RESEARCH REPORT ON CHINESE HIGH-TECH INDUSTRIES

U.S. China Economic and Security Review Commission

Prepared by NSD Bio Group, LLC
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Preface

In recent years there has been increasing concern with respect to the People Republic of China's (PRC) intensified activities and efforts towards selected high technology industries ("Sunrise") sectors - namely Biotechnology, Nanotechnology, and Electro-Optics of the PRC science and technology (S&T) industries. Issues driving interest in these areas are numerous and varied.

This report attempts to shed light and insight on specific issues addressing potential implications to U.S. military, economic, and national security as China continues its accelerative pace in securing and developing advanced technologies. In light of ongoing reconfigurations of the economic landscape on a worldwide scale, as a result of unprecedented constraints and collapses of financial markets and credit liquidity, insolvency of numerous businesses and operations, and a severe loss of collective confidence, though earlier priorities of overseas trends may have been adjusted accordingly, they still remain on the forefront. National concern in the United States has arisen that the country's once unparalleled position as leader in science and technology has been eroded by a number of factors. These external and internal factors include the globalization of S&T, the rise and development of science centers and technology zones in developing countries such as China and India, and the perception that the U.S. is not investing enough in its future given the existing pressures on its complex and interconnected S&T enterprise. It has been well documented and recorded that a loss of this leadership could potentially hurt the U.S. economy, living standards, and national security. Some would even argue that we are witness of the beginning of that erosion accelerated by the existing financial and economic upheaval.

The U.S. China Economic and Security Review Commission has requested NSD Bio Group, LLC to produce a one-time report addressing particular "Sunrise" sectors of the PRC, recognized as key drivers contributing to China's widening economic, financial, and national security development. The selected geographic areas covered in this report, reflects a desire to present a fair representation of the state of R&D on these specific sectors within the PRC in both well known and more established areas (Beijing, Shanghai, and Tianjin), as well as in lesser known, but emerging hubs of S&T activity (Harbin and Kunming) to the Commission.

This report draws on and adds to the many papers, reports, public hearings, and testimonies previously submitted and witnessed by the Commission as part of its long-standing mission to monitor and report to Congress, the economic and national security dimensions of the United States' trade and economic ties with the PRC.

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Part 1: Introduction

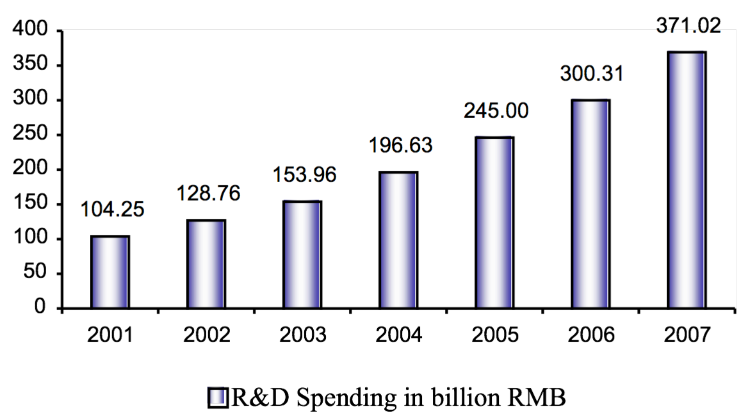
As the world's most influential developing country, China has been making remarkable efforts for many decades to catch up with developed countries in high-tech sectors. According to China's Prime Minister Wen Jiabao,[1] China's efforts to fuel the expansion of S&T includes the top five key areas:

1. Energy, Water resource, and Environment-protection technologies
2. Core technologies - Equipment Manufacturing and IT industries
3. Biotechnology
4. Aerospace and Marine Technologies
5. Basic scientific research and frontier technologies

- National R&D spending

China's spending on research and development (R&D) has increased dramatically in recent years (Fig 1). Based on our analysis on the official data released by China's National Bureau of Statistics, the Ministry of Science and Technology, and the Ministry of Finance, [2] China's spending on R&D has grown at an average of 22.54% annually between 2001 and 2007. The country's R&D spending reached a historic new high in 2007, with 371.02B RMB (54.6B USD) spending on R&D and 23.5% year-over-year increase. Its R&D intensity, namely the R&D spending as a percentage of GDP, climbed from 1.10% in 2001 to 1.49% in 2007. [2] Based on China's "11th National Economic and Social Development Five-year Plan", the country is aimed to increase the R&D intensity to 2% by 2010.

Figure 1: China's R&D spending (2001-2007) [2]



[1] Wen, Jiabao. Closing Speech at "National S&T Convention". Beijing, Jan. 11, 2006.
[2] Statistic Bulletins on National Spending on R&D 2001-2007. National Bureau of Statistics of China. Available at: http://www.stats.gov.cn/tjgb/rdpcgb/qgrdpcgb/index.htm (in Chinese)

Noticeable, private enterprises are playing an increasingly important part in China's R&D infrastructure. In 2007, Non-public enterprises in China accounted for 72.3% of the total spending, while government research institutions only accounted for 18.5% of the total spending, and university research institutions accounted for 8.5%. [3]

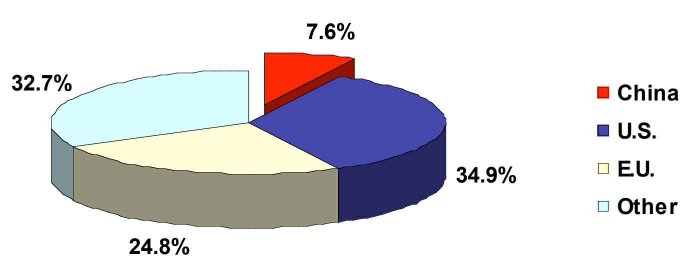
In China, the top 3 provinces or municipalities with the highest R&D spending in 2007 were Beijing, Jiangsu and Guangdong (Table 1). [3]

Table 1: Top 12 Provinces/Municipalities with the highest R&D Spending in 2007

Province	R&D Spending （billion RMB）	R&D Intensity (%)
Beijing	50.54	5.40
Jiangsu	43.02	1.67
Guangdong	40.43	1.30
Shandong	31.23	1.20
Shanghai	30.75	2.52
Zhejiang	28.16	1.50
Liaoning	16.54	1.50
Sichuan	13.91	1.32
Shanxi	12.17	2.23
Tianjin	11.47	2.27
Hubei	11.13	1.21
Henan	10.11	0.67

From the global landscape, China is currently the second to third highest investor in R&D, following the United States and Japan. However, China's global share remains at a much lower level (less than 8%), compared to 35% of global share of the U.S., according to the OECD data. [4]

Figure 2: China's Global Share in terms of Gross R&D Expenditure [4]



- R&D human resources stock

[3] National Statistics Bureau of China, Ministry of Science and Technology, Ministry of Finance. 2007 National Science and Technology Investment Statistic Bulletin, Jan. 9, 2009. Available at: http://www.casted.org.cn/web/index.php?ChannelID=14&NewsID=3551
[4] OECD Science, Technology and Industry Outlook 2008 Highlights. Available at : http://www.oecd.org/dataoecd/18/32/41551978.pdf

The growing number of the Chinese R&D labor force have played a key role in advancing China's research level. According to the National Statistics Bureau, China has 4.54 million S&T workers, 82% of them are engineers or scientists. [5] The number of Chinese returnees with overseas education background also showed an increase, growing from 20,000 in 2003 to 35,000 in 2005.[6]

An OECD study in 2006 showed that in China, the number of researchers increased by 77% between 1995 and 2004. China now ranks second worldwide with 926,000 researchers, just behind the U.S. (more than 1.3 million) and ahead of Japan. [7]

- Innovation system

For many decades, China's weak innovation capacities had become a significant bottleneck that hindered China's economical and social advancement. The country used to engage in reproduction of foreign-developed products, as a result of lack of Chinese-developed core competencies in advanced technologies.

In recent years, China has recognized the importance of innovation, and the government has put "independent innovation" on its top national agenda. During the 17th National Congress, which took place in October 2007, China's President Hu Jintao pointed out that the core of China's national development strategy is "To enhance China's capacity for independent innovation and make China an innovative country." [8] [9] The Ministry of Science and Technology of China emphasizes innovation as "the soul of a nation".

According to Mr. Xu Guanhua - Minister of Science and Technology, China has established a basic national innovation system since 2006. China takes pride in critical breakthroughs in recent years, including Manned Space Engineering (Shenzhou No. 5, 6,7), Jian-10 fighter plane, "Galaxy Serial Super-computer", core software; integrate circuit equipment, gas turbine, breeding technology for "Super Rice", Human Genome Project, and innovative new drug development.

Chinese government strives to promote enterprise-focused innovation system by helping many "National Key Enterprises" establish their technology platforms. By 2007, China has set up and recognized 499 "National Enterprise Technology Centers" and 4,023 "Provincial Enterprise Technology Centers", with a total investment of 80B RMB (~11.7B USD) for the former, and 2,000B RMB (~292.5B USD) for the latter, respectively [5]

- National programs to subsidize R&D

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[5] National Bureau of Statistics: Noticeable Achievements in S&T Innovation—14 of the serial report from "Reports on the 30 years since reform and opening" (in Chinese). Available at: http://www.casted.org.cn/web/index.php?ChannelID=14&NewsID=3453

[6] China Association of Science and Technology. Report on the Development of Science and Technology Human Resources in China, Apr. 29, 2008 (in Chinese)

[7] OECD: China will become world's second highest investor in R&D by end of 2006. Available at: http://www.oecd.org/document/26/0,2340,en_2649_37417_37770522_1_1_1_37417,00.html

[8] Hu Jintao. Report to the Seventeenth National Congress of the Communist Party of China. Oct. 15, 2007

[9] China's 2006 National Defense White Paper

Since 1986, Chinese governments at various levels have launched many public funding programs to subsidize R&D activities. These programs include the 863 Program, 973 Program, Gong Guan Program, National Key Technology R&D Program (Zhi-Zheng Program), National Key National Natural Science Foundation of China (NSFC), Climbing Mountain (Deng Shan) Program and 211 Project.

- Patents and publications

China's patent applications and authorizations also showed a double-digit increase, with an average increase of 16.7% and 25%, respectively, from 1986 to 2007. China's world-ranking in terms of patent application rose from the 22nd place in 1997 to the 7th place in 2007. The patent applications totaled 5,456 in 2007. [4]

China's ranking in scientific publications also jumped dramatically over the past two decades, as shown in Table 2:

Table 2: China's scientific publications in 2006[4]

	Number	World Ranking	
		2007	**1987**
SCI	71,000	5	24
EI	36,000	2	10
ISTP	65,000	2	14

- National High-Tech Parks

The Chinese government has been building and developing national level high-tech parks since 1988. Through 20 years' effort, national high-tech parks in China totaled 54 by the end of 2007, with 48,000 in-park enterprises, employing 6.5 million people. These high-tech parks generated a total of 5,500 Billion RMB of revenue in 2007. [4]

- China-foreign linkages

The growing relationship between China and the West is becoming increasingly essential among China's R&D endeavors. Chinese research institutions strive to establish a solid relationship with their foreign peers to keep current with the world's technology advancements. During the 1990s, thousands of Chinese researchers have been sent to the West to acquire research experience. Chinese institutions open their doors to the foreign academic or research delegates. At the beginning of the 21st Century, a growing number of returning scientists have been assigned important positions in many Chinese research institutions. In recent years, there has been a growing presence of foreign R&D operations in China.

Today, China is facing unprecedented opportunities and challenges to enhance its R&D capacities. Yet, Chinese scientists continue to make advancements in many high-tech sectors, particularly in the biotechnology, nanotechnology and electro-optics industries, as reported.

Part 2: Biotechnology

Biotechnology is one of the top five national S&T strategic development priorities, as designated by the 'National Mid-to-Long Term S&T Development Plan' (2006-2020). In December 2004, the State Council officially formed a 'National Biotech R&D and Commercialization Leading Group' to provide guidance on biotech research and commercialization. The Ministry of S&T has given extra support to the industry during the past two decades, since the launch of the 863 Program in 1986. Other government authorities such as National Development and Reform Commission (NDRC), Ministry of Education, Ministry of Health, Ministry of Agriculture, State Food and Drug Administration (SFDA), also give the Biotechnology sector high priority.

Today, modern biotechnology represents a 60B RMB (~8.8B USD) industry size in China, while traditional biotech industry has witnessed an astonishing 300B RMB (~44B USD) of annual revenue. 2,800 biotech firms or institutions employ a total of approximately 40,000 research professionals across China. [10]

China's earliest achievement in biotechnology can be traced back to 1965, when Chinese scientists successfully synthesized the world's first crystalline bovine insulin through seven years' efforts.[11] Chinese scientists also took the lead in synthesizing Yeast Alanine transfer RNA in the early 1980s.[11] Internationally, China participated and completed 1% of Human Genome Project (HGP) and 10% of HapMap Project. China also plays a significant role in the international collaborative Human Liver Proteome Project (HLPP). [10]

China is the world's largest producer for traditional biotech products such as vaccines, penicillin, Vitamin C, Monosodium Glutamate (MSG), beer, and Ammonia Acid. The country currently ranks the third place in planting trans-gene plants. China-developed P-53 injection is the first gene therapeutic ever approved in the world.

1. Current Efforts/Major Institutional Linkages (Beijing)

As the capital of China, Beijing is the political and culture center of China. It is also the center of creativity and research having 256 national research academies, institutions and universities, including the Chinese Academy of Sciences, Chinese Academy of Medical Sciences, Chinese Academy of Traditional Chinese Medicine, Tsinghua University, Peking University, China Agriculture University, Beijing Normal University.

