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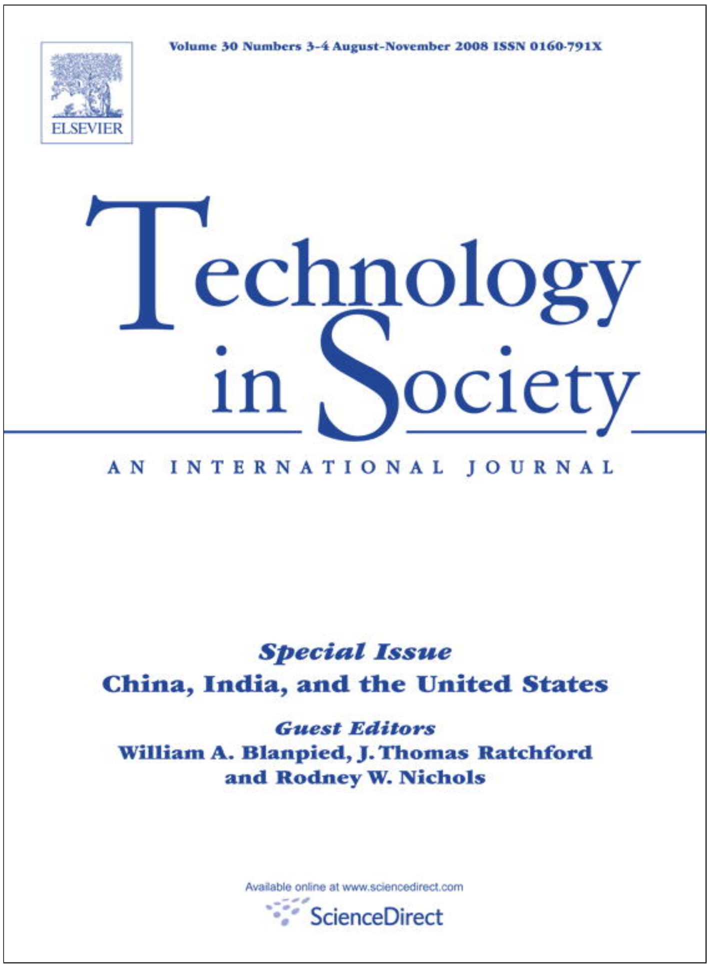

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National security challenges and competition: Defense and space R&D in the Chinese strategic context

Andrew S. Erickson, Kathleen A. Walsh *

US Naval War College, 686 Cushing Road, Newport, RI 02841,USA

A R T I C L E I N F O

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A B S T R A C T

Over the nearly six decades since the People's Republic of China (PRC) was established, the United States and China have followed very different political, military, and economic development paths. Yet, the approach each country is currently pursuing to enhance its military and commercial technology development, particularly in the defense and space areas, is becoming remarkably similar in many respects. This article outlines China's past and present strategies for developing defense and space capabilities, Beijing's phased approach to defense industrial and space R&D, and compares and contrasts these R&D efforts with the American approach. The article concludes with an assessment of the prospects for future US–China competition and/or cooperation in the realm of defense and space R&D.

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1. Introduction

Since the People's Republic of China (PRC) was established more than 60 years ago, the United States and China have followed very different paths toward political, military, and economic development. Yet, in the defense and space areas, each country's approach to military and commercial technology development is increasingly converging. We discuss China's past and present strategies for developing defense and space capabilities, then compare the R&D efforts of both China and the US. We conclude by assessing future prospects for US–China competition and cooperation.

2. Defense R&D: US and PRC differences are narrowing

Despite distinct cultural and political differences between the Chinese and American societies, when it comes to military modernization, current US and Chinese strategies for defense-related R&D increasingly share key characteristics. These include a growing reliance on commercial-sector R&D, increasing emphasis on cooperative global research ventures, continued state-funded defense research programs for developing next-generation technologies, and a focus on digital and information technologies to enhance efficiency and effectiveness in modern defense systems.

What accounts for the increasingly similar approach adopted by these two very different political cultures on opposite sides of the globe? One obvious reason is attraction to what works. Still the world's greatest military power, the US has many imitators, China not least among them. In fact, it was the demonstrated effect of US precision-guided munitions during the first Gulf War in 1991 that roused the PRC leadership from apparent complacency and led it to fundamentally re-think the manpower-intensive, low-tech "People's War" strategy of war fighting that had dominated since the time of

* Corresponding author. Tel.: +1 401 841 6429; fax: +1 407 841 3893.
E-mail address: kathleen.walsh@nwc.navy.mil (K.A. Walsh).

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Mao Zedong (Mao Tse-tung). This strategy, which held that China could defeat any enemy by waging an insurgent war of attrition, suddenly seemed fundamentally outmoded. It was not long before military scholars and leaders in Beijing were talking about preparing for "local wars under high-tech conditions." This fundamental change in strategic outlook set the PRC on a new development path of modernization that became the catalyst for a series of reforms in China's approach to conducting defense R&D. Most notably, these reforms include the incorporation of a deliberate dual-use approach.

Another reason for the growing convergence (in broad terms) of US and Chinese approaches to defense R&D is globalization. The current wave of enhanced global economic trade, investment, and interdependence was sparked by the digital revolution and advent of ubiquitous information and communications technologies (ICT) that spread worldwide in the 1990s. In the US, the digital revolution—initiated by Defense Department research into computer networking communications—led not only to what the world knows today as the Internet but also, arguably, to a "Revolution in Military Affairs" (RMA) in US defense planning and programming.[1]

In the aftermath of the first Gulf War, US military scholars also looked anew at military operations enhanced by ICT. A consensus emerged in the early 1990s among US analysts that ICT-enabled military platforms and systems constituted a new, innovative, and enhanced means of achieving long-term military objectives. The pursuit of RMA-enabled defense planning and platforms continues today and is being expanded further through the "transformation" of Department of Defense (DoD) bureaucracy and organizational processes. Consequently, US military planners today speak in terms of developing "capabilities" and conducting "effects-based operations" in addition to developing and applying new, more advanced technologies.

A core concept underlying the current RMA approach and prospects for its indefinite extension is the need to maintain access to the global marketplace of ideas, talent, and technology [3]. Today, US firms contribute approximately two-thirds of total annual US R&D spending, and perform about the same share of national R&D (as compared to government researchers) [4]. This includes commercial firms conducting defense-related R&D, which are often active in other commercial activities both at home and abroad.

