

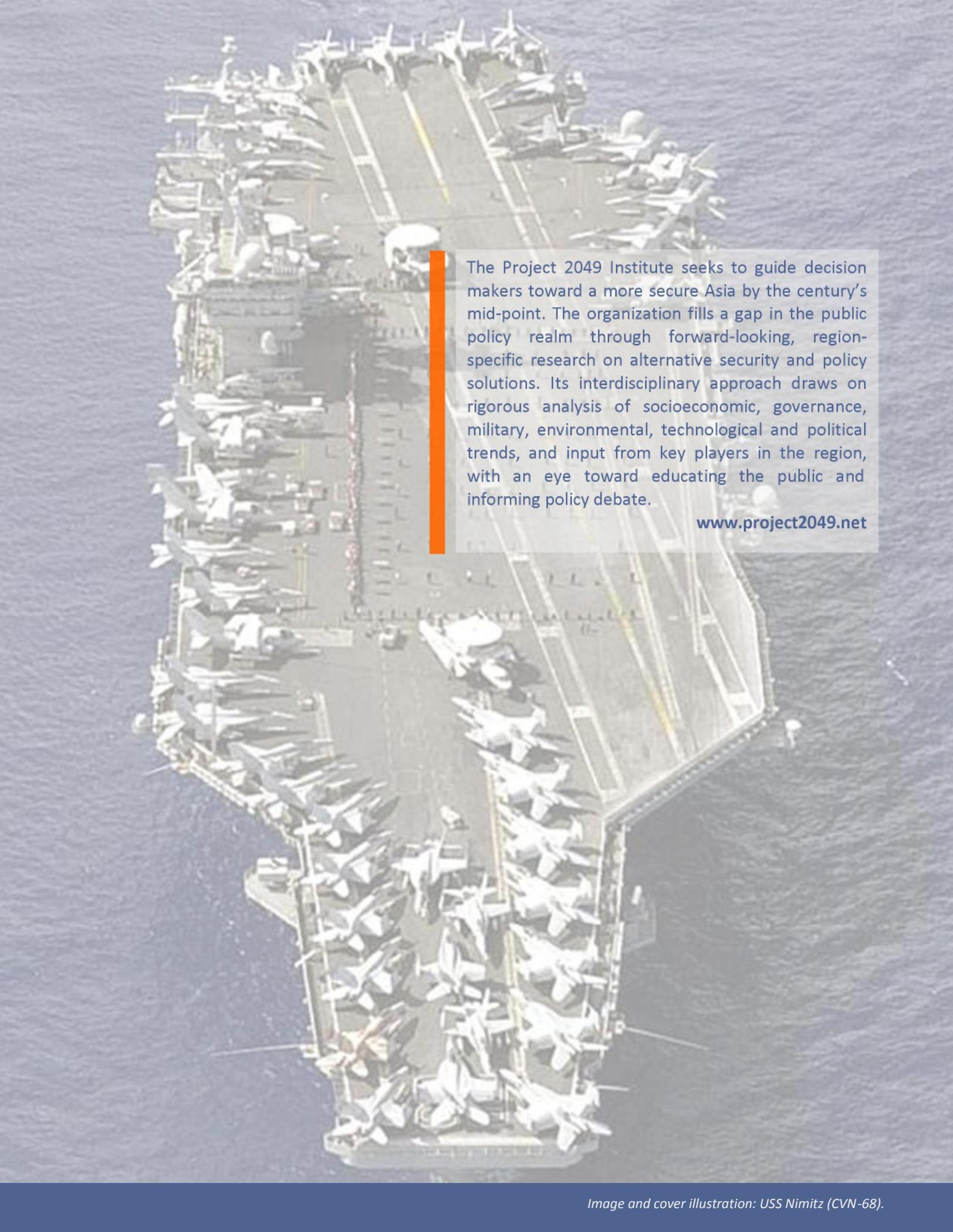
China's Evolving Conventional Strategic Strike Capability

The anti-ship ballistic missile challenge to U.S. maritime operations in the Western Pacific and beyond

Mark Stokes

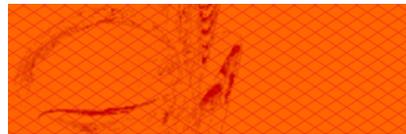
September 14th 2009

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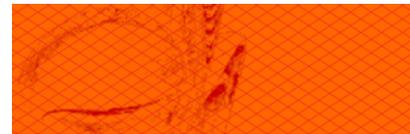
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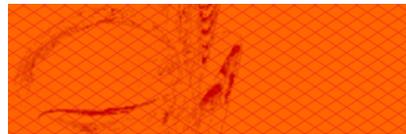
Executive Summary

The People's Republic of China (PRC) is developing a capability that could alter the strategic landscape in the Asia-Pacific region and beyond. Authoritative Chinese writings indicate research into and development of increasingly accurate and longer range conventional strategic strike systems that could be launched from Chinese territory against land- and sea-based targets throughout the Asia-Pacific region in a crisis situation. An imminent manifestation of long term intent would be the deployment of conventional medium range ballistic missiles capable of engaging naval combatants, including aircraft carrier battle groups, in the Western Pacific Ocean.

A primary driver for producing an anti-ship ballistic missile (ASBM) capability is to create the conditions necessary for resolution of differences with Taiwan on terms favorable to the PRC. An effective ASBM and persistent maritime surveillance capability could complicate the capacity of the United States to resist PRC use of force against Taiwan, thus undermining the letter and spirit of the Taiwan Relations Act (Public Law 96-8). Regional conventional precision strike assets also would be intended to enforce other regional sovereignty claims and ensure the security of sea lines of communication. Over the longer term, successful development and deployment of intermediate- and intercontinental-range conventional ballistic missiles and other precision strike assets would offer the PRC political leadership a flexible deterrent that could achieve strategic and operational effects against an enemy in a crisis.

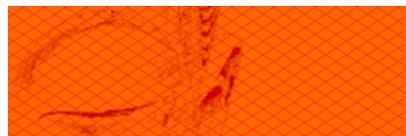
Many of the basic technologies needed for a rudimentary ASBM capability have been in development for more than 20 years. The core of this capability would be advanced missile-borne sensing and data processing supported by rough initial strategic cueing from a dual use maritime surveillance network. Barring deployment of effective defenses, an ASBM will give the Chinese People's Liberation Army (PLA) a precision strike capability against aircraft carriers and other U.S. and allied ships operating within 1,500 to 2,000 kilometers from the eastern coast of China. Manufacturing facilities for solid rocket motors associated with an initial ASBM variant, designated as the DF-21D, appear to have been constructed in 2009. Follow-on variants could extend an ASBM's range out to Guam, and incorporate more sophisticated trajectories and missile defense countermeasures. Chinese technical writings indicate preliminary conceptual development of a conventional global precision strike capability over the longer term.

Barring a visible and decisive American response, the PRC's successful deployment of an ASBM capability could diminish confidence in U.S. security guarantees not only in Taiwan but throughout the region as a whole. An effective ASBM and supporting maritime surveillance network would diminish the effectiveness of carrier-based assets, such as the F/A-18 E/F. As a result, the United States may increasingly rely on a greater number of affordable submarines able to operate in littoral areas, long range unmanned combat air platforms and prompt global strike assets, and hardening of U.S. military facilities throughout the region. Such moves could be accompanied by an assessment of potential conventional arms control and other risk reduction measures as means to manage possible conflict in the region.

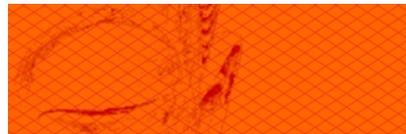


Abbreviations

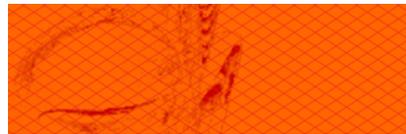
AESA – Active Electronically Scanned Array Radar
AIS – Automatic Identification System
AMARV – Advanced Maneuverable Reentry Vehicle
ASAT – Anti-Satellite
ASBM – Anti-Ship Ballistic Missile
ATR – Automated Target Recognition
CAD – Computer Aided Design
CAMA – China Astronautics and Missilery Abstracts
CARD – China Aerodynamics Research and Development Center
CASC – China Aerospace S&T Corporation
CASIC – China Aerospace Science and Industry Corporation
CAV – Common Aero Vehicle
CEP – Circular Error Probable
CETC – China Electronics Technology Group Corporation
CIWS – Phalanx Close-In Weapon System
CMC – China's Central Military Commission
COSTIND – Commission of Science, Technology, and Industry for National Defense
COTS – Commercial Off-the-Shelf Microelectronics Technology
CZ-4B – Chang Zheng 4B
DARPA – Defense Advanced Research Projects Agency
DDG-1000 - Zumwalt-class guided missile destroyers
DF – Dongfeng
DH - Donghai
DSPs – Digital Signal Processors
ECM – Electronic Countermeasures
ECCM – Electronic Counter-Countermeasures
ELINT – Electronic Intelligence
EMCON – Emission Control
EO – Electro-optical
FPGA – Field Programmable Gate Array



FY – Feng Yun
GAD – PLA's General Armaments Department
GAP – Glycidyl Azide Polymer
GBR – Ground-Based Radar
GERD – Gross Domestic Expenditure on R&D
GNC – Guidance, Navigation and Control Package
HAARP – U.S. High Frequency Active Auroral Research program
HCV – Hypersonic Cruise Vehicles
HIT – Harbin Institute of Technology
HJ-1C – Huan Jing space-based SAR systems, s-BAND.
HY-3 – Hai Ying space-based SAR systems
IIR – Passive Imaging Infrared
INF – Intermediate-Range Nuclear Forces Treaty
JDAM – Joint Direct Attack Munition
JK – Chinese airships
KKTT – Screen name of anonymous Chinese blogger
KKV – Kinetic Kill Vehicle
KT – Kaituozhe
LACM – Land Attack Cruise Missile
MEMS – Microelectromechanical Systems
MMW – Millimeter Wave
MOST – Chinese Ministry of Science and Technology
MPMs – Microwave Power Modules
MRBM – Medium-Range Ballistic Missile
NSV – Near Space Vehicles
NUDT – National University of Defense Technology
OTH – Over-the-horizon radar
OTH-B – Over-the-horizon Backscatter
PAC – Patriot Advanced Capability
PGS – United States' Prompt Global Strike Program
PLA – People's Liberation Army
R&D – Research and Development
RCS – Radar Cross Section
RMB – Renminbi
RTO – NATO Research and Technology Organization



S&T – Science and Technology
SAR – Synthetic Aperture Radar
SAST – Shanghai Academy of Space Technology
SASTIND – State Administration for Science, Technology, and Industry for National Defense
SBRIS – Space-Based Infrared System
SDI – Strategic Defense Initiative
SDRAM – Synchronous Dynamic Random Access Memory
SFW – Sensor-Fused Weapon
SM-3 – Standard Missile-3 – U.S. Navy's ballistic missile defense system
SoC – System-On-Chip
TRA – Taiwan Relations Act
TMD – Theater Missile Defense
UAVs – Unmanned Aerial Vehicles
UESTC – University of Electronic Science and Technology of China
UEWR – Upgraded Early Warning Radar
USAF – U.S. Air Force
VHSIC – Very High Speed Integrated Circuits
VLSI – Very Large Scale Integration



Introduction

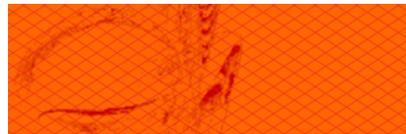
The People's Republic of China (PRC) is developing a capability that could alter the strategic landscape in the Asia-Pacific region and beyond. Chinese writings indicate a significant interest in – and a commitment of resources to – developing an assured capacity to hold at risk U.S. and other navies' ships at sea. Since at least the mid-1990s, authoritative Chinese writings have demonstrated intent to field conventional ballistic missiles to engage naval combatants, including carrier battle groups, in the Western Pacific as part of a broader aerospace campaign in response to perceived infringements on Chinese sovereignty.

Official statements from the Department of Defense (DoD), as well as other prominent observers, support the notion that the PRC is developing an anti-ship ballistic missile (ASBM) to counter aircraft carrier battle groups operating in the Western Pacific. DoD's 2009 annual report to Congress on PRC military capabilities offers in its opening summary:

Analyses of current and projected force structure improvements suggest that China is seeking the capacity to hold surface ships at risk through a layered capability reaching out to the "second island chain." One area of investment involves combining conventionally-armed anti-ship ballistic missiles (ASBMs) based on the CSS-5 (DF-21) airframe, C⁴ISR for geo-location and tracking of targets, and onboard guidance systems for terminal homing to strike surface ships. As described in an authoritative 2004 article for the Second Artillery Corps, the ASBM could employ "terminal-sensitive penetrating sub-munitions" to "destroy the enemy's carrier-borne planes, the control tower and other easily damaged and vital positions." This capability would have particular significance, as it would provide China with preemptive and coercive options in a regional crisis.¹

The PRC's growing arsenal of increasingly accurate and lethal ballistic and land attack cruise missiles already poses significant challenges to fixed targets on Taiwan, Okinawa, and other locations around China's periphery. However, evolutionary upgrades to existing conventional ballistic and land attack cruise missiles could enable the People's Liberation Army (PLA) to engage maritime targets. Chinese writings indicate a near term requirement to keep U.S. carrier battle groups at a distance of at least 2,000 kilometers (km) from China's eastern coastline. As one observer in a prominent journal commented:

The initiative is essential against an aircraft carrier battle group. That is, when a large and powerful aircraft carrier battle group is coming to intervene, we must take the initiative and attack it. We must destroy it or drive it back beyond 2000-3000 kilometers or more from the shoreline, and not allow it to approach closer. The offense is essential because "evasion" and