In 2007, Beijing spent 52.7B RMB (~7.7B USD) on R&D activities, including 26.4B RMB (~3.8B USD) from government, 21.01B RMB (~3.1B USD) from companies, and 2.76B RMB

[10] Liu, Yanhua. Enhance technology innovation and lead bioindustry. Speech for "2008 China Bioindustry Convention". Changsha, June 2008

[11] Chou Y., Jiang T., Zhang X., et. al. Overview of China's modern biotechnology and suggestions on facilitating biotech industrialization [in Chinese]. Modernizing Agriculture 2007, 2: 14-16

(~404.7M USD) from outside China. Beijing also received 12.27B RMB (~1.8B USD) research funding from national level projects, including 47% of the Project 973 funding and 22.8% of Project 863 funding.

Beijing is one of the most innovative regions in China, providing and encouraging an "entrepreneurial" environment for the Bio-industry. In terms of sheer numbers, Beijing has 507 national and city level research institutes, and its participants in this sector receives about one third of all national awards for technology innovations. In addition to the many biopharmaceutical and other biotech companies, research institutions have also contributed greatly to Beijing's innovation network. Supported by multiple investment mechanisms from the Beijing Municipal Commission of Science and Technology, in recent years several start-up R&D companies have been founded, such as Sino GenoMax Co., Beijing Weiming Kaituo, Sinovac Biotech, Syngenta Biotechnology (China), etc.

The region enjoys absolute leadership status in China for biomedical research. About 40% of national biological research funding is invested in Beijing, which supports many research institutions and universities. Beijing has established policies to accelerate the biopharmaceutical industry in its 11th Five-Year plan. With continued active participation in international collaborations, companies in Beijing have begun to proactively acquire technologies from abroad.

It is widely recognized that Beijing is one of the most energetic Biotechnology hubs in all of China. There are a number of specified sectors within the wide-ranging Bioindustry in Beijing, which continues to deepen. Two examples are Genomics and Stem Cell Research.

Beijing is the leader in China for genomics research, represented by several key technology enterprises, such as the Chinese National Human Genome Center, Beijing Genomics Institute (BGI) and Beijing Institute of Genomics of CAC. Active participants within the Beijing Stem Cell community includes the Stem Cell Research Center of Peking University, Institute of Transfusion Medicine, Academy Military of Medical Science, Blood Institute of the People's Hospital, Xuanwu Hospital, and the Weixiao Hematopoietic Stem Cells Bank.

In addition to institutions previously stated, additional leading institutions include the Beijing Proteomics Research Center (BPRC), a national proteomics research organization located in the Zhongguancun Life Sciences Park. BPRC was created from collaboration between the Chinese Academy of Sciences (CAS), Chinese Academy of Medical Sciences, Tshinghua University and Jiangzhong Pharma, with support from the Ministry of Science and Technology (MOST), National Development and Reform Commission (NDRC) and the Bureau of Science and Technology of Beijing Municipal Government, Chinese Academy of Military Medical Sciences and Jiangzhong Pharma. Recognized by the Human Proteome Organization (HUPO – www.hupo.org), the BPRC is the executive headquarters of the Human Liver Proteome Project (HLPP). After been recognized by MOST and China Human Proteome Organization, this center became the organizer and main contributor for the Chinese Human Liver Proteome Project (CNHLPP). In November 2006, BPRC formed a joint proteomics laboratory with Applied Biosystems; one of the leading key laboratories in China is the Viral Genetic Engineering

National Key Laboratory (Beijing Institute of Genomics of CAC), established in 1987, which also hosts the Microbial Genome Research Center of the Ministry of Health;

Other examples of firms includes Beijing Weiming Kaituo Agriculture Biotech Co., Ltd. (BWK) (www.bwkcrop.com/EN/News/Info/200808241828122274A9H558.shtml) BWK was founded by a consortium comprised of Peking University, the Institute of Genetics and Developmental Biology of CAS, Institute of Biotechnology of CAAS and the Beijing Academy of Agriculture and Forestry Sciences. The MOST approved and recognized this new corporation as the National Centre for Molecular Crop Design; Another of many examples, is the National Key Laboratory of Molecular Virology and Genetic Engineering (Vector Gene Technology Company Ltd.) (www.agtc.com.cn/agtc_en), partnering with Microbix Biosystems (www.microbix.com/), a Canadian company in 2004, as part of ongoing activities of Beijing's international collaborations.

2. Current Efforts/Major Institutional Significant Linkages (Shanghai)

Shanghai continues to play a leading role in the development of the Chinese Bioindustry, and the pharmaceutical sector in particular, with Biological medicine (Biomedicine) being a high priority of the Chinese government.

In Shanghai, there are more than 30 research institutes and close to nearly 40 laboratories and research centers at or above the provincial level focusing on biomedicine, agriculture biotechnology, and biologics manufacturing.

There are a significant number of enterprises involved in biomedicine, including 46 large and medium-size enterprises such as Shanghai Pharmaceutical Group and Shanghai Fosun Pharmaceutical Group. World-renowned multinational companies (MNC), such as GlaxoSmithKline (GSK), Johnson & Johnson, Bristol-Myers Squibb, Roche and Novartis, have long ago set up R&D facilities and/or headquarters in Shanghai. In addition, several domestic large and medium-size pharmaceutical groups, including Yangtze River Pharmaceutical Company Ltd, (http://www.yangzijiang.com) Shanghai Hengrui Pharmaceuticals, Huiren Pharmaceuticals, and Shenzhen Sanjiu Pharmaceuticals, have established production and R&D bases here.

Many types of collaborations are established between various institutions. Although far too many to all list, what follows is a fair representation of such connections as confined to the scope of this report.

Shanghai Institute for Biological Sciences has successively established multiple kinds of cooperative relationships with eight universities in Shanghai and its surrounding areas, including Shanghai Jiaotong University, Tongji University, Fudan University, East China Normal University, and Shanghai University of Chinese Traditional Medicine. The Institute Pasteur of Shanghai and Shanghai Municipal Center for Disease Control & Prevention (Shanghai Municipal Institute for Preventive Medicine) have signed cooperative agreement for scientific research projects.

Local and regional governmental connections include: Shanghai Institute for Biological Sciences and the Huzhou Municipal Government has jointly established the Shanghai Institute for Biological Sciences-Huzhou Technical Center for Industrial Biology; Shanghai Institute for Biological Sciences has partnered with Shanghai Xuhui District Government to establish Shanghai Juke Biotech Park; Other representative alliances are: Fudan University and Changning District; Tongji University's Science and Technology Departments and Guizhou Province; Fudan University and Nanchang Municipal Government.

Examples of connections with U.S./Western firms from 2002 and beyond include an alliance between the Shanghai Science and Technology Commission and the National Research Council Industrial Research Assistance Program (NRC-IRAP) on scientific-technical cooperation in support of Chinese-Canadian joint R&D efforts; between Shanghai Institute of Materia Medica (SIMM) and France Servier Laboratories Group towards cooperative R&D; and between the National Center for Drug Screening and Invitrogen Company on cooperative research projects; Shanghai Jiaotong University has established meaningful relationships (both cooperative scientific research and establishment of joint laboratory entities) with nearly 40 Western universities including Stanford University, Yale, Harvard, Massachusetts Institute of Technology, Ecole Normale Super, Cambridge University, Toronto University, Moscow Power Engineering Institute, and Kyoto University. In 2003, Cancer Hospital affiliated to Fudan University and MD Anderson Cancer Hospital - University of Texas signed an agreement on comprehensive cooperation.

3. Current Efforts/Major Institutional Significant Linkages (Tianjin)

As an important industrial base in northern China, Tianjin aggressively promotes Biotechnology as one of its most important economic and technological drivers. Categorized as a 2^{nd} (some would classify as 3^{rd}) tier city in China, Tianjin's continual infrastructure development and strong government support lays the foundation for the development of biomedicine, modern Chinese traditional medicine and industrial biotechnology R&D. This results in significant advantages in such fields as stem cells, biochips and biomedicine. On the strength of more than 500 production enterprises and R&D institutions, this industry generates annual sales revenue up to 30B RMB (~4.4B USD)

There are nearly 20 research institutes, 13 laboratories and 10 biological engineering centers at the Provincial level and two centers at country-level, which focuses on Biomedicine, Biologics, Biological Processing and Agricultural Biotechnology.

In the area of Biomedicine, there are a number of research and commercial institutions, including: Tianjin International Biomedical Research Institute, Tianjin Industrial Biotechnology R&D Center, Chinese Academy of Sciences, and Tianjin Institute of Pharmaceutical Research, to name a few. At present, there are more than 100 biological medicine enterprises, including Jinyao, Tasly and Tianjin Zhong Xin Pharmaceutical Group, ranking in the top 10 of Chinese Pharmaceutical companies. By the end of 2007, there was a labor force of 151,000 working in the biomedical field.

In Agricultural Biotechnology, prominent institutions include the Tianjin Municipal Institute for Resources and Environment, National Pesticide Engineering Research Center and the Tianjin Institute of Life Sciences Applications.

Prior intra-connections includes: a relationship between Tianjin Municipal Government and the Military Medical Science Academy of the Peoples Liberation Army (PLA) solidified on July 20 2005, on scientific-technical cooperation towards the establishment of a new drug research center in Binhai New Area focusing on R&D of new drugs, food security and environmental management.

In July 2006, the Institute of Genetics and Developmental Biology (IGDB) of the Chinese Academy of Sciences (CAS) and Tianjin Academy of Agricultural Sciences signed agreement to establish the Tianjin Center for Plant Molecular Breeding. On June 25, 2007, the Tianjin Municipal Government and CAS signed agreement to build CAS-Tianjin R&D Center for Industrial Biotechnology, the first scientific research institution of CAS in Tianjin. Recently on December 24, 2008, the Institute of High Energy Physics (IHEP), Chinese Academy of Sciences and the Tumor Hospital Attached to Tianjin Medical University (THATMU) announced plans to jointly set up a tumor molecular imaging lab. IHEP is an authoritative institution of molecular imaging science in China. THATMU is one of the largest tumor prevention hospitals in China. [12] And on May 18 2008 the Institute of Zoology, CAS, Institute of Genetics and Developmental Biology (IGDB) and Tianjin Central Hospital for Gynecology and Obstetrics jointly established the Research Center for Stem Cells and Regenerative Medicine (Beijing).

Examples of types and nature of linkages (or connections) with U.S./Western firms includes those such as the recent one between the Tianjin Science and Technology Commission and the Karolinska Institute in September 2008. In June 2006, the University of Texas M. D. Anderson Cancer Center and Tianjin Medical University Cancer Institute and Hospital announced an agreement to expand opportunities for collaborations in clinical, educational and translational cancer research; [13] Another case is the one of the National Foundation for Cancer Research (NFCR www.nfcr.org/) which cooperated with Cancer Hospital affiliated to Tianjin Medical University to establish the first domestic tumor tissues library in compliance with international standards in 2003. One other example is the Key Laboratory of Bioactive Material of Ministry of Education, Nankai University, which has established significant cooperative relationships with universities and research institutions in America, Canada, UK, Germany, Japan, Austria, Finland and Australia, and has completed eight international cooperation research projects including blood cleansing. In 1995, it became the tenth member of the International Faculty for Artificial Organs (INFA).

Tianjin has in place numerous connections established by her universities, hospitals, and research institutions. A few examples follow: Tianjin University and Nankai University jointly established a research institute and set up fund for scientific-technical cooperation and cooperative education. On July 6, 2007, Tianjin Agriculture Commission and Nankai University signed agreement to engage in comprehensive cooperation. Tianjin University and the Tianjin

[12] http://www.chinacsr.com/en/2008/12/24/3963-cas-builds-tumor-molecular-imaging-lab-with-tianjin-medical-university/
[13] http://en.wikipedia.org/wiki/Tianjin_Medical_University

Economic Development Zone jointly established the National University Science & Technology Park. Tianjin Medical University and Tianjin Cancer Hospital jointly established the Tianjin Cancer Research Institute.

4. Current Efforts/Major Institutional Significant Linkages (Harbin)

Biotechnology is one of five major backbone industries of Harbin, a sub-provincial city and the capital of the Heilongjiang Province in Northeast China. Since 2003, Harbin has attracted 36 national and provincial key projects. In addition, as a smaller city, approximately 20 international projects, including those of a cooperative research and development (R&D) nature have been initiated with many countries and regions including Russia, America, Canada, Germany, Japan and Korea. Harbin boasts 121 biomedical enterprises with total assets of 12.77B RMB (~1.87B USD). The gross output value in 2007 reached 21B RMB (~3.1B USD).

In Harbin there are a total of 54 scientific research institutes involved in the industry, in addition to 11 Engineering Centers, and 12 Key Laboratories. Most prominent are the Harbin Veterinary Research Institute (National Laboratory for Veterinary Biotechnology), Northeast Institute of Geography and Harbin Institute of Technology (HIT) – a major resource consisting of many departments for various technologies, among others.

Examples of intra-linkages or connections include those between the Heilongjiang Provincial Government and CAS on comprehensive scientific-technical cooperation, originated in March 2005. The Animal Husbandry Institute - Heilongjiang Academy of Agriculture Sciences, Heilongjiang Livestock Breeding Instruction Station, Northeast Agriculture University, Northeast Forestry University and Heilongjiang Animal Husbandry Institute jointly established the Heilongjiang Research Center for Embryonic Engineering and Technology in 2006.