This is the nexus at which US and Chinese defense R&D strategies converge: in a parallel interest in exploiting global commercial technologies for long-term defense purposes. Both China and the US are benefiting from—and incorporating into their defense strategies—international technology transfer opportunities through foreign direct investment at home and abroad, often by multinational corporations with extensive and varied technology portfolios. While there are additional obstacles, both domestic and foreign, with which China still must contend (i.e., structural, institutional, and political constraints) in order to effectively exploit global technology flows, the opportunities appear such that Beijing has adopted this clearly dual-use approach to enhancing both its commercial and defense capabilities.

In the course of China's own RMA-like transformation, its commercial, military, and defense-industrial sectors have shifted roles and responsibilities through a series of economic and defense-sector reforms instituted by Beijing since the early 1990s. Whereas just a decade or so ago China's government and military were the major contributors to PRC R&D efforts (defense-related and otherwise), today China's non-public commercial sector accounts for the majority of national R&D, both in terms of funding and performance (at roughly 60–70%), particularly in such inherently dual-use areas as ICT [5]. In terms of national R&D spending, China already ranks among the world's leaders (whether calculated nominally or based on purchasing power parity calculations).[2] In 2006, China spent a record 1.4% of its constantly growing gross domestic product (GDP) on R&D [6–8]. This equated to 300 billion *yuan* (US$37.5 billion) [8]. The goal outlined in China's "Medium- to Long-Term Plan for Development of Science and Technology (2006–2020)" (MLP) is to raise the percentage of annual GDP spent on R&D to 2.5%. If achieved, this would put China on a par with most developed countries in terms of annual percent of GDP spent on R&D and on what is considered a sustainable path for innovation (i.e., spending that reaches above 2% of GDP tends to stay near or above that level) [9].

China's exact defense R&D spending is not publicly announced, but analysts assess that it has grown substantially along with China's average 15% annual increases in defense spending since 1990 [10]. China's officially announced 2007 defense spending is $45 billion [11], although Western analyses suggest that the true budget equivalent may be as much as three times that.[3] As one long-term observer notes, "Nowhere, however, has Beijing's munificence been more strongly felt than in the PLA's equipment budget—that is, expenditures for procurement and (supposedly) research and development (R&D)," areas that may not be fully covered in Beijing's official defense budget calculations [13]. Although higher state spending on commercial and defense-related R&D will not in itself transform China's still-challenged defense industrial sector, it is a key contributor. China's long-running, state-sponsored science and research funding programs—among them the 863, 973, and Torch Programs—as well as initiatives outlined in Beijing's regular 5-year plans, provide substantial support and incentives for domestic and foreign R&D investments. According to official Chinese government statistics, in 2006 the PRC spending

[1] The concept of an RMA is not new. Military scholars have pointed to numerous periods in history when technology has been developed and/or deployed in significantly new ways so as to constitute an RMA. Examples include the advent of gunpowder, the use of sails and steel-hulled naval ships, naval power projected via aircraft carrier, the German *blitzkrieg* maneuver, and nuclear weapons. For a fuller discussion of RMA concepts and strategy, see [1,2].

[2] Calculations cited here and throughout the paper were made prior to the recent down-grading of the International Monetary Fund's estimates of China's annual gross national product and purchasing power parity rate in late 2007.

[3] It is useful to note that the US defense R&D spending estimate for FY2008 is $83 billion, nearly twice China's announced annual defense budget [12].

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on science and technology amounted to 168.9 billion yuan (or $23.5 billion), in nominal terms nearly five times the amount (349 million yuan) spent a decade earlier.

In addition to higher R&D spending, China's defense R&D efforts are being aided by other ongoing policy reforms. Four critical reform efforts were key to the remarkably fast transformation in China's defense-industrial sector that has become apparent over the past decade:

1. The decision by Mao's successor, Deng Xiaoping, to open the country to outside investment. First implemented in the 1980s, this policy expanded throughout the 1990s to allow more and different forms of foreign direct investment into China, thereby coinciding with the worldwide economic and technological phenomenon of globalization;
2. The set of decisions announced in 1998 to remove the military from commercial ventures and to separate military and defense-industrial efforts. Instead, defense enterprises now answer to a civilian hierarchy, are encouraged to interact more with commercial enterprises, and are responsible for a growing share of their own funding by becoming increasingly competitive and profit-oriented. China's state-owned enterprises (SOEs) and defense-industry conglomerates, which still dominate the defense sector, continue to struggle with this mandate despite national incentives to become more competitive;
3. The ongoing, if still slow-going (particularly in defense industries), privatization of SOEs; and
4. A 2003 reform in which Chinese leaders articulated a bold new strategy for defense industrial development that would depend on "mutual promotion and coordinated development of the defense and civilian technological sectors." While elements of this strategy are reminiscent of earlier PRC efforts to promote defense conversion (i.e., spin-off technologies from defense industries to commercial entities), the latest strategy focuses primarily on emphasizing spin-on technological advances from the commercial sector to the defense industry.[4] This dual-use, integrated civil–military strategy is driving China's current defense and space R&D efforts and may in part account for recent military modernization achievements.

China's path to a more modern defense R&D establishment has not been without significant obstacles, however. In initiating the transition from a military designed to conduct a "People's War" to one ready to operate effectively "under high-tech conditions," Beijing has had to adopt a phased approach to incorporating new commercial, technological, and competitive concepts into a defense sector still struggling with a Cold War legacy. This legacy includes a large defense industrial and research community located in China's hinterland, far from borders both land and sea, and more importantly, away from the dynamic, fast-advancing, and increasingly high-tech industrial coastal regions. Thus, central to this phased process has been an initial focus on developing key sectors, weapons systems, and units that have been variously termed "pockets of excellence" and "pockets of adequacy" [15].

3. Defense R&D: a phased approach to transforming defense sector development

Precise information on China's defense R&D strategies, policies, and priorities is difficult for outside analysts to discern definitively given the PRC's continued opacity on such sensitive matters. Nevertheless, some defense and R&D priorities have become apparent over time to careful observers of Chinese economic, scientific, technological, and military reforms. For instance, it appears that the PRC has adopted an overall phased approach to developing certain defense industrial sectors and technologies before turning to other, more difficult ones [15, p. 25]. China's latest Defense White Paper explains:

> Priority is given to upgrading technologies and products in the nuclear, space, aviation, shipbuilding, weaponry, electronics and other defense-related industries, so as to form a cluster of high-tech industries to drive the growth of China's economy. [10].

