated R&D content of block grants to universities described in note 56).

[68] See Kaiser et al. (1999) for a description on recent efforts to make higher education R&D data more internationally comparable.

[69] As an added indication of evolving government priorities in Russia, fully 27 percent of the government's 1998 R&D budget appropriations for economic programs were used to assist in the conversion of the country's defense industry to civil applications (AAAS and CSRS 2001).

[70] In the United States, "advancement of knowledge" is a budgetary category for research unrelated to a specific national objective. Furthermore, although GUF are reported separately for Japan, Canada, and European countries, the United States and Russia do not have an equivalent GUF category. In the United States, funds to the university sector are distributed to address the objectives of the Federal agencies that provide the R&D funds. GUF is not equivalent to basic research. For 1999, the GUF portion of total national governmental R&D support was 48 percent in Italy, 39 percent in Germany, 37 percent in Japan, and between 18 and 24 percent in the United Kingdom, Canada, and France.

APPENDIX ELEVEN
DOD Net Assessment Study of Chinese Military Indicators

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Warning Indicators for China's Military Transformation

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A country is serious about military transformation when a full-time transformation czar can be found at the very top of its political and military leadership. It helps if the uniformed military believes that a revolution in military affairs [1] is well underway, continues to be solidly behind the czar's vision, and sees the need to compete with other militaries by supporting very different concepts, experiments, doctrine, and materiel, as well as discarding legacy (outdated) officers, operational concepts, and organizations. This country, obviously not the United States, is China.

How did these and other transformation developments come to be? Anticipating the need to understand and to keep track of these kinds of issues, two products were developed about a decade ago by the Office of Net Assessment in the Office of the United States Secretary of Defense. They were intended to serve policymakers in crafting U.S military transformation and in long-term warning of the military transformation of others.
A preliminary assessment of the ongoing worldwide Revolution in Military Affairs (RMA) and indicators to track a military's RMA transformation were crafted. [2] The preliminary assessment focused on the information revolution and long-range precision weapons as the material basis for the ongoing RMA. But the assessment also demonstrated that doing well in this RMA required radical operational and organizational change. How past RMAs had played out, what the winners and losers did and did not do, were also recounted.
Transformation indicators were then created by drawing from the preliminary assessment; how institutions outside the military, e.g., businesses, were changing operationally and organizationally in the face of the information revolution; and, how businesses use indicators to assess competitors. [3]
The indicators were to be used for detecting the appearance of very different war fighting capabilities. There was little interest in evolutionary, continuous change or in military use of technology as a better way to do existing operational concepts using existing organizations. No interest was shown in opinions as to what a military might or might not be able to do; we wanted to know what they were actually doing. The intent was to detect trends, signs of change by militaries unlearning the past and creating entirely new warfare areas.
Indicators were crafted to be open to a wide variety of transformation indications. [4]
The indicator paper foresaw the need to assess long-term, high-consequence military trends. This was later articulated by Secretary of Defense Donald H. Rumsfeld who called for an approach to intelligence "… that does not wait for threats to emerge and be 'validated', but rather anticipates them before they emerge—and develops new capabilities to dissuade and deter those nascent threats."[5]
In collecting indications of military transformation, Chinese and other's use of perception management via strategic deception and denial should be considered. [6] For example, it may be in China's interest to have the United States and others believe that its military is decades behind in capabilities. Thus, on 16 July 2004, a newspaper with strong ties to China's military quoted Chinese military sources as saying Taiwan must become part of China in the next twenty years or face military action. [7] For some, this might imply China will wait for 20 years – possibly because of weakness - but twenty years is well beyond what China requires to take Taiwan militarily.

Because a military capability requires many key attributes, the indicator paper established nine categories for tracking military change and suggested what to look for, and where and how to look. [8] The nine transformation categories are: Jurisdiction, Policy & Procedures; Intelligence Priorities & Learning; Concepts; Studies, Simulations & Wargames; Experiments; Doctrine; Training; Organizations; and Materiel. The focus here is restricted to the first category: Jurisdiction, Policy and Procedures. Indicators for these are recounted, with corresponding indications of Chinese activity over the past decade then reported.