Harbin's institutions are engaged in many joint-cooperative projects with such countries as Russia, Japan, Israel and European Union. Since 2002, in cooperation with Russia, Harbin Pharmaceutical Group Bioengineering Company (Harbin Pharmaceutical Group Holding – www.hayao.com) has produced such products as Recombinant Human Interferon A2b (rIFN a2b), Recombinant Human Erythropoietin (r-HuEPO), Recombinant Human Granulocyte Colony Stimulating Factor (rhG-CSF) and Recombinant Human Granulocyte-Macrophage Colony Stimulating Factor (rhGM-CSF). In 2007, a joint Russian cooperative project of Heilongjiang Qiangr Biochemical Technology Development Co., Ltd (http://www.qiangr.com) produced a biological pesticide for Bacillus subtilis to effectively address the prevention and treatment of rice blast.

In 2003, the Ministry of Science and Technology and Heilongjiang University Science and Technology Departments jointly established a national key laboratory incubation base (Harbin Medical University) for biomedical engineering. Harbin Medical University has also established the Key Laboratory of Cell Transplantation of Ministry of Health for research endeavors. This relates to efforts of Harbin Biotech, a subsidiary of China Sky One Medical, of Heilongjiang

Province in the field of R&D of tissue and stem cell banks (umbilical cord blood stem cells), once exclusive domain of the government. [14]

5. Current Efforts/Major Institutional Significant Linkages (Kunming)

In recent years, there has been steady progress of the biotechnology industry in Kunming, the capital of Yunnan Province located in Southwest China. The broad total revenue of this industry in Yunnan Province had surpassed 200B RMB (~29.3B USD) in 2005. The province is aiming at doubling this figure to 400B RMB (~58.61B USD) by 2010, according to the Provincial Government's future plan released in March 2008. [15] The Provincial Government allocated 50M RMB (~7.3M USD) of special funds in 2008 at an attempt to fuel the expansion of the Bioindustry in Yunnan Province and will continue to increase its subsidization on this sector in the coming years. However, biotechnology industry in Yunnan is still not as developed as other major provinces in China. The status of biotechnology was realistically described as "Huge resource, but small industry" by the local government.

In the Yunnan Province, more than 320 companies are involved in the Biotechnology sector. Eighty percent of them engaged in the production and business of natural components and *Spirulina*. A few of them are engaged in industrial fermentation, vaccine, bio-products, biochemical engineering. Kunming Institute of Medical Biology (KIMB) is the biggest corporation to produce oral polio vaccine in the region.

Several well-established regional universities and institutes are engaged in biotechnology R&D. Kunming Institute of Zoology (KIZ), CAS (www.kiz.ac.cn) is one of 23 biological research institutes affiliated with the Chinese Academy of Sciences (CAS). With over 200 staff, the institute specializes in R&D of embryo engineering, genomics, peptide, and cell factors. In the past decade, KIZ has undertaken 300 research projects including 74 national projects, 88 CAS projects and 14 international collaboration projects. Domestic partnerships include those with Fudan University, Sun Yat-sen University, Hong Kong Chinese University, and many other institutes affiliated to CAS.

Kunming Institute of Botany (KIB), CAS (www.kib.ac.cn) In recent years, KIB has formed alliances with Novartis (Switzerland), Milan University (Italy), University of Marburg (Germany), and the Smithsonian Institute (U.S.). Domestically, KIB has active collaborations for research projects with many pharmaceutical companies such as Shanghai Sine Promod Pharmaceutical Co., Ltd., Yuxi Wanfang Natural Drugs Co., Ltd., and Yunnan Yuxi Weihe Pharma Co., Ltd.

Kunming Institute of Medical Biology (KIMB) is involved in vaccine research and production. Yunnan University is engaged in antibiotics, insecticides (973 program [i]).

[14] Hasthana Rajappa; BioSpecrrum Asia edition November1, 2007; June 20, 2008 (online)
[15] Yunnan Province launches future plan to expand bio-industry. Chuncheng Evening Post (Chung Cheng Wan Bao), Mar. 10, 2008. Available at: http://ev.cctv.com/20080307/101598.shtml

Kunming University of Science and Technology (KUST) participated in biofuel (National Key Technology R&D Program), biomedicine (863 Program), fermented food, biometallurgy, biopulping, bioprocess, and tissue culture of plant projects.

6. Government Policies, Initiative and Subsidies (Central)

1) Tax Subsidies/Incentives/Benefits

A) Regulations on Tax Policies for National High Technology Industries Parks

- The income tax of enterprise required by Parks shall be levied at a reduced rate of 15 per cent from the date of their establishment.
- The export tax of companies in Parks amounts to 70 per cent or more of its total output value of the year, the income tax shall be levied at a reduced rate of 10 per cent after being examined and approved by appropriate tax authorities.
- A new company in the Parks may, upon approval by the tax authorities, be exempted from income tax in the first two years in operation.
- Revenues from technology transfer transactions and consultative services are exempted from income tax.

Notification on preferential corporate income policy for technology innovation

- Deduct technological development expense before tax;
- Employee education expenditures are deducted from income tax
- Accelerated depreciation of equipment;
- Exempted from income tax in 2 years from the profit-making year, and income tax will be imposed at a reduced rate of 15 per cent afterwards.

B) Notice on Tax Policies Concerning Facilitating Development of Venture Capital (VC) - backed Enterprises

For a high-tech small-to-medium-scale private enterprise that has been supported by VC funds for more than 2 years, its income tax may be deducted up to 70% of the amount of investment.

C) National Taxation Policies on University S&T Parks and relevant fiscal and tax policies on S&T incubators –

Until December 31, 2010 for a science and technology park or incubator if/when complying with requirements, its building property and land are exempted from real estate tax and tax on urban land use, and its revenues from lending and providing incubation services are exempted from sales tax.

D) Provisions on the Exemption of Import Duties from the Articles Used for Scientific and Technological Development -

For scientific, research and technological development institutes, before December 31, 2010 and within reasonable quantities, imported articles required and utilized for scientific and technological development shall be exempted the customs import duties, value-added taxes and consumption taxes.

2) Financial subsidies

For Promotion of Joint Financing of Biotechnology Industry -

Provinces and cities shall establish guarantee system and establish special fund for development of Bioindustry, and the fund scale shall be no less than 5% - 10% of total allotment provided by State Development Bank in cooperation with financing platform for Bioindustry.

3) Government grants

Annually, the state provides all classes of project funds nearly 10B RMB (~1.46B USD). State Development Bank will provide loan for enterprise according to 5-10 times of the special governmental fund.

7. Government Policies, Initiatives, and Subsidies (Beijing*)*

As expected, Beijing has been and continues to be aggressive in providing various governmental support, and forming policies to cultivate and grow the Biotechnology sector.

Beijing Commission of Science and Technology

1) Guidance for Key Scientific and Technological Fields
Development (2005-2008)—Biotech related
1. New Materials
2. Biomedical
3. Agriculture
Government Grant

2) Beijing Nature Science Foundation—2009 Key Projects
Biological Sciences
Government Grant

3) Beijing Torch Program
Commercialization, high technologies
Financial Subsidies//Government Grant

4) Special Fund for Hi-Growth Enterprises Independent Innovation
Hi-Growth Enterprises
Government Grant

5) Special Fund for Professional incubator and Service System Construction
Professional Technology Business Incubator and
Municipal/University Science and Technology Parks
Government Grant

6) Beijing Technological Innovation Funds for Technology-based SME
Special Funds for Technological Innovation and Technology Transfer
Financial Subsidies

7) Special Fund for Technology Transfer Service
Professional technology transfer service providers,
Technology transfer offices (academic, state, corporate)
Government Grant

8) Special Fund for Scientific and Technological Consulting
Professional consulting organizations
Government Grant

9) Special Fund for Technological Introduction and Secondary Innovation of Enterprises
Government Grant

Beijing Industrial Promotion Bureau

1) Industrial Development Fund
Industrial technology improvement
Financial Subsidies

2) SME Development Fund
Manufacturing
Financial Subsidies

Beijing Municipal Bureau of Commerce

1) International Market Exploring Fund for SMEs
Encourage SMEs to explore international Market
Government Grant

Beijing Municipal Personnel Bureau

1) Encourage Overseas Returnees to Start an Enterprise in Beijing
Recruitment of Experienced Chinese-born Personnel
Tax Subsidies

8. Government Policies, Initiatives and Subsidies (Shanghai)

1) Tax Subsidies/Incentives/Benefits

A) Several provisions of Shanghai Municipal Government support towards the development of high-tech industries

- Value added tax and income tax rendered in three years dated from the selling of new products and products under pilot plant test may be refunded 100%.
- For any newly operated high-tech enterprise with an operating period more than 10 years, the value added tax and corporate income taxes rendered in 1-2 years dated from authentication may be refunded to such enterprise by 100% Corporate income tax rendered in 3-8 years may be refunded by 50%.
- For high-tech companies registered in the Zhangjiang Science and Technology Park, Jinqiao Export Processing Zone or Waigaoqiao Bonded Zone, the period for enjoying the preferential policy on VAT rebate may be extended for one year.
- An enterprise may use 150% of technological development expense incurred during the year to deduct the taxable amount of income on same year for Zhangjiang High-tech Zone.

2) Financial subsidies

For Promotion of the Development of High-Tech industries in Zhangjiang Park, Pudong New Area

- For an intermediary agency engaged in the high-tech R&D and conversion services, the relevant operating revenue and total profit obtained by providing services in the park in three years may be subsidized by 5% and 7% respectively.

3) Government grants

The Chinese government annually invests about 600M USD in the Shanghai Bioindustry, accounting for half of entire government investment in the life science sector. It is required policy that financial investment of city funds should account for more than 7% of financial expenditure in the same year, and investment by district/county should account for 5% of financial expenditure in the same year. The government also establishes a special fund for innovation of small and medium-sized enterprises to subsidize science and technology development.

9. Government Policies, Initiatives and Subsidies (Tianjin)

1) Tax Subsidies/Incentives/Benefits

A) Policies of Tianjin High-Tech Industrial Zone in support of enterprises (until December 5, 2013)

- For an enterprise with annual sales revenue over 10M RMB (~1.46M USD), subsidization of 20% R&D expenditures.
- Supply income tax relief and encouragement for high-end talents (personnel, management) for 5 years.
- If the scale of company's M&A requirements exceeds 50M RMB (~7.3M USD), provide discount for a year (≤5M RMB, ~730,000 USD).

B) Tentative Provisions of Tianjin Municipal Government on encouraging foreign entities/investors to invest in R&D of high and new technologies and commercialization projects

- Revenue from technical services is exempted from income tax and sales tax, and the revenue from buying share is tax free.
- For state-level new product and invented product, revenue from selling such product is exempted from income tax in 3 years dated from selling; for municipal-level new product, revenue from selling is exampled from income tax in 2 years; period of depreciation may be shorten by 30% - 50%
- Imported equipment, reagents and materials are exempted from customs duty and import-link taxes.
- Land grant fee will be refunded in three years. The enterprise may be exempted from trading fee, registration fee, drainage fee, fuel gas capacity increase fee and charge for electric distribution in the process of construction, and other fees will be charged at minimum rate.

C) Preferential policies on foreign-funded high-tech enterprise

- If the enterprise use profit for expansion, refund 100% or 40% of income tax rendered in the same year
- The proportion of intangible assets in registered capital may reach 35%.
- An enterprise registered in bonded area may be exempted from rent for a year, and its rent will be reduced for 2 years.
- The equipment imported for in-house use may be exempted from customs duty and import link tax.
- 50% of development cost is used to deduct tax amount payable.

2) Financial subsidies

In 2007, the Tianjin Government injected 3B RMB (~440.1M USD) in Binhai New Area in support of the development of Tianjin's Biotech sector, and is expected to continue funding albeit at a lower level in consideration of the current economic climate.

3) Government grants

Establishment of municipal fund for development of S&T for dissemination of financial aid for foreign funded enterprises involved in significant commercialization efforts. Annually, the government provides funding of 1B RMB (~146.7M USD) to support R&D projects.

10. Government Policies, Initiatives and Subsidies (Harbin)

1) Tax Subsidies/Incentives/Benefits

A) Harbin Preferential Policies on attracting investment;
Preferential policies of Heilongjiang Province

- Respectively allocate 10% from special fund for scholar project in order to cultivate and develop talents.

B) Tentative Administrative measure for examination and approval of overseas investment projects - Foreign funded high-tech enterprise may be exempted from tax for three years.

2) Government grants

Annual investment funds (600M RMB; ~87.9M USD) support of R&D projects. Funding is expected to continue although at a lower level, given the current economic environment.