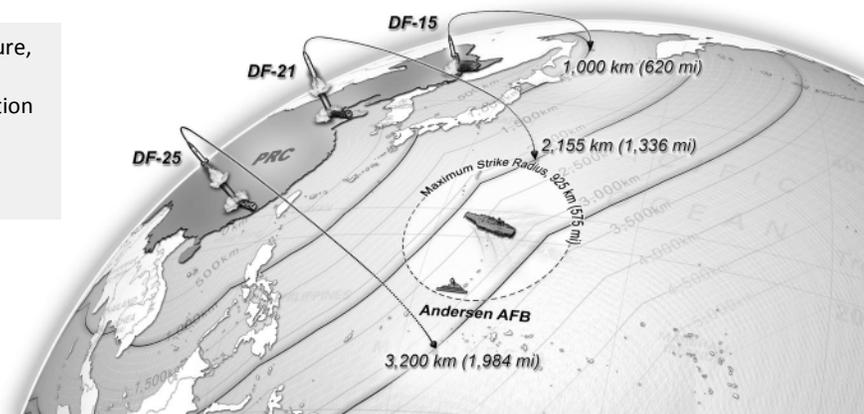
"concealment" is useless under the eyes of hundreds of satellites and in the face of the hundreds of "Tomahawk" cruise missiles with their range of thousands of kilometers, which every aircraft carrier battle group has. Trying to hide can only mean passively taking a beating. If we hope to win this war, we must attack and repel the big and powerful aircraft carrier battle group beyond our gates.²

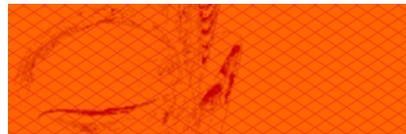
Looking beyond a regional maritime strike capability, China's defense industry has been evaluating the feasibility of a global conventional strike capability as an incremental follow-on to the successful deployment of an ASBM. Based on a broad survey of available literature, this paper posits that the PRC has a phased approach for development of a conventional global precision strike capability by 2025. The process can be divided into four key phases:

- The **initial phase** seeks to have a rudimentary 1,500 to 2,000km range ASBM capability available to the PLA by the end of the 11th Five Year Plan in 2010).
- A **second phase** would seek to extend these capabilities out to a range of 3,000km by the conclusion of the 12th Five Year Plan in 2015. China's aerospace industry has been analyzing alternatives to extend the range of the ASBM while maintaining precision. Among the options include a more advanced solid motor and a "boost-glide" trajectory that would complicate mid-course missile defenses.
- A **third phase** would focus on extending conventional precision strike capability out to 8,000km before the end of the 13th Five Year Plan in 2020.
- A **final phase** would involve a global precision strike capability by the conclusion of the 14th Five Year Plan in 2025.

Such a plan would not be set in stone. A number of events could result in cancellation or acceleration of the phases, including a change in threat perception; acceleration or cancellation of similar efforts in other countries, such as the U.S. Prompt Global Strike (PGS) program; a satisfactory conventional arms control program; a severe economic downturn or domestic political crisis and key technological breakthroughs or insurmountable obstacles.

Possible layered ASBM strike architecture, with 1,000, 2,000, and 3,000km range ASBM strike assets. The DF-25 designation is only a notional representation of a follow-on 3000-kilometer range ASBM capability.



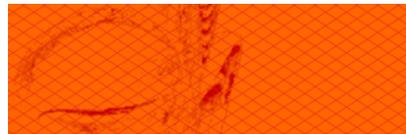


In the near term, the chances of success in fielding conventional ballistic and cruise missiles able to strike moving targets in the Western Pacific Ocean and South China Sea out to a range of 2,000 km are high. Manufacturing facilities for solid rocket motors associated with an initial ASBM variant, designated as the DF-21D, appear to have been constructed in 2009. Given the successful track record of its space and missile industry, the PRC could demonstrate early operational capability of an ASBM before 2012. There are also indications of investment into research and development of a maritime variant of existing extended range land attack cruise missiles, such as the Donghai-10 (DH-10).

Research on many of the key enabling technologies for an ASBM and other extended range conventional strike capabilities began in 1986 under the auspices of the 863 Program, China's answer to the U.S. Strategic Defense Initiative (SDI). Key technologies include:

- Very high speed integrated circuits, including advanced digital signal processors, "system on chip" (SOC) processors that pack a range of computing functions onto a single integrated circuit, synchronous dynamic random access memory (SDRAM), and compact micro-machined electro-mechanical systems (MEMS) that offer significant increases in precision and require much less space than traditional inertial measurement units;
- Compact yet powerful amplifiers that energize on-board radar systems to target ships at long distances and a wide range of frequencies along the electromagnetic spectrum;
- Missile-borne synthetic aperture radar (SAR) and automated target recognition software that offers "fire and forget" autonomous guidance and navigation;
- Thermal protection that shields a re-entry vehicle from the extreme heat generated from re-entering the atmosphere at hypersonic speeds and gliding in near space for an extended period of time;
- Optimized antenna placement and other measures to mitigate the radiofrequency blackout caused by a plasma sheath that forms around flight vehicles transiting at hypersonic speeds in the atmosphere;
- Active or passive millimeter wave radar and imaging infrared "hit to kill" terminal guidance that allows the warhead to pursue specific aim points on an aircraft carrier or other naval combatant;
- Missile defense countermeasures that ensure the ability of an ASBM to reach its target.

In addition to the missile system, Chinese research and development (R&D) appears to be focused on the means to maintain a persistent track on maritime targets of interest. In a contingency, an integrated architecture of near space airships,³ space-based remote sensing assets, over the horizon skywave radar systems, and conventional unmanned aerial vehicles would offer continuous, all-weather surveillance and strategic cueing for an ASBM. Existing and future data relay satellites and other beyond line of sight communications systems would relay targeting data between the theater and the Joint Theater Command as well as Second Artillery's operational-level Command Center.



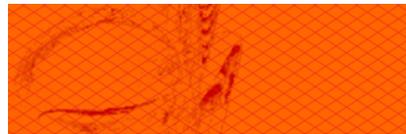
Aerospace power is emerging as a key instrument of PRC statecraft and a number of drivers are at the foundation of China's aerospace modernization and ASBM program. The most fundamental is the perceived need to deter moves in Taiwan toward *de jure* independence by demonstrating the ability to complicate foreign intervention in response to PRC use of force. Therefore, an ASBM is increasingly viewed as a key facet of an integrated air defense system. Other drivers include a strong interest to enforce perceived sovereignty claims in the East and South China Seas and ensure access to energy. In addition, an ASBM capability could be driven by a broader goal of developing a military that is commensurate with China's rise as a major global power. As the technology for ASBM and broader conventional strategic strike programs become within the grasp of China's defense R&D community, it may be difficult to resist incorporating extended range regional precision strike assets into the PLA.

In this scenario, China's success in fielding an integrated regional reconnaissance-strike capability could have significant strategic implications. As Andrew Erickson and David Yang wrote in a seminal May 2009 U.S. Naval Institute *Proceedings* article, a demonstrated ASBM capability "could alter the rules in the Pacific and place U.S. Navy carrier strike groups in jeopardy." The authors note "even the perception" that the PLA is equipped with an ASBM could have "profound consequences for deterrence, military operations, and the balance of power in the Western Pacific."⁴ China's success in fielding a regional and global precision strike capability could extend the threat envelope to military facilities in Hawaii, and perhaps even space-related and other military facilities in the continental United States that are likely to be involved in a Taiwan-related contingency.

An ASBM could indeed complicate the ability of the United States and other countries in the Western Pacific and South China Sea to operate in the region. Aircraft carriers are a visible symbol of American power, and usually play a major role in responding to contingencies around the world. The United States Navy operates twelve large aircraft carriers, with flight decks as large as four acres, which are the centerpiece of America's maritime strategy in the Asia-Pacific region. Other critical surface assets include AEGIS-equipped destroyers and amphibious assault ships. The prospect of an ASBM and other maritime capabilities is already affecting DoD investment decisions. Concerns over the ASBM are said to have played a major role in the decision to curtail the Navy's DDG-1000 program.⁵ *Defense News* reported in August 2008:

One source familiar with (a U.S. Navy) classified briefing said that while anti-ship cruise missiles and other threats were known to exist, "those aren't the worst." The new threat, which "didn't exist a couple years ago," is a "land-launched ballistic missile that converts to a cruise missile." Other sources confirmed that a new, classified missile threat is being briefed at very high levels. One admiral, said another source, was told his ships should simply "stay away. There are no options."⁶

The goal of an ASBM capability is primarily political in nature, with the secondary consideration being suppression of air operations. Because of hardening limitations, aircraft



carriers supporting short range fighter operations within range of ASBMs could become even more vulnerable than fixed airbases in the Western Pacific. An ASBM flying a depressed, boost-glide trajectory – one in which the missile would remain within the upper atmosphere or near space for most of its flight – could negate the effectiveness of sea-based mid-course missile defense interceptors, such as the Standard Missile-3 (SM-3).

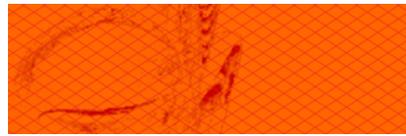
The successful deployment of an ASBM and other extended range precision strike systems do not spell the end of aircraft carriers or the emergence of China as a military peer competitor of the United States. However, China does not need to catch up or surpass the United States in order to complicate U.S. intervention in a Taiwan scenario. To ensure U.S. preparedness against these new capabilities it will require a review of American strategy, operational doctrine, and force modernization plans and programs.



Standard Missile-3 launch.

Source: Military Pictures website.

This study examines the implications of the PRC's ASBM research and development and other extended range strike capabilities for the United States. More specifically, it summarizes the driving forces behind development of an ASBM capability; addresses the technological and industrial issues most relevant to the development and fielding of such a capability, as well as associated sensor and communications requirements; outlines campaign theory that could guide the use of ASBMs; and assesses implications for United States policymakers and warfighters in the Western Pacific, including potential effects such a reconnaissance-strike complex could have on U.S. ability to deter PRC use of force against Taiwan or other partners in the region.



The Driving Forces: Taiwan and Beyond

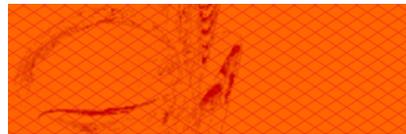
There are at least four drivers behind the PRC's investment into an ASBM and other conventional strategic strike capabilities: 1) deterring moves in Taiwan toward *de jure* independence and creating the conditions for unification on terms favorable to the PRC; 2) defending PRC sovereignty and other interests beyond Taiwan; 3) great power status and national pride; and 4) technology push.

Checking Taiwan

An ASBM is most relevant in a future scenario involving U.S. intervention in the event of PRC use of force against Taiwan. Since entering the inventory of the PLA in the early 1990s, conventional ballistic missiles have been one of the most effective tools of political and military coercion of the PRC. As a symbolic metric of intent, the PRC's expanding arsenal of conventional ballistic missiles across the Taiwan Strait is intended to deter political support in Taiwan for *de jure* independence and coerce the island's population to support unification with China on Beijing's terms.⁷ In order to deter moves toward *de jure* independence, Beijing has made conventional ballistic and land attack cruise missiles a visible and central element of its Taiwan strategy.⁸

However, it appears that leaders in Beijing are also expanding their strategy. As Beijing showers Taiwan with economic carrots, its military stick is increasingly being pointed at the United States. The reason is that the center of gravity for final resolution on the Taiwan issue may lie in Washington D.C. rather than in Taipei. Confident of America's military backing, Taiwan's political leadership is able to deal with counterparts in Beijing from a position of confidence and strength. From Beijing's perspective, U.S. arms sales and the U.S. naval presence in the Western Pacific – best symbolized in the form of an aircraft carrier – have been the most important factors in preventing the unification of Taiwan with the motherland. A demonstrated capability to unleash a lethal strike the most visible symbol of American power would be intended to caution the Taiwan people that their future is with China, rather than in *de jure* independence, indefinite separation from mainland China, or a virtual alliance with the United States.⁹

As a corollary, the PRC appears to view development of an ASBM capability as strategically defensive. Most aerospace industry studies address an ASBM capability in the context of defending against sea-based assets, such as Tomahawk cruise missiles and other strike systems. To quote one long-time China watcher, "the Chinese armed forces are obsessed with defending China from long-range precision air strikes."¹⁰



Other Sovereignty Claims

Motivations for a counter-carrier capability would transcend a Taiwan scenario. Maritime surveillance capability, matched with an effective ASBM and other conventional strategic strike systems, would enable PRC political leaders to apply effective military measures to support sovereignty claims in the South China Sea and Senkaku Islands. As its January 2009 *Defense White Paper* highlights, “China places the protection of national sovereignty, security, territorial integrity, safeguarding of the interests of national development, and the interests of the Chinese people above all else.” Retrofitting existing short and medium range ballistic missiles with a guidance, navigation, and control package tailored for the maritime environment could enable precise targeting of Japanese or other naval combatants that would bypass any existing missile defense systems. An extended range strike capability would allow China to defend its interests in other parts of the world, including assured access to energy resources transiting through the Straits of Malacca and perhaps even the Indian Ocean.

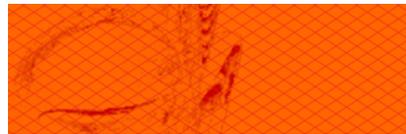
Great Power Status and National Pride

Beyond regional contingencies, success in deploying an ASBM and conventional precision global strike capability would reflect the rise of China as a major global power. A strong modern military is viewed as commensurate with China's growing role in the international community, and ability to project power over distances, without necessarily having to deploy forces overseas, could mark China as a leading global player. Policymakers view a strong military, presumably including a conventional strategic strike capability, as one aspect of a broader international competition in comprehensive national strength and science and technology.¹¹

The ASBM program also appears to be a source of national pride, and the topic has become a fashionable subject within China's popular media.¹² Because the PRC restricts information regarding defense-related developmental programs, it is difficult to judge what is valid and what is conjecture. While not necessarily authoritative, China's blogosphere, bulletin board systems, and popular media may offer hints into what this capability entails.¹³ Given government control over the domestic cyberspace, articles indicate how Beijing authorities would like the world – and especially Taiwan – to perceive its emerging military capabilities. In addition to detailed technical assessments referencing authoritative sources, other articles assert that there are at least three conventional ASBM variants of different ranges.¹⁴ Regardless of their validity, speculative analyses and commentary regarding the ASBM program reveals a sense of national pride in being able to counter U.S. aircraft carriers.