Jurisdiction

This purpose of this category was to determine if key people in a country really believed a discontinuity in warfare was underway. If so, jurisdiction over decisions and resources needed to transform its military may have been assigned or assumed. [9]

For example, in the American Civil War, a discontinuity in warfare was made possible by the rifle, the telegraph, and the railroad. [10] A vision of needed transformational change was conceived by President Abraham Lincoln, who also assumed jurisdiction and a hands-on approach to operational and organizational change.

Alternatively, jurisdiction may be entrusted to the various military services, a general staff, or a joint command. An informal transformation group, something like the U.S. Department of Defense's "airmobile mafia" of the 1950s, might also exist. In considering China, we want to know the structure and processes of these formal and informal groups. As during previous periods of discontinuous change, only a relatively small number of people are involved in the initial stages. [11] Discovering who these people are and whether they have the authority and power to institute transformation are necessary.

Indicator: Is China Taking a Laissez-Faire Approach to Transformation? Is There a "Transformation Czar"? And, If So, What Is the Czar's Vision of Future Warfare? Is the Czar Empowered with Broad Authority?

China's transformation czar is former President Jiang Zemin. Jiang has led, and continued until late September 2004 to lead, a full-time, People's Liberation Army (PLA) transformation in mind, spirit, and action. [12] Possibly because of his engineering and dialectical experience, Jiang realized many years ago that a major discontinuity in warfare was underway. As a political and military leader, he also understood the necessity of transforming the PLA. He probably also had the advantage of focusing on one major threat and one strategic problem. The enemy was the U.S. military, and the strategic problem was anti-access, i.e., denying the U.S. military its strategic backbone: power projection. [13]

Jiang Zemin's vision of future warfare, based on the ongoing revolution in military affairs [RMA], has been articulated in numerous writings. [14] His major points seem to be:

1. Historically, mankind has seen cold steel warfare, hot arms warfare, and mechanized warfare, and is now entering the stage of informational warfare.
2. China's military has yet to complete its mechanization, and the U.S. is leading in the information arena. Further, Chinese military structures remain far too hierarchical and bloated. The great barrier to transformation is the lag of organizational relationships in relation to information relationships. A reorganization of all combat groupings will be necessary.
3. China will not just follow and imitate, but will gain first place. But first place cannot be achieved by proceeding sequentially and waiting for mechanization to be completed before proceeding with informatization. This requires a policy of advancing simultaneously by leaps and bounds. The competition is about expediting the switchover from mechanization to informatization.
4. To gain first place, China must accept intense confrontation and competition, and must create more than imitate. Innovation, the soul of the new RMA, is needed in new operational concepts, strategies, organizations, and materiel.
5. How to fight and how to transform the military under the new conditions is the new management focus. As a late starter or second mover in the competition, China has special advantages.
6. As mechanization proceeds, information can be introduced leading to changes in organizations and operational concepts. In time, information will be seen as determining changes in mechanization, and eventually mechanized organizations becoming information organizations.

7. Resources must be placed into projects already enjoying a high starting point and which are highly effective.
8. Informatization concepts and materiel must be followed with weapon platforms and test beds for experimentation.
9. Old ideological thinking, taboos, policies, and procedures must be discarded.
10. Wars will no longer be won by a single service organization but by a system of new organizations. Ground-war thinking must be replaced by multidimensional, integrated thinking.

Jiang Zemin's vision is appropriately general for setting more specific policies, goals, and objectives. Taking their lead from Jiang, the Central Military Commission and academic institutions, such as the Academy of Military Sciences, have weighed in with insightful concept papers and field and fleet experiments. [15]

Jiang had the clout to make transformation happen. He largely controlled the military budget and did not have to worry about such things as parliamentary oversight. He was the agent of change, not individual services, as in other countries. He could, and he did, hire and fire. He had established transformation policy, oversaw its implementation and made sure transformation was swift.