As the following analysis points out, there is a strong strategic rationale underlying this approach that may also foreshadow where China's defense R&D efforts will be focused in the future.

3.1. Information and communications technologies (ICT)

China is currently undertaking a program of "informatization," that is, an effort to infuse the defense sector with digitized, information-based, and networked capabilities so as to promote an RMA with Chinese characteristics. Beijing sees this effort as useful and necessary for transforming a still-oversized People's Liberation Army (PLA) into a modern and professional fighting force capable of fighting what Beijing now terms "local wars under the conditions of informatization" [16]. This informatization strategy seeks to exploit the ICT revolution to help the PRC leapfrog from a traditionally mechanized force to the next-generation type of military capable of delivering precision-guided munitions, global

[4] This strategy relates to the decision made at the 16th Party Congress in 2003 to update Deng Xiaoping's former defense conversion strategy as outlined in a 16-character slogan to a new 16-character set that would clarify the new strategic vision. A brief history and detailed description of this new dual-use civil-military strategy can be found in [14].

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positioning-supported operations, and other forms of modern high-tech warfare. Accordingly, IT research remains a continuing objective, as outlined in China's MLP, which identifies priorities through the year 2020 for national S&T and R&D efforts. Other strategic research priorities over the next 15 years include [17]:

- Agriculture
- Energy
- Environment
- Information Industry and modern services
- Manufacturing
- National defense
- Public health
- Public security
- Transportation
- Urbanization and development
- Water and mineral resources

For Chinese strategic thinkers, an initial focus on developing ICT-based military capabilities makes sense for several reasons. First, Chinese military strategists view the growing US dependence on information-based planning, programming, and operations as not only a strength but also the American military's key vulnerability. Given the US military's demonstrated technological edge, PRC strategists do not expect to be able to combat US forces symmetrically or one-on-one in the event of conflict. Yet, Washington's reliance on ICT-based military technology is also viewed as providing Beijing with a possibly effective asymmetric opportunity. PRC forces might be able to deter US operations or disrupt US communications capabilities as a disabling first step. This could be particularly relevant to a conflict over the status of Taiwan, as Beijing's diplomatic strategy seeks to deter the US and other nations from intervening in this situation. Its military doctrine appears to emphasize the need for a rapid Chinese *fait accompli* should conflict erupt. Accordingly, Beijing has devoted much effort to what it terms "information warfare" (IW) capabilities.

The focus on informatizing China's defense sector also leverages the vast amounts of foreign direct investment that have flowed into the PRC over the past 25 years. The ICT revolution has fueled the current wave of globalization in China and elsewhere, as computer hardware, software, and networked telecommunications have transformed the way the world works, plays, and converses. The increasingly ubiquitous and dual-use nature of ICT has made this technology hard to control—certainly much more difficult than during the Cold War, if not impossible. ICT ubiquity has, in turn, initiated a new trend in overseas high-tech investment (commonly referred to as "outsourcing" or "offshoring") that has evolved over time to include not just overseas manufacturing but also foreign-invested R&D in places like China [18–20]. Given concerns regarding such issues as protection of intellectual property rights, high-tech investments of this sort were deemed unlikely until quite recently. Today, however, China is a leading recipient of foreign R&D investment (by location), the majority of which focuses on developing ICT-related capabilities (e.g., computer hardware, software, telecommunications equipment).[5] Some analysts have calculated foreign R&D investment in China to be around $3 billion per annum, though this is at best a rough estimate.[6] Nevertheless, it is clear that this trend has also begun to penetrate China's interior to include places such as Xian, a growing computer software development hub. Thus, as an initial focus for China's defense R&D efforts, informatization makes a great deal of sense. It has also resulted in some early success stories, with domestic Chinese IT firms (e.g., Legend, Huawei, ZTE, and Lenovo,) able to compete more effectively with foreign enterprises in domestic and some overseas markets. These same firms are increasingly a source of China's defense-related R&D, much as US and multinational firms conduct a mix of civilian and defense research.

3.2. Shipbuilding

Another defense-related sector in which China has focused its early transformation-oriented defense R&D efforts is shipbuilding. An obvious factor in the decision to focus on developing technology for the shipbuilding sector—both commercial and defense industrial—is the necessary proximity of its facilities to China's Special Economic Zones (SEZs). These areas were targeted for initial economic opening in the 1980s; their success led to a subsequent need to transport exports from these and other coastal areas to overseas markets. China's dynamic coastal region currently boasts the country's most advanced commercial technology centers and commercial R&D capabilities. Unlike other defense sectors that were moved westward to establish a "Third Line Defense" during the Cold War, China's shipbuilding industry necessarily remained coastal. In fact, China's shipbuilding industry development strategy mirrors its overall coastal technology development strategy wherein the three major high-tech investment regions—the northeastern Bohai area, the Yangtze River Delta region surrounding Shanghai, and the Pearl River Delta region around Guangzhou—are also the areas of

[5] China ranks among the top destinations for R&D investment in a number of recent surveys. See, for instance [7, p. 133].

[6] This calculation was made by multiplying the number of foreign R&D labs (then pegged by the PRC government at 750) by the average number of researchers, their typical salaries, and amount of salary accounting for R&D expenses. See [21].

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concentration for development of the shipbuilding sector, as outlined in the recently published ''Medium- to Long-Term Science and Technology Development Plan'' [22–24]. As a result, this Cold War geostrategic disadvantage is today viewed as a considerable technological advantage for developing both China's defense and commercial shipbuilding sectors, and therefore has been an early priority among the PRC's defense R&D modernization attempts.

China's emergence as a net oil importer in 1993 has provided further impetus, particularly for construction of more complex tankers in addition to the simpler bulk carriers that were previously the industry's commercial focus. Drawing on a large, extremely cheap labor pool and an increasing proportion of modern, large-scale facilities, China has already compensated for some technological and logistical shortcomings to become the world's third-largest shipbuilder. The growth in world demand for shipping, which has accompanied globalization, has certainly also stimulated China's shipbuilding industry ambitions. As outlined in the ''Medium- and Long-term Development Plan for China's Shipbuilding Industry,'' China aims to be the world's largest by 2015 [25].