The Technological Imperative

A final driver is simply that the necessary technology is, or soon will be, available for an ASBM and extended range precision strike capability. If the technological capacity exists, the incentives to design, develop, and manufacture global and regional precision strike systems may prove irresistible.¹⁵ Most Chinese engineering studies view striking aircraft carriers with

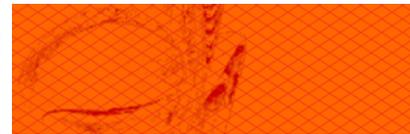


ballistic missiles as well within China's technological capacity.¹⁶ The resources certainly exist. China's total Gross Domestic Expenditure on R&D (GERD) tripled between 2000 and 2006.¹⁷ Under its 15-year "Medium to Long-Term Plan for the Development of Science and Technology," China seeks to become an "innovation-oriented society" by the year 2020, and a technological leader by 2050. According to the plan, China will invest 2.5 percent of its gross domestic product in science and technology (S&T) by 2020, up from 1.34 percent in 2005. The plan also calls for China to become one of the top five invention patent holding countries in the world and for Chinese-authored scientific papers to become among the world's most cited.¹⁸

Another enabling factor has been the breakdown of stovepiped R&D efforts within China's defense S&T community. For example, the PLA's General Armaments Department (GAD) formed a series of national-level technology development coordination bodies to overcome bottlenecks. One example is the Precision Guidance Expert Group [精确制导专家组], which brought together the nation's leading industry and academic authorities on terminal guidance technologies. Many of the members of 863 Program expert groups also serve as members of GAD expert groups.¹⁹

In addition, China's manned space program may have produced spin-offs to aid an ASBM program. Engineers within the same bureaucratic structure fulfilling military contracts may stand to benefit from the knowledge created from the experience. A decade-long reform program, including the introduction of technical standards and competition in defense acquisition, may have been successful in enhancing the capability of China's defense industry. Finally, mechanisms to enhance technology diffusion and absorption and increased access to foreign expertise may have enabled the defense industry to overcome technical bottlenecks at the component or sub-system level.²⁰

A final technological factor could be that the ASBM and follow-on concepts for a global conventional precision strike capability could be China's answer to U.S. conventional PGS programs. A conventional strategic strike capability could be one step in a longer journey to reach technological parity with the United States and the rest of the world by 2050.²¹ From technical writings, China's defense industry appears to be conducting R&D that mirrors the U.S. PGS program, which centers on the Common Aero Vehicle (CAV) intended to strike targets anywhere in the world within hours. In other words, Chinese policymakers may be emulating what they perceive to be past success and potential of the United States military and technological capacity.



China and its Evolutionary Path to an ASBM

Since deployment of its first ballistic missile in the 1960s, the PLA and China's aerospace industry²² have steadily taken incremental steps toward greater range, survivability, accuracy, and effectiveness against a wide range of targets. China's ASBM program is part of a broader effort to field the means to detect, track, and strike fixed and mobile targets at sea with precision throughout the Asia-Pacific region. According to the March 2009 Report to Congress on *Military Power of the People's Republic of China*:

*China is developing an ASBM based on a variant of the CSS-5 MRBM as a part of its anti-access strategy. The missile has a range in excess of 1,500km, is armed with a maneuverable warhead, and when incorporated into a sophisticated command and control system, is intended to provide the PLA the capability to attack ships at sea, including aircraft carriers in the Western Pacific Ocean.*²³

The CSS-5 referenced in the Report is the Dongfeng-21 (DF-21), a solid fueled medium range ballistic missile (MRBM) that began development in the 1960s but introduced into the PLA Second Artillery in the early 1990s. The latest variant of this MRBM is the 1,750km range DF-21C, which technical writings indicate is modeled after the terminally-guided U.S. Pershing II ballistic missile and is reported to have a circular error probable (CEP) of 50 meters or better. The first successful test flight of the terminally guided DF-21C MRBM appears to have taken place on December 19, 2002.²⁴ The test revealed problems with the re-entry vehicle, and a second test took place about six months later, in June or July 2003. The DF-21C R&D phase is said to have taken only 24 months.²⁵

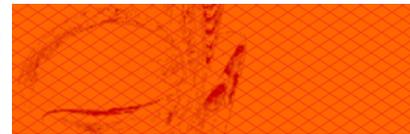
A follow-on variant of the DF-21C is the DF-21D, a 1,500 to 2,000 km range ASBM that could be available to the PLA by the conclusion of the 11th Five Year Plan in 2010. It is not unusual to modify a precision strike system originally intended for ground targets for the maritime environment - the Joint Direct Attack Munition (JDAM) and Sensor Fused Weapon (SFW) are two examples. However, given its flight characteristics, it is not easy to modify a ballistic missile to go after moving targets at sea. Yet Chinese engineers appear confident that they can do it. To complicate matters, the ballistic missile is only one component of a "system of systems" that also would include near space-based, space-based, airborne, and surface-based sensor architectures.



Top: Pershing-II missile launch.

Bottom: A DF-21 missile en route to a military parade rehearsal.

Source: The Associated Press.



One Chinese technical analysis argues that an ASBM and subsequent strategic strike programs entail four phases. The first phase will involve fielding of a rudimentary 1,700 to 2,000km range ASBM by the end of the 11th Five Year Plan in 2010. A second phase, scheduled for completion by the end of the 12th Five Year Plan in 2015, would incorporate sophisticated aerodynamic maneuvering capability that would not only enhance a missile's ability to penetrate missile defenses, but also extend its range. The third phase would end with the fielding of a boost-glide missile [助推-滑翔式导弹] capable of intercontinental strikes by 2020. A final capability, deployed before 2025, would be a hypersonic cruise vehicle for global operations.²⁶

ASBM Program Management: The R&D Cycle, Chief Designers, and Program Managers

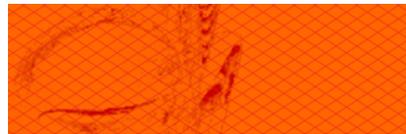
The above approach is consistent with past Chinese R&D practices. An ASBM program would likely adhere to the space and missile industry's traditional approach of conservative, incremental upgrades to existing missile variants. Indeed, China's aerospace R&D strategy has its roots in a directive issued by the State Science and Technology Director Nie Rongzhen in the 1960s. The strategy, "Three Moves in a Chess Game" [sanbuqi; 三步棋], calls for three variants of each model to be in the R&D cycle at any one time. Under this concept, the variants should be in three increasingly advanced stages of R&D: 1) preliminary research; 2) model R&D involving design, development, testing, design reviews, and then finalization of the design [定型]; and 3) low rate initial production.

Preliminary Research [yuxian yanjiu; 预先研究 or yuyan; 预研]

Chinese defense industries stress preliminary research as the foundation for follow-on stages of development. Preliminary research also allows the mastering of mature technologies which in turn reduces R&D time and risk. For example, due to substantial preliminary research work, one unidentified medium-range ballistic missile system took only 21 months to design, quite a feat compared to other systems which have taken up to a decade in the making. Preliminary research has two categories:

- Generic technologies applicable to multiple systems across various enterprises, including telemetry, aerodynamics, synthetic aperture radar, millimeter wave radar, GPS exploitation, hypersonics, and artificial intelligence;
- Basic technologies applicable to a specific system, for instance, a movable spot beam antenna for a communications satellite or a new missile propulsion system.

The PLA GAD's Integrated Planning Department's Preliminary Research Bureau [zongzhuang zonghe jihua bu yuyan ju; 总装综合计划部预研局] is the supervisory body for this phase. It is responsible for developing and coordinating China's national-level defense-related five-year and longer range plans; establishing priorities; and managing the portion of the overall defense R&D budget allocated for basic research.



China Aerospace Science and Industry Corporation

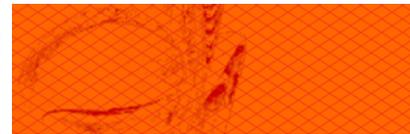
Preliminary research for aerospace technology is funded via a number of means. The primary contributor within GAD is the Weapons and Equipment Basic Research Fund. The fund awards two year projects valued around 50,000 to 2 million RMB. Other funding sources include the GAD-managed Defense Technology Cross-Enterprise Fund; Defense Technology Key Laboratory Fund; China Aerospace Corporation (CASC) Innovation Fund; and China Aerospace Science and Industry Corporation (CASIC) Support Fund. Additionally, preliminary research has been supported by the National 863 Program, the National 973 Program, and the National Natural Sciences Program (discussed below).

Contracts are tendered on a competitive basis on projects that seek to achieve breakthroughs in selected areas of defense technology.²⁷ Organizations that execute basic research contracts can be PLA-affiliated units, defense industry, or civilian education institutions. Because published technical articles are a metric of international technological competitiveness, the findings of many preliminary research projects are published in a wide range of professional journals after a security review. Approximately 45 percent of preliminary research projects flow directly into the model R&D stage, while another 40 percent are used as a foundation for follow-on preliminary research projects. Only 14 percent of preliminary research projects are civilian in nature.²⁸

Model R&D [xinghao yanzhi; 型号研制]

After completion of preliminary research, a review process determines if risks have been sufficiently mitigated to move into the R&D stage. The model R&D phase is lengthy, costly, and closely monitored by GAD. Each model R&D program that emerges from the preliminary research phase requires a new GAD-managed contract. Although it may vary by industry, the model R&D phase is divided into four sub-phases:

- *General systems design.* A chief designer is appointed to monitor various sub-system design and R&D efforts. Chief designers and deputy chief designers managing sub-systems would rely heavily on computer aided design (CAD) and other modeling and simulation tools.
- *Prototype [样机].* Design is revised after a series of ground tests to ensure the model meets technical specifications.
- *Flight testing [飞行试验].* After ground testing, flight tests are carried out beginning with simple ones, and traversing through a series of increasingly complex tests.
- *Commission.* After successfully completing flight testing, the system is reviewed by a design certification [设计定型] board, and if approved, will enter small batch production [小批生产].



The model R&D phase is characterized by selection and assignment of a chief designer [*zongsheji shi*; 总设计师] and one to six deputy chief designers to coordinate the technical aspects of R&D, including coordinating with a vast supply chain. Deputy chief designers would generally oversee the major sub-systems. Typical sub-systems could include the solid rocket motor sub-system; guidance, navigation, and control sub-system; warhead or post boost vehicle sub-system; and ground equipment sub-system. As a result, deputy chief designers are often not from within the chief designer's organizational chain of command.

Another leadership position is the Program Manager [*zongzhijui*; 总指挥] for administrative program management. The program manager would ensure that requirements and timeliness standards of the PLA are being met. Usually, a chief designer is from an academy's design department or sometimes from the academy headquarters. The administrative and technical departments and teams work closely together to ensure an economy of effort, timely production schedule, manpower, materials, funding, and other related considerations. GAD plays a leading administrative, and possibly even technical role, in especially complex projects that draw from resources of various industries within China's S&T community.²⁹

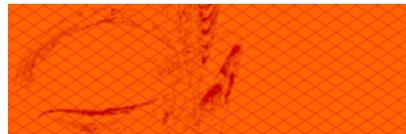
In short, an ASBM program that is in the R&D phase would be assigned a chief designer, a small handful of deputy chief designers, and a program manager. The chief designer and his deputies would coordinate the efforts of as many as 20 suppliers, while the program manager would manage budgetary and other administrative issues. The R&D phase would draw to a close once the ASBM design is approved after flight testing and approved by a PLA GAD-led design finalization committee.

Low Rate Initial Production

After design finalization, the ASBM would enter into low rate initial production and assigned to operational PLA units. In line with the Three Moves on a Chessboard R&D strategy, the DF-21C is most likely in full rate production. A ground-launched maritime variant of the DF-21C – the DF-21D – is in the R&D phase and preparations are underway to begin production. A more advanced variant of the DF-21D ASBM, perhaps the DF-21E, would be in the preliminary research phase.

The R&D System: Leveraging National Assets for Technology Development

Successful fielding of an ASBM system would reflect the broad investment that China has made in S&T over the last 20 years. Much could be attributed to one particular program – the 863 Program – that facilitated the development of key technologies.³⁰ Catering to both civilian and military requirements, the 863 Program is managed by China's Ministry of Science and Technology (MOST), cuts across organizational boundaries, and helps to breakdown stovepiped R&D efforts within China's civilian and defense S&T community.³¹ The 863 program, China's answer to the United States' SDI and Europe's Eureka program, has served as a funding source for a range of R&D programs and as a mechanism to leverage the talent



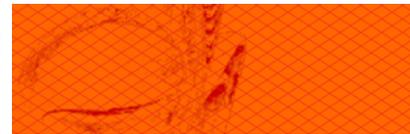
that resides in China's university system.³² According to one estimate, 70 percent of the members of expert groups that manage individual technology development areas received advanced degrees from American, European, and other foreign universities.³³

One example of how 863 Program initiatives could translate into a successful ASBM capability is the ASAT that was tested in January 2007. One senior Chinese space engineer with direct access to details on both the ASAT and ASBM programs confided that the ASAT and ASBM guidance and control packages share a common technological foundation.³⁴ Both the ASBM and ASAT kinetic kill vehicle require compact and high speed on-board computing and software. Common technologies also could include passive imaging infrared (IIR) and millimeter wave (MMW) seekers and automated target recognition (ATR) software.³⁵

In addition to the various expert groups that support the 863 Program, the GAD's S&T Committee has formed a number of national-level defense R&D laboratories around the country and at least 20 national-level working groups comprised of China's foremost authorities in key technological areas. Presumably, the purpose is to leverage and pool resources to review progress, offer advice to the PLA GAD for resource allocation, and overcome technological bottlenecks. Many of the members of 863 Program expert groups also serve as members of GAD expert groups.³⁶ Examples of individual PLA GAD-led technology working groups include:

- General Missile Technology [总装备部导弹总体技术专业组]
- Precision Guidance Technology [总装备部精确制导专业组]
- Computer and Software Technology [总装备部 计算机及软件技术专业组]
- Satellite Technology[总装备部卫星有效载荷及应用技术专业组]
- Radar Sensor Technology [总装备部雷达探测技术专业组]
- MEMS Technology[总装备部微/纳米技术专业组]
- Simulation Technology [总装备部仿真技术专业组]
- Stealth Technology [总装备部隐身技术专业组]
- Opto-Electronics Technology [总装备部光电子技术专业组]
- Aircraft Technology[总装备部飞机专业组]
- Target Characteristics and Signal Control [总装备部目标特征信号控制专业组]
- Inertial Technology [总装备部惯性技术专业组]