The new Central Military Commission supports transformation, and the People's Liberation Army will use transformation criteria for war planning, officer training and promotion, doctrine, organizational change, and materiel acquisition. [16]

Jiang reportedly once told Central Military Commission members that his remaining task was to set the RMA as the guiding principle for the PLA reform. But as noted by a top student of the Chinese military, You Ji, observed: "Resistance has come from two schools of thought within the PLA: The former clings to the idea that war on the ground remains the key to any ultimate victory. The latter advocates military modernisation through generational upgrading. Put in another way, it is about realizing modernisation through mechanization (hardware building up) before informatization (software and IT development)."[17] Jiang spoke for the third and far more radical school, which holds that, a competition is underway and speed is all-important. The PLA must use the information revolution now to discontinuously advance PLA mechanized warfare capabilities.

Indicator: Who Constitutes the Formal Top Military and Political Leadership? Do They Support Transformation? What Do They See as the Most Significant Obstacles to Transformational Change and How Are They Overcoming These?

China's top military leadership is the Central Military Commission (CMC). As the supreme leading organ of the armed forces of the People's Republic of China, it directs and commands the national armed forces. [18] The CMC membership, as of early 2004, was:

Chairman: Jiang Zemin

Vice-Chairman: Hu Jintao, Guo Boxiong, Cao Gangchuan

Other CMC Members: Xu Caihou, Liang Guanglie, Liao Xilong, Li Jinai

The People's Liberation Army has supported Jiang's vision of future warfare for at least fifteen years. [19] Each CMC member believes a revolution in military affairs is underway, and each is an advocate for transformation. Except for Jiang Zemin, each was expected to stay in his position of power for many years. The new CMC membership is younger, better educated, and more professional than its predecessors. [20]

- General Guo Boxiong, Vice-chairman of the Central Military Commission, was given a specific mission when Jiang, Hu, Jintao and other CMC leaders conducted meetings of selection and appointment: to apply the RMA in PLA modernization."[21] General Guo will serve ten years in his position. [22]
- Cao Gangchuan is Defense Minister. James Mulvenon points to Cao's support of Jiang's jurisdiction [as in Cao's remarks after an important Jiang trans–formation speech] and concludes: "China's armed forces will definitely use General Secretary Jiang's important July 1 speech as its armament guideline."[23]
- Xu Caihou, Director of the General Political Department, is a long-time supporter of Jiang's transformation. [24]
- Liang Guanglie, Chief of the General Staff of the People's Liberation Army, is responsible for moving the PLA from an infantry-centric military to one joining all Services together by way of the information revolution and other revolution in military affairs insights. [25]
- Liao Xilong is Director of the General Logistics Department of the People's Liberation Army. As a military region commander, Liao is credited with successfully executing a major experiment in logistic reform,

what might be called a single, integrated and joint logistic system in the U.S. The reform is now being carried out in all military regions.

- Li Jinai is Director of the PLA General Armaments Department. This top military appointment is unusual because Li was a Political Commissar. "… General Li's major mission is to realize the grand plan laid by Jiang and the CMC to achieve a generational leap in terms of software and hardware development in the PLA in the next decade or so."[[26]]

The most significant obstacle to transformational change has been the deep and abiding power and value system of army generals, as reflected in the fact that the navy and air force are called the People's Liberation Army Navy and the People's Liberation Army Air Force. To overcome this, Jiang Zemin took a number of initiatives. For example, he stressed, over the past five years or so, the need to move from a land-centric view to one embracing sea, air, and electromagnetic dimensions. The CMC will continue to decrease the Army's influence by adding the transformation-oriented commanders of the 2nd Artillery, Navy, and Air Force. [[27]] Notably, the Navy head is a former Commandant of the Academy of Military Sciences, perhaps the prime source of transformation concepts and experiments. The land army has suffered the greatest reduction in manpower, and is getting the least amount of modernization resources. This reflects Jiang's success in "concentrating the resources on something but giving up on something else."