A further reason for prioritizing shipbuilding is that as an industry involving extensive dual-use technologies, it again offers China the opportunity to leverage its considerable access to leading high-tech investors, knowledge, and resources from around the world for defense-industrial development purposes. Indeed, China's shipbuilding industry first began to diversify its activities in the 1980s to include commercial production as part of Beijing's earliest defense conversion efforts [15, p. 109]. This early dual-use approach (focused mainly on spin-off or defense-to-commercial technology transfer), paired with China's current ''combining'' strategy (which emphasizes spin-on technology transfer from commercial to defense industry), is what has marked China's shipbuilding industry as among the most successful commercial *and* defense-industrial sectors in China. As concluded in a recent detailed study:

> [The industry's] growing commercial business activities, especially its interactions with foreign shipbuilders, have allowed China's shipbuilding industry to improve the quality and efficiency of its research and development techniques, production processes, and management practices…These trends are also reflected in the improvements in Chinese warships commissioned in the late 1990s and in many of the new naval projects currently coming online. [15, p. 110]

Commercially developed technology for shipbuilding does not lend itself seamlessly to naval shipbuilding needs, but there is significant overlap that China can exploit for military ends (e.g., hull design and construction, modular construction techniques, and safety equipment—though not other systems such as advanced radar and weapons systems) [15]. Nonetheless, China appears to intend to do just that, by having co-located its commercial shipbuilding facilities alongside military counterparts in the same shipyard. China's two main state-owned shipbuilding enterprises—China State Shipbuilding Corporation (CSSC) and its offshoot, China Shipbuilding Industry Corporation (CSIC)—both design and produce commercial as well as naval vessels and equipment. In this regard, it is interesting that the PLA Navy's new high-speed, wave-piercing *Houbei*-class missile catamaran (Type 2208), which is currently being constructed at multiple shipyards, appears to have been derived from a ferry designed by Australia's INCAT corporation [26].

Lastly, the shipbuilding industry provides substantial down-range advantages. As a recent study points out, ''Shipbuilding boosts the entire industrial chain, including the steel industry, as well as the metallurgical and machine–tool sectors, among others'' [27]. It is also relatively labor-intensive, and so provides coastal regions with large-scale employment programs, which are needed to accommodate the many laborers continually attracted to China's vibrant coastal economic zones. Thus, it is not surprising that the shipbuilding sector, for all the reasons outlined above, is among Beijing's first commercial *and* defense-industrial R&D priorities.

3.3. Nuclear power

A third sector that is receiving renewed attention and priority among China's national R&D allocations is the nuclear energy sector. The PRC first developed nuclear weapons decades ago, demonstrating its nuclear ability with its first detonation in 1964. This effort was guided by a State-controlled S&T plan (the 12-year plan spanning the years 1956–67) that outlined clear priorities among China's defense R&D interests and focused the defense research establishment on the task of developing nuclear weapons as well as a ballistic missile launch capability.[7] Since this effort's historic and high-profile success (both nuclear weapons and the missiles to launch them undergird strategic deterrence), this dedicated approach to planning defense R&D continues to influence considerably Beijing's strategic thinking about how best to realize the country's future technological ambitions. Consequently, Beijing continues to champion dedicated, state-generated S&T and R&D priorities in its contemporary 5-year and longer-term S&T development plans, with nuclear science among the sectors receiving priority. This massive, top-down approach also persists in the form of major state R&D funding programs (e.g., the 863, 973, and Torch Programs). Whether this strategic approach remains best suited to 21st century defense industry development remains an open question.

There is today, however, renewed interest in expanding China's nuclear-power capacity and technological capabilities (along with other energy-producing sectors). An obvious driver for this present interest is the need to develop power supplies sufficient to meet the demand of China's skyrocketing economy. This demand is matched only by that of the

[7] This effort is also known as ''the two bombs and one satellite'' program (*liangdan yixing*).

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world's leading nuclear power companies, which see in China a rich opportunity for a return on investment for generations to come. China's own estimates suggest that the country's energy consumption could increase 30-fold by 2030 (from 1560 million tons of oil equivalent in 2005 to three billion tons per year in 2030) [28].

As with other key strategic sectors of China's economy, Beijing is promoting a policy of ''indigenous innovation'' (*zizhu chuangxin*) in an effort to limit China's overall reliance on foreign technology and imports. The goal, as outlined in China's ''15-year Medium- to Long-Term Science and Technology Plan,'' is to achieve by 2020 a 60%/30% differential between the respective contributions of indigenous and foreign technologies to national economic growth. Among its engineering megaprojects, the plan includes work on large-advanced nuclear reactors. Specific projects include development of indigenous fast breeder reactors and nuclear fusion, which are funded under the state-directed 863 plan [28].

Unlike in the past, however, R&D in China's nuclear and other strategic sectors are increasingly funded by industry. For instance, the distribution of R&D funding for refinery, coking, and nuclear fuel processing in 2004 equated to approximately 78% R&D funding from industry and 15% from government, with bank loans and other funding sources accounting for the remaining 7% [28]. Thus, while Beijing persists in drafting long-term S&T plans reminiscent of the historic 12-year plan era in order to direct national resources to specific research priorities, the implementation and success of these plans increasingly rests on Chinese industry and its ability to undertake advanced R&D that will meet both private-sector demands and broader state interests, including defense needs. As a result, both sides of the government–industry relationship have adapted to this new approach to pursuing R&D, with government officials today characterizing state-generated S&T plans as ''guidelines'' for industry development rather than detailed mandates, and leading Chinese enterprises willing (or forced) to take on more defense-industrial R&D projects as part of their expanding portfolios.

As in the other sectors addressed, China's pursuit of nuclear technology is spurred by access to advanced technologies from around the globe paired with the potential this technology transfer holds for defense industrial development. As one recent study notes: ''China is currently the world's biggest market for nuclear power equipment manufacturers…To be permitted to participate in the construction of nuclear plants in China, companies from other countries are required to transfer technology there'' [28]. This general model holds true for other strategic industry sectors as well, in which Beijing continually conditions market access on technology transfer arrangements including foreign R&D investments. While this strategy has created difficulties, overall it continues to yield benefits for China, and it has become a core part of its defense industrial development model for the future.