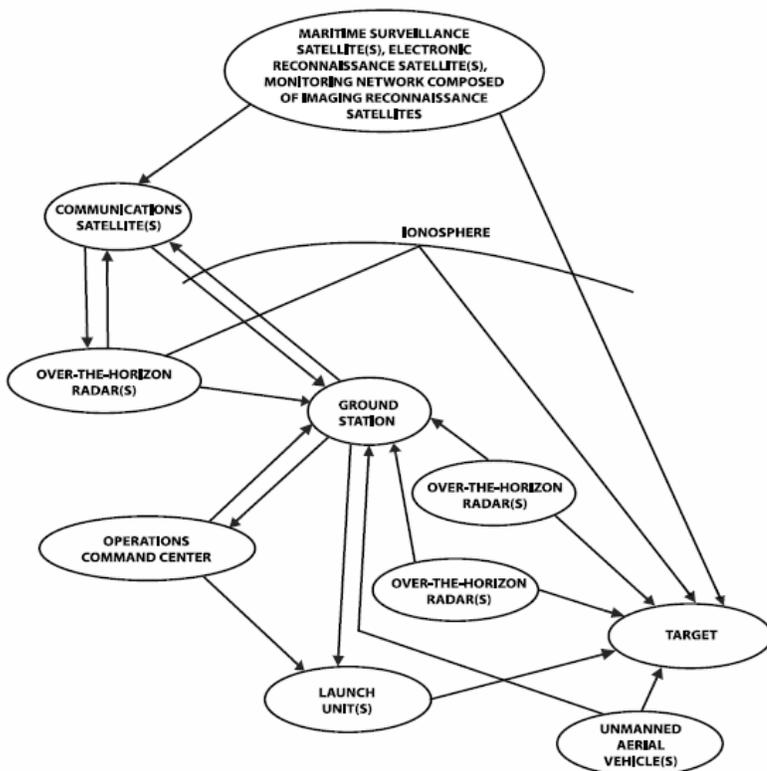
In addition, at least 45 PLA GAD-certified Key National Defense S&T Labs [国防科技重点实验室] are housed in selected research institutes and civilian universities. Their purpose is to foster civilian, defense industry, and military collaboration in addressing key strategic technologies and fostering innovation in dual use technologies. For example, Key National Defense S&T Labs have been established at Shenzhen University for automated target recognition, missile guidance and control at the 12th Research Institute under CASC, C⁴ISR at the 17th Research Institute under CASIC, and multispectral image information processing technology at Huazhong University.³⁷



China's Growing Battlespace Awareness: Putting the Eyes and Ears in Places

The expanded collaboration between the PLA, defense industry, and civilian universities has the potential to create synergies that could result in significant advances in key areas of defense technology. This R&D management model would apply not only to an ASBM, but also to an expanding battle space awareness network that is currently under development. An effective strategic strike capability, including an ASBM, depends on maritime surveillance detection, tracking, targeting, and battle damage assessment. Maritime surveillance is a national-level priority and one of eight key areas designated under the 863 Program.

Chinese writings indicate that integrated maritime surveillance architecture probably includes four components: 1) near space airships; 2) space-based remote sensing; 3) over the horizon (OTH) backscatter radar; and 4) conventional unmanned aerial vehicles.

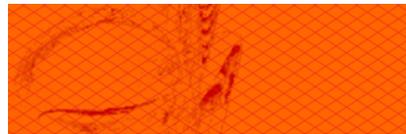


Schematic Diagram of Target Reconnaissance and Location System.

Source: Andrew S. Erickson and David D. Yang, "Using The Land To Control The Sea? Chinese Analysts Consider the Antiship Ballistic Missile," *Naval War College Review*, Autumn 2009, Vol. 62, No. 4, pp. 53-86.

In their preliminary research work, engineers from the CASC First Academy's design department outlined sensor requirements for ASBM strategic cueing as early as 2000. While the space segment may offer the greatest accuracy and resolution, designers note that satellites are unable to produce real time information.³⁸ However, satellites should be able to cue other sensors, such as the OTH radar and UAVs (unmanned aerial vehicles), in order to provide surveillance and tracking data into the operational command center on a near real time basis. The shortcoming of the OTH radar is its lack of resolution. However, sensors should work together as an integrated system to offset the shortcomings of each, and provide accurate position information to the missile unit just prior to launch.³⁹

The biggest challenge likely remains the systems integration and multi-sensor fusion. From a design and programmatic perspective, one organization will be solely



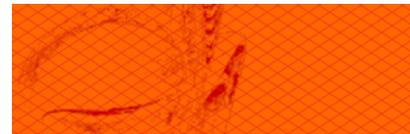
responsible for designing the C⁴ISR architecture, including developing the software and hardware that would be used in a Second Artillery command and control center.⁴⁰ The system would include automatic identification system (AIS) technology to distinguish between commercial shipping and military targets.⁴¹

Persistent Near Space Maritime Surveillance

Over the next five years, near space flight vehicles [*jinkongjian feixingqi*; 近空间飞行器] may emerge as the predominant platform for a persistent wide area maritime surveillance capability. Near space is generally the region between 20 and 100km (65,000 to 328,000 feet). The near space realm is too high for fighter jets and too low for orbiting satellites. However, coverage from near space vehicles (NSVs), such as an airship, approaches that of satellites in low earth orbit, while offering significant improvements in resolution. An airship is a lighter-than-air aircraft with propulsion and steering systems. Duration of flight far exceeds that of UAVs and begins to approach those of satellites. NSVs are said to be “inherently survivable.” One U.S. Air Force study concluded that they have “small radar and thermal cross sections, making them fairly invulnerable to most traditional tracking and targeting methods.” Powered at least in part by light, high efficiency solar cells, airships flying slowly in the near space domain NSVs also offer a relatively inexpensive means for persistent broad area surveillance.⁴²

NSVs are not without their challenges though. Because the air is considerably less dense than at lower altitudes, NSVs require unique propulsion systems. Larger wing areas are required to compensate for the loss of thrust from jet engines as altitudes increase. Propeller-driven vehicles are option, but they require large diameters or must be installed in large numbers. Exposure to ozone can be corrosive to some materials, and cosmic radiation can result in radiofrequency blackouts on occasion.⁴³

Nevertheless, the PLA Second Artillery and China's defense R&D community have become increasingly interested in NSVs for reconnaissance, communications relay, electronic countermeasures, and precision strike operations.⁴⁴ For reconnaissance missions, SAR surveillance and electronic intelligence appear to be priorities.⁴⁵ For R&D and manufacturing support to the PLA and other customers, the aerospace industry has established two new research institutes dedicated to the design, development, and manufacturing of near space flight vehicles. The center of China's near space vehicle design, development, and manufacturing is the 068 Base in Hunan province, which established a Near Space Flight Vehicle R&D Center in 2005. Current projects include the JK-5, JK-12, and JKZ -20 airships [飞艇].⁴⁶ Following a series of closed door conferences initiated in 2006, the CASC First Academy 10th Research Institute, also known as the Near Space Flight Vehicle Research Institute [临近空间飞行器研究所], was established in October 2008.⁴⁷ In June 2009, a CASC manufacturing facility in Chengdu (7304 Factory) initiated testing on an engine designed to support a near space flight vehicle program.⁴⁸



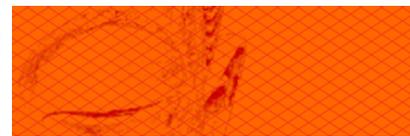
Space-Based Sensors

While its near space ambitions are relatively new, the PRC has embarked on a major civil space program that is predominantly driven by the desire to stand among equals in the international community.⁴⁹ However, as in most space programs, there is a military element. A number of authoritative journals have advocated accelerating and expanding China's space-based surveillance system, including the need for a "space-based theater electronic information system" that covers an area of 3,000km².⁵⁰ Unverified sources indicate that a strategic cueing network for an ASBM capability would rely heavily on a dual use satellite architecture that is reportedly being put into place ahead of schedule.⁵¹

As a general rule, a sensor of choice likely would be SAR since it permits detection over a wide area under many conditions. This could be enhanced by use of high-resolution electro-optical (EO) sensors to gather more information on ship classification. The narrow swaths of EO systems, however, may limit their use to predetermined locations. A data relay satellite, such as the *Tianlian-1* launched in April 2008, allows sensors to operate beyond line of sight of ground stations in China.⁵² Engineers have developed concepts for an even more sophisticated data relay architecture in the future.⁵³

Synthetic Aperture Radar Satellite. An ASBM and regional strike capability would rely in part on high resolution, dual use space-based SAR for surveillance and targeting of U.S. aircraft carriers and other naval combatants. SAR satellites use a microwave transmission to create an image of maritime and ground based targets. They can operate night or day and in all weather conditions, and are therefore well suited for detection of ships in a wide area. As Chinese engineers have noted, SAR imagery is key for automated target recognition of ships at sea.⁵⁴ Processed SAR imagery may depict a ship in various ways, depending on weather conditions, ship orientation and construction, and beam focus. A SAR satellite is also able image ship wakes from which information on ship speed and heading can be deduced. Ships are usually moving targets, so it is important to report the detection of a ship as soon as possible after satellite overpass.

China is expected to have at least two types of space-based SAR systems in orbit by 2012 – the HJ-1C and the HY-3. Preliminary research on space-based SAR system was initiated in the late 1980s, and systems engineering began in 1991.⁵⁵ Partially funded by the 863 Program (specifically the 863-308 program), an airborne L-Band SAR capability was viewed as an intermediate step toward a space-based system at the turn of the century. With completion of an on-board SAR image processing sub-system in 1994, China's S&T community and Commission of Science, Technology, and Industry for National Defense (COSTIND) approved the final design and associated high speed data transmission system in May 1995. By 1997, the airborne SAR capability was tested and fielded. It was followed by a successful ground simulation system for a SAR satellite program in the late 1990s.⁵⁶ The SAR satellite antenna is the product of a joint R&D effort with the Russian Moscow Power Engineering Institute's Special Design Bureau, an entity under the Russian Space Agency, and China Academy of



Sciences Institute of Electronics.⁵⁷ Like Russian SAR satellites, the HJ-1C is said to operate in the S-Band.⁵⁸

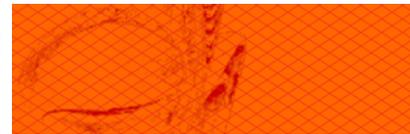
China's first generation space-based SAR system is part of a small disaster-monitoring satellite constellation. The constellation, consisting of two electro-optical satellites (HJ-1A and HJ-1B) and two SAR satellites (HJ-1C) in sun synchronous orbits, is scheduled to enter into operation by 2010.⁵⁹ The two EO satellites were launched on September 6, 2008 and the first SAR satellite (HJ-1C) has been preparing for a 2009 launch. The constellation is expected to expand to four EO and four SAR satellites in the near future, which are expected to increase the revisit rate, thereby expanding surveillance coverage. Unverified sources indicate that the Yaogan-5, launched from Taiyuan in December 2008 on a LM-4B, was an experimental SAR satellite. Another SAR satellite, referred to as the Yaogan-6, was launched on April 22, 2009.⁶⁰

With the HJ-1C first-generation SAR satellite nearing deployment or already deployed, R&D on a second-generation SAR satellite system – the Haiyang-3 (HY-3) – is well underway. Developmental work is reported to be nearing completion. Manufacturing of sensors and satellite frame was slated to begin in 2009, with the first launch scheduled for 2012. Initial requirements call for one HY-3 satellite to be launched every five years. Operating in the X-Band in a sun synchronous orbit and with an expected life of at least three years, the HY-3 is said to have a high as a one meter resolution.⁶¹

Electronic Intelligence Satellites. To augment its ground-based collection, China may be resurrecting an electronic intelligence (ELINT) satellite program that was dormant for over 20 years. Aircraft carriers and other major surface combatants have a prominent electromagnetic signature as well as acoustic, and infrared signature, and a large radar cross section (at least 10^5 square meters, and as much as 10^7 square meters).⁶²

Although emission control (EMCON) operation of carriers is feasible for limited periods of time, their air operations depend on electromagnetic radiation. The radio signals that a ship generates can be intercepted by a range of collection platforms. The PLA experimented with ELINT satellites, euphemistically called “technical experimental satellites” [*jishu shiyan weixing*], in the mid-1970s under the Shanghai Bureau of Astronautics' 701 Program.⁶³ For unknown reasons, the program was discontinued. However, technical writings indicate that China's space industry has resurrected the program and intends to field a satellite-borne electronic reconnaissance system. At least one design under evaluation is a constellation of small electronic reconnaissance satellites to ensure precise location data and survivability.⁶⁴

Launch on Demand Microsatellites. In a crisis situation, China may have the option of augmenting existing space-based assets with microsatellites launched on solid-fueled launch vehicles. In July 2002, the space and missile entity formed a new business division – CASIC Academy of Information Technology – to develop and manufacture small satellites for civilian and military customers. More specifically, the academy focuses on microsatellites and nanosatellites weighing 100 kilograms (kg) and below for remote sensing, communications, navigation, satellite navigation receivers, and mobile satellite ground stations.⁶⁵ The rapid



launch on demand capability appears to be one of China's aerospace industry's most ambitious efforts to field a product through privately raised funds.⁶⁶

The CASIC Fourth Academy developed the Kaituoze (KT) small launch vehicle in order to serve the domestic and foreign market for boosting satellites weighing less than 100kg into low earth orbit. The developmental program is said to have begun in November 2000, with the third-stage motor successfully tested on 25 February 2001. Aerospace industry reporting indicated that the initial test on the first stage in September 2002 failed to achieve the anticipated outcome. There are conflicting reports regarding subsequent tests. *China Space News* reported that a 2003 test launch of the four-staged KT-1 launch vehicle was successful; the flight test focused on stage and satellite separation.⁶⁷

The KT-1, which supposedly was developed through CASIC's self-raised capital and is said to be capable of delivering a 50kg payload to a 400km altitude sun-synchronized orbit.⁶⁸ Planned follow-on variants include the KT-1A, with a carrying capacity of about 100 to 200kg. The KT-1A consists of a new larger diameter first stage motor, topped by the first two stages of the basic KT-1 vehicles. Plans for a KT-2 were based upon the CASIC Sixth Academy's ability to field larger diameter motors (e.g., 1.7 meters in diameter) that could boost 300 to 400kg payloads in low earth and sun-synchronized orbits.⁶⁹

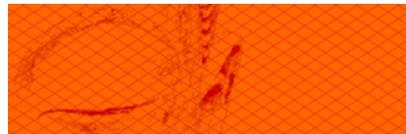


The KT-1 small launch vehicle.
Source: Nautilus Institute.