Support for Jiang's vision also comes from the top political level. For example, during the March 2004 National People's Congress, Premier Wen Jiabao set the primary policy line for the military, namely, that China "must actively seek to promote the revolution in military affairs with Chinese characteristics and make efforts to achieve developments by leaps and bounds in national defense and armed forces modernization" and this "must be dominated by informationization and based on mechanization." In this, "independent innovation" will be crucial. [[28]]

Indicator: Are Future Leaders Likely to Maintain Military Transformation Momentum?

Getting the word out about the need to transform China's military has been an enduring effort by Jiang Zemin, all senior military leaders, and school and academy heads. Transformation commentaries, forums, and seminars often feature the participation of the highest military leadership. [[29]]

Hu Jintao, China's President, not only supports transformation now as CMC Chairman, but also is also likely to do so in the future. [[30]] During the 16th CPC National Congress, Hu's speech on the RMA reflected Jiang's position that a discontinuity in warfare was underway, and that this was the consensus of the military and civilian leadership. [[31]] Hu became CMC chairman with Jiang's departure. In 2001, Hu reportedly led a "reform group" to reduce China's twenty-four group armies to eighteen, and reorganize the three naval fleets into eight to ten integrated fleets. [[32]] A campaign to study President Hu's commitment to transformation has been launched by the General Political Department, suggesting that Jiang Zemin's transformation efforts will endure for many years. [[33]]

Included in Jiang Zemin's military transformation vision is what he believes the Communist Party represents to the Chinese people. Known as the "Three Represents," General Xu Caihou's special and enduring task is to ensure that its military dimensions should not become a competition of "empty talk."[[34]] Xu's other tasks include assisting Hu Jintao in officer selection for the next round of leadership changes.

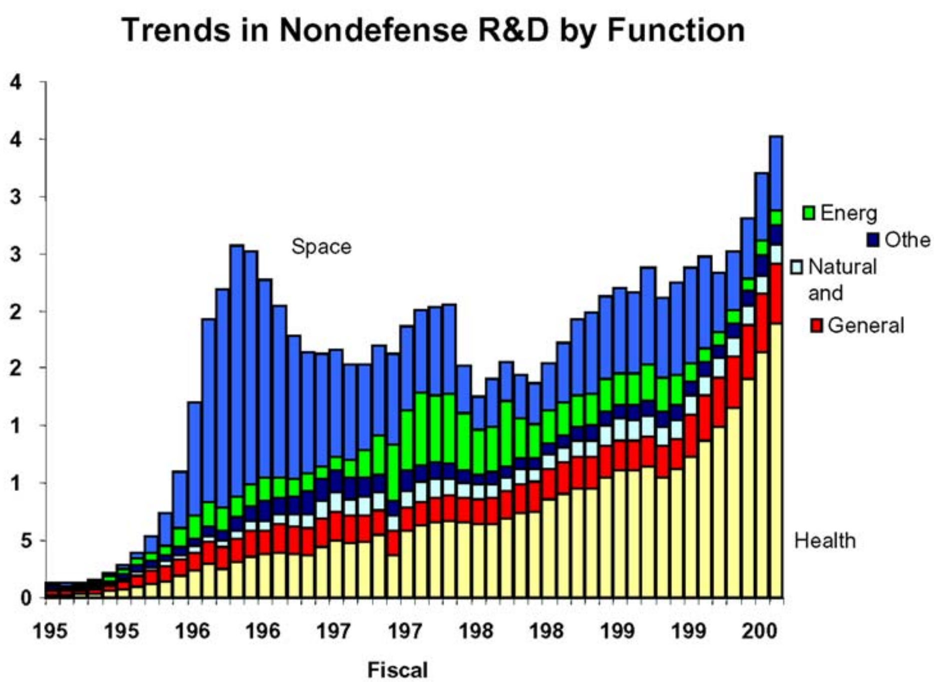
Policy and Procedures

Knowing something about top-level military and civilian transformation jurisdiction, what explicit or implicit transformation polices might follow? [[35]] What might be China's key military transformation policy premises: A competition is underway; is swiftness important? Is there a goal to do well? Do the policies amount to a genuine imperative to transform? [[36]]

Is there a transformation strategy? What are the indications of transformation progress? How does China think about transformation and, especially, how does it assess itself and other's transformation progress? Do RMA or legacy, status quo advocates conduct war games and war planning?

