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CHINA'S (NOT SO HIDDEN) DEVELOPMENTAL STATE: BECOMING A LEADING NANOTECHNOLOGY INNOVATOR IN THE 21ST CENTURY

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Abstract

In this paper we examine the role of the Chinese Government in fostering advances in nanotechnology, looking at the promises and pitfalls of state-led development in the world's fastest-growing major economy. Like many countries involved in catch-up development, China is convinced that manufacturing prowess alone is insufficient to becoming a leading economic power in the 21st century. Our concern is how the debate over innovation is reflected in China's approach to national development, with a particular application to nanotechnology. In many countries, including the United States, government spending on nanotechnology is seen as essential to creating world leadership in this emerging fielding. The U.S, for example, is currently spending $1.5 billion annually on its National Nanotechnology Initiative – primarily to foster basic research and development. In comparison with the U.S. approach, in China – which has an economy that is transitioning from state-owned to privately-owned enterprises, and still suffers from a lack of private investment capital – nanotechnology is being funded largely through government sources. Moreover, in China, such funding extends more broadly across the value chain than in the United States, from fundamental research to commercialization. Through field research and extensive interviews, this paper documents China's state-led efforts to become a global nanotech leader, evaluating the effectiveness of these efforts.

Introduction: The Push for High-Tech Global Leadership

Like many countries involved in catch-up development, China is convinced that manufacturing prowess alone is insufficient to becoming a leading economic power in the 21st century. China's overarching goal is to become an "innovation-oriented" society by the year 2020 (OECD 2007: 17). Innovation is difficult to define, and even harder to operationalize. The Organization for Economic Cooperation and Development (OECD) defines innovation as "new products, business processes and organic changes that create wealth or social welfare," while Richard Lyons, Dean of UC Berkeley's Hass School of Business, offers an even more succinct formulation: "fresh thinking that creates value" (*The Economist* 2007: 2). How to become innovative in the contemporary global economy, and why it matters, has generated a plethora of ideas, concepts, and hypotheses.[2] Our particular concern here is how the debate over innovation is reflected in China's approach to national development, with a particular application to nanotechnology.[3]

By way of background, China is not alone it its push to become a leader in nanotechnology: the United States, Germany, Japan, and some 40 other countries are betting that nanotechnology, among other high-tech approaches, will provide the key to a $2.6 trillion market by 2014– sufficient to confer global economic leadership on the country that attains first mover advantage through innovation (Holman *et al* 2007: iii). It is estimated that $11.8 billion was invested globally in nanotechnology research and development (R&D) and commercialization in 2006 - $5.8 billion from governments, $5.3 billion from corporations, and $700 million from venture capital (Holman *et al* 2007: 11-12). Private investment slightly outstripped public investment for the first time in that year. Governments worldwide have clearly been drivers of nanotechnology during its early stages, and private venture capital remains limited.

In terms of government spending, the United States is the world leader, with $1.53 billion allocated for 2009, roughly a quarter of global central government investment in nanotechnology. U.S. government spending is coordinated through the National Nanotechnology Initiative (NNI), "a multi-agency U.S. government program aimed at accelerating the discovery, development, and deployment of nanometer-scale science, engineering, and technology" (US NNI 2008e). Initiated during the last year of the Clinton Administration, the NNI has invested some $7.2 billion since it began funding programs and projects in 2001 (AZoNano 2008). Today it encompasses 26 Federal agencies with nanotechnology-related programs, providing funding for 13 of them. More than half of the proposed FY 2009 funding ($818 million, or 54 percent) is directed at those agencies that fall under the American Competitiveness Initiative: the National Science Foundation (NSF), the Department of Energy's Office of Science (DOE-OS), and the Department of Commerce's National Institute of Standards and Technology (DOC-NIST). These three agencies have seen

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[2] See *The Economist's* (2007) special report on innovation for a review of some of these views.

[3] The US National Nanotechnology Initiative defines nanotechnology as "the understanding and control of matter at dimensions of roughly 1 to 100 nanometers [where] the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of atoms and molecules or bulk matter. Nanotechnology R&D s directed toward understanding and creating improved materials, devices, and systems that exploit these new properties" (US NNI 2008). Lux Research (a private firm that tracks nanotechnology) offers a similar but pithier definition: "the purposeful engineering of matter at scales of less than 100 nanometers to achieve size-dependent properties and functions" (Holman *et* al, 2007: Figure 1.2). A nanometer is one billionth of a meter. Human hair averages roughly 100,000 nanometers thick (there is considerable variation depending on hair color and texture), while a DNA molecule is 2-3 nanometers in width.

their combined budgets grow by 22 percent during the three-year period since 2006, reflecting the Bush Administration's plan to "double funding for key agencies supporting innovation-enabling research in the physical sciences and engineering over the next ten years, as part of the American Competitiveness Initiative" (US NNI 2008a).[4]

Apart from Defense and Homeland Security related applications, the principal force driving public investment in nanotechnology has been the goal of competitiveness: to make the U.S. a world leader in this emerging technology. The NNI identifies four overarching goals on its website (US NNI 2008b):

- Advance a world-class nanotechnology R&D program.
- Foster the transfer of new technologies into products for commercial and public benefit.
- Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology.
- Support responsible development of nanotechnology.

NNI funding thus far has been largely directed at supporting basic R&D, for example, through the funding of more than 60 multidisciplinary research and education centers across the United States – primarily universities, but also the National Laboratories and some government agency facilities (US NNI 2008c).[5] The budget proposed for 2009 identifies eight different program component areas, almost all of which are primarily directed at basic research (US NNI 2008d). While there is clearly spill-over from basic R&D to commercialization, the U.S. approach has largely been on government support for the former. The NNI has called for working with industry to foster technology transfer and commercialization. For example, its Nanoscale Science, Engineering, and Technology (NSET) Subcommittee in 2006 announced plans to "expand its activities to reach out to U.S. industry for input on research needs and to identify opportunities for technology transfer from NNI-funded research activities" (US NNI 2006: 41), as well as "increase Federal-State coordination and improve knowledge management of and access to NNI assets [such as] user facilities and instrumentation" (vi).

Some limited U.S. federal funding has gone to directly promote the commercialization of nanotechnology, primarily through Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants, made to businesses with fewer than 500 employees (Holman *et al* 2008: 29). Between 2007 and 2007, federal government SBIR/STTR programs provided between $80 and $90 million in nanotechnology-related grants each year, about 17 percent coming from the NSF [6] (US NNI 2006: Tables 7 and 8; Rudd 2007). While these grants are seen as an important source for the commercialization of nanotechnology, they are minor in relation to total funding.

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[4] The overall growth in NNI funding during the same period was 13%. Among the 13 agencies funded under the NNI, the largest share proposed for 2009 goes to the Department of Defense ($431 million, 28.2% of the total); NSF is to receive $397 million (26.0%), DOE $311 million (20.4%), NIH $226 million (14.8%), and NIST $110 million (7.2%). The other eight agencies (NASA, EPA, NIOSH, USDA Forest Service, USDA Extension, DOJ, DHS, and DOT) share the remaining $52 million (3.4%). Source: calculated from US NNI 2008, 2009.