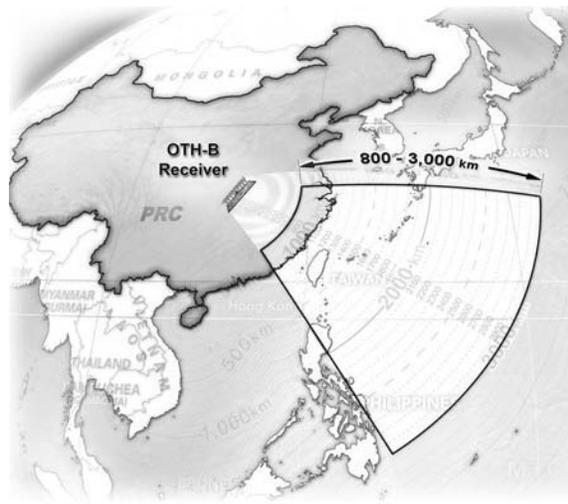
Over the Horizon Radar

In addition to space-based and airborne sensors, an over the horizon backscatter (OTH-B) radar system would be a central element of ASBM-related strategic cueing architecture.⁷⁰ In fact, it could be argued that the OTH radar system could well define the range limits of China's maritime precision strike capability. Skywave OTH radar systems emit a pulse in the lower part of the frequency spectrum (3-30MHz) that bounces off the ionosphere to illuminate a target – either air or surface – from the top down. As a result, detection ranges for wide area surveillance can extend out to 3,000km.⁷¹ Located about 100km away from the transmitter, a skywave OTH radar array receiving station sometimes can be as long as 2.5km.⁷² In addition to resolution issues, Chinese engineers cite challenges stemming from sea clutter that makes it difficult to discriminate ocean targets. However, engineers are confident in the ability of OTH radars to detect aircraft carriers, airborne assets, and other targets operating with range of the radar system.⁷³

China began development of OTH sensors in November 1967. Qian Xuesen was assigned the responsibility of developing a ground wave OTH sensor able to detect targets at 250km. The radar was to provide targeting data for their embryonic anti-ship cruise missile program. In the 1970s, an experimental ground wave OTH radar, with an antenna length of 2300 meters,



was deployed in Xinxiang. Foreign export restrictions, however, prevented China from obtaining technology which was needed for further improvements. Since 1985, developments in computing, microelectronics, and digital signal processing have permitted further advances in China's OTH technology. Chinese institutes, such as the Harbin Institute of Technology (HIT), have most recently concentrated on improving the OTH sensor's electronic counter counter-measure capabilities and digitizing the radar system. There is also some interest in developing a mobile version of the OTH radar. China has already deployed an experimental sky-wave OTH radar that tracked aircraft targets at a range of 1,000km. Chinese systems engineers believe the OTH system can contribute to an integrated air defense system. In 1995, HIT tested a new high frequency radar system capable of detecting low altitude and sea-skimming targets as well as naval targets.⁷⁴



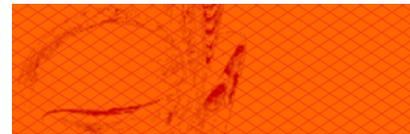
OTH detection ranges for wide area surveillance can extend out to a maximum 3,000km.

Today, China is said to have at least one skywave and one surface wave OTH radar system. The skywave system, which has both civilian and military applications, supports China's scientific community, for both atmospheric and oceanic studies, as well as the PLA. For the latter, the existing network is strategic in nature and transmits air tracking information directly to the PLA National Operations Command Center via a data transmission network.⁷⁵

One U.S. study assessed that the OTH radars may have two critical drawbacks in providing targeting data. First, the resolution may be poor, making it difficult to distinguish a naval combatant from a tanker. Secondly, the radars' large, fixed arrays are vulnerable to attack in wartime. As a result, assuming there is a willingness to escalate a conflict through strikes against targets on Chinese territory, radar installations are likely to be among the priorities for elimination.⁷⁶ In addition, high frequency radars likely are susceptible to jamming.⁷⁷

Conventional Unmanned Aerial Vehicles

Conventional high altitude, long endurance UAVs likely would augment space- and ground-based systems. Sources of unknown reliability indicate that the Northwest Polytechnical University has been assigned the task of developing and producing a high altitude, long endurance UAV. CASC's Eleventh Academy (China Academy of Space Aerodynamics), which was formed on the basis of the 701st Research Institute, is also engaged in the UAV design.⁷⁸ AVIC's Chengdu Aircraft Factory has been engaged in R&D on a UAV, dubbed the Xianglong [祥龙], with a cruise speed of 750km/h, altitude of 18,000-20,000 meters, and a maximum range of 7,000km. The UAV is said to utilize electro-optical and SAR sensor packages, and Chengdu also is developing a variants for communications relay and electronic warfare. The system completed ground testing in October 2008, and the maiden flight is expected to take place before the end of 2009.⁷⁹



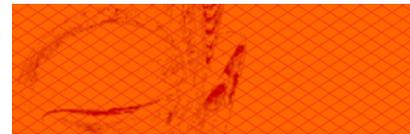
Putting the Pieces in Place: A Review of Possible ASBM Technical Characteristics

Operational deployment of an initial ASBM capability before 2012 would be the result of at least six years of preliminary research and at least eight years of dedicated R&D. Preliminary research appears to have begun in 1996 shortly after the Taiwan Strait missile crisis. In Chinese aerospace industry writings, analysts noted how such a capability would require four components: ocean surveillance; mid-course guidance; terminal guidance (such as an active millimeter wave seeker); and applicable control systems to maneuver the re-entry vehicle to the target.⁸⁰ A number of aerospace industry programs, possibly including the ASBM, were put on the fast track in Spring of 1999.⁸¹ There are indications that preliminary research and a major proof of concept study were concluded in 2002 or 2003. One of the members of a proof of concept team – Xin Wanqing from the CASC First Academy (China Academy of Launch Technology) – was recognized for his efforts through a series of awards.⁸²

Following aerospace industry reorganization, China's Central Military Commission (CMC), PLA GAD, and State Council most likely awarded the ASBM R&D program to the CASIC after completion of preliminary research work in 2002. Confident that the basic technologies were available and the chances of success are sufficiently high to warrant the investment, the move from the preliminary research to the R&D phase appears to have coincided with an internal CASIC reorganization, including the creation of a new academy to lead the ASBM R&D and manufacturing work. As the alter ego to CASC, CASIC specializes in conventional defense and aerospace systems, including tactical ballistic missiles, anti-ship and land attack cruise missiles, air defense missile systems, direct ascent anti-satellite (ASAT) interceptors, small tactical satellites and associated tactical satellite launch vehicles.⁸³

CASIC's Fourth Academy – the CASIC Academy of Launch Vehicle Technology – is probably the business division leading the R&D and production of an ASBM capability. With more than 5,000 employees, the Fourth Academy was established in July 2002 and specializes in design, development, and manufacturing of the DF-21 MRBM and associated variants. Variants include the land-based ASBM, the KT solid-fueled satellite launch vehicle, and possibly a sea-launched version the ASBM.⁸⁴

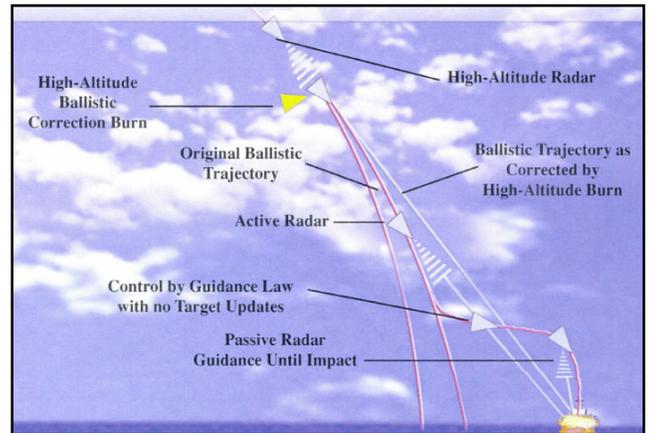
The CASIC Fourth Academy would be responsible to the State Administration for Science, Technology, and Industry for National Defense (SASTIND), PLA GAD, and the PLA Second Artillery for ASBM technology development, source selection, manufacturing and retro-fit work; procurement of sub-systems or components; management of supplier firms, as well as testing, validation, and administration.⁸⁵ The Fourth Academy's business model marks an evolutionary departure from previous aerospace industrial practices. Under its "small core, large collaboration" [*xiaohexin, daxiezuo*] philosophy, the Fourth Academy specializes in systems integration and managing complex supply chains. In the case of the DF-21C, for



example, the Fourth Academy oversaw more than 20 sub-contractors, of which less than half were within CASIC.⁸⁶ The ASBM variant would be expected to have a similar supply chain, or even a more complex one, if the CASIC Fourth Academy also assumes responsibility for development of a tailored ASBM sensor fusion center for the Second Artillery.

Guidance, Navigation, and Control

Building on the successes of the terminally guided DF-21C and DF-15C⁸⁷ programs, development of an ASBM program would depend heavily on advanced microelectronics and an upgraded guidance, navigation, and control (GNC) package.⁸⁸ Technical studies address a wide range of GNC issues, including the need for some form of mid-course update, missile-borne SAR, ATR, terminal guidance, thermal protection, and radiofrequency blackout associated with a flight vehicle traveling at hypersonic speeds in the upper atmosphere.⁸⁹ Key R&D organizations most likely include the CASIC Fourth Academy's 17th Research Institute, CASC First Academy's 12th Research Institute, and a GAD-managed National Defense S&T Key Laboratory for Missile Guidance and Control Technology [导弹制导与控制技术国防科技重点实验室] that was established within the 12th Research Institute in December 2005. The senior designer responsible for the GNC sub-system could draw from the reservoir of expertise that resides within the GAD's Precision Guidance Expert Working Group [总装备部精确制导专业组].⁹⁰

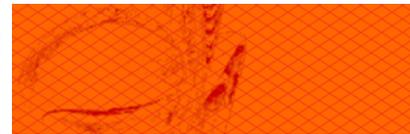


ASBM guidance, navigation and control.
Source: Worldwide Maritime Challenges, Office of Naval Intelligence, 2004.

The Microelectronics Foundation for an ASBM Program

A combination of military-funded R&D programs and the growing availability of commercial off-the-shelf (COTS) microelectronics technology are enabling the PRC to make rapid advances in the “informationization” of its armed forces.⁹¹ Nothing reflects this trend better than the ASBM and supporting C⁴ISR program.

On-board sensors are designed to withstand extreme environmental conditions (extreme heat, extreme cold, vibration, and gravity forces), process information at lightning speed, and generate sufficient radiofrequency power to acquire and track a moving target at sea as early as possible. Along these lines, advanced microelectronics and embedded software would serve as the foundation of a future ASBM capability. Inherently dual use and perhaps even commercially driven, microelectronic components and materials, with extremely high power density and relatively insensitive to the environment, are key enablers for sensors needed to perform under specialized conditions.

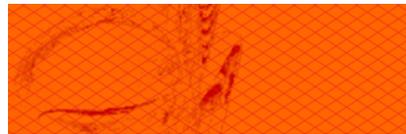


Advances in semiconductor manufacturing, such as very large scale integration (VLSI) techniques, have led to a considerable reduction in the size of electronic products. A reduction in the size of electronics opens up space for terminal guidance systems or multiple or larger warheads. Among the electronics-related technologies are very high speed integrated circuits (VHSICs) and associated computers and software. VHSIC applications included digital signal processors (DSPs) for the missile's radar and other guidance and control applications and on-board electronic warfare systems. In addition, SOC integrated circuits allow for multiple functions to be fitted onto a single chip, thus reducing space and increasing efficiency. China also is investing in developing efficient, lightweight, and compact amplifiers and microwave power modules (MPMs; [微波功率模块]) to energize powerful missile-borne seekers.⁹²

There may also be an ability to generate greater radar power by using more advanced materials in microelectronics. On October 28, 2008, the aerospace industry, in partnership with Xidian University, opened a new national-level R&D center in Xian dedicated to the development of advanced semiconductor devices, with a special emphasis on gallium nitride (*danhuaajia*; [氮化镓]) materials.⁹³ Gallium nitride substrates, for example, offer as much as five times the power density as other materials, making it ideal for high power radar and communications requirements. Gallium nitride compounds also have superior high-temperature performance and can handle higher voltages. Gallium nitride devices, often referred to as “wide-band-gap” devices, are capable of covering a wide range of frequencies and generating greater power levels in smaller areas at higher temperatures. This helps reduce the need for cooling, which then offers new opportunities for cutting system size, weight and cost.⁹⁴

An ASBM's guidance and control system, including use of SAR and ATR, require tremendous computational power. As early as 2000, engineers from CASC First Academy's 14th Research (responsible for re-entry vehicle and payload development) highlighted the importance of developing a sophisticated on-board computer system for missile control. In one study, engineers examined the optimal commercially available digital signal processors.⁹⁵ Because the motion and speed of a missile prevents image quality sufficient for ATR, Chinese microelectronics engineers have developed real time missile-borne DSP [*shuzi xinhao chuliqi*; 数字信号处理器] algorithms based on a field programmable gate array (FPGA), specialized microprocessors, as well as a SDRAM chip.⁹⁶

China's industry also has been focused on developing advanced MEMS [微机电系统] as a means to reduce the weight of guidance systems. MEMS technology allows for the packaging of millions of instructions per second into very small space with very low power consumption. A key focus of China's ASAT kinetic kill vehicle (KKV) program (e.g., the 863-409 or 863-801 Project focus areas) has been high performance MEMS-based three axis accelerometer chips or miniature gyroscopes that enable incredibly small inertial measurement units (IMUs).⁹⁷ In 2006, at least one PLA-commissioned study investigated the utility of MEMS-based technology being applied to fuses to detonate a warhead after penetrating a hardened structure.⁹⁸ As a general rule, commercial requirements, such as the need to detect changes in acceleration for



automobile air bags, are believed to be driving the need for smaller inertial measurement packages.⁹⁹