Biotechnology Competitiveness and Implications

To preface the following conclusions, there have been numerous articles, studies, and growth projections on the future landscape of China's high tech sunrise sectors compiled before and during the nascent stages of the recent worldwide financial disruptions, many of which are still unfolding. We posit that the expected timetables from many of these publications are to be significantly modified (or in some specific cases discounted altogether) to the degree of timing and reported allocations, due to lingering uncertainty in the capital markets, in both the public and private sectors. The socio, political, and economic dynamics have changed and as a result, all industries including Biotechnology has been affected, as implied in the "Economic Blue Paper", published by the Chinese Academy of Social Sciences, and other sources. [16]

With more than 300 public biotechnology companies employing over 130,000 people and representing about $400 Billion in market capitalization, the U.S. is home to the majority of the global biotechnology industry's revenues, profits, and jobs. The environment for innovation includes public policies, such as patent protections and incentives for discovery. Today, more research and development of new medicines is taking place in the U.S. than in any other country.[17] As the largest biopharmaceutical market in the world, the U.S. has benefited greatly from advances to emerge from biotechnology. In China, the pharmaceutical market is expected to increase from approximately $12 Billion per year to $48 Billion by 2015. [18] It is accepted that an environment in which intellectual property (IP) is nurtured and protected, is essential to developing a thriving domestic biotech industry. Indicators [19] utilized to report trends (past, current, and future) and gaps includes the number of scientific paper citations and global biotechnology patents, which are led, not surprisingly by the U.S. (past and current strengths) However when measuring other indicators, such as high school proficiency and biotechnology patent growth (developing, future), the U.S. ranks near the bottom in both of these measures, with China ranking first in biotechnology patents growth.[20] This strongly suggests to no great surprise, that given the well-documented and widely-debated issue of the robust support, subsidies and other resources provided by the Chinese government in this sector – not only in the major and emerging cities as outlined in this report, but in other regions still below the radar as well, this may prove to be a future challenge. [21]

In 2007, Beijing R&D expenditures for the Biotech industry totaled roughly $7.7 Billion from government, the private sector, and foreign investment. Beijing was the beneficiary of 47% funding from China's National Basic Research Program, Project 973 plan, which concentrates more on early-state research projects, and 22.8% funding from the National High-Tech R&D

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[16] 'China's Poor, Young and Restless' December 19, 2008 China Brief; Xinhua News Agency, November 24, 2008; February 17, 2009 USCC Hearing on China's Role in the Origins of and Response to the Global Recession Panel II: China's Short term and Long Term Economic Goals and Prospects testimony

[17] Pharmaceutical Industry Profile 2008 (Washington, DC: PhRMA, March 2008)

[18] 'Beyond Borders: The Global Biotechnology Report 2007', Ernst & Young

[19] U.S. Competitiveness in Science and Technology, Titus Galama, James Hosek; RAND National Defense Research Institute, 2008

[20] Ibid.

[21] Meeting per U.S. Congressman Joseph Sestak's office January 8, 2009

Program - Project 863 initiatives, which focuses more on applied research and commercialization for an estimated $1.8 Billion. In addition to Shanghai, also comparatively advanced in this sector, and Shenzhen (not analyzed in this report) these "Biotech clusters" of China will continue to grow, albeit not as spectacularly as in recent years.

Northern China with Tianjin leading the way is aggressively promoting Biotechnology as one of its most important economic and technological engines. In Northeast China, Harbin has designated Biotechnology as a backbone industry of the future. Along with Kunming, whose Provincial government invested ~$ 7.3M realizing slow but steady growth, these three cities are potentially positioned for significant growth in the Biotechnology industry. China's central government initiatives and subsidies, particularly in tax breaks, are arguably quite liberal, if compared to the U.S., and in the past, these policies have strongly encouraged entrepreneur activity for small businesses. The local governments have likewise been very positive for emerging companies in this sector.

It is well documented that China's Biotechnology industry have been and continues to be enormously assisted by American companies' off shoring practices. It's no surprise that this alone has been a critical factor in enabling China to gain advantages towards overtaking America's role as leader in Biotechnology. [22] Lax regulatory oversight (until very recently), less stringent environmental laws, and comparatively lower wages continue to be the most obvious benefits to companies' bottom line.

As pointed out earlier in the report, as a result of China's increased spending on S&T, the number of scientists and engineers has risen exponentially.[23] This factor alone is a significant advantage, which could potentially have implications considering on a percentage basis, the number of American-born graduates in the sciences has steadily declined. Because of the obvious high priority in China's national strategies, it is very likely that this trend will continue, in spite of the current financial situation. The Obama administration's prioritizing of science and technology education investment will counter this trend and should not be allowed to abate in the near or long term.

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[22] 2003 'Foreign High-Tech R&D in China' Risks, Rewards, and Implications for U.S.-China Relations; Kathleen Walsh
[23] The Communist Party of China, Central Committee Proposal on the Formation of the 11th FYP

Part 3: Nanotechnology

1. Current State of R&D

China is rapidly catching up to the United States in nanotechnology. Nanotechnology research in China first initiated in the late 1980s, when several Chinese academic research organizations became interested in nanomaterial (then called ultra-fine materials) research. The Chinese authorities quickly responded to the efforts of these Chinese scientists and launched a "Climbing Mountain" project focused on nanomaterial science in 1990. This project was led by Dr. Dongsheng Yan of the CAS Shanghai Institute of Ceramics, and Duan Feng from Nanjing University, and Lide Zhang from CAS Institute of Solid State Physics, under the supervision of the State Science and Technology Commission (SSTC), the predecessor of the current Ministry of Science and Technology (MOST)[24]. Since then, nanotechnology has been recognized as one of the priority areas by the government. It is also one of a handful of areas China started at the same time and kept growing at the same pace with major developed countries such as United States and Japan.

According to Dr. Chunli Bai, Executive Vice President of the Chinese Academy of Sciences (CAS) and the Chief Scientist of the China National Steering Committee for Nanoscience and Nanotechnology, in 2005 there were more than 50 universities, 20 research CAS institutes, and 300 industrial enterprises, which have been engaging in the nanotechnology research, employing more than 3,000 research scientists nationwide.[25] Though this assertion was based on incomplete data, it is assumed this critical mass has increased.

China is considered to be one of the world's leading countries in the nanotechnology research, in terms of the number of research papers that Chinese nano-scientists have published. An article authored by Dr. Liu and Dr. Zhang summarized the academic performance of Chinese researchers in recent years, based on the statistics from Thomson Science Citation Index (SCI). [26] Their research showed that the total number of publications from China mainland on nanotechnology increased by 30% annually in the past decade. In addition, according to R. N. Kostoff, (Scientist 18, 10, 2004), China ranked first place in terms of publications in nanotechnology.

Table 3: Number of Nanotechnology Publications authored by Chinese researchers and Citations by Year [26]

Year	Number of papers	Number of citations
1995	244	1984

[24] Zilong Peng, Wei Meng, Peihua Liu, "Analysis of Function and Status of CAS in National Nanotechnology Research", *Bulletin of Chinese Academy of Sciences*, 20(3), 188-193, 2005
[25] Chunli Bai, "Ascent of Nanoscience in China", Science, 309, 61-63, 2005
[26] Li Liu and Jingjing Zhang, "Characterizing Nanotechnology Research in China", *Science Technology & Society*, 12(2), 201-216, 2007

1996	336	3608
1997	487	4824
1998	624	6367
1999	932	10341
2000	1197	12675
2001	1732	13549
2002	2411	15384
2003	3498	13622
2004	4138	6048

Chinese researchers have made groundbreaking achievements over the past decade.[25]

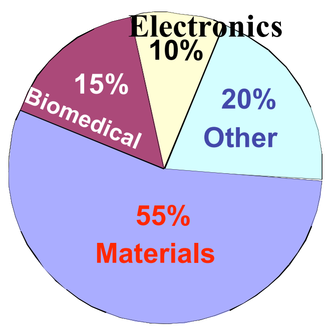
- Dr. Sishen Xie and his research group at the CAS Institute of Physics invented a template-based growth method in 1996, by which both the diameter of multi-walled carbon nanotubes (CNT) and the directional growth could be controlled. These features are important because they determine the properties and technological potential of these materials. The same research group synthesized the world's smallest carbon nanotubes (0.5nm in diameter) in 1999.
- Dr. Shoushan Fan and his research team at Tsinghua University made yarns out of carbon nanotubes. After appropriate heat treatment, these pure CNT yarns should eventually be able to be woven into a variety of macroscopic objects for different applications, such as bulletproof vests and materials that block electromagnetic waves.
- Dr. Ke Lu and his colleagues at the CAS Institute of Metal Research in Shenyang, discovered the superplastic property of nanostructured copper in 2002. The metal, with its nanoscale grains that are far finer than the grains of which standard copper is composed, can be elongated at room temperature to more than 50 times its original length without breaking. In 2004, Lu's group discovered another kind of nanocopper phenomenon, so-called copper growth twins, which is a specific type of crystalline microstructure. Copper with these nanoscale structural motifs has a tensile strength about 10 times as high as that of its conventional counterpart, while retaining electrical conductivity comparable to that of pure copper.
- Dr. Dong Yuan Zhao and his colleagues at Fudan University demonstrated a general synthetic strategy for creating stable multi-component materials—such as mixed metal phosphates, mixed metal oxides, and metal borates—featuring a variety of porous structures. Such materials could lead to new families of catalysts, environmental filtration devices, and other technologies that rely on molecular interactions occurring in tiny nanoscale spaces. A morphological control approach was reported to selectively form SBA-15, a well-known silica-based material harboring a highly ordered hexagonal arrangement of nanoscale pores.

The Nanotechnology industry is growing rapidly in China. According to the 2007 China Nanomaterial Consulting Report and reference[27], the overall size of Chinese nanomaterial market is 3.5B RMB (~513.5M USD) in 2005, and 4.1B RMB (~601.5M USD) in 2006,

[27] "Review on Application and Commercialization of Nanotechnology in China" CAS information center, unpublished (in Chinese)

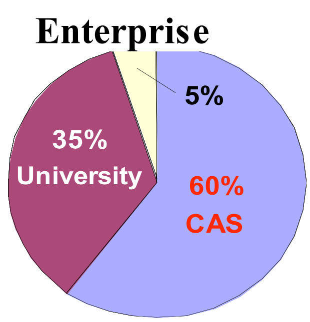
with over 15% annual growth in the past six years. An estimated 1000 enterprises are involved in nanotechnology-based commerce in China. Our research suggests that ~ 50% are located in Beijing, Shanghai, Guangdong, Jiangsu and Zhejiang provinces. The major products are nanoscale powders of oxides, carbon nanotubes (CNT), fullerenes, and various types of coatings incorporating nanomaterials. A total of 31 production lines of nanomaterials have been established in China, and the annual production of these materials is estimated to be 30 million tons. Other products include anti-bacteria and photocatalysts.

Figure 3: Application of nanotechnology in various industries in China



Source: National Center for Nanoscience and Technology of China

Figure 4: R&D activity distribution in various institutions



Source: National Center for Nanoscience and Technology of China

With respect to patent application, from 1986 (when the first nanotechnology patent application was filed) to October 2007, the number of patent applications reached 18,629 - with roughly 30% of them having been approved by the State Intellectual Property Office (SIPO) of PRC.[26]

Beijing:

In Beijing there are over 80 nanotechnology-related companies, roughly 10% of the total number of businesses in all of China. The products include powders, coating, photocatalysts, anti-bacteria products, magnetic materials, and measurement instruments.

Shanghai:

In Shanghai there are over 3,000 people involved in nanotechnology-based industries in Shanghai [28]. Of those, 30% are R&D staff, 40% have college degree and above. There are over 100 nanotechnology companies in Shanghai; 60% are small start-ups, and most own the intellectual properties of products' technologies. Ten percent of them obtained methodologies and techniques from technology transfer activities from foreign firms.

35% of these companies are in the chemical industry, active in manufacturing powder and developing powder modification techniques. From 2002 to 2005, annual growth rate of nanotechnology production in Shanghai was 32%. However there are still challenges in this fast-growing field, such as the difficulties in getting investment, getting consumer recognition, lack of detection standards, unknown long-term effects to environment and to patients of medical applications based on nanotechnology.

Tianjin

As of the end of 2007, there were 14 nanotechnology companies in Tianjin, involved in R&D of nanopowders, nanocoating, and electronic devices, and relatively few companies in both Harbin and Kunming.

As of December 2008, there were only a limited number of nanotechnology companies in Harbin and Kunming.

2. Major Research/Commercial Institutions

Beijing:

- Beijing Sokang Nano Cooperation (www.sokang.com.cn) was established in September 2001, invested by the Sokang Group. The company set up a joint lab with Tsinghua University, and several graduate programs with Beijing University of Aeronautics and Astronautics, Beijing Institute of Technology, and Beijing University of Chemical Technology. The company continues to carry out research projects that are sponsored by national and local funding agencies, including three

[28] "Shanghai Nanotechnology Industry Development Report", Shanghai Nanotechnology Promotion Center, 2006

863 Plan projects. Past projects included: High-performance heat-resistant coatings (collaboration with China Building Materials Academy); Fire-resistant coatings on steel structures used in Beijing Olympic Games (collaboration with Beijing University of Chemical Technology); Binary nano-interface technology and application (collaboration with CAS Institute of Chemistry). Other projects include four Beijing Technology Innovation plans: Application of nanomaterials in building materials; Preparation of multi-functional nano-colloids and their application in coatings; Air-cleaning technology using nano photocatalysis; and Application of nano protecting layer in contamination resistance of stone grounds. The company now has products including photocatalysis-based air purification system, using TiO_2 nanoparticles dispersed in various media; nano-protection liquid, which generates self-cleaning effect after coating on various surfaces. All technologies are company-owned (the company obtains 5-7 patent licenses annually).

- Beijing Zhongke Saina Glass Technology Ltd. (www.zksnglass.cn) is a high-tech and specialized glass company located in the Haidian district of Beijing, which focuses on nano self-cleaning glass application. The company was established in December 2004, and inherited technologies developed from the Institute of Chemistry, Chinese Academy of Sciences. Their products have been applied at the National Center for Performing Arts, Beijing Olympic Basketball Gymnasium and Shenyang Lily Tower.

- Ecobenign Plastics (www.ecobenign.com, EBP) is an environmental technology company, specializing R&D of eco-friendly biodegradable plastic materials. Company provides low-cost, eco-friendly and easy-to-use total solutions for users to mitigate “white pollution” (Referring to the pollution caused by a great number of plastic bags being littered all over the place. Over 2 billion bags are believed to be dumped in China every day, where the non-degradable bags are clogging up land, drains and rivers, and harming wildlife). By incorporating transition-metal nanoparticles into plastics, the oxidation-based degrading is accelerated because of nanoparticulate catalyzation of generation of free radicals from hydrogen peroxide.