[5] The principal vehicle for NSF funding (as of October 2008) has been 15 Nanoscale Science and Engineering Centers (NSECs) on 15 university campuses, and 22 university-based Materials Research Science and Engineering Centers (MERSECs), 4 of which are fully dedicated to nanotechnology research, with while 18 have one or more nanotechnology research groups. The DOE has Nanoscale Science Research Centers at 5 National Laboratories (Argonne, Lawrence Berkeley, Sandia/Los Alamos, Brookhaven, and Oak Ridge). For a complete listing (and websites) of NNI centers, networks, and facilities, see http://www.nano.gov/html/centers/nnicenters.html.

[6] In 2005, for example, under the NNI seven agencies granted a total of $87.4 million in SBIR and STTR awards. Nearly half (47.7%) were made by the Department of Defense. Other agencies included NIH (18.6%), NSF (16.3%), DOE (9.3%), NASA (6.9%), EPA (1.1%), and NIST (0.1%).

In comparison with the US approach, in China – which has an economy that is transitioning from state-owned to privately-owned enterprises, and still suffers from a lack of private investment capital – nanotechnology is being funded largely through government sources. Moreover, in China, such funding extends more broadly across the value chain than in the United States, from fundamental research to commercialization.

In this paper we shall examine the role of the Chinese Government in fostering advances in this emerging technology area, looking at the promises and pitfalls of state-led development in the world's fastest-growing major economy.

Data Sources

The following analysis is based on an examination of Chinese government publications (in Chinese and English), as well as field interviews conducted during five weeks of research carried out during the summers of 2006 and 2007. To date we have conducted 59 interviews: 38 in China (Beijing, Tianjin, Shanghai, Hangzhou, Suzhou, and Dalian), six in Hong Kong, eight in Taiwan, and seven in the United States. One of the authors (Cong Cao) has done extensive previous research on China's high technology policy.[7] The breakdown of our interviews, by type of organization, is summarized in Table 1:

Table 1: Organizational Setting of Interviews

Type of organization	**Number of Interviews**
Governmental	10
Quasi-governmental (semi-private)	3
Government-funded Incubator	5
University, including labs	19
Companies	17
Other	5
Total	**59**

China's Emphasis on Government Support for Indigenous Innovation

During the past 20 years China has invested heavily in science and technology (S&T), using reforms in the S&T management system, including higher education, to boost the emergence of a national innovation system that could generate indigenous innovation (*zizhu chuangxin*) of technologies in areas including biology, information technology, and nanotechnology. Beginning with the Third National Conference on Science and Technology in 1995 when the "Decision on Accelerating Scientific and Technological Progress" was announced (U.S. 1996), "indigenous innovation"[8] has been heralded as a major source of

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[7] Cong Cao, *China's Scientific Elite*, London and New York: Routledge 2004; Cong Cao and Denis Fred Simon, *Talent and China's Technological Edge*, Cambridge and New York: Cambridge University Press, forthcoming; Richard Suttmeier, Cong Cao, and Denis Fred Simon, "China's Innovation Challenge and the Remaking of the Chinese Academy of Sciences," *Innovations* (summer 2006): 78-97); Cong Cao, Richard P. Suttmeier, and Denis Fred Simon 2006, "China's 15-year Science and Technology Plan," *Physics Today* 59: 12 (December 2006): 8-120

[8] While the 1995 Conference did not formally use the term "indigenous innovation," it did call for an increased capacity "to create technology indigenously and master key industrial technologies and systems design technologies" (section 4, as reported in U.S. 1996). At the same time it also stated that "while developing scientific and technological capabilities primarily on our indigenous efforts, adequate attention should also be assigned to the acquisition and assimilation of foreign technology. On the basis of equality and mutual benefit, a significantly

China's future economic development. Science, technology and education were identified as the tools that will create national prosperity. In October 2000, Chinese Communist Party Secretary and Chinese President Jiang Zemin pointed out in his report in the fifth plenary session of the fifteenth party central committee: "We should concentrate our efforts to make breakthroughs on such fields as genome science, information science, nano-science, life science and geosciences" (NIBC 2006, p. 14). By the time the 11th Five-Year Plan (2006-2011) was unveiled in 2005, innovation had become the centerpiece of China's economic strategy, and the goal was to harness China's human capital to promote indigenous innovation through S&T in order to address the country's social, environmental and global competitive challenges.

In our project, the emphasis is not on whether the development of nanotechnology will be successful in an ultimate sense ("revolutionary breakthroughs" are rare in such early-stage technologies), nor do we even need to demonstrate China's relative accomplishments vis-à-vis the United States and other advanced economies. Rather, our analytical focus is twofold: To better understand China's current development strategy, which both designates nanotechnology as a major national priority and provides substantial resources to achieve its objectives, and to shed light on some of the institutional and policy challenges that must be addressed for technological leapfrogging to work. A key question is whether China's seemingly top-down and government-centered approach toward S&T policy can succeed in creating the bases for genuine innovation, in the current absence of strong market signals and private capital support for high-tech commercialization. Whether or not the Chinese government is in a position to target certain technology areas as frontrunners for funding is a hotly contested topic.

As we shall show, such concerns may be at odds with several distinctive features of the innovation process, including China's approach to technological leapfrogging, the institutional features of China's innovation system (which in practice blur the top down/bottom up distinction), and nanotechnology's status as an early stage emerging technology.

Leapfrogging Development: the New "Great Leap" Forward?

The concept of technological leapfrogging (essentially taking an industrialization short cut) was coined in 1985 by Luc Soete with specific reference to the international diffusion of technology and the industrial development of economic growth associated with the microelectronics industry. Soete (1985) highlights the significant advantages that can be felt by "late industrializers" in terms of catching up to global technological leaders, citing Japan as the most apt example (at the time). More recently, it has been linked to countries such as China, which has explicitly jettisoned the traditional notion of sequential or "catch up" industrialization typically advocated for developing economies -- notions dating back a half a century or more (see, for example, Rostow 1960).

China in particular is racing toward high-technology development, while continuing to exploit its comparative advantage in labor-intensive industries (Friedman 2006). In doing so, China – and by implication other developing countries, if they follow China's example – could potentially prompt considerable shifts in the global economy. What makes China unique, however, is its attempt to combine its low-cost advantage in export-oriented industrialization, its large domestic market for advanced manufactures via import-substituting industrialization, and its burgeoning talent pool of scientists and engineers associated with the R&D process in high-technology development into a single development strategy.

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greater level of international S & T cooperation and exchange through official, non-governmental, bilateral and multilateral channels should be vigorously assumed" (PRC 2003).