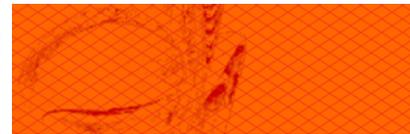
Mid-Course Correction: Keeping the Missile on Track

An ASBM would likely need to update its tracking and positioning in mid-course or soon after reentering the atmosphere (see below for a discussion on re-entry challenges). Two options for mid-course updates are a command uplink from the ground, or an autonomous “fire and forget” search and track mode on the flight vehicle itself, with the latter being preferable.¹⁰⁰ One PLA Navy assessment presents a third option of a sensor data link feed from a lead flight vehicle to missiles in trail.¹⁰¹ Missile designers appear to be most focused on high altitude missile-borne radar for adjusting the missile’s trajectory and perhaps for target acquisition. Second Artillery operational analysts have developed programs for a missile’s on-board computer to map out a “no escape” footprint for an aircraft carrier based on calculations of an aircraft carrier’s maneuverability.¹⁰²

The “Fire and Forget” Option: Synthetic Aperture Radar Guidance. Chinese defense technology authorities are investing resources into a missile-borne SAR capability for high altitude corrections [修正] and target acquisition.¹⁰³ Like most radar systems, a SAR system transmits a radiofrequency pulse toward a target or area, and then collects the reflected signal. However, SAR helps to create a comprehensive image by observing the target from a variety of angles. A DSP helps to store images. The range of a SAR sensor would depend upon transmitter power, frequency used (S-, C-, X-, or Ka-Band), antenna dimensions, detector sensitivity, as well as the size of the target. With microelectronics, power sources, and computing as enabling technologies, Western technical analysts view SAR’s ability to provide a high-resolution image in all weather at long ranges as an optimal solution for precision strike.¹⁰⁴

China’s defense R&D community appears to be investing significant resources into fielding a missile-borne SAR capability that would be integrated with satellite positioning and inertial navigation systems. Intimately connected to China’s air- and space-based SAR programs, the advantages of missile-borne SAR include all-weather capability, high resolution, extended range imaging, and autonomous guidance. During flight, a SAR seeker could penetrate cloud cover to acquire a maritime surface target, and then turn it over to another active or passive seeker in the terminal flight phase. An on-board SAR system would be activated after slowing the missile down to below hypersonic speeds (usually below Mach 5, depending on various factors).¹⁰⁵ A number of technical studies also discuss an integrated high altitude and low altitude guidance system.¹⁰⁶

Challenges of utilizing SAR for missile navigation and guidance include the high speed of the missile, sudden changes in speed and motion, and high “squint” angles. As a general rule, the SAR sensor should operate while the vehicle is on a linear flight path at a constant altitude. As a result, missile-borne SAR presents significant technical challenges. Chinese engineers highlight the need for a highly accurate and high-speed miniature inertial measurement unit



(MIMO) to compensate for the motion of the missile and the quality of SAR components. Specific SAR modes that Chinese engineers are researching include spotlight SAR, in which a beam is maintained on a specific target for maximum resolution.¹⁰⁷ Engineers have also developed electronic warfare simulations to ensure survivability of on-board SAR systems.¹⁰⁸ In terms of cost, technical commentators have noted that radar package may be the most expensive aspect of an ASBM program.¹⁰⁹

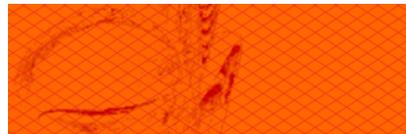
A CASC First Academy simulation in 2001 modeled a ballistic missile for optimal altitudes for activating a high altitude target acquisition system. The missile would start its glide and speed control measures at 200km altitude. At 80km altitude, the re-entry vehicle would activate its on-board radar system to acquire the target, and allow for more refined course corrections. However, engineers note that the high altitude engine burn time would be too long thus exposing the re-entry vehicle to missile defenses. The authors therefore argue for shorter glide duration.¹¹⁰

The ASBM and Hit-to-Kill Terminal Guidance. While SAR appears to present significant technical challenges, China has a well-established foundation for terminal guidance. An ASBM and other conventional strategic strike capabilities may be viewed as a natural, incremental progression from the successful deployment of a first generation terminally-guided ballistic missile and the successful test of a direct ascent ASAT KKV in 2007. Senior CASC design engineers have claimed that ASBM terminal guidance would not differ in principle from that used in air-to-air or surface-to-air missiles.¹¹¹

DF-21C technologies would include a sophisticated onboard computer, terminal phase maneuvering, and ATR technology. ATR matches images collected through radar and infrared sensors on the missile with images in the warhead's onboard computer collected from strategic cueing sensors. According to a Chinese aerospace industry technical analysis, the Pershing-II's terminal guidance radar was a 90 x 45 centimeters and weighed 45.5kg. The amplifier had a power of 60 kilowatts (kW) and the radar operated in the J-band, specifically at 20 gigahertz (GHz). The Pershing-II's 641.7kg¹¹² warhead carried out a control maneuver at 40km in altitude in order to brake to a speed of Mach 6 to 8. The terminal guidance radar would be activated at an altitude of 15.25km. At an altitude of 4.5km, the radar could image an area spanning 35km².

Beyond the DF-21C, a former high ranking aerospace industry official opined that an ASBM would share many of the same guidance technologies the ASAT system that was tested in January 2007.¹¹³ Basic technologies for the ASAT KKV developed under the 863 Program (specifically the 863-409 and 863-801 focus areas) include a mid-wave infrared seeker, couple charged devices (CCDs), all-digital fiber optic gyroscope, major simulation facilities, millimeter wave (MMW) seeker, and diamond coating technologies.¹¹⁴

The development of MMW technology is a national R&D priority, and is a likely candidate for ASBM terminal guidance package.¹¹⁵ Most likely operating in the Ka-Band portion of the frequency spectrum, MMW terminal guidance systems are compact, can achieve high resolution, and have a range of dual use applications. Unlike side-looking SAR systems, a



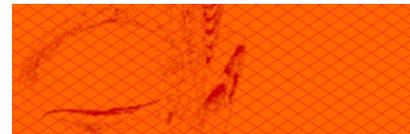
MMW radar seeker can track targets at nose on or high angles of attack. On the civil side, MMW sensors are increasingly being used for collision avoidance systems in the auto industry. Ranging in frequency between 30 to 300GHz, MMW technology also is used air collision avoidance systems. At the same time, MMW technologies have become common in air defense and anti-ship missile systems. MMW seekers are perhaps best known for “hit-to-kill” capabilities associated with the terminal missile defenses, such as the Patriot PAC-3 missile. MMW also is used for robotics, concealed weapons detection, broadband communications satellites, and terrain mapping radar.

Chinese aerospace engineers have been refining technologies for developing advanced MMW seekers for missile terminal guidance.¹¹⁶ The principles associated with intercepting a target the size of a mini-van traveling above Mach 20 and hitting an aircraft carrier are similar, except that the aircraft carrier is a much larger and slower moving target. Priorities in developing a MMW terminal seeker appear to include miniaturizing a high powered amplifier.¹¹⁷ Engineers are developing hardware-in-the-loop simulations and testing MMW missile seekers in “realistic flight scenarios.”¹¹⁸

Imaging Infrared and Laser Guidance. MMW terminal guidance on ballistic missiles often is discussed in the context of an integrated MMW/IIR seeker.¹¹⁹ IIR seekers offer significant precision, and are critical for striking moving targets while traveling at high velocities.¹²⁰ Aircraft carriers have a prominent infrared signature when contrasted with the ocean background. In order to minimize weight of the missile, an uncooled infrared seeker would likely be preferred as a cooled infrared seeker requires a more complex cryogenic assembly to cool the focal plane array. In addition to IIR seekers, engineers in the aerospace industry and Second Artillery have explored the feasibility of a laser terminal guidance system.¹²¹ The Second Artillery has completed at least one technical requirements assessment on a CO₂ coherent laser imaging radar for ballistic missile terminal guidance.¹²²

Aerodynamic Issues: Flying Through Unfriendly Skies

Another challenge that Chinese aerospace engineers are addressing is ensuring the ability to utilize on-board radar systems upon re-entering the atmosphere. In addition to re-entry heating, Chinese technical writings outline issues associated with a blackout of communications that happens at hypersonic speeds after a ballistic missile or other flight vehicle re-enters the atmosphere. After re-entry, an ASBM would likely maneuver to disrupt missile defenses and reduce the re-entry speed to a glide on a relatively even path in order to permit on-board sensors to acquire a target. Problems that Chinese engineers have noted include radiofrequency blackout periods due to ionization of the atmosphere above certain re-entry speeds. The radiofrequency blackout problem is the result of a high-temperature plasma shield that is formed at hypersonic speeds (above Mach 5) in near space. The plasma absorbs electromagnetic waves, which creates an electromagnetic shield around the flight vehicle.¹²³ In the case of an ASBM, the plasma shield would prevent the radar from generating a signal or getting an update from a ground station. However, Chinese media reporting



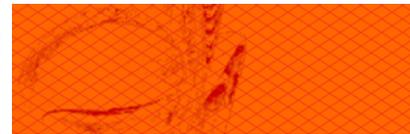
indicates that the issue is being resolved. The blackout period during the Shenzhou-7 mission was allegedly kept to a minimum.¹²⁴

Heating also could pose problems for a re-entry vehicle that glides for an extended period of time after re-entering the atmosphere. Heating would likely serve as a limiting factor for a boost-glide ASBM, and a thermal protection system could add significantly to the weight.¹²⁵ The most likely candidate for resolving technical issues associated with a thermal protection system is CASC's First Academy's 703rd Research Institute.¹²⁶ The institute has been examining extreme heat resistant materials, and in December 2007 a new ablative thermal protection system was certified for integration onto an unidentified re-entry vehicle.¹²⁷ Another study looking toward a conventional global strike capability outlined a requirement for a re-entry vehicle to be able to maintain a presence in an extreme heat environment for 300 to 700 seconds. In one test, a carbon-carbon composite solution was able to withstand extreme heat for 600 seconds.¹²⁸

Countering U.S. Missile Defenses

To reach their targets, ASBMs would need to be able to counter missile defenses. With studies and research on U.S. missile defense systems providing the foundation, Beijing is prioritizing missile defense countermeasures to ensure the viability of its ballistic missile force and ensure its ASBM could penetrate fleet defenses.¹²⁹ A key driver of the 863 Program was ensuring the effectiveness of China's nuclear deterrent in the face of U.S. missile defense programs. These programs include technical countermeasures, saturation and exhaustion, as well as asymmetrical measures, such as counter-space operations. The PRC is investing significant resources into countering missile defense through the development of technical penetration aids. Contemporary Chinese literature on technical countermeasures is focused on "two categories and eight major penetration technologies" [*liangdalei, badatufang jishu*]. These include counter-surveillance and counter-intercept technologies.¹³⁰

Chinese research and development into counter-surveillance [*fanzhencha*] systems is centered on electronic countermeasures, stealth, decoys, and fast burn motors. From China's perspective, passive and active electronic countermeasures (ECM) are a fundamental yet effective means of ensuring ballistic missiles are able to reach their targets. Chinese missile engineers also have been studying on-board jammers for more than a decade.¹³¹ Development of jammers and electronic counter-countermeasures (ECCM) is of sufficient importance to warrant a research institute solely dedicated to space and missile electronic warfare.¹³² Chinese literature cites use of passive electronic countermeasures, such as chaff, to confuse enemy ground radar systems, such as UEWR systems.¹³³ Measures under investigation include electronic and infrared countermeasures on board reentry vehicles, as well as carrying out hard kills against enemy theater missile defense (TMD) radars through the use of anti-radiation missiles.¹³⁴ Under the 863-409 program, the Nanjing University of Science and Technology was awarded a contract for developing space vehicle, warhead MMW and IR passive countermeasures, including use of expanded graphite.¹³⁵



Counter-intercept [*fanlanzai*] measures seek to deny missile defense interceptors the ability to properly engage their targets. These include multiple maneuvering reentry vehicles and hardening or spinning of ballistic missiles. China has had the capability to develop and deploy a multiple reentry vehicle system for many years, as well as maneuverable reentry vehicles that can complicate missile defense tracking. Maneuvering is also essential for terminal guidance packages.¹³⁶

In addition to the techniques described above, a range of other technical and operational countermeasures also is under consideration. These include trajectory techniques, indigenous missile defense development, ASAT development, and possibly multi-axis strikes, including use of submarine launch ASBMs. One article addressing missile defenses argues that it is difficult in general to defend against a 3,000km range ballistic missile targeted against ships at sea.¹³⁷



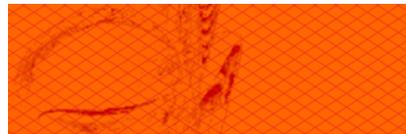
A graphic representation of missiles targeting an aircraft carrier which has been popular on Chinese blogs and forums. Source: <http://bbs.163.com/>.