- Veeco's China Nanotechnology Center was formed in November 2002 as a collaboration center between US-based Veeco Instruments Inc. and the CAS Institute of Chemistry. The center provides the Institute of Chemistry's molecular nanotech R&D division with "super-advanced" measuring and controlling devices.

- Beijing CISRI-Gaona Materials and Technology Co. Ltd. (www.superalloy.cn) established in November 2002, is a subsidiary of CISRI (China Iron and Steel Research Institute Group, www.cisri.com). The company has patents from CISRI’s institute of high-temperature materials and institute of powder metallurgy and has its own research capability on functional nanomaterials. Current products include alloys and nanomaterials. The company has a production base of 11,000 square meters in Zhongguancun Yongfeng High-tech Park.

Shanghai:

- Shanghai Nanotechnology Promotion Center (SNPC: www.snpc.org.cn) is a government agency under the Science and Technology Commission of Shanghai Municipality (www.stcsm.gov.cn). Established in July 2001, the Center oversees nanotechnology activities in Shanghai. The mission of SNPC is to carry out the strategies and decisions of the leading group on Nanoscience, Engineering and Technology of Municipality, to organize resources and coordinate diverse research efforts, and to promote the development of nanotechnology in Shanghai.

- National Engineering Research Center for Nanotechnology (www.nercn.com.cn) was established by National Development and Reform Commission of China in October 2003, and is the only nation-level engineering research center for nanotechnology and applications in China. Shanghai National Engineering Research Center for Nanotechnology Co. Ltd., which is established by Shanghai Jiaotong University, Fudan University, Shanghai Institute of Microsystem and Information Technology, Shanghai Zizhu Venture Capital Co. Ltd., and other shareholders operate this center.

- Karlet Nanomaterials (Shanghai) Co. Ltd. (www.karlet.com) is a high-tech company based on National Advanced Coating Engineering Center at Fudan University, and is the production unit of the research center. The company tries to develop construction wall paintings, which incorporate nanomaterials to solve problems such as fracture and decolorization.

- Shanghai Huzheng Nanotechnology Co. Ltd (www.hznano.com) has developed nanoscale (0.2nm-20nm) powders, colloids and liquors products with Au, Ag, Pt and Cu, as well as nanoscale metal oxide such as SnO, Tio2, ITO, and ATO. Currently they are producing full-range indoor air purifying products including photo-catalyst, cool-catalyst and other decontaminants used to remove formaldehyde, benzene, ammonia and TVOC. In particular, their Nano-Silver series antibacterial materials have been widely applied in fields such as ceramics, plastic, coating, textile, paper, cosmetics, medicine and commodities.

Tianjin

- China National Academy of Nanotechnology and Engineering is a state-owned research institution, supported by Ministry of Science and Technology, Ministry of Finance, Chinese Academy of Sciences, and local government.

Harbin

- Jinshiyuan (http://jsyjt.excce.com) produces anti-glue coating that incorporates nanoparticles. When painted onto walls and other surfaces, they exhibit resist dust-resistant properties.

- Another company in Harbin HIT (Harbin Institute of Technology) Xiande Nanotechnology Development Co. Ltd. (www.xd-nm.com.cn), which produces water purification systems, anti-bacteria clothing, etc.

Kunming

- Kunming Yunda Biotechnology Company (www.ydbiotech.com) is a high-tech biotechnology company formed with an initial investment of 20M RMB (~2.92M USD) from Hong Kong Jinshili Group, Yunnan University and others. The company focuses on developing test papers based on monoclonal antibodies. Gold nanoparticles and magnetic nanoparticles have been used to enhance the performance such as detection limits and speed. The products include Hepatitis B-Gold, HIV-1/2-Gold, Hepatitis B-Magnetic, and HIV-1/2-Magnetic test papers. Accuracy is above 99%.

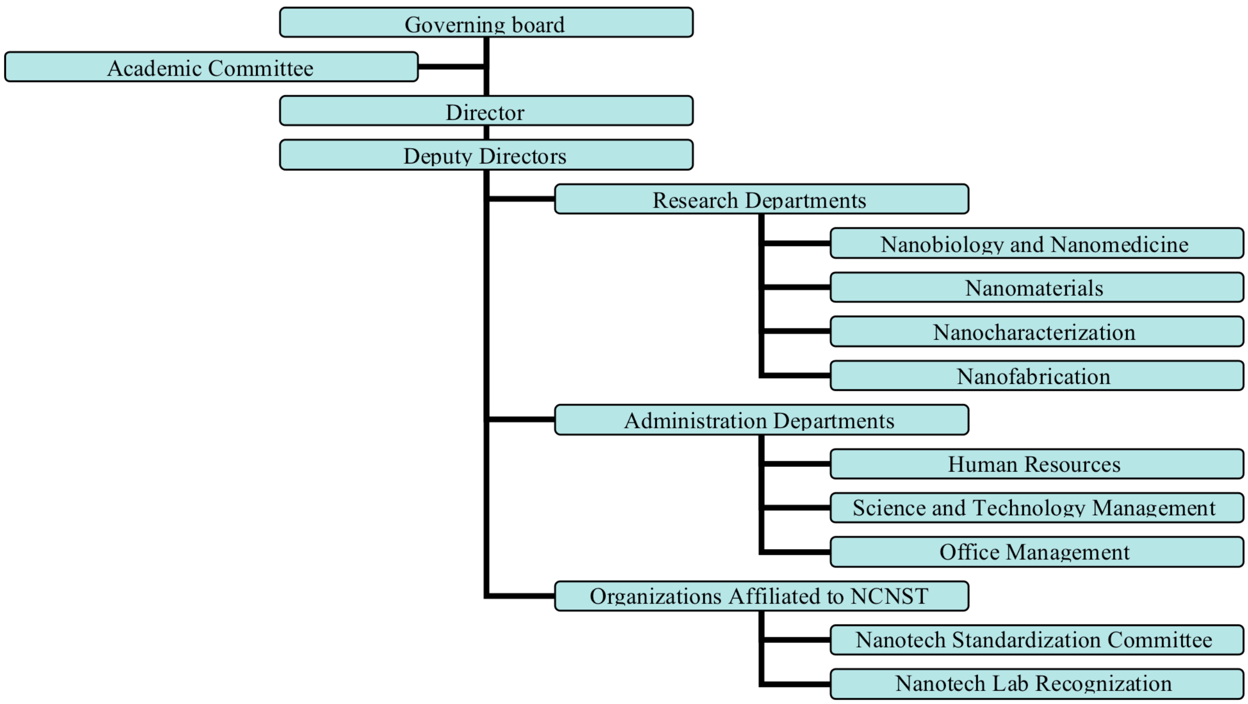
- Kunming Hande Nano-biotechnology Co., Ltd. (www.ydnano.com) was established in January 2008 in Kunming, with registered capital of 2M RMB (~292,000 USD). The company performs R&D in biomedicine, medical instruments and health and fitness. Currently the company focuses on nano-silver based anti-infectious products, including sprays, liquids and others. These are based on the company's own intellectual properties.

3. Major Academic Centers

Beijing

Basic research in nanotechnology is heavily pursued in Beijing. There are 500 research institutes (including CAS institutes), over 70 universities (including Peking University and Tsinghua University), around 380,000 R&D staff, and roughly 500 participants in academia. Beijing has more than 50 national key laboratories and more than 30 national engineering centers, over 33% of the total of China. Among these, approximately 30 institutions are intensively engaged in nanotechnology research, including CAS Institute of Physics, Institute of Chemistry, Beijing University, Tsinghua University and others.

- National Center for Nanoscience and Technology of China (NCNST, www.nanoctr.cn) was established in 2003 by the Chinese Academy of Sciences and Ministry of Education. The governing board has representatives from Ministry of Science and Technology, National Science Foundation of China (NSFC) and local government. The NCNST mainly consists of the following divisions: nano-processing & nano-device laboratories, nano-materials & nano-structure laboratories, nano-medicine & nano-bio-biotech laboratories, nano-structure characterization & test laboratories, and various databases for nanoscience. The organization chart is as follows:



- Tsinghua Foxconn Nanotechnology Research Center (www.foxconn.com.cn) was established in August 2003 through a joint venture formed by Tsinghua University and the Foxconn Group. Foxconn group invested 300M RMB (~44M USD) while Tsinghua University provided land of 13,000 square meters. The research is mainly focused on nanotechnology applications in information technology. Research on carbon nanotube carried out in this centre has gained worldwide recognition. Director Shoushan Fan has published his research in scientific journals such as Science and Nature. In December 2001, they announced a new approach to the production of carbon nanotubes at a rate of 15 kilograms per hour, 60 times faster than the speed at which they had originally been produced.[29]

[29] Alexander Nemets. China's Nanotechnology Revolution", The Jamestown Foundation - China Brief, Volume 4 Issue 16, 05 August 2004

- Department of Advanced Materials and Nanotechnology (http://amn.coe.pku.edu.cn), College of Engineering, Beijing University, was established in 2006 jointly by Georgia Institute of Technology and Beijing University. Professor Zhonglin Wang from Georgia Tech is now the first department chair.

Shanghai

- The Nanoscience and Technology Research Center of Shanghai University (http://www.sro.shu.edu.cn/zhuanxiang/nanocenter/index.asp), was established in May 2000. The main research areas are: nanomaterials, nanobiology and micro- and nano-mechanics. The center is in the process of establishing a base in Shanghai for nanotechnology application pilot testing.

- Shanghai Jiaotong University recently established a Nano Bio-medical research center, and Professor Hongchen Gu is the director.

- Research Institute of Micro/Nano Science & Technology (RIMNST) (http://mnri.sjtu.edu.cn), a spin-off from Shanghai Jiaotong University, was created in 1983 and was the first research institute working in micro/nano-related field in China at that time. Since then, the RIMNST at Shanghai Jiaotong University has grown and now covers many research platforms such as microfabrication, nanofabrication, micro/nano system integration, micro/nano analysis, etc. The RIMNST is organized into a cutting-edge research laboratory as the Key Laboratory of Micro/Nano Processing, which is furnished with state-of-the-art equipments for various micro/nano research activities. Current research areas at RIMNST includes: (1) Non-Silicone micro fabrication and MEMS; (2) Nano-bio medical technology; (3) Nano fabrication and Nano-Electro-Mechanical Systems.

Tianjin

The Cancer Nanotechnology Research Center jointly founded by Tianjin Medical University, National Center for Nanoscience and Technology of China, and Institute of High Energy, CAS was established August 24, 2007 in Tianjin. The center aims to use nanotechnology for early diagnostics and treatment of cancer, and to develop drugs based on nanotechnology. Deputy Director Yuliang Zhao has discovered that C82 nanoparticles selectively kills cancer cells with low cytotoxicity.

Harbin

Although there are scattered research efforts in Heilongjiang University (preparation of nano-film of magnesium oxide carried out in Department of Chemistry and Chemical Engineering), Harbin University of Science and Technology (preparation of polyimide/silica nano hybrid film by sol-gel approach carried out in College of Material Science and Engineering), Harbin Institute of Technology (wear resistant nano ceramic coating), there is no academic center formally established for nanotechnology research in Harbin.

Kunming

Nanotechnology research is carried out in Yunnan University (sensors based on carbon nanotubes and zinc oxide nanostructures), Kunming University of Science and Technology (surface modification of nano titanium oxide); at this time there is no academic center devoted to nanotechnology.

4. Government Policies Initiatives/Subsidy Support (Central Government)

a) Nature and levels of policy support

Nanotechnology has enjoyed state funding since the late 1990s through National 863 Hi-Tech R&D Plan, National Basic Research Program (973 Plan, www.973.gov.cn), National Science Foundation of China (NSFC) programs and others. These plans provided huge investments for nanotech projects from both the central and local governments. According to Bai [25], from 1990 to 2002, the country's 863 Plan funded 1000 nanotechnology projects and total investment reached $27 Million. During the same period, NSFC approved nearly 1000 small-scale projects in related areas.
The 973 Plan was initiated in 1997 and has been devoted to basic science research. The plan supports 8 categories including: agriculture, energy, information, environment and resources, population and health, materials, multidisciplinary and interdisciplinary science. Nanotechnology-related projects are mostly the materials sectors, information, and energy. Participants are mostly from universities and research institutions.

b) Major Programs and Development Focus

Examples of current major programs and development focus include:

1) **Microstructure and physical property study of material at nano-scale** (Year started – 2002)

Search for novel principles, methodologies and techniques for nanometer scale characterization of microstructures and physical properties of nanostructures; Develop electron energy loss spectroscopy combined transmission electron microscopy with simultaneous high spatial （2A） and energy （0.2eV） resolution, single molecular vibration spectroscopy, and cryogenic spin-polarized scanning tunneling microscopy that is able to resolve single atom magnetic moment.

2) **Properties and applications of Nanoscale Materials and Structures** (Year started – 2005)

On the basis of the globe status and trends of nanoscale materials, combining the new requirement from IT, fabrication, biology, medicine, health care and other high tech industries, this project will push up the investigation on nanomaterials towards a higher level. For developing nanomaterial science, the contents of the project have been extended. The key changes, comparing with the last 973 projects have focused on the following aspects: 1. random fabrication to controllable fabrication; 2. wide exploring of new phenomena to systematic investigation of unique properties, stability of properties, and factors that influence properties; 3. from the synthesis to the relation between structures and properties. The key scientific issues solved in this project are as follows: 1. dynamics of controllable growth of nanoscale materials and structure and thermodynamics in the nanoscale limited systems. 2. design, synthesis and properties modulation of nanoscale different material structures and their arrays; 3. structures, properties and nanosize effect of one-dimensional nanomaterials; 4. investigations and applications of novel properties for nanomaterials and nanostructures; 5. dynamic process on nanostructuralization of metal materials and the study of mechanics, electronics and other properties of nanometer metal bulk materials; 6. magnetic transport properties in nanocomposite materials; 7. notable law of energy transition for nanoscale energy source materials. The goals of this project are: 1. development of several kinds of utilizing nanomaterials and nanostructures; 2. development of controllable synthesis and the integration of technical requirements with IT compatibility processes, and providing a basis for further property study of nanomaterials and nanodevice design; 3. The clarification of the relationship between microstructure and intrinsic properties in terms of advanced properties and of potential applications, realizing the functional design and modulation.