Two powerful forces, globalization and the rapid advance of information technologies, have made China's distinctive approach to technological leapfrogging possible. These forces have compressed both space and time to the point where China is able to upgrade on several very different levels simultaneously: labor-intensive exports (e.g., nondurable consumer goods), advanced manufacturing (e.g., autos and electronics), infrastructure development (e.g., highways, ports, logistics, and communications), and knowledge industries (e.g., biotechnology and nanotechnology). The choice of this development strategy can only be explained by China's expansive vision of its role as an emerging global power and its domestic politics oriented toward rapid economic growth and so-called "market socialism." Whether China can successfully sustain this strategy is an open question, but it will require a complex and evolving set of policies and institutions to concurrently manage everything from exchange rates and industrial incentives, to education, migration, labor market, and S&T policies. Nanotechnology in China illustrates both the potential and difficulties of this leapfrogging strategy, which ultimately seeks to bypass the traditional movement up the value chain.

In the eyes of some China-watchers, technological leapfrogging – driven by initiatives that originate in the central government – is doomed to fail. Efforts to create an "innovative society" via leapfrogging are seen as hampered by a lack of private sector resources in China, as well as by bureaucratic rivalries among key state agencies (Suttmeier, Cao, and Simon 2006b). Innovation is said to require market-driven incentives, while China's investment- and export-driven growth is said to have been at the expense of consumption, and hence is a drag on the economy (Lardy 2006). Furthermore, as a strategy for growth, "indigenous innovation" is viewed as suffering from "techno-nationalism," which is largely at odds with the FDI-oriented development model China has thus far used effectively to bring in new technologies (Serger and Breidne 2007).

We question the dismissal of China's innovation potential on the grounds that it is based on an exclusively Beijing-led model of development. We prefer more nuanced formulations that emphasize modular, loosely coupled approaches to innovation – for example, John Hagel III and John Seely Brown's focus on "creation nets," "open innovation," and "process networks" (Brown and Hagel 2005; Hagel and Brown 2006). Such approaches favor open over closed systems, recognizing that a balance needs to be struck between open "pull" and closed "push." Similarly, Lynn and Salzman (2007a; 2007b) argue that real "innovation shifts" are occurring in places like China, but that to understand these we need to look at the role of cumulative and incremental innovations, the dynamics of collaborative advantage, and the role of local technology entrepreneurs.

Finally, we need to consider the distinction between "technology push" and "demand pull" as it relates to nanotechnological innovation in China. The implication is that new or unexpected sources of demand can help a technology take off.[9] The flip side of this argument is that potential roadblocks to expected demand can arise, such as the concerns about potential environmental and/or health risks of nanotechnologies or that a backlash to consumer goods similar to the controversy surrounding genetically modified organisms (GMOs) might occcur. In either case, we would need a more open-ended and flexible understanding of how innovation occurs in the real world.

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[9] This is a key element in Clayton Christensen's influential notion of "disruptive technologies" (see Christensen, 2000).

China’s Developmental State: Science and Technology Policy

Technological leapfrogging requires state investment in areas where the market is unable or unwilling to provide the resources for growth, such as promising technologies with longer-term commercial horizons, such as nanotechnology. Given the importance of the central government as a driver of S&T in China, in this section we focus on the role of the key central governmental institutions in shaping China’s efforts. The National People’s Congress (NPC), China’s highest organ of the state power and legislature, through its Standing Committee and the Committee on Science, Technology, Education, and Health, has the authority to enact and amend an S&T related law, which is typically drafted by a government agency. The NPC also monitors the implementation of such laws and approves state budget on S&T. Constituting ministries of the State Council, China’s cabinet, such as the Ministry of Science and Technology (MOST), Education (MOE), Agriculture (MOA), Health (MOH), Industry and Information Technology (MIIT), Environmental Protection (MOEP), the National Development and Reform Commission (NDRC), the now defunct Commission of Science, Technology, and Industry for National Defense (COSTIND), and so on, allocate resources to programs related to their respective ministerial missions.

The Chinese Academy of Sciences (CAS), an entity with multiple functions in research, high-tech industrialization, technology transfer, and training, plays a significant role in S&T policy-making through its honorific members, along with members of the Chinese Academy of Engineering (CAE), an advisory institution providing services for decision-making of the nation’s key issues in engineering and technological sciences (Cao 2004). The National Natural Science Foundation of China (NSFC) mainly supports basic research and mission-oriented research projects through a competitive peer review process. Finally, the Ministry of Finance (MOF) has become increasingly important in scrutinizing budgets put forward by ministries and monitoring the usage of the funds. During the policy-making process, members of the Chinese People’s Political Consultative Conference (CPPCC), an advisory body, also voice their opinions; this body includes many who are not members of the Chinese Communist Party (CCP).

Nevertheless, it is the CCP that has final say in S&T policy formulation, as it does in virtually all matters in China. Although the CCP Central Committee does not set S&T policy directly, it inserts influence through the State’s leading group mechanism. A leading group usually is set up within the State Council to tackle issues involving more than one government agency and it is chaired at least by a vice premier who is likely a member of the CCP Central Committee Politburo or its Standing Committee – China’s de facto governing body – so as to mobilize resources and coordinate efforts. Given the importance attached to “strengthening the nation through science, technology, and education” (*kejiao xingguo*), China’s S&T policy has became a national development strategy since the mid-1990s, and the State Leading Group for Science, Technology, and Education has been led by the premier.

In May 2000, a group of experts jointly proposed to the CPC Central Committee and the State Council that “our country should accelerate the industrialization of the nanotechnology and occupy this world-wide frontier area as soon as possible,” which was quickly taken up as a priority research area by members of the CPC Central Committee (NIBC 2006). A vice premier or a state councilor runs the operations of the leading group, which is also composed of the chiefs of the leading science, education, and economic agencies from MOST, NDRC, MOE, MOA, MOH, MII, MOEP, COSTIND, and MOF; the presidents of CAS and CAE; and a deputy secretary-general from the State Council. Many of the bureaucrats working at this level are scientists or engineers by training.

The State Leading Group for Science, Technology, and Education is responsible for studying and reviewing the nation's strategy and key policies, and for discussing and reviewing major tasks and programs, related to these three areas, and for coordinating important issues related to science education involving agencies under the State Council and regions. The Leading Group seems to be considerably more active and important in setting the nation's science, technology, and education policy. It meets a couple of times a year, usually prior to major national policy announcements or conferences, to discuss critical issues the nation faces in science and education, and to approve important initiatives and programs. The Leading Group also has invited leading scientists to update its members and members of the State Council on "hot" science, technology, and education related topics, including nanotechnology.

The drafting of the Medium and Long-Term Plan for the Development of Science and Technology toward 2020 (MLP) was the most important task of the Leading Group and one of the major tasks of the State Council and the CCP between 2003 and 2006. Soon after Wen Jiabao assumed the premiership at the Tenth National Party Congress in March 2003, he convened a Leading Group meeting on 30 May to launch the drafting of the MLP (in fact, the MLP was first discussed at a Leading Group meeting early the year when Zhu Rongji was still the premier and chair of the Leading Group). Premier Wen also chaired the leading group of the MLP drafting with MOST coordinating the process. He presided over a series of State Council sessions on results of strategic research for the MLP between April and August 2004 and convened an MLP leading group meeting and a State Council meeting on 10 May and 8 June, 2005 respectively to deliberate on the plan.