Propulsion Systems

An ASBM would be powered by solid rocket motors manufactured by the CASIC Sixth Academy, based in Hohhot, Inner Mongolia. The DF-21D ASBM appears to be integrating a new solid rocket motor. A May 2006 *China Space News* article highlighted the successful test of a new motor for a new type of missile, which was attended by senior CASIC and Second Artillery representatives.¹³⁸ In August 2009, the Hohhot city government announced the CASIC Sixth Academy's Honggang Factory (also known as the 359 Factory) completed a construction project for manufacturing of DF-21D solid rocket motors.¹³⁹

There are signs that both of China's aerospace solid rocket motor academies – CASC Fourth Academy and the CASIC Sixth Academy – are working to field more advanced solid propulsion systems, while another CASC business division is developing a new generation of liquid-fueled propulsion system.¹⁴⁰ Various business units within CASC and CASIC are conducting R&D on hybrid solid/liquid fueled engines, scramjet engines, and a new generation of solid rocket motors that are larger, have greater thrust, or offer significant reduction in the IR signature. Much of the Chinese technical literature on solid motors focuses on glycidyl azide polymer (GAP), XLDP, CL-20, and other advanced solid propellants. With reducing the effectiveness of U.S. Space Based Infrared Satellite (SBIRS) systems as a key driver, GAP and other propellants may offer a faster burn rate and lower signature than traditional propellants, such as HTPB.¹⁴¹

A hybrid upper stage could support some type of post-boost vehicle. CASIC Sixth Academy began R&D on a hybrid solid-liquid engine for attitude control in 2004 and successfully tested a prototype (*yangji*; [样机]) in July 2007. While the primary application was said to be for



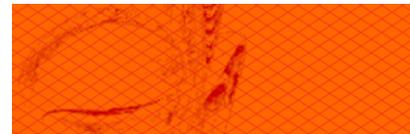
propulsion of small satellites, such a capability could have applications for flight vehicles as well. In fact, one GAD modeling and simulation study assumed that both extended range air defense interceptors and ballistic missiles would share a common re-ignitable upper stage that would be activated at an altitude of 40 to 60km.¹⁴²

Testing: Proving it Works

Test and evaluation is the primary means to ensure the customer that a weapon system functions well in its intended environment. Before a design finalization (*dingxing*; [定型]) committee certifies the design of an ASBM or other extended range precision munitions, a series of integrated flight tests would be needed to prove its effectiveness. After design finalization, the system would enter its low rate initial production [小批生产] phase.

In the R&D phase, testing of the ASBM would involve hardware-in-the-loop simulation of the guidance and control system, wind tunnel, as well as motor and flight vehicle testing in the run-up to a test of the entire system. China has a robust test and evaluation infrastructure. PLA GAD-certified Key National Defense S&T Labs [国防科技重点实验室] are housed in selected research institutes and civilian universities and are intended to foster civilian and military interaction in selected key technologies and foster innovation in key dual use technologies.¹⁴³

CASC's China Academy of Aerospace Aerodynamics, or the 11th Academy, has at least two hypersonic wind tunnels, one for testing of a flight vehicle at Mach 3.5 to Mach 8, the other at Mach 5 to Mach 10. One source indicates that it is capable of testing flight vehicles at speeds of up to Mach 12. It also conducts simulations of stage separation, thrust vector control, boundary layer transition, and extreme heat conditions.¹⁴⁴ Another testing facility is the China Aerodynamics Research and Development Center (CARD), located in Mianyang, Sichuan province. Likely to be supporting preliminary research, CARD has been analyzing alternative re-entry vehicle designs, arguing in favor of biconic configuration with flaps, similar to that used on the U.S. Advanced Maneuverable Reentry Vehicle (AMARV).¹⁴⁵



Order of Battle and Command and Control Issues: Who Pushes the Buttons?

The PLA Second Artillery's conventional short and medium range ballistic and cruise missile force has grown significantly over the past decade, and this trend is expected to continue. Specific production number, order of battle, and details on how a first generation ASBM and extended range anti-ship cruise missiles would be deployed are currently unknown. The Second Artillery relies entirely on CASIC and CASC for its inventory of ballistic and land attack cruise missiles. The CASIC Fourth Academy 307 Factory located in Nanjing will probably be responsible for final assembly and manufacturing of the DF-21D ASBM, as well as other DF-21 MRBM variants.¹⁴⁶ The March 2009 *Military Power of the People's Republic of China* indicated that China's capacity for MRBM production may have doubled. This assessment is also supported by China's own aerospace industry reporting.¹⁴⁷

DF-21D ASBMs would be assigned either to existing DF-21 brigades or more likely to newly formed brigades. According to one unconfirmed analysis, two DF-21 anti-ship capable brigades will be deployed, with six battalions each possessing 17 launchers.¹⁴⁸ For logistical and security reasons, the Second Artillery is unlikely to mix nuclear and conventional DF-21 variants in the same brigade. Currently, the PLA Second Artillery is said to have three DF-21 brigades in eastern China. Two are subordinate to the 52nd Base, the army-level Second Artillery organization located opposite Taiwan.¹⁴⁹ In addition, the PLA formed a relatively new DF-21 unit under the 51st Base (the 96117 Unit or 822 Brigade) in the vicinity of Laiwu, Shandong province.



Nanjing 307 Factory, probable location of DF-21D final assembly. Source: Google Maps.

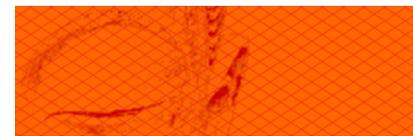
Chizhou

Laiwu

Location of three reported PLA Second Artillery DF-21 brigades in eastern China.

Qimen



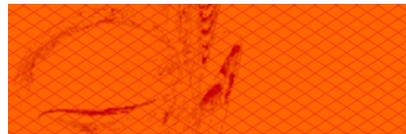


Reliable Chinese references indicate that a standard DF-15 SRBM brigade has six battalions with two companies per battalion. While not yet clear, it appears that existing DF-21 MRBM brigades consist of only three battalions, although these may be the units with nuclear missions. As conventional DF-21 brigades are established, it is possible that they could follow a similar organization to the DF-15 brigades with six battalions, each consisting of two companies.¹⁵⁰

A Second Artillery manual indicates that strike operations against U.S. naval formations would be controlled, directed, and coordinated within a Joint Theater Command (*lianhe zhanyi zhihuibu*; [联合战役指挥部]). PLA officers envision the Second Artillery implementing a four phase operational plan: (1) operational preparations phase (*zuozhan zhunbei jieduan*; [作战准备阶段]), (2) campaign mobility phase (*zhanyi jidong jieduan*; [战役机动阶段]), (3) missile strike phase [*daodan tuji jieduan*; 导弹突击阶段], and (4) enemy counterattack phase [*kangdi fanji jieduan*; 抗敌反击阶段].¹⁵¹ Subordinate service-level command and control entities would include conventional missile and navy corps-level [*juntuan*] commands, as well as a range of cells directly supporting the Joint Campaign Command. Specifically, the command and control system would include a basic command center that houses the decision center [*juece zhongxin*], firepower center, intelligence center, information operations center, and communications center. The system also would include alternative, forward, and rear command centers.¹⁵² The reserve post would assume duties as the primary command post if the latter is neutralized.

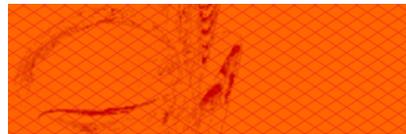
The Second Artillery corps-level [*juntuan*] command center would be subordinate to the Joint Campaign Command and have operational authority over a handful of conventional missile brigades (excluding nuclear-equipped missiles). However, due to the unique operational characteristics of the Second Artillery, there could be situations in which the campaign command could come under the direct command authority of the Second Artillery headquarters in Beijing. One command and control challenge is a possible scenario where conventional brigades subordinate in peacetime to two or more bases are called into action. Its structure would mirror the Joint Campaign Command system, but with greater prominence given to coordination among brigades for surveys of launch points, tactical intelligence, weather, sea states, and real time targeting data.

A key requirement for strike operations, according to senior Second Artillery authorities, would be real-time sensor information on aircraft carrier battle groups. Targeting cells would need to establish links with central authorities, Joint Campaign Command, and lateral Service commands for real time feeds from domestic military and civilian satellite imagery and other sensors. Ballistic computer cells would be responsible for computer updates to launcher and missile on-board computer systems. It would also need to plan for possible high tempo operations, normally involving three echelons – the peacetime garrisons, the operational area's central depot and transfer points, and pre-surveyed launch areas. Most launch preparations for both the missile and warhead are carried out in the central depot, in between the garrison and pre-surveyed launch sites.¹⁵³



A Second Artillery [*juntuan*] would normally be divided into three groups: the basic strike group [*jiben tujicun*]; the reserve strike group [*yubei tujicun*]; and the support group [*baozhangcun*]. Both the basic and alternative strike groups would include a predetermined number of brigades, and electronic countermeasure and defensive operations units. The support group would include operational, logistics, and equipment support units. The reserve strike group is normally one-third the size of the basic strike group.¹⁵⁴

Use of Second Artillery firepower in support of a maritime area blockade would require close coordination with the Navy command, particularly for intelligence and weather inputs.¹⁵⁵ To deter an aircraft carrier battle group, Second Artillery reserves the option of a demonstration strike to either flank of an aircraft carrier for shock and deterrence purposes.¹⁵⁶ As a final note, aerospace engineers have outlined an interesting launch concept of a central missile and warhead storage facility linked in a star pattern by underground rail with as many as five silos, although this was primarily intended for nuclear equipped ballistic missiles.¹⁵⁷



Beyond the ASBM

The ASBM program is likely only one facet of a broader and longer term approach to a more diversified extended range strike capability. Authoritative Chinese aerospace journals indicate more than passing interest in precision strike capabilities that could enable the PLA to neutralize U.S. Air Force and Navy runways, logistics facilities, and command and control targets on Guam. Further in the decade, there could be a more capable follow-on.

As a starter, there is a growing body of evidence that China is examining alternative launch modes for an ASBM. Space and missile engineers have conducted a range of feasibility studies regarding air and submarine-launched conventional ballistic missiles. CASIC-led preliminary research into air launched solid-fueled vehicles is said to have begun in 2000.¹⁵⁸ Airborne platforms are viewed as fuel-efficient since launch would be from a high altitude so the missile could enjoy velocity benefits. Aerospace industry executives have outlined a conceptual design for a 1 meter diameter solid motor that could lift a 50kg microsatellite into a 500km altitude orbit from a converted B-6 bomber.¹⁵⁹ While not confirmed, some indications exist that some testing has taken place. Another variant, similar to a winged cruise ballistic missile, is for near space flight.¹⁶⁰ PLA Navy aviation analysts have assessed the utility of air-launched ASBMs in countering the Phalanx close-in weapon system (CIWS).¹⁶¹

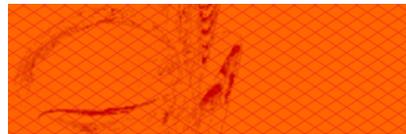
PLA Navy and aerospace industry engineers have advocated development of a submarine launched ASBM.¹⁶² PLA and aerospace industry studies advocate a mix of strike assets to counter aircraft carrier battle groups, including both ballistic and extended range cruise missiles.¹⁶³ One study from 2001 compares the various options and concludes that the priority should be submarine-launched ballistic missiles for striking aircraft carrier battle groups, military bases and other critical nodes in the region.¹⁶⁴

Beyond the ASBM: A Boost-Glide Ballistic Missile

A growing number of engineers have been calling for a modification to existing ballistic missile designs toward ones that adopt characteristics of both ballistic and cruise missiles. As two aerospace engineers put it:

“The traditional ballistic reentry mode of reentry vehicle cannot meet the demand of the new battle environment. A new-style lift re-entry weapon platform is an optimal key to solve this problem.”¹⁶⁵

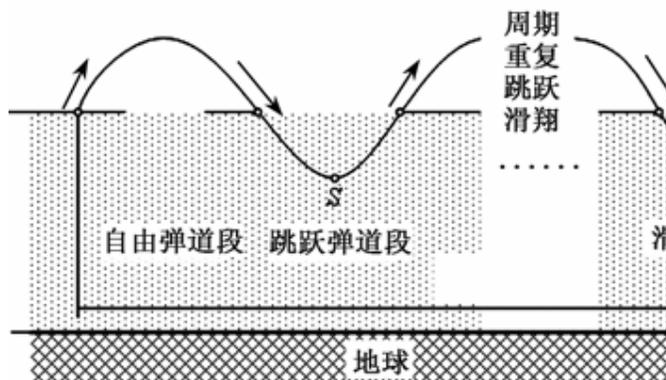
Chinese engineers appear to be conducting preliminary research into a conceptual design for a follow-on ASBM missile variant that adopts a boost-glide [*zhutui-huaxiang*; 助推-滑翔] trajectory. Instead of flying on a normal ballistic path that takes the missile into space before



returning to earth, the boost-glide missile skips in and out of near space, at altitudes between 20 and 100km.¹⁶⁶ In its initial stage of flight, sources indicate that the flight vehicle would reach hypersonic speeds of Mach 8 to Mach 12.¹⁶⁷ Because the missile remains in the atmosphere for most of its flight, the system blurs the distinction between a cruise and ballistic missile.

One benefit of a boost-glide system would be to complicate mid-course missile defenses, such as the SM-3 by flying below the minimum altitude at which some missile defense interceptors can hit their target and maneuvering in flight. A second is to extend the range of existing ballistic missiles. One study, for example, asserts that a basic boost-glide capability would extend the range of a missile by 31.2 percent.¹⁶⁸

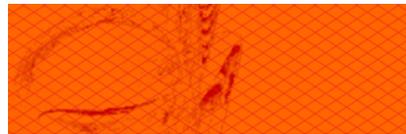
The boost-glide concept was first developed by Eugene Sanger and other German aerospace engineers in the 1930s and refined by Dr. Qian Xuesen, the father of China's space and missile program, while at the U.S. Jet Propulsion Laboratory (JPL) in 1951. Because it remains in the atmosphere for a good part of its flight, a missile on what CASIC Third Academy designers refer to as a "Qian Xuesen trajectory" [钱学森弹道] would adopt hybrid characteristics of both ballistic and cruise missiles.¹⁶⁹ In Sanger's concept, a launch vehicle would propel itself to the upper atmosphere then glide with no power until it hit denser air. It then would use kinetic energy to skip off the atmosphere back up to higher altitudes, similar to a stone skipping along water. Each skip reduces the available energy allowing the missile to glide towards its target. Sanger calculated that a missile launched from Nazi Germany would require three skips to strike a target in the eastern United States. The Russians also reportedly flight-tested a similar boost-glide vehicle in 2005.¹⁷⁰



A conceptual diagram of boost-glide skip trajectory from a Chinese aerospace industry study. The graph depicts the missile's skipping trajectory in and out of the atmosphere and space.

Source: Hu Zhengdong et.al., "Trajectory Performance Analysis and Optimization Design for Hypersonic Skip Vehicle," *Journal of Astronautics*, 2008 (1), pp. 66-71.