3) **Nanotoxicological Study of Manufactured Nanomaterials: China Nanosafety Research Project** (Year started – 2006)

With the rapid development of nanosciences and nanotechnology, diverse types of manufactured nanomaterials have been currently utilized in thousands consumer products to improve their performance such as industrial products, semiconductors, electronics, stain-resistant clothing, ski wax, catalysts, other commodity products such as food, sunscreens, cosmetics, automobile parts, etc. They will also be increasingly utilized in medicines for purposes of clinic therapy, diagnosis, and drug delivery. However, recent studies on the biological impacts of nanomaterials show signs that some of the nanoparticles exhibit unforeseen toxicity to living organisms, and some nanomaterials may become potentially harmful sources that possibly cause vitally new injury to the human health. Accordingly, how to develop nanotechnology safely? This has already become a big challenge for both scientists and governments worldwide. China has established the Laboratory for Bio-Environmental Health Sciences of Nanoscale Materials, where scientists conduct multidisciplinary study on the biological effects of nanomaterials such as identification and quantification of hazards resulting from exposure to nanomaterials and the public health aspects of nanoparticles in air, water, other parts of the environment, foods, and nanodrugs, by assimilating knowledge and techniques of nanoscience, toxicology, medicine, life sciences, chemistry and physics, etc. The objectives of the project are to meet the national demands of development of the potential benefits of nanotechnology. The project mainly aims to understand the following key issues. (1) The ability of nanoparticles breaking through the biological defense systems: Study on the basic law of interactions between nanoparticles and the biological barriers, the elucidation of internal biological pathways and how nanoparticles can enter the human body; (2) What the nanoparticles do after entering the human body, i.e., their biological activities in vivo; (3) ADME and toxicity of nanoparticles in vivo; (4) Relationship between the nanotoxicity and nanosized characterizations; (5) Modeling for prediction of biological safety of nanomaterials, etc.

4) Fundamental Investigation of Molecular Electronics
(Year started – 2006)

This project will focus on the fundamental research of Molecular Electronics. Molecular Electronics can be divided into two parts: Molecular Material for Electronics (MME) and Molecular-Scale Electronics (MSE). MME includes molecular materials and all devices based on molecular materials, such as organic solar cells, transistors, memory and sensing devices. MSE focuses on the research of electronic devices at molecular scale, including techniques for devices fabrication, devices measurement, interconnection and integration, new concept/effect/principle as well as related theory of devices. MME is the basis and premise of MSE, which has potential applications and brilliant market prospect. MSE is the target of the new generation of electronic devices. This project aims at the fundamental questions of Molecular Electronics, which will first focus on the controllable design, synthesis and assembly of new functional molecular materials as well as their physical chemical properties. Then, the materials with outstanding optical, electrical or magnetic properties will be applied in MME to investigate their potential applications as well as the working principle and applicable theory. Finally, these materials will be used in MSE to extend them into molecular scale devices and molecular circuit. With the execution of this project, it could be predicted that the development of Molecular Electronics in China will be advanced.

5) Applied Basic research of microfluidics in chemistry and biomedical science (Year started – 2007)

Microfluidics is involved in the manipulation of the control of fluids (especially those containing chemical and biological species) at microscopic scale, and is an interdisciplinary field between methodology and technology. The main experimental platform of microfluidics is the microfluidic chip, also called Lab-on-a-Chip. It refers to chemical or biological lab constructed on chips several square centimeters in size, with manipulation units at micron scale. The key problems this project will solve are high-throughput, low-cost and low-waste chemical synthesis inside microfluidic channels; microfluidics theory, techniques and methods for drug screening and disease diagnostics.

5. Government Policies Initiatives/Subsidy Support (Local/Provincial Governments)

Beijing

Beijing municipal government supports local nanotechnology R&D through management by Beijing Municipal Science and Technology Commission (www.bjkw.gov.cn), and mostly through the Commission's new materials center. The annual budget is ~100M RMB (~14.7M USD) and research professionals in Beijing are eligible to apply for various projects under this program. Since most national-level research institutions are located in Beijing and they get support primarily from MOST and NSFC, the Beijing ST Commission focuses not on basic research but on applied research and commercialization of nanotechnology.

As to the development focus of the city, according to the "Guideline of Key Fields of Science and Technology Development in Beijing" published by the Beijing Municipal Science and Technology Commission, the local government will focus on the following sections: information technology, new materials, biomedicine, health care, advanced manufacturing, and modern agriculture.

New materials development is of high-priority in Beijing's high-technological development. Special attention is given to electronics and information industry related materials, new energy materials, biomedical materials, special metallic materials, nanomaterials, advanced construction materials, advanced automotive materials, etc. Nanomaterials refer to application of nanotechnology to improve properties of textiles and construction materials. Advanced construction materials refer to high performance, environment-friendly materials. Advanced automotive materials refer to rare-earth permanent magnet electrical generator and advanced polymer materials.

Shanghai

Shanghai municipal government supports local nanotechnology R&D through initiatives and efforts by the Shanghai Nanotechnology Promotion Center. The annual budget is estimated to be 100M RMB (~14.7M USD) and research professionals in Shanghai can apply for various projects under this program.

According to "Shanghai Eleventh Five-year Plan on Science and Technology Development", the focus in Shanghai area over the next few years will be on: information technology, advanced manufacturing, environmental technology, and health.

In the area of IT, Shanghai will continue support for R&D in integrated circuits (including design, test, processing and material for 90 nm fabrication; IC design and technology, nano and micro-technology, device and interconnect, etc.); In advanced manufacturing, Shanghai will continue to support industry designing, modern process and manufacturing, system integration, and advanced material development. These include new energy and low-energy-cost equipments, new transportation equipments, biomedical devices, electronic devices, and precise digital manufacturing equipments.

Tianjin

Tianjin is relatively strong in fields such as IC design, biomedicine, biochips, modernization of Chinese medicine, nanomaterials, electric cars, and others. There are 46 national-level and 113 municipal research institutions located in Tianjin. In the next decade, Tianjin will support 46 key technologies including electronics/IT, biological and modern medicine, chemical engineering, modern service industry and others. [30]

Tianjin will also support 12 science and technology projects: Semiconductor lighting; basic application software and high-end general chip; energy-saving automobiles; membrane technology; new air traffic management system; wind power equipments; new seed selection and industrialization; IT application in international transportation and logistics hub; biomass application; sea-water desalination; pollution protection and remediation in the Bohai gulf; and treatment of major diseases.

[30] "Tianjin Science and Technology Development Eleventh Five-year Plan" (in Chinese)

Nanotechnology Competitiveness and Implications

While it is positioned that Chinese S&T capabilities as a whole do not yet qualify as world class, [31] China's nanotechnology capability is an exception, particularly in nanomaterials where Chinese scientists are leaders in the field. [32] Testimony by Dr. Ehrhard suggests that nanotechnology ''should prove to be a critical enabler that will yield a variety of unsettling economic and security challenges, and as a result, many nations are aggressively pursuing research and development in this area. It stands to reason that the [United States] should both pursue its own nanotechnology initiatives and also closely monitor similar developments in China.''[33]

Nanotechnology is still considered in its infancy. Accordingly, measures such as revenues, market share, and global trade statistics — which are often used to assess and track U.S. competitiveness in other more mature technologies and industries — are not available for assessing the relative U.S. position internationally in nanotechnology. Nevertheless, many experts believe that the United States remains the global leader in nanotechnology. However, some of these same experts believe that in contrast to many previous emerging technologies — such as semiconductors, satellites, software, and biotechnology — the U.S. lead is narrower, and the investment level, scientific and industrial infrastructure, technical capabilities, and science and engineering workforces of other nations are more substantial than in the past. [34] [35] Similarly to the BioIndustry, China is producing more scientists and engineers (not only in China, but on U.S. soil), thus gaining competitive advantages in innovation and discovery in nanoscience.

From our very focused research, it is evident that there is no question that China is rapidly catching up to the United States in nanotechnology. Research in China began in the late 1980s, almost the same time as the U.S. The Chinese government on all levels has been and continues to be a staunch supporter of the field as evidenced by beneficial policies. Since this beginning, nanotechnology has been recognized as one of the priority industries by the government, and one of a handful of areas, which are keeping pace with the U.S. Based on various sources of statistics and data, between 300 and about 1000 enterprises are operating in this space. The U.S. in comparison has over 1000 nanotechnology companies in addition to more than 600 manufactured-identified consumer products available on the market.[36]

Of the three sunrise technologies researched and analyzed for this report, nanotechnology fundamentals and applications are used heavily in both Biotechnology and Electro-Optics (including nanophotonics, nanoelectronics). It is this awareness that current trends in China's

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[31] John Parmentola, Briefing on American and Chinese Science and Technology Developments, briefing to the U.S.-China Economic and Security Review Commission, Wright-Patterson Air Force Base, Ohio June 29, 2007

[32] Christine M. Anderson, Briefing on American and Chinese Science and Technology Developments, briefing to the U.S.-China Economic and Security Review Commission, Wright-Patterson Air Force Base, Ohio June 29, 2007

[33] U.S.-China Economic and Security Review Commission, Hearing on the U.S.-China Relationship: Economics and Security in Perspective, testimony of Thomas P. Ehrhard, February 2, 2007

[34] CRS Report for Congress; Nanotechnology: A Policy Primer; May 2008

[35] Meeting per U.S. Congressman Joseph Sestak's office January 8, 2009; "U.S.-China S&T at 30", Science Volume 323, January 30, 2009; www.sciencemag.org

[36] 'Nanotechnology Oversight: An Agenda For The New Administration', Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars, June 2008; www.nanowerk.com

nanotechnology R&D efforts could potentially have economic and political implications for the U.S. as outlined below.

Globally, nanotechnology is expected to account for 11 percent of manufacturing jobs by 2014. [37] Nanotechnology can help the government deal with many of the major problems it faces, such as energy, climate change, water supply, and homeland security. It's not too far-fetched that military applications of nanotechnology could alter the balance of power among nations. The Geneva Forum in November 2007 pointed out that most research into military applications of nanotechnology at that time took place in the U.S. It was also assumed that other major countries, including China also conducted such research on nanotechnology-based materials and systems for military use, though it is widely known that this is an area the U.S. aimed to exploit fully to maintain technological superiority [38] Within this context it remains America's interest in terms of military and national security concerns that agreement on specific multi-lateral international constraints beyond rudimentary provisions contained in existing treaties be considered. This is arguably a relevant concern, in light of China's continued advancement in this space.

A widespread adverse event from nanotechnology manufacturing or a nanomaterial could confront government agencies with a crisis and bring development of the technology to a halt. On a more personal level, nanotechnology may also produce materials that could have the same effect on lungs as asbestos, damage human DNA or wipe out bacteria necessary for the functioning of ecosystems.

The combination of poorly understood risks and increasing commercial product flow led the World Economic Forum to declare the risks of nanotechnology as one of the two major technological risks facing the planet. (The second risk is an attack on or a system failure of the global information infrastructure.). [39]

Nanotechnology applications can be characterized as passive or active. [40] The distinction is important because it highlights the magnitude of the technological breakthroughs still to come with nanotechnology. Passive applications are those in which the nanomaterial or structure does not change form or function. Almost all the discussions about regulating nanotechnology in the U.S. to date have focused on passive applications. Passive nanostructures are materials that are typically added to existing products and materials. Active nanostructures or nanomaterials by contrast are able to change their form or function. A simple example is an anti-cancer drug in which a dendrimer (a type of nanomaterial) is designed to find cancer cells, attach itself to the cells and then release a chemical that kills them. From this project, it is inferred that most, but certainly not all of the current research and development activities in the targeted areas China are also of this nature.

On a more complex level, the increasing overlap between biotechnology and nanotechnology will eventually lead to nanosystems being used to assemble large systems that might include

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[37] Lux Research 2006, vol. 1, p.19

[38] 'Military Applications Of Nanotechnology: Challenges For Arms Control', Dr. Jurgen Altmann, Geneva Forum; "Military nanotechnology – how worried should we be?" November 13, 2006; www.nanowerk.com

[39] World Economic Forum 2008, p. 51

[40] "Nanotechnology Risk Governance", International Risk Governance Council 2007

replacement limbs for humans or complex robots. As of 2007, the Food and Drug Administration (FDA) had approved 24 nano-based drugs, and an additional 26 nanodrugs were undergoing clinical trials. [41]

The meaning of oversight in the context of active nanostructures is a challenge experts are just beginning to face. On this note, China has been on the forefront in issuing national standards for nanotechnology supported by the Ministry of Science and Technology (MOST), Ministry of Health (MOH), and other agencies. In 2003, the Lab for Bio-Environmental Health Sciences of Nanoscale Materials was established at the Institute of High Energy Physics, CAS. In this laboratory, researchers from the nanoscience, biological, toxicological, environmental sciences and chemical fields work together to explore the biological and environmental (including both the positive and negative) effects of nanoscale materials. The research activities include not only ways to identify the possibly adverse effects of nanomaterials, but also ways to recover or reduce the release of nanoparticles in manufacturing processes and how to eliminate nanotoxicity. [42] In accordance to the National Science Foundation of China's 11th Five Year Plan, in 2006 it was reported that for the three prior years, government financial support for nanotechnology Environment, Health and Safety (EHS) research in China had increased to about $10 Million, roughly 10% of total government investment. [43]

In April 2005, China became the first country to issue national standards for nanotechnology, thereby laying groundwork for international standards, and improving its clout in the global nanotechnology market. [44]

As stated earlier in this report, one of the major development projects of the Central Government is the China Nanosafety Research Project. In August 2006, NCNST established the China Lab for the Bio-Environmental Effects of Nanomaterials & Nanosafety to focus on the economic, environmental and social aspects of the research, standardization, regulations of nanotechnology. The missions of the China Nanosafety Lab mainly include, (1) Conducting methodological and metrological studies of nanoparticle detection; (2) Identification and quantification of nano-hazards to humans and the environment; (3) Exploring the behaviors of nanoparticles in the environment (air, water, soil, and other parts including foods and nanodrugs, etc.), and their health impacts; (4) Accumulating experimental data on nanotoxicology and nano-ecology; (5) Drafting regulatory frameworks for research and industrial activities on nanotechnology; (6) Establishing standard procedures for safety assessment of nanoproducts for nano-industries/ enterprises including assessment methods, and identifying the toxicity classes of nanomaterials.