The CCP Central Committee Politburo not only devoted a late December 2004 study session to the discussion on China's S&T development strategy toward 2020, but also approved the MLP in late June 2005. In February 2006, the State Council formally issued the MLP, presumably after intensive negotiations between governmental agencies, especially on mega science and engineering programs which may involve some billion yuan for each. In May 2006, Premier Wen convened another Leading Group meeting to discuss how to implement the MLP, after which the State Council issued a series of detailed implementation measures assigned to various government agencies.

As previously noted, one of the themes underlining the MLP and indeed China's S&T policy in recent decades is that China should achieve leapfrog development in S&T. With such rapid economic growth over the past three decades, the reasoning goes, China can afford to invest previously unthinkable sums of money in S&T areas whose long range breakthroughs may not only significantly change the scientific landscape but also bring about significant economic benefit. Nonetheless, given its limited financial and human resources, it is impossible for China to launch an effort on all fronts; instead, China should "do what it needs and attempt nothing where it does not" (*you suo wei, you suo bu wei*), which has been another important theme of China's S&T policy.[10] China arguably has little choice but to be selective in supporting research

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[10] This theme was taken from the then CCP General Secretary Jiang Zemin's report to the 15th CCP Congress in 1997, which reads, "We should formulate a long-term plan for the development of science from the needs of long-range development of the country, taking a panoramic view of the situation, emphasizing key points, *doing what we need and attempting nothing where we do not*, strengthening fundamental research, and accelerating the transformation of achievements from high-tech research into industrialization" (emphasis added). This was in turn adapted from the May 1995 decision of the CCP and the State Council to push forward China's S&T progress, although the wording was slight different – "catching up what we need and attempting nothing where we do not" (*you suo gan, you suo bu gan*).

endeavors to concentrate and best utilize scarce resources. The challenge then becomes how to make the right choices that not only embraces a global strategy of S&T development, but also leverages China's existing advantages to realize its potential.

Although MOST gets the mandate for China's S&T related matters, reinforced by its power over the implementation of mega science programs authorized by the MLP, it is not the only government ministry that plays a significant role in China's S&T policy making and implementation. In fact, according to some estimates, MOST controls only about 15 percent of R&D expenditure appropriated by the Chinese government, which means other government agencies are as important as (if not more important than) MOST in planning, budgeting, and organizing S&T and R&D activities.

Nevertheless, there is risk associated with the Chinese approach. If the bet is wrongly placed, as Japan did for its fifth generation computer program in the 1980s, the policy could be detrimental. In the MLP case, if the areas most critical to the basic scientific breakthrough are not the four chosen, not only would China be wasting enormous amounts of resources – both financial and human – and missing a new scientific revolution, the nation would also be trapped at its current level of S&T development for a prolonged period. This is why some Chinese scientists – especially those working overseas, who presumably had a better understanding of how science is "supposed to work" – were critical of the approach of picking champions. Unhappy with the way that MOST organized the State High-Tech Research and Development Program (also known as the 863 Program) [11] and the State Key Basic Research and Development Program (also known as the 973 Program),[12] whose achievements were viewed by some as incommensurate with the amount of investment, skeptical scientists proposed limiting MOST's power or even dissolving MOST and replacing it with an Office of Science and Technology under the premier which would be responsible for formulating China's S&T policy only. They also campaigned to divert MOST's funding power to mission-oriented government agencies and to increase funding to NSFC, which has been doing relatively well in administering resources for basic research in China. As it turns out, their opinions were not taken seriously in the final deliberation (Suttmeier, Cao, and Simon 2006).[13]

China's Nanotechnology Initiative: Top Down or Bottom Up?

It has been argued that China, as a state-centered economy, is trying to drive nanotechnology development from the top through large government investments. As early as 2001, addressing an international forum on nanomaterials, President Jiang Zemin stated explicitly that "the development of nanotechnology and new materials should be regarded as an

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[11] The 863 Program was seen as a key vehicle for improving China's high-tech competitiveness, through the development of six advanced technologies selected as central to promoting economic growth: electronics, supercomputers, telecommunications, avionics, GPS, and nanotechnology (MOST 863 2001, Larson, 2004).

[12] The 973 Program sought "to strengthen the original innovations and to address the important scientific issues concerning the national economic and social development at a deeper level and in a wider scope, so as to improve China's capabilities of independent innovations and to provide scientific support for the future development of the country" (MOST 973 2004).

[13] In recent years, MOST also has been criticized for its inaction in handling misconduct in scientific research in China. The appointment of Wan Gang, a non-CCP member, as the minister of science and technology in April 2007, bypassing another non-CCP member high-ranking vice minister, seems not only to signal that the importance of non-CCP members in government but also to indicate that the government may not be satisfied with MOST leadership, and in turn the progress of Chinese science, in spite of tremendous money put into it. They may want someone with no previous relations with the ministry to bring in new ways of thinking and management.

important task of the development and innovation in S&T. The development and application of nanomaterials and nanotechnology is of strategic significance to the development of high technology and national economy in China" (NIBC 2006).

Yet this exclusively state-centered, top down view of China's high-tech planning does not adequately take into account the complexities of China's approach. China's approach is a hybrid model blending government and market forces (Xu *et al* 2006). Moreover, there are large and growing scientific and professional communities that are heavily invested in promoting the advance of nanotechnology. These include the physicists and chemists who have long worked in such areas as carbon nanotubes and nanopowders, the applied scientists and engineers who are transforming nanomaterials into commercial products, and the rising class of entrepreneurs and venture capitalists who are concerned about bringing new nano-enabled products to the market. In many regards, the innovation and commercialization ends of the R&D spectrum have been working in relative isolation from each other in nanotechnology. Each group has its own agenda. In between are the engineers, who often seem to be working alongside the applied scientists, but who often have close communications with potential customers as well, linking the R&D aspects of the innovation process – for example, in biomedical engineering, where the drug delivery prospects of nanotech are most apparent. The complex ties between these different communities of scientists, engineers, and business people make it difficult to think of innovation exclusively in terms of top-down versus bottom-up or even government versus market influences.

In broader institutional terms, it is not accurate to simply equate "top down" with governmental and "bottom up" with market-led investments in nanotechnology; China's approach is more complex than this simple dichotomy suggests. Different levels of governmental support (central, provincial and local) and different government agencies vary in the degree to which they can be accurately characterized as either top down or bottom up. Nanotechnology is supported by a variety of public sector ministries and agencies that operate at diverse levels of government. These governmental actors have different agendas and incentive structures, and as a result nanotechnology projects are subject to conflicting and sometimes contradictory performance criteria. There is a division of labor in what and how they fund projects (e.g., people, equipment, cheap land, tax reductions). They also tend to have very different time horizons and attitudes toward financial risk: as one moves from central to provincial to local levels of government funding, the time horizon for return on investment becomes shorter, and there is a tendency to move from intangible (basic research) to tangible (commercial products) results. At the local level especially, government officials expect a quick turn-around in terms of technological development and market applications (Cheng 2007).