More questions can be asked. Is China formulating transformation-competitive strategies? Is it interested in influencing competitors' choices so that the institutions and leadership of other nations either deny, delay, or fail to adequately recognize that a welfare discontinuity is rapidly developing, thereby lulling them into "comfort zones” that appeal to their existing value systems, cognitive consistency, resistance to change, or desire for incremental change? [[37]]

APPENDIX TWELVE
Trends in U.S. R&D by Function



RECOMMENDATIONS OF THE SELECT COMMITTEE

TRANSMITTED ON JANUARY 3, 1999
TO THE PRESIDENT AND CONGRESS

Nuclear Weapons

1. Semi-Annual Report by the President on PRC Espionage

The Select Committee recommends that the President report to the Speaker and Minority Leader of the House, and the Majority Leader and Minority Leader of the Senate, no less frequently than every six months on the steps, including preventive action, being taken by the Department of Energy, the Department of Defense, the Federal Bureau of Investigation, the Central Intelligence Agency, and all other relevant Executive departments and agencies to respond to espionage by the People's Republic of China (PRC) as typified by the theft of sophisticated U.S. nuclear weapons design information, and the targeting by the PRC of U.S. nuclear weapons codes and other national security information of strategic concern.

2. Urgent Priority to Department of Energy Counterintelligence Program

As a matter of urgent priority, the Select Committee believes the Department of Energy must implement as quickly as possible and then sustain an effective counterintelligence program.

To this end, the Select Committee recommends the following:

3. Implementation and Adequacy of PDD-61

The appropriate congressional committees should review, as expeditiously as possible, the steps that the Executive branch is taking to implement Presidential Decision Directive 61 and determine whether the Administration is devoting, and Congress is providing, sufficient resources to such efforts and whether additional measures are required to put an adequate counterintelligence program in place at the Department of Energy at the earliest possible date.

4. Comprehensive Damage Assessment

The appropriate Executive departments and agencies should conduct a comprehensive damage assessment of the strategic implications of the security breaches that have taken place at the National Laboratories since the late 1970s (or earlier if relevant) to the present and report the findings to the appropriate congressional committees.

5. Legislation to Implement Urgent and Effective Counterintelligence

The appropriate congressional committees should report legislation, if necessary, to facilitate accomplishment of the objectives set forth above.

6. Five-Agency Inspectors General Examination of Scientific Exchange Program Risks to National Security

The Select Committee recommends that the Secretaries of State, Defense, and Energy, the Attorney General, and the Director of Central Intelligence direct their respective Inspectors General and appropriate counterintelligence officials to examine the risks to U.S. national security of international scientific exchange programs between the United States and the PRC that involve the National Laboratories. Such Executive department and agency heads shall transmit the results of these examinations, together with their views and recommendations, to the Speaker and the Minority Leader of the House, the Majority and Minority Leaders of the Senate, and appropriate congressional committees no later than July 1, 1999.

7. Congressional Examination of Whether Department of Energy Should Maintain U.S. Nuclear Weapons Responsibility

The Select Committee recommends that the appropriate congressional committees consider whether the current arrangements for controlling U.S. nuclear weapons development, testing, and maintenance within the Department of Energy are adequate to protect such weapons and related research and technology from theft and exploitation.

8. Intelligence Community Failure to Comply with National Security Act; Need for Congressional Oversight

In light of the fact that the heads of Executive departments and agencies of the intelligence community failed adequately to comply with congressional notification requirements of the National Security Act with respect to the theft of secrets from the National Laboratories, the Select Committee urges Congress to insist again on strict adherence to such legal obligations.