3.4. Space and satellites

Like the shipbuilding and nuclear sectors, China's space sector benefited early on from exposure to foreign technology, equipment, and know-how as well as extensive state-funded research (as part of the aforementioned 12-Year Plan). This combination, coupled with substantial Soviet assistance in the late 1950s, helped the PRC develop missile and launch capabilities. Following the sudden withdrawal of Soviet advisors in 1960, and considerable indigenous effort under the leadership of foreign-educated experts (e.g., Qian Xuesen), in 1980 China successfully tested the Dong Feng-5 ICBM. Its deployment in hardened silos the following year gave China the ability to strike the US for the first time. Since then, China has developed all major types of advanced missiles, and offers many for export.

Only in the past decade or so, however, has Beijing focused more extensively on expanding commercial capabilities as a means of ultimately spinning-on know-how to the defense-industrial sector. In part, this latter strategy was likely driven by the expanding global market for launch services following the explosion of the space shuttle *Challenger* in 1987, when the US looked to Russia and China for additional satellite launch capacity. This presented China with another dual-use technology transfer opportunity from a broad range of suppliers worldwide, as well as a means to support a strategic industry amid broader military budget cuts to stimulate economic development. Satellite launch services proved to be a rich avenue for technology transfer, but one that would become highly controversial following the US Congressional investigations into US firms' unsanctioned activities in China as well as likely Chinese espionage activities. The resulting 1999 Cox Commission Report, and the measures it triggered, no doubt hindered to some degree China's plans to exploit the commercial launch market. Subsequently, however, China's missile launch and other aerospace capabilities have improved substantially, and China has engaged in robust technological cooperation with Russia, the European Union, and others.

Satellite development supports China's strategy of efficient investment that leapfrogs traditional stages of technological development [29]. Since the mid-1990s, and despite efforts to enhance US export controls governing dual-use satellite technology by giving it a ''munitions'' designation (though most countries consider it to be in the commercial rather than munitions category), China's satellite industry sector has advanced demonstrably. China reportedly has in orbit 14 communications satellites, 3 navigation satellites, 3 meteorological satellites, 6 imagery and remote sensing satellites, and 8 scientific satellites [30]. In addition to using GPS and GLONASS, and working with the European Union on the *Galileo* navigation satellite system, China has deployed its own gradually growing system of *Beidou* navigation and positioning satellites, which currently provide limited navigation coverage accurate to within about 20 m [31]. Since 2000, China has also orbited a variety of small oceanographic research, imagery, and environmental research satellites and established dedicated small satellite design and production facilities. The latter advances were made possible in part due to collaborative R&D relationships China has with British and Brazilian entities. In addition, China's Aerospace Tsinghua Dong

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Fang Hong (DFH) Satellite Co. has reportedly established a joint venture with a Japanese high-technology enterprise based on the Mainland, and intends to ''gradually seize [a portion of] the small satellite market'' [32].

In addition, China is developing micro-satellites (weighing less than 100 kg) for remote sensing, as well as networks of imagery and radar satellites. This could enable rapid reconstitution or expansion of China's satellite force in the event of any disruption in coverage [32]. These increasingly sophisticated micro-satellites also have the potential to permit the use of satellite constellations to increase survivability, decrease cost, and increase reliability, particularly of communications (as opposed to reconnaissance) missions. According to the latest Department of Defense assessment of China's military capabilities, ''China hopes to have more than 100 satellites in orbit by 2010, and to launch an additional 100 satellites by 2020'' [30]. In a development that mirrors Western efforts to reduce costs and enhance reliability, satellite buses (i.e., standardized platforms) quite literally constitute the backbone of China's micro-satellite efforts and bode well for China's future competitiveness in this industry sector.

3.5. Aviation

Based on the paradigm set out thus far, it follows that the defense R&D strategy applied to China's aviation sector would follow a similar pattern of exploiting commercial technology opportunities resulting from globalization dynamics and high levels and advanced forms of foreign investment on the mainland. In fact, where China has succeeded in attracting foreign-invested production and co-production facilities as well as technology training programs that have typically accompanied Boeing, Airbus, and other foreign offshore manufacturing, there have indeed followed demonstrated advances in China's defense sector in areas such as avionics and machine-tooled precision components [30].

China's aviation sector, however, has long lagged behind other commercial and defense industrial development efforts. Among other reasons, the PRC inherited no domestic aviation industry; it located the majority of infrastructure in backward hinterlands (where much of it remains today); and (as was not the case with missiles or even satellites) failed to protect it from devastating political excesses (e.g., the factional infighting and utterly unrealistic goals of the Cultural Revolution). An ambitious attempt to construct a full-size commercial jetliner in the early 1980s failed, and has yet to be repeated [34].

Following rapprochement with the US in 1972, however, there arose substantial diplomatic benefits from importing readily available Boeing and Airbus aircraft, particularly as both the US and the European Union have significant trade deficits vis-à-vis China. Thus, since the PRC has yet to develop its own large commercial airframe (as distinct from regional-size jets such as the jointly developed ARJ21, which entered production in 2006), it is not entirely surprising that advances in the defense realm have been slow to come as well [33].

Another key factor is that where a steady supply of advanced jet fighters and components have been available to China (i.e., the *Sukhoi*-series fourth-generation fighters from Russia), there has likely been less relative urgency to develop this sector than others [34].

Nonetheless, the co-production and training programs China reportedly has demanded as a part of the Russian *Sukhoi* jet fighter purchases (and, many believe, also technology copied from Israel's *Lavi* fighter program due to similarities in design) have helped elevate PRC defense capabilities and likely facilitated the surprising appearance in December 2006 of China's first indigenous fighter, the J10 [35], There still remain technological challenges, however, in both commercial and defense sectors, particularly mastery of modern engine technology, which China continues to import. While Russia remains a reliable supplier, US and European export controls stemming from the Tiananmen era have restricted China's access to this critical technology and helped to slow both commercial and defense industrial development.

In the meantime, China is focusing on informatizing its air force by upgrading older platforms with modern avionics and developing new systems for future-generation fighters [10]. China has also in recent years demonstrated other impressive advances including fielding of a relatively advanced AWACS platform [36]. Nevertheless, China still has some way to go before its military can claim to have leapfrogged significantly ahead in modern jet fighter and related military aviation technology.