The central government is the principal funder of nanotechnology. The largest source of funds, and the biggest individual grants, come from the Ministry of Science and Technology (MOST). The National Natural Science Foundation of China (NSFC) provides much smaller grants (roughly equivalent to $30,000-$45,000 over three years), which are administered using more objective and universal criteria. The Chinese Academy of Sciences (CAS) also supports nanotechnology initiatives, but it has a more diversified funding philosophy than MOST. Even within central government support for R&D in China, there is a contrast between MOST (top down, "mega science") vs. CAS (bottom up, including its Knowledge Innovation Program, which is touted as a bottom-up initiative).[14] Provincial governments can also be significant – not

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[14] Many CAS members privately report that this is in fact a " top design" (*ding ceng she ji*) approach, originating under the initiative of Lu Yongxian who was president of the CAS in 1998 (for a discussion of the CAs and Knowledge Innovation Program, see Suttmeier, Cao, and Simon 2006a, 2006b).

only in those containing the major cities (such as Beijing and Shanghai), but also provinces such as Zhejiang, which neighbors Shanghai, that hope to promote their regional universities as major players by setting up collaborative university science centers (Zhejiang, for example, has partnered with UCLA to set up the Zhejiang-California International Nanosystems Institute, although with mixed results). Finally, local governments also frequently play a key role, particularly in major cities (examples include the Shanghai Nanotechnology Promotion Center and the Suzhou Industrial Park). Both provincial and local governments can also partner with foreign investors, as with the China-Singapore Suzhou Industrial Park Development Corporation.

When choices have been made for public investment, they often address the most pressing challenges facing China in agriculture, the environment, population, health, and national defense. The selection of four mega programs in basic science areas by the MLP – nanotechnology, development and reproductive biology, protein science, and quantum research – in fact represents an effort to do this. Within nanotechnology, China plans to focus on those nanomaterials and nanodevices that promise to have the most immediate payoff in addressing such immediate problems as air and water purification, materials with great tensile strength that can be used in a variety of industrial applications, as well as targeted drug delivery. China is already a world leader in the production of carbon nanotubes, for example (Fan 2007). According to Liu Zhongfan, Professor of Physical Chemistry at Peking University, “China is far better now than it was ten years ago – more people are working here and more [and better] instrumentation is appearing in China… policymakers are beginning to understand that nanodevices are actually the most important part of nanotechnology, not synthesis or incorporation” (Liu 2006).

China’s political leadership has lent its support for nanotechnology, with an added push from leading scientists both inside and outside of China. CAS Executive Vice President Bai Chunli, a pioneer and champion of nanotechnology research in China, has been an alternate member of the CCP Central Committee,[15] whose lecture to the Politburo and the State Council in 2000 was deemed to be an influential one. Yet China did not realize the value and significance of nanotechnology to science as well as application potentials for the economy until much later than other, more technologically advanced countries. The fact that countries such as the United States had formulated national nanotechnology initiatives made it easier for Chinese scientists to make their case to the scientific and political leadership. Xie Sishen, who now heads up the National Center for Nanoscience and Technology in Beijing, explained that well-respected foreign scientists suggested to Jiang Zemin, Hu Jintao and others that nanotechnology was worth paying attention to:

> Governments around the world and delegations from other countries, especially those from advanced countries, frequently mentioned nanotechnology and conducted exchanges and collaborations with China... [this] provided information continuously, which made the Government realize its importance from pure basic research to application to impacts on economy and society (Xie 2007a).

The connection of Chinese scientists to the international nanotechnology community, and especially to Chinese-origin nano-scientists and engineers overseas, has helped China move

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[15] Bai, executive vice president of the CAS with the rank of a full minister, is in line to succeed Lu Yongxiang as president. But Bai, an alternate member of the CCP Central Committee since the 15th CCP Congress in 1997, was not promoted a full member in the recently concluded 17th CCP Congress while Lu kept his full membership, which is rare as he is over 65, the age limit for being a full member. Therefore, it will be interesting to see whether a changing of the guard will happen at the CAS.

toward the frontier of international nanotechnology research. Chinese nanotechnology researchers have thus far achieved some impressive results, especially in nanomaterials. Furthermore, returnees and exchanges with overseas Chinese scholars have brought new ideas into the laboratory, along with increased participation by Chinese scientists and engineers in international exchanges, widespread international collaborations, and attendance at high-level symposiums (Xie 2007a).

In nanotechnology, it was MOST, the State Planning Commission (the predecessor of NDRC), MOE, NSFC, and CAS that jointly analyzed the strength, weakness, opportunities, and threats in the development of nanotechnology in China (Diagram 1). The outcome of the exercise was to establish a national steering committee on nanotechnology in 2001, which in turn formulated an Outline for the National Nano Science and Technology Development (2001-2010) as a roadmap. Under the guidance and coordination of the national steering committee, chaired by the Minister of Science and Technology, various nanotechnology related programs have been supported and implemented at MOST, MOE, CAS, and NSFC; in the meantime, NDRC has provided funds for infrastructure building and innovation activities at enterprises. A new national steering committee was appointed in June 2007.

[Diagram 1 about here]

There is a division of labor among these state institutional players. MOST, for example, through the 863 Program and the 973 Program, funds mission-oriented nanotechnology projects (the 973 Program no longer supports nanotech projects as they are now under the aegis of the MLP, also administered by MOST); CAS positions itself in the national nanotech landscape with its forward-looking and strategic advantage; universities have the responsibility of not only conducting cutting-edge research themselves but also turning out students with the capabilities to do so; and NSFC awards grants to the best projects and researchers with possibility to achieve breakthrough at frontier of international research, mainly on the basis of scientific merit judged by peer review. Nevertheless, such a division is not rigorously observed. With competition for funding getting intense, leading nanotechnology scientists and institutions are likely to receive funding from many available sources, which then outsource or subcontract the projects.

In the first two years of the MLP implementation, 22 institutions have been selected to lead 29 projects (Table 2). Of them, 12 are CAS institutes, including the Chinese University of Science and Technology and the National Center for Nano Science and Technology (NCNST) which are also CAS affiliates; the rest are key (*zhongdian*) universities, with the CAS Institute of Chemistry, Beijing University, the CAS Institute of Physics, NCNST, and Tsinghua University having more than one project. Beijing, Shanghai, Jiangsu, and Anhui stand out as the leading centers of nanotechnology and well-known nanotech scientists, such as Jiang Lei at the CAS Institute of Chemistry, Peng Lianmao and Liu Zhongfan at Beijing University, Li Yadong at Tsinghua University, Yang Hui at the CAS Suzhou Institute of Nano-Tech and Nano-Bionics, among others, are among the chief scientists leading the efforts. The projects are in the categories of nanomaterials, devices and electronics, biology and medicine, and characterization and structure.