International Actions

With respect to international actions by the United States, the Select Committee recommends:

9. Need for PRC Compliance with the Missile Technology Control Regime

The United States should insist that the PRC adhere fully to, and abide by, the Missile Technology Control Regime and all applicable guidelines.

10. Need for U.S. Leadership to Enforce Missile Technology Control Regime

The United States must vigorously enforce, and seek multilateral compliance with, the Missile Technology Control Regime.

11. Need for U.S. Leadership to Establish Binding International Proliferation Controls

In light of the demise of the Coordinating Committee on Multilateral Export Controls (COCOM) and the insufficiency of the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, the United States should work, including in the context of the scheduled 1999 review of the Wassenaar Arrangement, to establish new binding international controls on technology transfers that threaten international peace and U.S. national security.

12. U. S. Action to Improve Multilateral Tracking of Sensitive Technology Exports

In light of the demise of COCOM and the insufficiency of the Wassenaar Arrangement, the Select Committee recommends that the United States take appropriate action, including in the context of the scheduled 1999 review of the Wassenaar Arrangement, to improve the sharing of information by nations that are major exporters of technology so that the United States can track movements of technology and enforce technology control and re-export requirements.

13. U.S. Action to Stem Russian Weapons Proliferation to PRC

In light of the PRC's aggressive military technology acquisition campaign and its record as a proliferator, the United States should work to reduce the transfers of weapons systems and other militarily significant technologies from Russia and other nations to the PRC. These actions should include strengthening international measures, including economic incentives, to encourage Russia to become a full partner in stemming the proliferation of weapons.

14. New Legal Requirements for Executive Branch Reporting on Proliferation

Appropriate congressional committees should report legislation requiring the Secretary of State, the Director of Central Intelligence, and the heads of other relevant Executive departments and agencies to report in a timely fashion to appropriate congressional committees, including the House Permanent Select Committee on Intelligence and the Senate Select Committee on Intelligence, on technology transfers that raise a proliferation concern and on the implementation of all the foregoing recommendations for international actions by the United States.

Satellite Launches

15. Implementation of the Strom Thurmond National Defense Authorization Act for FY 1999

The Select Committee expects that the Executive branch will aggressively implement the Satellite Export Control Provisions of the Strom Thurmond National Defense Authorization Act for FY 1999.

16. State Department Should Have Sole Satellite Licensing Authority

To protect the national security, the congressional judgment that the Department of State is the appropriate agency for licensing both exports of satellites and any satellite launch failure investigations must be faithfully and fully implemented.

17. State Department Need for Adequate Personnel and Resources for Satellite Export Licensing

To protect the national interest in foreign commerce, the Department of State must ensure, consistent with national security, that satellite export licenses and notices to Congress are acted on in a timely fashion and that exporters are informed about the progress of their applications and have access to appropriate dispute resolution procedures. In order to achieve the foregoing, the Executive branch and the Congress should ensure that the Department of State has adequate personnel and resources devoted to processing export license applications.

18. Corrective Tax Legislation for Satellite Exports

To ensure that satellite manufacturers are not disadvantaged in such collateral areas as tax credits by the transfer to the State Department of responsibility to license satellite exports, the appropriate congressional committees should report necessary legislation.

19. Heightened Requirements for Defense Department Monitoring of Foreign Launches

The Department of Defense must give high priority to its obligations under the Strom Thurmond National Defense Authorization Act, including requirements for (i) recruiting, training, and maintaining a staff dedicated to monitoring launches in foreign countries of U.S. satellites; and (ii) establishing and monitoring technology control plans to prevent any transfer of information that could be used by the PRC to improve its missile launch capabilities.

20. Defense Department, Not Satellite Firms, Should Be Responsible for Security at Foreign Launches

The Select Committee recommends that the appropriate congressional committees report legislation providing that, in connection with foreign launches of U.S. satellites, the Department of Defense shall contract for security personnel who have undergone background checks to verify their loyalty and reliability. The number of guards shall be sufficient to maintain 24-hour security of the satellite and all related missile and other sensitive technology. The satellite export licensee shall, as a condition of licensure, be required to reimburse the Department of Defense for all associated costs of such security.