3.6. Differences have narrowed, but the gap remains

As outlined in this section, while China remains substantially behind the United States in most military capabilities, the differences that exist today between the nations' strategies for pursuing defense R&D in an age of globalization have largely narrowed to the point where there may be as many commonalities as there are remaining distinctions. Both US and PRC defense R&D strategies seek to promote dual-use technologies developed largely by private enterprises conducting business around the globe. Both countries, moreover, are blessed with the ability to attract the world's leading high-tech investors and researchers to their shores, thereby enhancing potential overall R&D capacity. Both also continue to supplement commercial R&D efforts with government-funded programs designed to strategically guide national R&D efforts and prioritize strategically important sectors.

The differences, however, largely involve China's need to continue its defense sector structural reforms and its phased approach to defense industrial development as the nation tries to leapfrog ahead to a 21st century military force. Overcoming the institutional, ideological, and even geographic legacies of the past will be an arduous, protracted process. When it comes to translating strategy and policy into modern defense systems, China had to contend with both the

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advantages and disadvantages of being a late developer. On the one hand, China's efforts to develop and implement more advanced military systems remains hampered by lingering institutional, ideological, and geographic legacies of the past. Also, as a PLA commentary recently suggested, China still has difficulty diffusing technology through its defense industrial system [37]. In addition, the leadership confronts many other pressing priorities, such as the need to maintain social stability by ensuring that the income gap between coastal and interior provinces does not widen further and that large numbers of arguably redundant workers employed in military SOEs are not simultaneously laid off. But, on the other hand, China's deficiency in major, indigenously developed, digitally enhanced, competitive defense systems and technologies allows for potentially very rapid advancement from a low-tech starting point. While this may not permit Beijing to leapfrog the capabilities of advanced Western nations on a broad scale, it is already allowing it to leapfrog some stages of development that those nations previously had to follow to attain their present technological leadership. These considerations, along with China's continued pursuit of dual-use technology transfer opportunities resulting from expanding global economic interactions, also help to explain Beijing's present-day phased approach to defense sector R&D.

These realities have led Beijing to take a somewhat ambitious approach to defense R&D and industrial sector development, which is likely to be reflected as well in the types of defense platforms China fields over the next few decades as well as the timing of these demonstrated capabilities. As has already been witnessed in recent years with the surprisingly rapid pace of the emergence of new defense capabilities (e.g., China's J10 fighter, Type 093 and 094 nuclear submarines, small satellites, and information technology), China's dual-use approach to enhancing defense R&D may continue to catalyze surprisingly swift advances in the years to come. Where this phenomenon has perhaps become most apparent of late is China's space R&D activities, as discussed in the following section.

4. Space R&D: mixed military and commercial motives

As compared with China's overall approach to pursuing defense R&D, its space-related R&D efforts are characterized by a more mixed set of motives. These include not only exploiting commercial spin-on technologies for defense applications but also expectations of a large degree of defense spillovers to the overall economy, the prestige factor of having a manned space program, and the deterrent effect of demonstrating, deploying, and indigenously developing sophisticated space-based capabilities. China is also actively developing space-related technologies as a critical element of its (previously outlined) defense R&D and informatization efforts.

4.1. China's evolving space program

China has joined the elite power club of nations that have achieved manned space flight; only the United States and Russia can claim the same. The PRC's first manned mission took place with the successful launch of the *Shenzhou V* spacecraft in October 2003; a second *Shenzhou* launch followed in 2006, and a third is planned for 2008. China's manned space program—known as the "921 Program" after the year and month in which the country's first manned space craft design was presented to authorities—has been part of a long-running effort to expand China's space-based capabilities.

In fact, China has focused on developing space technologies for over 50 years. Beginning in 1956 as part of Beijing's aforementioned 12-year S&T plan, space capabilities have been labeled a priority for defense R&D. As previously noted, China's early efforts in this domain, which focused on ballistic missile and satellite launch development, were quite successful and benefited from the enormous national resources dedicated to the R&D mission during those years. However, in the intervening period following these advances and the latest manned space missions, China demonstrated only intermittent advances and space-related innovations.

This lull can partly be explained by periodic disruptions in China's internal and international policies. For example, the Sino-Soviet political split removed Soviet technical assistance abruptly in 1960. The period of the Cultural Revolution (1966–76) severely impaired China's defense R&D efforts, although the space and satellite sector weathered it better than most other research fields. The 1980s and 1990s witnessed intermittent technological advances as well as defense-sector reform efforts. Throughout this time, however, space remained a priority for defense R&D. But another major shift came in 1998 through a series of defense industry reform measures that separated military and commercial development and production activities [38,39]. Unlike in other key sectors discussed thus far, there was a deliberate attempt by Beijing to limit potential dual-use and civil–military technology transfers in this sector, likely due to concerns over the military enterprises' potential interest in pursuing profit-making ventures rather than focusing on defense needs [15]. Since 1998, however, the authorities have reformed the sector once again and followed suit with other key defense industrial sectors by transforming the space sector back into a combined effort in terms of dual commercial and military research, production, and policymaking [40]. Today, as noted in China's latest Defense White Paper,

> Major scientific and technological projects, such as manned space flights and the Lunar Probe Project, are being carried out to spur the leapfrogging development of high-tech enterprises combining military and civilian needs and to bring about overall improvements in defense-related science and technology [41].

The scope of China's space programs and R&D objectives has also changed over time. During the PRC's early years, Beijing had to be selective in deciding on which space programs to devote its limited financial resources. Thus, nuclear

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weapons and the ballistic missile capability necessary to deliver them (along with satellites) received clear priority. Consequently, China maintained a limited space agenda through the mid-1990s, when Beijing was first able to vigorously pursue a broader range of space technologies and capabilities. This change was due to (1) ever-increasing coffers of export revenues and foreign investment, which Beijing could devote to more ambitious defense and space R&D programs; (2) the impact of globalization on the satellite industry, which provided rich new opportunities for commercial applications and spin-on technologies; (3) the need for secure satellite-based communications platforms to support China's informatization efforts throughout the PLA and civilian economy; and (4) China's concerns over renewed US efforts to deploy missile defense forces internationally, which Beijing views as threatening to its relatively limited nuclear force. In addition, China has also received substantial technical assistance through international cooperative agreements with the European Union and Russia and has various other cooperative arrangements with Canada, France, Spain, and Brazil. As a result, China today is both willing and able to pursue a more comprehensive portfolio of space activities and R&D.