[Table 2 about here]

While it remains to be seen whether the projects selected will contribute to China’s ability to leapfrog in nanotechnology, it is arguable that there is a resource concentration factor in the current arrangement. The first two-year fund of 262 million RMB($38 million) has been allocated for the 29 projects which presumably are composed of researchers from more than one institution, and the funding intensity for each project – less than 5 million RMB per year on average ($721,000) – is hardly significant. Also of concern is how scientists working on different projects collaborate with each other to generate synergy and what benchmark will be used to evaluate the first two-year performance and determine their continuous funding (in fact, one would also be interested in knowing how these projects have been selected and whether scientists were on equal footing in the process). Although the projects are supposed to be basic-research oriented under the MLP, some deal with applied nanotechnology. There are further questions about how they are related to other MOST-administered programs related to nanotechnology, especially the 863 Program and the Torch Program,[16] which are focused on high-tech industrialization, and presumably some are led by the same chief scientists.

Private Capital: A Limited Resource

In our focus on the developmental state in China, we have not directly addressed the role of private capital, in part because the bulk of nanotechnology's global commercial promise remains in the future, and thus commercialization prospects remain limited. Nonetheless, we can offer some preliminary thoughts of the role of market investments, based on our research to date. These include centralized investments by large vertically integrated multinationals, various forms of network-based international collaborations, and small-scale new firm startups that focus on commercial products.

Multinationals: A great deal of attention has been given to the more than 1,000 R&D centers that have been established by foreign multinationals in China during the past decade. In many cases, these R&D centers seem much closer to the "D" of development than the "R" of research (e.g., localization and de-bugging of products). However, the Microsoft Research Center in Beijing has been touted as "the Bell Labs of China" for its pioneering research activities (see Buderi and Huang 2006), and IBM, General Electric, Siemens, and other top multinationals are also doing innovative projects in China. Lynn and Salzman (2007a) make the case that significant innovation is taking place in emerging economies, but often this is in the form of "process innovations" rather than the functionality of products.

International collaborations: There are many forms of international collaboration, including: formal institutional partnerships involving universities and corporations; study abroad programs, in particular post-graduate degrees earned by Chinese in the USA, Japan, and Europe; ethnic ties, most notably the recruitment of overseas Chinese scientists and engineers to return to China; and informal personal ties, such as the mentoring of former graduate students. Universities are an important component of China's nanotechnology initiative because it is first and foremost a science-based program.[17]

Entrepreneurial initiatives, such as small firm startups: These are most common in Hong Kong and Taiwan, although we have seen examples of these in China as well. It is also clear that investors, including venture capitalists and local governments, expect to see real products as a

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[16] The Torch Program is intended to produce high-tech products involving new materials, biotechnology, electronic information, integrative mechanical-electrical technology, and advanced and energy-saving technology – products that have commercial potential for both Chinese and foreign markets. It involves, among other things, the creation of high-tech industrial development zones.

[17] Why should we consider international collaborations as a form of market investment in high technology development? If we view nanotechnology as a value chain that has distinctive governance structures, then international collaborations may be a form of relational governance, which has different characteristics than hierarchies (vertical firms) and markets (entrepreneurial start ups). "Captive" and "modular" forms of governance, which complete the fivefold global value chains typology, may also have analogues in nanotechnology (see Gereffi et al., 2006).

tangible result of their investments. This is a relatively weak area in China, although we identified more cases in Taiwan and Hong Kong. In the nanotechnology value chain, companies occupy different positions on the innovation → applied research → commercialization spectrum.

The Long March Through the Valley of Death: The Central Role of Public Funding

In business terms, the "valley of death" refers to the transitional period between basic R&D for a new technology (technology creation) – when public funding typically provides support – and commercialization, when a marketable product attracts private sector support. In China, the valley is long and deep. State-run firms – which still account for an estimated 43 percent of GDP, despite China's commitment to privatization[18] – tend to be bureaucratic and conservative, shunning potentially risky investments in favor of short-term, more predictable returns. The emerging private sector, including many small and medium enterprises (SMEs), remains small, under-capitalized, and generally risk-averse. This poses a challenge for the Chinese government's heightened emphasis on leapfrogging development through nanotechnology, whose major payback remains ten or more years in the future. The amount of money allocated from Beijing for nanotechnology is not large by international standards (Xie 2007b), although it is difficult to accurately estimate total public spending for nanotechnology in China, given the wide range of funding sources and the difficulty of defining what qualifies as nanotechnology, and as a result estimates vary widely. Estimates range from as little as $230 million for the five-year period 2000-2004 (Bai 2005: 63), to $160 million in 2005 alone (Bai and Wang 2007: 75), to $250 million in that same year (Holman *et al* 2006: 25). Although even the highest figures are still considerably less than the U.S. is publicly investing (as noted previously, $1.5 billion in 2008), China's governmental spending on nanotechnology may not be far off when adjusted for purchasing power parity, by taking into account labor and infrastructure cost differences (nanotechwire.com 2005). As noted by one of China's nanotechnology leaders:

> The Chinese government should develop nanotechnology and at least aid in the national program, but there are so many important issues that should be considered, so I don't think that nanotechnology will be the top priority. Nanotechnology is in the basic research stage right now. So, nanotechnology cannot bring the benefits immediately (Xie 2006).

Throughout our interviews, the most pervasive theme to emerge was that of the importance of government funding and support for nanotechnology throughout the value chain, not only for basic research, but well into commercialization (this topic came up in more than half of our interviews). Esther Levy, editor of the journal *Advanced Materials*, who has reviewed numerous submissions to her journal by Chinese scientists, saw the question of government funding as key: "The Chinese are very hard working, As long as the government keeps funding them, they will progress. The question is, will the government funding be patient long enough"(Levy 2006)? As one interviewee commented, "there is a saying in China that those who do research on atomic bombs (*yuanzi dan*) don't make as much as those who sell tea eggs (*chaye dan*)" (Xu 2006). He noted that this situation has to change, since economic returns (rather than pure patriotism) will be required if China is to achieve its high-tech aspirations. Another informant – an Academician with the Chinese Academy of Engineering, and Chairman of

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[18] OECD (1995) "Policy Brief: China's Governance in Transition" (September) (http://www.oecd.org/dataoecd/49/13/35312075.pdf). In 1997 President Jiang Zemin called for privatization (*feigongyou*, or "non-public ownership") of state-owned enterprises (SOEs), a plan that was ratified by the 9th National People's Congress the following year.

China's Desalination and Water Reuse Society – explained the challenges of developing seawater filtration that employs nanotechnology, a NSFC-funded project that has yielded promising results in the laboratory:[19]

> However, it is a little hard to estimate the timeframe for industrializing the new process. China Water Tech is currently working on optimizing the process. And speed for it to move to industrialization will depend on government funding and industrial interest. Government funding is usually not at all enough to industrialize a technological process, industrial involvement is crucial. However, larger scale demonstration of this process needs to be done (likely via government funding) before industry would become interested (Gao 2006).