21. Need for Adequate and Permanent Force of Well Trained Defense Department Monitors

The Department of Defense shall ensure sufficient training for space launch campaign monitors and the assignment of adequate numbers of monitors to space launch campaigns. The Department of Defense also shall ensure continuity of service by monitors for the entire space launch campaign period, from satellite marketing to launch, and, if necessary, completion of a launch failure analysis. In addition, the Department of Defense shall adopt measures to make service as a monitor an attractive career opportunity.

22. Need for Full and Timely Reporting of Technology Passed to PRC, and of Foreign Launch Security Violations

The Department of Defense monitors shall maintain logs of all information authorized for transmission to the PRC, including copies of any documents authorized for transmittal, and reports on launch-related activities. Such information shall be transmitted on a current basis to the Departments of Defense, State, and Commerce, and to the Central Intelligence Agency. Such documents shall be retained for at least the period of the statute of limitations for violations of the International Traffic in Arms Regulations (ITAR). In addition, the Department of Defense shall adopt clear written guidelines providing monitors the responsibility and the ability to report serious security violations, problems, and issues at the overseas launch site directly to the headquarters office of the responsible Defense Department agency.

23. Application of Export Control Laws to Space Launch Insurers

The Select Committee recommends that relevant Executive departments and agencies ensure that the laws and regulations establishing and implementing export controls are applied in full to communications among satellite manufacturers, purchasers, and the insurance industry, including communications after launch failures.

24. Expansion of U.S. Launch Capacity in National Security Interest

In light of the impact on U.S. national security of insufficient domestic, commercial space-launch capacity and competition, the Select Committee recommends that appropriate congressional committees report legislation to encourage and stimulate further the expansion of such capacity and competition.

High Performance Computers

The Select Committee supports the sale of computers to the PRC for commercial but not military purposes. The Select Committee recommends that the appropriate congressional committees report legislation that requires the following:

25. Legislation to Require Comprehensive Testing of HPCs, Clustering, and Massive Parallel Processing in National Security Applications

The Select Committee recommends that appropriate congressional committees report legislation directing the Department of Energy, in consultation with the Department of Defense, to conduct a comprehensive review of the national security implications of exporting high-performance computers (HPCs) to the PRC. This review should include empirical testing of the extent to which national security related operations can be performed using clustered, massively-parallel processing or other combinations of computers.

26. Annual Threat Assessment of HPC Exports to PRC

The Select Committee recommends that appropriate congressional committees report legislation directing the Intelligence Community to conduct an annual comprehensive threat assessment of the national security implications of the export to the PRC of HPCs and other computers that can be clustered or combined through massively parallel processing.

27. End Use Verification for PRC Use of HPCs

The Select Committee recommends that the appropriate congressional committees report legislation that requires:

- As a condition to U.S. HPC export licensing, the establishment by the PRC of an open and transparent system by September 30, 1999, which provides for effective end-use verification for HPCs sold or to be sold to the PRC and, at a minimum, provides for on-site inspection of the end-use and end-user of such HPCs, without notice, by U.S. nationals designated by the U.S. Government.

- Failure to establish such a system by that date should result in the U.S. Government's lowering the performance level of HPCs that may be exported to the PRC, the denial of export licenses for computers destined to the PRC, or other appropriate measures.

- An independent evaluation of the feasibility of improving end-use verification for HPCs in the PRC, and preventing the use of such HPCs for military purposes.

28. U.S. Leadership for Multinational HPC Export Policies

The Select Committee recommends that the appropriate congressional committees report legislation that requires efforts by the Executive branch to encourage other computer-manufacturing countries, especially those countries that manufacture HPCs, to adopt similar policies toward HPC exports to the PRC.