Indeed, as some commentators have noted, "China is on the fast track into space" [42]. Not only is the PRC pursuing manned space activity, but Beijing has also outlined plans to explore the lunar surface through the ambitious *Chang'e* Program. The first stage of this Chinese Lunar Exploration Program (CLEP) got under way in late October 2007 with the successful launch of the *Chang'e-1* spacecraft whose mission is to map and analyze the moon's geographical features, weather, and soil [43]. Chinese National Space Administration (CNSA) spokesman Li Guoping also used the occasion of the *Chang'e* launch to call for "private enterprises to join the space technology development and attract public funds into the aerospace-related research, manufacture and trade" [44]. The program's ultimate goal is to land a robotic lunar explorer on the moon's surface by 2020 [44]. The European Space Agency is assisting this program by offering ground operations and spacecraft support as well as data and expert exchange programs [44].

To accomplish these varied and ambitious space efforts, China appears to be following the same dual-use technology development strategy first employed by the US National Aeronautics and Space Administration (NASA) [42]. This strategy seeks to exploit the technological spillover effects that space science and research can have on the economy. These include commercial and defense sector spin-offs as well as improvements in education programs and attracting more PRC students to "hard" sciences (e.g., physics, math, and engineering), not to mention the excitement and innovative energies the prospect of space travel could generate among China's growing entrepreneurial class. China's closest equivalent to NASA—CNSA—plays a similar role in promoting China's space ambitions and achievements domestically and internationally.[8]

It should also be emphasized that the advances in defense R&D outlined in the previous section rely in large part on China's growing space-based capabilities. Beijing's ongoing informatization strategy is tying China's commercial and defense sector to the digital domain of ICT to enhance technological advances and capabilities. But as China's dependence on computer technology and telecommunications grows, so too does Beijing's interest in developing an independent capacity to control information and telecommunications platforms. This is a key incentive, beyond the excitement and spillover technology effects of space travel, which is driving China's fast-paced space and satellite development programs. These same platforms can also be applied to information and space-warfare operations, a field in which China has shown both substantial interest and worrisome capabilities.

Finally, another core reason why China has long pursued manned space missions and other space-related programs is simply because, for both substantive and symbolic reasons, such capability is viewed in China and elsewhere as one of the indicators of great power status. China is among an elite few to achieve manned space flight and seems intent upon expanding this horizon, even beyond where the US and Russia have ventured.

Where is China headed from here? Beijing recently outlined its near-term scientific and technological development plans in the 11th 5-year plan for Aerospace Development. This plan, which was released by the Commission of Science, Technology, and Industry for National Defense (COSTIND) in October 2007, outlines the following nine missions to be accomplished by the year 2010:

1. To enhance the capabilities of scientific research on space products, and shorten the current research cycle.
2. To implement key scientific and technological projects, including manned flight, the Moon probe, the high resolution Earth-observation system, the Compass Navigation Satellite System, and the new generation of carrier rockets.
3. To improve innovation capabilities, and overcome key technical difficulties such as satellite payloads and deep-space exploration.
4. To hasten the development of space technology, expand the application of satellites, and kick off research projects to make space products more accountable and longer lasting.
5. To optimize the structure of the space industry, form a complete industrial chain from satellite manufacturing to projection and application, and promote satellite exports.
6. To continue research on space science and establish the space environment monitoring and forecasting system.
7. To strengthen industrial management and create a good environment for space development.

[8] According to China's latest Space White Paper, "The China National Space Administration (CNSA) is the country's governmental organization responsible for the management of space activities for civilian use and international space cooperation with other countries, and responsible for implementing corresponding governmental functions" [45].

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8. To strengthen education and foster talent.
9. To strengthen international exchanges and cooperation [46].

As a result of these measures, as a recent CCTV documentary suggests, China has begun ''shaking the heavens'' and the Earth when it comes to space-related R&D [47]. However, China still has some way to go in improving its innovative abilities and matching those of other space powers, particularly in terms of its ability to apply these technological and R&D gains to its broader commercial and defense industrial efforts.

5. Conclusion

China's modernized approach to conducting defense and space R&D appears increasingly similar to the approach followed by the US and other major powers' defense and space establishments. These shared characteristics—an industry-driven, innovation- and global market-oriented defense sector—should theoretically enhance opportunities for cross-border collaboration and technology transfer. As our analysis shows, facilitating international exchanges of technology and collaborative R&D is a distinct part of China's development strategy for both the defense and space sectors.

Yet, there are a number of reasons why such technological cooperation in the defense and space realms remains problematic in the near term. The most obvious, at least with regard to US–China defense or space R&D collaboration, is political. Economic sanctions still in place since the 1989 Tiananmen Square crackdown ''prohibit the export of arms, satellites and dual-use items used for crime control unless there is a Presidential waiver. US policy since Tiananmen Square is to deny export of controlled dual-use technology to the Chinese military and police'' [48]. While US export controls, particularly when pursued independently without multilateral support, are not necessarily effective in restraining China's access to advanced dual-use technologies or its modernization efforts, there is little reason to think this long-standing policy is about to change. Several European countries have appealed to the United States in the past few years to collectively lift the Tiananmen sanctions, but to no avail thus far. In response to these pressures, in fact, the Department of Defense (DoD) has added a new section to its annual report assessing Chinese military power entitled ''Implications of Lifting the EU Arms Embargo,'' which outlines the dangers DoD believes this step could pose for US national security.

Moreover, while China has become relatively more transparent in its commercial and defense policymaking practices over the past decade, legitimate concerns remain in Washington and elsewhere about the overall lack of transparency that surrounds China's defense-industrial and military-sector development plans, programs, and policies. As long as this is the case, chances of US–China defense R&D cooperation remain slim. Nonetheless, due to China's deliberate strategy of developing its defense sector by exploiting globally available dual-use technologies and utilizing a phased-development approach, in which progress in one industry sector is expected to compound progress in others, much opportunity exists for the PRC to rapidly modernize its defense and military capabilities, as has been particularly apparent over the past few years.

Space exploration, on the other hand, offers greater near-term potential for a more collaborative US–China relationship. The CNSA, along with a dozen other space agencies, has taken part in developing NASA's ''Global Space Exploration Framework,'' an international strategy to synchronize different existing national space programs' plans to explore the solar system [49]. The global commons that outer space represents offers the potential for more collaborative, international endeavors in pursuit of a common end.

Another objective of space exploration is the benefits that such activities accrue to a nation's economy. This is an end that Washington and Beijing also have in common. As cited in the NASA Framework report, ''Global scale space exploration is an engine of scientific and technical progress. Problem-solving drives innovation and the bigger the problem, the greater the innovation'' [49].