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[41] Zhang, L., et al., 2007. "Nanoparticles in medicine: therapeutic applications and Developments," Chemical Pharmacology and Therapeutics

[42] 'Current developments in China on the safety of manufactured nanomaterials', Institute of Physics, CAS, Notational Center for NanoSciences and Technology, National Technical Committee 279 on Nanotechnology of Standardization Administration of China; 4-17-2007

[43] 2006 Powerpoint of NSFC's 11th Five-Year Plan, Major Project: Environmental activity and Health impact of ambient superfine particles (2006-2010); www.nanoctr.cn

[44] Worldwatch Institute, State of The World 2006

This is an area of increased interest to the U.S. as demonstrated by congressional testimony on the National Nanotechnology Initiative Amendments Act of 2008, advocating a minimum of 10% of the federal government's nanotechnology R&D budget to this research. [45]

Of the five cities researched and analyzed, Beijing and Shanghai exhibited most of the R&D and commerce in nanotechnology, and any future capabilities will likely emerge from those two areas, in addition to the Guangdong and Jiangsu provinces. In terms of funding, the amount of support in China for nanoscience and nanotechnology is relatively small (~$160M USD) compared with that of the United States. The National Nanotechnology Initiative (NNI) established in FY 2001 to coordinate federal nanotechnology R&D, is the federal structure for promoting the development and use of nanotechnology. Budget expenditures have increased steadily from 2007 ($1.425B) to an estimated 2008 budget of ~$1.491B to a proposed 2009 budget of ~$1.527B. [46]

The National Nanotechnology Initiative Amendments Act of 2009, which passed the House earlier this year for Senate action will strengthen the National Nanotechnology Program if approved, while demonstrating a long-term commitment to this industry of major importance.[47]

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[45] U.S. House of Representatives Committee on Science & Technology Hearing on 'The National Nanotechnology Initiative Amendments Act of 2008', April 16, 2008

[46] National Nanotechnology Initiative FY 2009 Budget & Highlights

[47] H.R. 554: National Nanotechnology Initiative Amendments Act of 2009

Part 4: Electro-Optics Industry

Section 1: Infrared Technology

1. China's Progress in R&D of Infrared Technology

Over the past twenty years, China's maturing transformation towards openness has resulted in increased exposure and dialogue in the nation's optoelectronic industries. In many of China's strategic scientific plans, optoelectronic technologies are given much prominence, as illustrated among the seven major plans of the 863 Program. China has set up six industrial bases for optoelectronic activities (Beijing, Wuhan, Shanghai, Shijiazhuang, Shenzhen, and Changchun). Beginning in 2000, there have been increased efforts towards creating and cultivating Optoelectronic Industry Development Zones in support of this evolving sector, at least 13 in number. In recent years, the Chinese infrared (IR) commercial market has developed steadily. Currently, approximately 400 entities (institutions, companies, organizations) are engaged in the support, R&D, and production of infrared (IR) products for China's domestic market. Major companies engaged in infrared materials, devices and system development includes North China Research Institute of Electro-optics (NCRIEO, www.ncrieo.com.cn), Institute # 8358 of the China Aerospace Science and Industry Corporation (CASIC), the Kunming Infrared Optics Company (www.kiro.cn/en/), a subsidiary of Kunming Institute of Physics, and the Shanghai Institute of Technical Physics CAS (www.sitp.ac.cn/), and the China Optics and Optoelectronics Manufacturing Association (www.coema.org.cn/English.htm).

Two primary IR development trends are presented here.

1) Infrared optoelectronic physics research

The main driving force of infrared optoelectronic physics development is increasing its application use. One of the most important outcomes is the research of large scale infrared focal plane arrays (IRFPA) for different wave bands: mid-infrared, far-infrared wave bands, laser, infrared mono-photon detector, and THz optical source and detector. Most of which have important applications in missile or related weapons guidance sensors, infrared astronomy, manufacturing inspection, thermal imaging for firefighting, medical imaging, and infrared phenomenology (such as observing combustion, weapon impact, rocket motor ignition), among others.

2) Infrared optoelectronic material and FPA device information acquisition technologies

Satellite-carried high resolution infrared cameras are one of many existing products used for IR information acquisition. China continues to research and develop materials to construct high-quality, high resolution FPAs. In recent times, China has developed significant experience working with materials such as mercury-cadmium-telluride (HgCdTe), Indium Antimonde (InSb), and Indium Gallium Arsenide (InGaAs) used for development of FPAs.

2. Major Domestic Participants (Academic and Corporate)

As the IR sector continues to grow and deepen, several universities, institutions, engineering centers, and companies continue to be active players in the field. A few of the many are listed in this section, including Shanghai Institute of Technical Physics CAS (www.sitp.ac.cn/), one of the leading participants in the IR sector.

- NCRIEO (www.ncrieo.com.cn), is one of the earliest established institutes in both the IR and Laser fields in China. Since 1970, NCRIEO has been a force in the laser and IR technology becoming the first entity involved in the comprehensive study of photovoltaic technology.
- Institute of Optics and Electronics, Chinese Academy of Sciences (IOE), (www.ioe.ac.cn) also named Chengdu Institute of Optics and Electronics, founded in 1970, is the largest institute of Chinese Academy of Sciences (CAS) in Southwest China. IOE participated in the Pilot Project of Knowledge Innovation Program (PPKIP) of Chinese Academy of Sciences (CAS) in 1999 and was recognized as one of the elite institutes of CAS in 2006.
- China North Industries Group Corporation (NORINCO) (www.norinco.com) is an important mega state-owned key enterprise under the direct administration of the Central Government and a strategic group of China to react to challenges and crises. NORINCO brings together the key research and production forces of the Chinese military-industry complex. It is the largest weaponry-manufacturing group in China. It researches and develops high technological weapons of various areas such as precision striking, amphibious assaulting, long-range suppression, air defense anti-missile, information night vision, high effective destruction, etc. for the military, playing a fundamentally strategic role in the modern construction of China national defense.
- China Electronics Technology Group Corporation (CETC) (www.basuo.com.cn/) established in 1970 is a specialized research and development institute engaging in optical fiber & cable technology, the main specialties include: optical fiber & cable and connector technology, optical fiber sensing technology, optical fiber & cable technique specialized equipment technology and optical fiber communication system engineering technology. In recent years, the institute was conferred a title of Advanced High Technology Enterprise by the Science Commission of Anhui Province and the National Science Commission.
- China Aerospace Science and Technology Corporation is the main contractor for the Chinese space program, established in 1999. It is a state-owned enterprise having a number of subordinate entities which design, develop and manufacture a range of spacecraft, launch vehicles, strategic and tactical missile systems, and ground equipment.

3. Examples of Major Alliances with U.S./Western Interests

Cooperation between domestic and foreign research institutions has been and continues to be either specific projects or technology-oriented research and development in nature.
Two recent examples includes: an agreement between the Institute of Semiconductors CAS (www.semi.ac.cn) and Chalmers University of Technology (www.chalmers.se/en/) in November 2008, and between Changchun Institute of Optics, Fine Mechanics and Physics, CAS (www.ciomp.ac.cn:8111/index.asp) and Carleton University (www.carleton.ca/) in December 2008.

- **The Effectiveness of Foreign Technology Transfer**

From China's point of view, the facilitation of technology transfer from foreign companies has been effective. In the Superconducting IR detection technology space, China has successfully introduced and applied a number of foreign advanced technologies, into both their military and civilian sectors.

Chinese military, industrial and medical detector demand has increased in proportion to both domestic and international demand. IR detection technologies can be used in industrial automation, early medical diagnosis of cancer, fires, anti-theft alarm and remote sensing, and astronomical observation used in geological prospecting. Superconducting infrared detector is a resource, used in meteorological satellites and is the ideal detector widely used in missiles, infrared detection, and tracking systems.

China's military remains the biggest end-users of IR detectors. Future applications of Fiber-optic probe requirements will continue to rise. Except for IR thermal imaging detection, the Chinese IR market is still relatively small compared with industrialized countries, and holds great potential. The market for high-performance multi-color IR focal plane arrays, in addition to smart chip-based smart image processing technology will continue to increase. At present, there are relatively few Chinese suppliers of IR heat image apparatus.

4. Science and Technology Parks/High Tech and Economy Development Zone

- The Kunshan Photoelectric Industrial Park, based within the Kunshan Development Zone builds upon the region's strong optical electronic industry. Kushan, a satellite city in the greater Suzhou region in southeast Jiangsu, just outside Shanghai. After several years of development, several flagship companies, such as Longteng Photoelectricity and Dexin Electron, have established operations in the park. Longteng Photoelectricity has evolved to become the 3rd leading producer line of 5th generation TFT-LCD (Thin film transistor liquid crystal display) systems behind Jingdongfang Technological Group (www.boe.com.cn) and SVA Group (www.sva-usa.com).

- Xiamen Optoelectronic Industrial District includes 34 photovoltaic companies, 20 of which are large scaled. One of the tenants, Sanan Electronics (www.sanan-e.com) has developed into China's largest LED wafer and chip manufacturer. The Industrial District is also home to such companies as Hualian Electronics (www.xmhl.com), Acer Electronics, and the Ruihua Electronics Group.

- Kunming Opto-electronics industry base is a collaborative project of the Yunnan Provincial Government and the China North Industries Group Corporation. This project includes establishing and operation of IR thermal imaging machine production lines, IRFPA controller production lines, materials processing, as well as solar cells (60 Megawatts) production lines.

5. Governmental Policy Advocacy and Financial Support

China's preferential policies for the Electro-Optics sector are similar to those of other S&T industries targeted by the Chinese Government. One example of regional government support includes the Yunnan Province Information Industry Development Program of the Eleventh Five-Year Plan.

Section 2: Laser Technology

1. China's Progress in R&D of Laser Technology

Due to the significant impact on China's social, technological and scientific advancement, laser technologies are considered as one of the national strategic key industries by the Chinese government. Recognizing the increasing importance of this sector in other countries, the government has realized the significant role that laser applications have in virtual every facet of modern society, including consumer electronics, information technology, science, medicine, industry, law enforcement, entertainment, military [48], and national security. Laser technology and laser processing were listed as one of the "National Key Construction Projects" and "S&T Gongguan Program" in China's 6th, 7th, 8th and 9th Five-year Plan. Two of the main research tasks and goals of China's '973' National Basic Research Program includes:

(a) Exploring and developing novel laser concepts, such as optical parametric chirped pulse amplification (OPCPA); searching for solutions to the key scientific problems for creating a new generation of laser conditions, such as ultrahigh laser field, extremely short pulse duration,

[48] 2008 Annual Report to Congress; Military Power of the People's Republic of China

wavelength tunability, and new wavelength coverage; making breakthroughs in the international competition of petawatt (1PW=1015W) level laser technology; and establishing a world-class research center for ultrafast high field science in China, and

(b) Exploring the new frontiers of high field, high energy density physics and high field nuclear physics, and laying scientific foundations for the development of strategically important high technologies, such as fast ignition scheme of laser fusion, compact particle accelerator with ultrahigh accelerating gradient, and table-top high brightness X-ray and γ-ray sources.

2. Structure of Laser Industry

Presently, major Chinese laser product manufacturers are primarily located in developed provinces and cities such as Hubei, Beijing, Jiangsu, Shanghai and Guangdong (including Shenzhen and Zhuhai special zone). Annual sales of laser products in each province and city have exceeded 100M RMB (~14.7M USD) and that of Hubei province has gone over 1.2B RMB (~176M USD). These two outputs are approximately 90 per cent of the national total in the laser product market. As the 11th Five-Year Plan continues to be implemented, it is expected that this industry will continue to grow and expand. [49]

Applications of Laser technologies include:

Medicine: Bloodless surgery, laser healing, surgical treatment, kidney stone treatment, eye treatment, dentistry
Industry: Cutting, welding, material heat treatment, marking parts
Defense: Marking targets, guiding munitions, missile defense, electro-optical countermeasures (EOCM), alternative to radar
Research: Spectroscopy, laser ablation, Laser annealing, laser scattering, laser interferometry, LIDAR, Laser capture micro-dissection
Commercial: laser printers, CDs, barcode scanners, thermometers, laser pointers, holograms
Laser lighting displays: Laser light shows

In 2004, excluding diode lasers, approximately 131,000 lasers were sold worldwide, with a value of US$2.19 Billion.[50] In the same year, approximately 733 million diode lasers, valued at $3.20 Billion, were sold.[51]

3. Technology Development

From over 40 years of development, China has established a strong technology foundation and skilled talent pool for the laser industry. The country has set up four state-level laser processing

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[49] www.coema.org.cn/E_laser.htm
[50] Kincade, Kathy and Stephen Anderson (2005) "Laser Marketplace 2005: Consumer applications boost laser sales 10%", Laser Focus World, vol. 41, no. 1.
[51] Steele, Robert V. (2005) "Diode-laser market grows at a slower rate", Laser Focus World, vol. 41, no. 2.