Export Legislation and Other Technology Controls

The Select Committee believes that it is in the national interest to encourage commercial exports to the PRC, and to protect against the export of militarily sensitive technologies. To this end:

29. Reauthorization of Export Administration Act

The Select Committee recommends that the appropriate congressional committees report legislation to reenact the Export Administration Act, with particular attention to re-establishing the higher penalties for violation of the Act that have been allowed to lapse since 1994.

30. Prioritization of National Security Concerns With Controlled Technologies; Continuous Updating

Relevant Executive departments and agencies should establish a mechanism to identify, on a continuing basis, those controlled technologies and items that are of greatest national security concern.

31. Executive Department Approvals for Exports of Greatest National Security Concern

With respect to those controlled technologies and items that are of greatest national security concern, current licensing procedures should be modified:

- To provide longer review periods when deemed necessary by any reviewing Executive department or agency on national security grounds; and

- To require a consensus by all reviewing Executive departments and agencies for license approval, subject to appeal procedures.

32. Streamlined Licensing Procedures

With respect to controlled technologies and items that are not of greatest national security concern, current licensing procedures should be modified to streamline the process and provide greater transparency, predictability, and certainty.

33. Effect of Maintaining Looser National Security Controls for Hong Kong Since Its Absorption by PRC on July 1, 1997

The Select Committee recommends that appropriate congressional committees report legislation requiring appropriate Executive departments and agencies to conduct an initial study, followed by periodic reviews, of the sufficiency of customs arrangements maintained by Hong Kong with respect to the PRC and the appropriateness of continuing to treat the Hong Kong S.A.R. differently from the PRC for U.S. export control purposes. Such a study should consider, among other things, the implications of unmonitored border crossings by vehicles of the People's Liberation Army.

34. Mandatory Notice of PRC or Other Foreign Acquisition of U.S. National Security Industries

The Select Committee recommends that appropriate congressional committees report legislation amending the Defense Production Act of 1950 to require notice to the Committee on Foreign Investment in the United States (CFIUS) by all U.S. companies that conduct national security-related business of any planned merger, acquisition, or takeover of the company by a foreign entity or by a U.S. entity controlled by a foreign entity. The amendment also should require Executive departments and agencies to notify CFIUS of their knowledge of any such merger, acquisition, or takeover.

Intelligence/Counterintelligence Issues

35. Comprehensive Counterintelligence Threat Assessment of PRC Espionage

Supplementing its recommendations with respect to security at the National Laboratories, the Select Committee further recommends that Executive departments and agencies with counterintelligence expertise undertake a comprehensive counterintelligence threat assessment of PRC espionage targeted against U.S. public and private entities.

36. Legislation to Improve Sharing of Sensitive Law Enforcement Information within the Executive Branch

The Select Committee recommends that appropriate congressional committees report legislation to authorize and direct the Department of Justice to promptly share national security information, on a classified basis, with appropriate Executive departments, agencies, and entities. To achieve this objective, the Select Committee recommends the creation of an appropriate interagency mechanism.

37. Five-Agency Inspectors General Examination of Countermeasures Against PRC Acquisition of Militarily Sensitive Technology

The Select Committee recommends that appropriate congressional committees require the Secretaries of State, Defense, Commerce, and the Treasury and the Director of Central Intelligence to direct their respective Inspectors General to investigate the adequacy of current export controls and counterintelligence measures to protect against the acquisition by the PRC of militarily-sensitive U.S. technology, and to report to Congress by July 1, 1999, regarding their findings and measures being undertaken to address deficiencies in these areas.

38. All-Source Intelligence Analysis of PRC Plans for Technology Acquisition

The Select Committee recommends that appropriate congressional committees report legislation directing the Intelligence Community to undertake and maintain a current, all-source analysis of PRC aims, goals, and objectives with respect to the acquisition of foreign, and particularly U.S., technologies, including, for example, PRC efforts to exploit the open character of U.S. society by penetrating businesses, academic and social institutions, and political practices. Such legislation should include a requirement to report on the adequacy of resources, encouragement, and priority status accorded all-source intelligence collection and analysis by relevant Executive departments and agencies concerning the PRC and PRC counterintelligence.