This is not to say, however, that there are not serious obstacles to potential US–China space and R&D collaboration. Although China has made clear its interest in participating in the International Space Station activities, this has not been permitted due to US technology transfer concerns. Prospects for enhanced cooperation had looked more promising following the historic visits in 2006 by CNSA and NASA officials to one another's countries, although the latter's visit ended abruptly due to China's lack of reciprocal transparency. Then, in January 2007, China made headlines by shooting down an ageing weather satellite in a demonstration of a new anti-satellite (ASAT) weapons capability. This remarkable test sparked a renewed debate over whether a new space arms race has begun, this time focused mainly on a US–China competition [50]. While these concerns may be premature, there is no question that the potential now exists.

There is also a broader question: can two competing powers—one long established, the other a fast-rising power—peacefully co-exist, or will they eventually come into conflict? There are adherents on both sides of this long-running debate. Those with a Liberal Internationalist or Constructivist world view believe that nations can shape their environment toward more peaceful ends; meanwhile Neo-Realist theorists view the world as an anarchic system in which nations must further their own self-interests, often by balancing (i.e., competing with) other powers or bandwagonning along with an existing power center. With regard to China's rise, the outcome remains to be determined.[9] But it seems clear

[9] For a broad overview of these various schools of thought, see [51,52].

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that China is becoming more competitive with the United States in both defense and space R&D endeavors, although the two are far from parity.

Yet, given the approach that China has adopted, which is transforming the country's defense and space R&D establishments to be increasingly like (but certainly not identical to) the US system, is there greater potential for our two great countries to cooperate more substantially? The simple notion that similar entities are more able, and therefore more likely, to cooperate suggests that there is reason to be optimistic. Just as US and European defense firms compete, cooperate, and on occasion merge, the more Chinese defense firms, research institutes, and production facilities are compatible in terms of purpose, practices, standards, and skill sets with those of other countries, the more appealing they will be as prospective partners (or takeovers) in international defense R&D. The more appealing Chinese firms become, the greater the pressure will be on US, European, and other international authorities to amend existing trade and export control policies. In the meantime, China is pursuing defense industrial development in a way that seeks to minimize the effect of Western sanctions while maximizing the potential that can be gleaned from a truly globalized economy. This strategy is likely to lead China to continue prioritizing development of those sectors and sub-sectors that have high dual-use technology advantages and to use any resulting advances to aid long-term development of more advanced, military-specific platforms.

It is military concerns, however, that currently motivate Washington to impose technology transfer restrictions on China and to exclude it from positions of leadership in the international space community. China's persistent lack of military transparency exacerbates the situation, and Beijing's continued lack of an explanation for its recent ASAT test—the largest single human source of satellite-endangering space debris in history—raises pressing questions concerning the uses to which Beijing intends to put its growing space capabilities. Yet space development is so important to China (as it is to all major powers) that Beijing will not accept foreign attempts to limit its progress in this regard. Partially in response to US restrictions, China has pursued robust space relations with Argentina, Brazil, Canada, France, India, Malaysia, Pakistan, Russia, Ukraine, the United Kingdom, the ESA and the European Commission. It has conducted exchanges with relevant government organizations in Algeria, Chile, Germany, Italy, Japan, and Peru.[10] As noted, Russia and the European Union in particular have provided China with significant amounts of space systems and related technologies. Beyond this technological acquisition and sharing, Beijing is using space cooperation to engage in what might be termed "geotechnological balancing," or the use of space activities to restrict American power and to try to reshape the international system in its favor.[11] A key component of this strategy is the promotion of East Asian regionalism, with Beijing the leader. This approach is reflected in the October 2005 establishment of the Asia-Pacific Space Cooperation Organization (APSCO), which is headquartered in Beijing [54].

Looking ahead to the longer term, today's competition could turn into a more cooperative arrangement given the tendency of the international system to promote specialization—and, hence, cooperation—among power centers. In other words, while the US and China (among others) may be rising competitors today, in the long term our distinct competitive advantages and disadvantages in the realm of defense and space R&D are likely to become more pronounced, and market forces will likely begin to divide tasks accordingly. This "learning" process at the systemic level of international relations, however, takes a very long time to work itself out. In the meantime, China is likely to continue its phased approach to developing defense R&D capabilities with the aid of ever-increasing foreign investments while expanding into new and, for now, independent frontiers in space R&D.

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Dr. Andrew S. Erickson is an Assistant Professor in the Strategic Research Department at the US Naval War College and a founding member of the department's China Maritime Studies Institute (CMSI). Proficient in Mandarin Chinese and Japanese, he received his Ph.D. and M.A. from Princeton University and graduated magna cum laude from Amherst College. His research, which focuses on East Asian defense, foreign policy, and technology issues, has been published in *Orbis*, *Journal of Strategic Studies*, *Comparative Strategy*, *China Security*, *Naval War College Review*, *Undersea Warfare*, *Space Policy*, *Geopolitics of Energy, Pacific Focus* and *Joint Force Quarterly* (forthcoming). Erickson is coeditor of *China's Energy Strategy* (Naval Institute Press, 2008), *China's Future Nuclear Submarine Force* (Naval Institute Press, 2007) and *China's Nuclear Modernization*. He is a member of the Council for Security Cooperation in the Asia Pacific (CSCAP), and can be reached at andrew.erickson@nwc.navy.mil.

Kathleen (Kate) Walsh is Assistant Professor of National Security Decision Making at the US Naval War College. Her research focuses on China and the Asia-Pacific, particularly issues related to international security, technology transfer and globalization, nonproliferation and export controls. Her recent works include "China's anti-satellite test: a 21st century Sputnik?," *China defense, security and space policy brief* (Arlington, VA: George Mason University; Fall 2007); "China R&D: a high-tech field of dreams," *Asia-Pacific Business Review*, Volume 13, Issue 3 (July 2007), pp. 321–335; and "Soaring Eagle, Flying Dragon: Industrial R&D and Innovation in the United States and China," Proceedings of the US–China Forum on Science and Technology Policy (VA: George Mason University, 2007), pp. 215–236. She is also author of *Foreign High-Tech R&D in China: Risks, Rewards, and Implications for US–China Relations* (Stimson Center, June 2003) and *US Commercial Technology Transfers to China* (US Department of Commerce, 1999). She can be reached at kathleen.walsh@nwc.navy.mil.