Usually, different government funding sources are used for each step on the chain of technology towards industrialization. The 973 program of MOST is dedicated to fundamental research, the 863 program (also of MOST) funds applied research, while the "Industrialization Support Plan" (also of MOST) supports projects in initial stages of industrialization. For real industrialization projects, usually the central and local Commission of Development and Reform provides funding. However, usually the Commission only provides 15% of the total of what is needed to set up the company, and 85% has to be raised by the company (which is yet to be formed).

At the level of basic research, funding comes primarily from the central government agencies mentioned earlier. For example, NSFC provides growing support for nanoscience and technology through both its General Program, as well as its Major Program (focused on major scientific and technological issues that are interdisciplinary in nature, such as nanotechnology). As of summer 2007, there were some 670 ongoing projects with "nano" in the title, totaling 800 million RMB (roughly $115 million), 8% of the total budget (Li 2007). Most of these were relatively small grants (300,000 RMB, approximately $43,000) for three years of project funding, in such areas as nanomechanics, novel nanostructures, quantum dots, carbon nanotubes, and novel cancer and gene therapies. Proposals are peer reviewed, and awards issued on a competitive basis. One challenge, we were told, is that since nanotechnology is multidisciplinary, it is sometimes difficult to know where to apply. On the other hand, this also provides new opportunities for funding, if researchers are able to identify their work as nanotechnology (Liu 2006).[20]

At the local level, various forms of incubation play a key role. For the Beijing region, the Nanotechnology Industrialization Base of China (NIBC) – located 100 km from Beijing, in the Tianjin Economic and Technological Development Area – serves this role. NIBC was established by MOST in December 2000, in conjunction with CAS, universities, and private enterprises. Its distinguishing feature is that it is essentially "a government organization run by market forces," reflecting the belief that

> …pure state ownership does not work well for technology innovation or management…
>
> What the NIBC does is to take results from university and institutes, and help scientists to

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[19] Dr. Gao is one of the founders for membrane technology in China. He is also the first one who introduced the term nano filtration to China in 1993.

[20] The relabeling of earlier work as nanotechnology, in pursuit of the increased funding that available for this emerging technology, is something we have not yet explored in China. We suspect, however, that it may be significant – as it likely is in the United States and other countries that have directed increased funding into this area.

commercialize the results. It takes a systematic approach that goes to the end of the commercialization pipeline.[21]

The NIBC Entrepreneurship Investment Co. Ltd is the vehicle for incubating new companies, acquiring existing companies, and preparing initial public offerings. In 2005, the Chinese National Academy of Nanoscience and Engineering (CNANE) was established under the same administration, with a primary focus on R&D rather than commercialization. It is unclear to us how large a role these institutions actually play; during our visit in 2006, the principal operation we observed was the manufacturing of non-nano pharmaceuticals, as a form of income generation for the facility.

Shanghai has its own incubator in the form of the Shanghai Nanotechnology Promotion Center (SNPC), which is funded largely by government initiative, particularly the Shanghai municipal government as well as the NDRC, although local enterprises have also contributed.[22] It was founded in July 2000, with the Center's formal establishment in 2001. SNPC is subordinate to the Science and Technology Commission, the lead organization in Shanghai concerned with advancing the city's high-technology profile. The SNPC provides training for scientists and engineers on the specialized instruments used in nanoscale research, and has several university-affiliated 'industrialization bases' for the purpose of transferring research on nanomaterials and nanoparticles to the estimated 100-200 SMEs reportedly engaged in nano-related R&D in the Shanghai area. Roughly a third of its 25 person staff are science and engineering professionals.

The Center's main focus is to promote commercialization This is achieved in various ways: by funding basic application research;[23] through a research platform designed to help with the commercialization process; through the provision of nano materials testing; through the hosting of workshops and international conferences on nanotechnology; and through education (including a certificate program) and outreach to raise public awareness about nanotechnology. As an incubator,[24] the SNPC provides services for startups before and as they enter the market – services that include legal advice for establishing a company, a variety of technology-related services, and help with marketing products. The Center also loans out lab and office space as well as a testing center that provides the costly equipment required for nanomaterial characterization – equipment that most startups could not afford. It currently supports some 70-80 companies, of which perhaps half are nano-related, with grants ranging from 50,000 RMB for smaller projects to 1 million RMB for large ones.

While there is some private industry investment in nanotechnology (local examples include limited investments by Baosteel and Shanghai Electronics), it is clear that local government funding plays a key role. During our visit to the SNPC, we saw a number of examples of such support – firms housed within the Center's complex that receive public funding as well as access to Center support and services. Three examples are illustrative. The Shanghai

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[21] Handout from NIBC (August 3, 2006)

[22] Information was obtained in interviews at the SNPC with LI Xiaoli (Project Manager), SHI Liyi, and Min Guoquan (August 7, 2006), and with ZHU Simon (SNPC Chinese Industry Association for Antimicrobial Materials & Products; Shanghai NML Nanotechnology Co., Ltd), ZHANG Bo (Shanghai AJ Nano-Science Development Co., Ltd), and Fu Lefeng (Shanghai Sunrise Chemical Company) (August 3, 2007).

[23] As one prominent example, we were told that SNPC helped to fund and manage a project involving the use of atomic force microscope tips to locate DNA molecules that involved CAS and Shanghai Jiao Tong University, which was featured on the cover of *Nano Letters*.

[24] The SNPC has three incubators, each associated with a university: one affiliated with Shanghai University, and two with the Hua Dong Science and Technology University (East China University of Science and Technology).

Sunrise Chemical Company, which employs about 80 people making nano-coatings and nano-photo catalysts, received two-fifths of its initial capitalization of 5 million RMB ($721,000) from government sources. The Shanghai NML Nanotechnology Co., Ltd develops anti-bacterial and photo catalysts for use in textiles and plastics. Last year they began exporting the final products employing their materials (such as coffee cups that use nanopowders) to the U.S. and Australia. While the company has not received money from SNPC, it does have access to the Center's training and information services. One final example is the Shanghai AJ Nano-Science Development Company, which manufactures Atomic and Scanning Tunneling Microscopes, two key instruments used in nanotechnology. AJ Nanoscience's principal funding comes from the Shanghai Aijian Trust Investment Company, a Chinese firm with significant Hong Kong ownership[25] that invests in SMEs. The company gets public support as well: it receives funding from the Shanghai municipal government for R&D, relies on technology developed initially in CAS's Institute of Applied Physics, and has some projects with the Shanghai branch of CAS.[26] AJ Nanoscience, which was established in 2001, reportedly has 60 percent of the domestic market in their area of instrumentation – although the market is dominated by international players such as the U.S.-based Veeco Instruments.[27]

Shanghai also supports the "Climbing Mountain" (*Dengshan*) Action Plan, which provides dedicated funding for joint projects that must be led by companies in collaboration with an academic partner. Within the plan, most work is contracted between university researchers and engineers/business partners from companies. The Plan specifically earmarks funding for nanotechnology, with projects divided between basic and applied research intended for nanotechnology commercialization (Jia 2006). In Shanghai, as is typical of funding at the local level, the government provides funding both for local players and local collaboration with foreign companies such as Unilever (Li and Wang 2006). Particularly at the provincial and local levels, funding for nanotechnology R&D thus blurs the line between top-down and bottom-up approaches (Li, Shi, and Min 2006).