(technology) research centers, and many research or academic institutions including Huazhong University of S&T, Shanghai Institute of Optics and Fine Mechanics, CAS, Beijing University of Technology, Changchun Institute of Optics, Fine Mechanics and Physics, CAS, North China Research Institute of Electro-optics (NCRIEO), Institute of Semiconductors, CAS, and other institutions.

China has acquired core competencies in the following products:

- Ti sapphire Laser-pumped Yb (Solid State Laser)
- YAG Microchip Laser (Solid State Laser)
- Traditional CO_2 Laser with high-power (Gas Laser)
- YAG Laser (Solid State Laser)
- Nd Laser diode side pumping, (Solid State Laser)
- YV04 (Solid State Laser)
- Medium or Low-efficiency semiconductor laser
- Miniature Green Laser Pumped by Diode Laser

Table 1: Lasers developed by major institutions

Type		**R&D Level**	**Commercialized Level**	**Notes**
CO_2 Laser	Transverse-Flow	10-50kW	<2000W	Domestic ordinary level
			<3000-5000W (few)	Available in Hubei
	Axis-Flow	6000W	<4000W	Imported and manufactured by Hubei
	Radio Frequency-excited	200	200	Domestic first-class
Semiconductor Laser	Serial High-power Semiconductor Laser	100W	60W	Available in China
YAG Solid Laser	Lamp-pumped	3000W	<2000W	Domestic ordinary level
	Diode Laser-pump	3000W	<200 W	Available in Hubei

Green Laser	Double Frequency	200W	100W	Under R&D
UV Laser	Triple Frequency	10W	8W	Domestic first-class level
Fibre Laser	Commercialized	1000W	None	N/A

Source: State Key Laboratory of Laser Technology, Huazhong University of Science & Technology

4. Commercialization Efforts

In the mid-1990s, a growing number of laser enterprises emerged in China. The domestic sales revenue generated by laser processed devices has grown by over 20% annually, and reached 3.6B RMB (~526.6M USD) in 2007. Today, there are more than 100 commercial institutions in China specializing in producing lasers and laser-applied devices. Major laser processing device manufacturers are listed in Table 2.

Table 2: Major laser processing device manufacturers in China

Institutions	**Main Products**
Wuhan Chutian Laser (www.chutianlaser.com)	Medical laser devices and laser processed devices
Wuhan HuaGong (HG) Laser (www.hglaser.com)	Lasers, laser-processing and medical laser devices
Wuhan Optics Valley Laser (www.ovlaser.com)	Lasers, laser-processed devices, laser processing station
Shanghai Institute of Laser Technology (www.shlaser.com)	Lasers, laser-processing and medical laser devices
Shanghai Institute of Optics and Fine Mechanics, CAS (www.siom.ac.cn)	Lasers, laser processing and medical laser devices
Beijing Daheng Laser (www.dahenglaser.com)	Laser-processed devices
Shenzhen Han's Laser (www.hanslaser.com)	Laser-processed devices such as laser marker, etc.

Wuhan Golden Sky Laser (www.goldenskylaser.com)	Super-power lasers, lasers, laser-processed devices
Guangdong Yueming Laser (www.ymlaser.com)	General laser-processed devices
China Lasers (Wuhuan) Co. (www.chinaovlaser.com)	Semiconductor pumped solid lasers and processed devices
The 27th Institute of Ministry of Information (Henan)	Military laser ranger-finder, laser detection
Huazhong Univ. of S&T (www.hust.edu.cn)	Lasers, laser-processing, medical devices
Beijing Institute of Optoelectronic Technology (www.bioet.com.cn)	Medical laser devices, laser-processed devices, ranger-finger devices
Laser Institute 722 Factory	Lasers, laser-processing, medical devices
North China Research Institute of Electro-optics (www.ncrieo.com.cn)	Laser processed machines and military range-finder devices.
No. 5308 Factory	Military range-finding devices

Table 3: Companies whose revenue has exceeded 100 Million RMB (~14.6M USD) in random order

	Company
1	Shenzhen Han's Laser Co.
2	Wuhan Chutian Laser Group
3	Wuhan HuaGong (HG) Laser Co.
4	Wuhan Optics Valley Laser Co.
5	Guangdong Yueming Laser
6	Wuhan Telecommunication Devices Co Ltd.
7	Accelink Technologies Company, Ltd.
8	Wuhan HuaGong Genuine Optics Tech Co., Ltd
9	NeoPhotonics China (Shenzhen)
10	Fiberxon (Shenzhen) Technology
11	Jiangsu Shuguang Optoelectronic Co., Ltd.
12	Shenyan Dalu Laser Co.
13	Changzhou Laisai Laser Tech Co.
14	Hubei Huazhong Photoelectronic Tech Co.
15	Shanghai Unity Prima Laser Machinery Co. (Sino-Italy)
16	South-west Institute of Technical Physics

17 Fujiang OCLI-CASIX Co. (wholly foreign-owned)

**Source: State Key Laboratory of Laser Technology,
Huazhong University of Science & Technology**

5. Science Parks

- Optics Valley of China (OVC):

OVC is located in the 50-square-kilometer East Lake (Dong Hu) New Technology Zone in Wuhan. It is home for many academic and research institutions engaging in laser technology development, including Huazhong University of S&T, Wuhan Research Institute of Post and Telecommunications, Wuhan University, Wuhan Branch of CAS, and No. 717 Institute. OVC is also home to 40,000 Chinese scientists specializing in optoelectronics or laser technologies research. As one of the leaders in laser technology, Huazhong University of S&T set up a state-level key laboratory of laser technology in the 1980s and a national laser processing engineering center in the early 1990s. OVC also hosts over 20 large-scale, influential laser companies such as Chutian Laser, Huagong Laser, Unity Primer Laser, etc.

Wuhan Chutian Laser has formed a joint venture with ESC/SharPlan based in Israel. Wuhan Huagong (HG) Laser acquired an Australia-based Farley Laser Lab. Wuhan Huagong Hengxing Laser partnered with Prima N. A. (U.S.) and imported its CO_2 laser production technology. Wuhan Unity formed a joint venture with Italy-based PRIMA Laser.

Electro-Optics (Laser/Infrared) Competitiveness and Implications

Although U.S. firms continue to dominate in the defense sector for imaging and sensor technology, Japan, France, Korea, China, and other nations are meeting commercial demand. [52] According to a previous study by the Department of Commerce, Bureau of Industry & Security, China achieved 159 percent growth in electro-optics (including Laser IR) exports from 2001 to 2005, the world's second highest growth rate during that period. [53] Because U.S. export controls on many optoelectronic products prevent U.S. companies from supplying these items to end-users in a number of nations, including China, this market is therefore open to non-U.S. manufacturers, and China has had an incentive to maximize the development of its optoelectronics industry. This dynamic is only one reason China is likely to retain a major presence in the electro-optics industry over the next ten years. One National Intelligence Council study estimated that a combination of China's centrally planned focus on developing night vision technology, and its ability to exploit export opportunities, will enable China to develop a significant capacity and move into second place in the world in this field by 2014, surpassing all other nations except the United States. [54] Though the focus of this report were on selected areas, our research was more comprehensive, and analyses suggests that Beijing and Shanghai, along with Wuhan, Jiangsu, and Suzhou are furthering their R&D in this sector at a much rapid pace, than other regions in China.

It is widely recognized that Electro-Optics is oftentimes thought of as "dual-use" technology, in which U.S. based products and technologies are acquired by China, for commercial use, having capabilities to be designed for military use. This, combined with China's robust efforts towards advancing "sunrise" technologies, could potentially prove to be challenging in the future. Though codified into law [55], exceptions have continually been made, allowing flow-through of potentially sensitive technologies. In addition, the U.S. Commerce Department has allowed growing trade in such items that may have a military use but are not weapons in and of, themselves. This suggests a contrast in official policy of refusing export license applications for dual-use items to Chinese military end-users. [56] [57]

"In a 2005 exchange regarding U.S. exports of dual use technologies to China, former Department of Defense official Lawrence Korb (then with the Center for American Progress) told Peter Lichtenbaum, then Acting Undersecretary for Industry and Security of the Department of Commerce, that "…the United States exports equipment and technology to China that actively contributes to Beijing's ability to wage war." Korb noted that U.S. exports were not "…being

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[52] U.S. Department of Commerce, Bureau of Industry and Security, Defense Industrial Base Assessment: U.S. Imaging and Sensors Industry (Washington, DC: October 2006), p. I-1

[53] U.S. Department of Commerce, Bureau of Industry and Security, Defense Industrial Base Assessment: U.S. Imaging and Sensors Industry (Washington, DC: October 2006), p. VII-12

[54] National Intelligence Council, Science and Technical Intelligence Committee, Global Technological Assessment of High Performance Mercury Cadmium Telluride Infra-Red Focal Plane Arrays, September 2004, p. 20

[55] H.R. 3792, Foreign Relations Authorization Act, Fiscal Years 1990 and 1991, (Considered and Passed by House)

[56] See, "An E-mail Exchange between the Department of Commerce and the Center for American Progress," March 27, 2005, http://www.americanprogress.org/issues/2005/03/b727703.html

[57] National Intelligence Council, Science and Technical Intelligence Committee, Global Technological Assessment of High Performance Mercury Cadmium Telluride Infra-Red Focal Plane Arrays, September 2004, p. 20

used in a manner consistent with our national security and nonproliferation interests." [58] Appropriate safeguards are needed on dual-use technologies while ensuring U.S. competitiveness commercially. Better interagency coordination/agreement is an area, which needs improvement. [59]

As one example, China is said to be acquiring a variety of foreign (including U.S. and American allies) technologies, which could be used to develop an anti-satellite (ASAT) capability. Beijing already may have acquired technical assistance which could be applied to the development of laser radars used to track and image satellites and may be seeking an advanced radar system with the capability to track satellites in low earth orbit. It also may be developing jammers, which could be used against Global Positioning System (GPS) receivers. In addition, China already may possess the capability to damage, under specific conditions, optical sensors on satellites that are very vulnerable to damage by lasers. Beijing also may have acquired high-energy laser equipment and technical assistance, which probably could be used in the development of ground-based ASAT weapons. [60] [61]

Additional Considerations

As the United States anticipates and anxiously welcomes China's inevitable continual ascendance into a peaceful and prosperous country, much debate and discourse continues surrounding the future course its leaders will set for its country. If current trends persist, notwithstanding the present global financial and economic downturn, by 2025 China will have the world's second largest economy, fueled significantly by such high-tech industries as Biotechnology, Nanotechnology and Electro-Optics, targeted by its government, among others. China will also become a leading military power, as one of the many outcomes of this progression. U.S. security and economic interests could face new challenges if China becomes a peer competitor that is militarily strong as well as economically dynamic and energy hungry. [62] [63]

According to the 2006 National Security Strategy, a critical component of the strategy was the establishment and pursuit of continuous strategic dialogue with China to build understanding, improve communication, and to reduce the risk of miscalculation.[64] As China continues to modernize and develop military capabilities primarily focused on a potential Taiwan Strait conflict, but which could have application in other contingencies, the U.S. DoD is equipped to respond to China's expanding military power, and to the uncertainties over how it might be used.

[58] Richard Fisher, Jr., "China's Military Employment of American Dual-Use Technologies, International Assessment and Strategy Center, August1, 2008
[59] Meeting per U.S. Congressman Joseph Sestak's office January 8, 2009
[60] (www.globalsecurity.org/space/world/china/asat.htm)
[61] Bruce W. MacDonald, "China, Space Weapons, and U.S. Security, Council on Foreign Relations Special Report No.38, September 2008
[62] Global Trends 2025: A Transformed World; National Intelligence Council, November 2008
[63] 2009 and 2008 Annual Report to Congress, Military Power of the People's Republic of China, U.S. Department of Defense
[64] Presidential 2006 National Security Strategy

[65] At the same time, it is both assumed and determined that other elements of the U.S. Government will be also be heavily involved towards refining a comprehensive strategy to shape China's choices. [66]

China is the one ascendant state with the potential for competing with the United States. For the foreseeable future, the U.S. will be required to hedge against China's growing military modernization and the impact of its strategic choices upon international security. It is likely that China will continue to expand its conventional military capabilities, emphasizing anti-access and area denial assets including developing a full range of long-range strike, space, and information warfare capabilities.[67]

It is common knowledge that China continues to develop disruptive technologies, some based on applications of nanotechnologies and electro-optics (lasers, infrared technologies) to circumvent traditional advantages. Examples include development of anti-satellite capabilities and cyber warfare. [68] Other entities, groups, particularly non-state actors, are developing asymmetric tactics, techniques, and procedures that seek to avoid situations where our advantages come into play. [69]

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[65] National Defense Strategy, June 2008; US Department of Defense
[66] Ibid.
[67] Ibid.
[68] U.S.-China Economic and Security Review Commission, Hearing on "China's Proliferation Practices, and the Development of its Cyber and Space Warfare Capabilities", Washington, DC May 20, 2008
[69] National Defense Strategy, June 2008; Department of Defense