Conclusion: China's Developmental State

China's dedication to high-technology growth is evident in its policies supporting efforts to leapfrog development through targeted science megaprojects in nanotechnology, development and reproductive biology, protein science, and quantum research. As we have shown, China's approach to nanotechnology is heavily state-centered, with public investment originating at all levels of government, and ranging from support for basic research to funding intended to promote commercialization. While the United States has not been a focus of this paper, we noted in the introduction that the U.S. National Nanotechnology Initiative is primarily directed at the research end of the value chain, with more limited inroads into direct support for bringing products to market. In this China clearly differs from the United States – a divergence that is not surprising, given the more restricted business environment for "indigenous development" in China.

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[25] Hong Kong Mingli Co. bought more than 40 percent of Shanghai Aijian Trust Company in 2004, signaling a much greater openness to foreign investors on the part of Chinese trust companies. See Zhao 2005.

[26] We were told that when profits are realized, they are shared with CAS members who created the technology.

[27] AJ Nano-Science's instruments typically sell for roughly one-quarter the price of their foreign counterparts. Interview with ZHANG Bo, Manager of Research & Production Department, Shanghai AJ Nano-Science Development Company (August 3, 2007).

While the CCP Central Committee does not have its mandate to set S&T policy directly, it does maintain a significant level of influence vis-à-vis a state leading group mechanism. The leading group for S&T policy formation has been set up within the State Council to tackle issues involved with large-scale planning involving more than one government agencies. There is a National Steering Committee for Nanotechnology, chaired by the Minister of Science and Technology, that coordinates the efforts in nanotech research and industrialization and determines the priority areas for support. Under the Medium and Long-Term Plan, the money comes from MOST, although the chief scientist, Bai Chunli, is from CAS.

The Chinese model is not as clear cut as the "top down/bottom up" debate would suggest, since both are seen in the development of nanotechnology. For example, the Chinese Academy of Science's Knowledge Innovation Program (KIP) is typically treated as a "bottom up" example, but it in fact involves something called "top design" within the academy. While the 863 and 973 Programs are primarily bottom up, they would never have gone forth without the support from the top leadership, Deng Xiaoping in the case of the 863 Program and Jiang Zemin in the case of KIP (which is funded largely through the 973 Program). On the other hand, the management of these programs, especially those under MOST, is top down, with significant input/decision-making from bureaucrats, which has been criticized within the Chinese scientific community (Suttmeier and Cao 2004)

Whether China's efforts to achieve first-mover status in nanotechnology are successful remains to be seen. Whether there will be any large-scale pay off also remains an outstanding issue in the future development of nanotechnology-enabled market applications. However, China has clearly shown itself to be very committed to adding high-technology initiatives like nanotechnology to its top national priorities, thereby showing the dynamism of its contemporary developmental state.

Diagram 1 The Framework of Nanotechnology Research in China

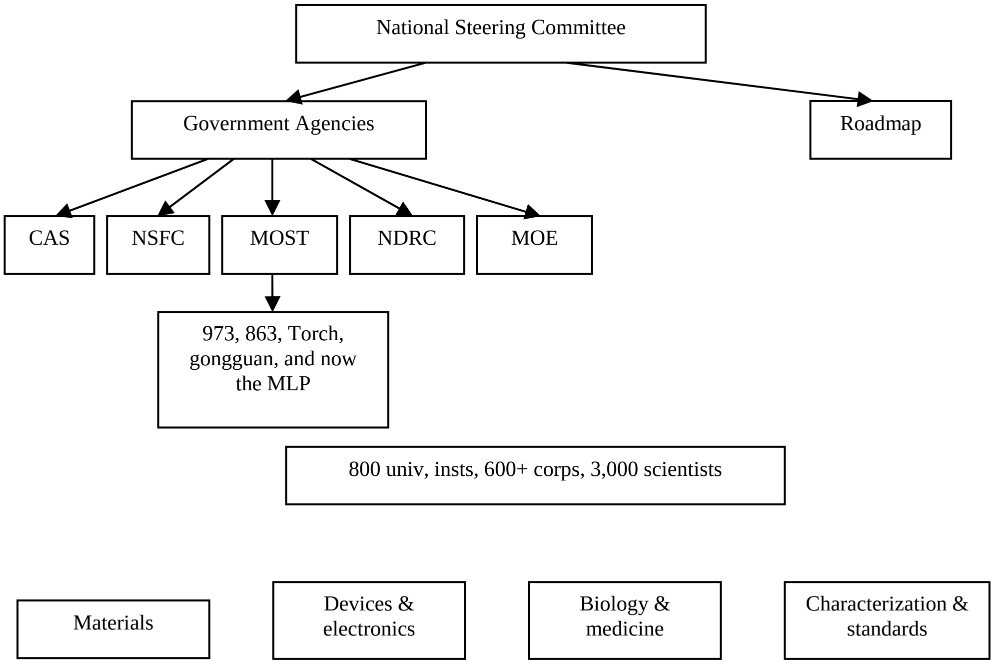

Table 2 Nanotechnology Projects under the MLP (2006-2007)

Leading Institution	Location	Number of projects	Funding (RMB million)
Dongnan University	Jiangsu	1	4.9
Chinese University of Science and Technology	Anhui	1	4.8
CAS Shanghai Institute of Applied Physics	Shanghai	1	11.2
CAS Shanghai Institute of Microsystems and Information Technology	Shanghai	1	14.0
CAS Institute of Chemistry	Beijing	3	35.5
CAS Institute of Semiconductor	Beijing	1	4.6
CAS Hefei Institute of Physical Science	Anhui	1	13.6
CAS Institute of Physics	Beijing	2	13.3
CAS Technical Institute of Physics and Chemistry	Beijing	1	5.0
CAS Institute of Theoretical Physics	Beijing	1	9.0
CAS Institute of Metal Research	Liaoning	1	5.8
Sun Yat-sen University	Guangdong	1	11.7
Beijing University	Beijing	3	31.3
Beijing University of Aeronautics and Astronautics	Beijing	1	9.3
Nanjing University	Jiangsu	1	8.7
Nankai University	Tianjin	1	4.8
Sichuan University	Sichuan	1	10.8
National Center for Nano Science and Technology	Beijing	2	16.2
Fudan University	Shanghai	1	11.2
Wuhan University	Hubei	1	5.5
Tsinghua University	Beijing	2	17.3
CAS Suzhou Institute of Nano-Tech and Nano-Bionics	Jiangsu	1	13.6
Total		29	261.8

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