Chinese industry publications indicate interests in a boost-glide capability and perhaps onward to a CAV, similar to that carried out under the United States' Prompt Global Strike program.¹⁷¹ The CASC First Academy, CASIC Third Academy and PLA designers have conducted feasibility studies of CAVs, and appear to believe China could overcome the technical obstacles to fielding such as system.¹⁷² In one study, CASC First Academy engineers noted use of a ramjet engine for the CAV and cited issues associated with heating and use of infrared terminal sensors when going after sea-based and land-based targets. After detailed analysis, First Academy designers were able to identify 10 key technologies that are needed to

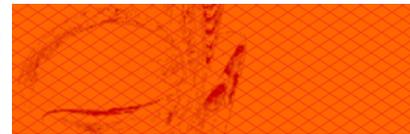


successfully field a CAV for global precision strikes. Assuming the key technical issues can be resolved; engineers believe that a Chinese CAV could enter the R&D phase in the 12th Five Year Plan.¹⁷³ Another study estimates that unit cost for a CAV in the United States would be U.S. \$1.5 million, and significantly less in China.¹⁷⁴ Another group assessed that a Chinese CAV capable of global strike missions is feasible.¹⁷⁵

Beyond the ASBM: Hypersonic Cruise Vehicles

The PRC aerospace industry is investing R&D funds into increasingly capable cruise missiles.¹⁷⁶ There are indications that an anti-ship variant of the DH-10 land attack cruise missile with a range of 3,000km may be under development. Beginning in 2002, CASIC Third Academy designers and engineers have argued their case in prominent, authoritative industry journals that cruise missiles could be adjusted to fulfill the requirements of longer range precision strikes – at least out to 8,000km – against a broad range of targets, including ships at sea.¹⁷⁷ Analysis was conducted to compare the operational effectiveness of cruise and ballistic missiles, presumably as part of a business campaign to capture the lead for the strategic counter-carrier program. However, to ensure the ability to penetrate maritime defenses, designers highlight the need for new propulsion systems, reducing the missile's radar cross-section, increasing maneuverability, and even exploiting advantages in near space.¹⁷⁸

Perhaps building on an extended range or counter-carrier DH-10 program, China's defense R&D community also appears to be investing in conceptual design work on hypersonic cruise vehicles (HCV). Although concepts vary, the U.S. HCV program is a USAF/DARPA effort to develop an air-breathing platform that could deliver a 5,000kg payload for distances up to 17,000km in two hours at speeds up to Mach 6, travelling at near-space altitudes. Similarly, one Chinese study published the results of modeling and simulation of a scramjet-powered vehicle with a range of between 1,000 to 2,000km, flying toward its target at an altitude of 25 to 30km and speed of Mach 6.¹⁷⁹ Another study described a HCV adopting a skipping trajectory with an upper altitude of 60km and lower of 30km.¹⁸⁰ In addition to addressing specific guidance, navigation, and control issues, Chinese aerospace engineers have also been carrying out basic research into an air-turbo rocket propulsion system, an air-breathing system that combines elements from both turbojets and rocket engines. Simulations validated one design that operates at speeds up to Mach 4 and altitudes of up to 11km.¹⁸¹



Concluding Comments: Bringing it Back to Taiwan and Beyond

In short, sufficient evidence indicates that China is serious about fielding a capability that could undercut the capacity of the United States to assist Taiwan in a conflict against China. While it appears certain that preparations are in place to begin ASBM production, what is unconfirmed is when an ASBM will be operationally available to the PLA. However, an ASBM test could be subtle, with no need for an official declaration or acknowledgement.

One sign would be an ASBM demonstration - a test detectable by U.S. surveillance systems. After a successful test, there will probably be a delay before for the word to leak out from the U.S. intelligence community. Alternatively, China could decide to conduct separate tests for the guidance package, flight vehicle, and attitude control system. Chinese references note the possibility of using hardware-in-the-loop or other simulation systems to test an ASBM guidance package. However, PLA authorities would probably want to have a high degree of confidence that the completed system works before giving the aerospace industry the green to begin full scale production.

With facilities prepared to begin at least the low rate initial production, aerospace industry authorities may be ready to test in the near future. The sooner PLA can certify the system; the sooner China's defense industry can confirm a production contract. However, a more likely scenario is for China's civilian leaders to wait for a propitious time to approve a full, integrated flight test. The year 2011 – a year before Taiwan's presidential elections in March 2012 – could represent just such a window to repeat the symbolic 1995-1996 tests timed to influence the 1996 elections.

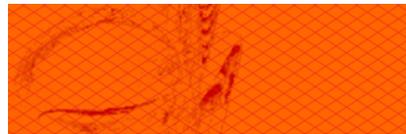


The USS Nimitz which traveled through the Taiwan Strait in 1995 and deployed off Taiwan's coast in 1996.

Source: NATO.

Visible deployment of a growing arsenal of ballistic missiles is intended to create a sense of vulnerability and psychological pressure among the majority of Taiwan's population who may be inclined to support political movements and leaders associated with Taiwan independence.

The next opportunity for Taiwanese to express support for *de jure* independence or an illusive *status quo* through national elections is 2012, and therefore may serve as a milestone for demonstrating an ASBM capability. China's deployment of an ASBM capability could change the nature of the strategic game. From Beijing's perspective, the goal is to create the conditions for cross-Strait unification on terms favorable to the PRC. The United States is viewed as the principle remaining roadblock to unification. Along these lines, a goal could be to create the perception within Taiwan of U.S. weakness and vulnerability, as well as a real Chinese capability to complicate America's capacity to intervene in a future crisis.

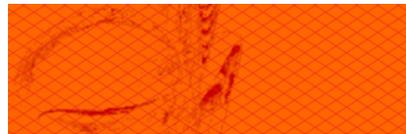


In short, PRC ASBMs and an integrated sensor network could indeed pose significant challenges to United States military operations in the Asia-Pacific region. However, ASBMs likely would not operate in isolation. Backed by a persistent maritime surveillance network, theater ballistic and extended range cruise missiles would operate in conjunction with submarines, conventional naval aviation, and electronic attack assets. Beijing appears increasingly confident of its ability to deny U.S. carrier battle groups the ability to intervene in a Taiwan scenario efficiently, effectively, and safely. Over the next five to 10 years, follow-on ASBM variants flying at a boost-glide trajectory, incorporating a maneuvering re-entry vehicle, and multiple independently targeted warheads, likely would stress the ability of U.S. mid-course missile defense interceptors. Forced to operate out of range of PRC ASBMs, the effectiveness of carrier-based assets, such as the F/A-18 E/F, would be even more limited than they already are when forced to fight at greater ranges than in the past.¹⁸²

Barring visible and decisive American programs that could negate the political and operational effects, the PRC's successful deployment of an ASBM capability could diminish confidence in U.S. security guarantees not only in Taiwan but throughout the region. As Beijing's political leadership proceeds with a concerted effort to defeat U.S. forces in the Taiwan Strait, the relevance of the Taiwan Relations Act (TRA) should increase. While most focus on the arms sales provisions of the TRA, the act also has another key requirement: "to maintain the capacity of the United States to resist any resort to force or other forms of coercion that would jeopardize the security, or the social or economic system, of the people on Taiwan."

Recent statements appear to indicate that steps are being taken to counter the potential deployment of an ASBM. In January 2009, Secretary of Defense Robert Gates said the Department of Defense is making good progress toward developing a "number of programs" to counter Chinese technological advances that could "put our carriers at risk."¹⁸³ However, it is not certain if these programs will be successful. As time goes on, the United States may need to re-examine priorities and rely more on smaller ships, a greater number of affordable submarines able to operate in littoral areas, long range unmanned combat air platforms, and hardening of U.S. military bases facilities throughout the region, including Kadena Airbase on Okinawa and facilities on Guam and Hawaii.

Furthermore, indications exist that the PRC's defense industry is looking beyond the successful fielding of a regional ASBM capability. With advanced missile-borne sensing and data processing, based only on rough initial strategic cueing from a dual use maritime surveillance network, an initial ASBM would give the PLA a precision strike capability against U.S. and allied ships, including aircraft carriers, at ranges between 1,500 and 2,000km. A follow-on variant would likely extend an ASBM's range to 3,000km, and incorporate a more sophisticated boost-glide trajectory and missile defense countermeasures. Subsequent technological advances could extend a conventional precision strike capability out to 8,000km. Perhaps mirroring similar U.S. programs, technical writings indicate a concept for a conventional precision strike capability over the long term. A successful, longer term effort to develop a global conventional strike capability, similar to the U.S. PGS programs, could present additional challenges. In a future Taiwan scenario involving U.S. military intervention,

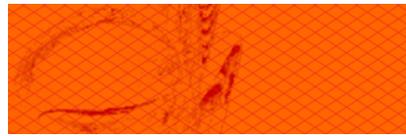


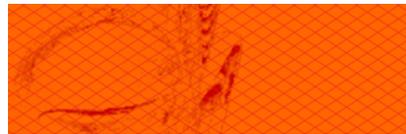
the PRC could reserve the option to conduct conventional precision strikes against unhardened facilities that support U.S. operations, including facilities in Hawaii, the continental United States, Australia, and elsewhere.

The ASBM and other extended range conventional strike capabilities have significant arms control implications. Most relevant is *The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles*. Also known as the Intermediate-Range Nuclear Forces (INF) Treaty, the United States and Russia are constrained in fielding nuclear and conventional ground-launched ballistic and land attack cruise missiles with intermediate ranges, defined as between 500 to 5,500km. U.S. Naval War College's Andrew Erickson has argued that China's ASBM program may generate pressure in Washington and Moscow to revise or abandon the treaty, and that other nations, such as Japan, may feel compelled to develop similar capabilities as well.¹⁸⁴

China faces no such treaty constraint, and is free to develop and deploy intermediate range ballistic and land attack cruise missiles. Restrictions in fielding precision strike missile assets in the Asia-Pacific region may increasingly place the United States at a disadvantage in deterring PRC use of force against Taiwan. Therefore, an option is to engage counterparts in Beijing in a bilateral arms control dialogue to limit deployment of conventional medium, intermediate, and intercontinental range missiles. A centerpiece of discussions could be the implications of Chinese and U.S. conventional global strike capabilities. Another option is negotiating with authorities in Moscow for an exception to the INF Treaty to permit U.S. fielding of medium and intermediate range missiles in the Asia-Pacific region.¹⁸⁵

As a final note, successful PRC development and production of an ASBM capability also has implications for U.S. interests in counter-proliferation. Key technologies, especially those related to the on-board guidance systems, could become tempting items for international customers. The proliferation of ASBM-related technologies to countries of concern, such as North Korea, Iran, and others, could gravely affect U.S. interests around the world.





APPENDIX ONE

CHINA AEROSPACE SCIENCE AND INDUSTRY CORPORATION (CASIC)

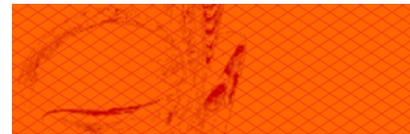
中国航天科工集团

The China Aerospace Science and Industry Corporation (CASIC) is one of China's most prominent aerospace and defense enterprises. Formed in June 1999 and employing more than 100,000, CASIC products include short and medium range solid fueled ballistic missiles, anti-ship and land attack cruise missiles, air defense systems, anti-satellite kinetic kill vehicles, tactical satellite launch vehicles, tactical microsatellites, command and control systems, and a broad range of associated sub-systems and components. CASIC also supports national-level requirements for basic research.

As a first tier contractor, CASIC is organized in a manner similar to U.S. defense corporations, with a corporate-level structure and various business divisions (academies). Like U.S. defense enterprises, each academy focuses on a specific core competency. However, while U.S. defense companies tend to be divided into further specializations within a business division, CASIC academies are organized into R&D and/or design departments, research institutes focusing on specific sub-systems, sub-assemblies, components, or materials; and then testing and manufacturing facilities. Each academy also has its own business intelligence institute. CASIC has an export management subsidiary (previously CPMIEC and now CASIC Foreign Trade Company), although international sales appear to generate a much smaller portion of its total revenue as compared to U.S. counterparts.

A prominent characteristic of both CASIC and CASC is the relative youth of their leadership. Almost all corporate-level and academy executives are well under 60 years old, and most are in their 40s. The older generation they replaced appears to have moved into science and technology (S&T) advisory board positions. One explanation is that much of China's education system, particularly the institutions specializing in aerospace engineering (Harbin Institute of Technology, Beijing University of Astronautics and Aeronautics, etc), grounded to a halt during the Cultural Revolution from 1966 until 1978. As a result, the generation now leading the aerospace industry received their undergraduate degrees in the early- to mid-1980s, served as senior designers on major programs in the 1990s, and then moved into management positions in the 2000s, after about 20 years of engineering and mid-level management experience. Few from this generation appear to have been educated in the U.S. or Europe. However, a large portion of the engineers and managers now working in R&D centers and design departments, research institutes, and manufacturing facilities likely have had more international experience.

CASIC appears to be grappling with the challenge of how to transition from an inefficient, Soviet-influenced organization toward a lean, profitable, competitive, and internationally



recognized defense corporation. Specifics on CASC/CASIC's contracting and accounting systems are currently unavailable. However, as it attempts to move toward a more market-oriented system, including listings on the Shanghai stock exchange, the industry is becoming more transparent.

According to its website, CASIC assets [资产总额] as of 2008 totaled U.S. \$14.6 billion (RMB 100 billion), up from \$10.1 billion (RMB 69.3 billion) in 2005. In comparison, Boeing had U.S. \$53 billion in fixed assets in 2008, Lockheed Martin had \$33.4 billion, Northrop Grumman had \$30.2 billion, General Dynamics had \$28.4 billion, and Raytheon \$23.3 billion.

CASIC revenue [营业收入] amounted to U.S. \$4.7 billion (RMB 49.6 billion) in 2007, up from \$3.4 billion in 2005. Its net profit was U.S. \$498 million (RMB 3.4 billion) in 2007, up significantly from \$161 million (RMB 1.1 billion) in 2005.

Salaries likely are a major expense for CASIC. One rough estimate is that personnel expenses amount to at least RMB 5 billion.¹⁸⁶

In July 2002, CASIC underwent an internal reorganization and adopted its current name (it previously had been the *China Aerospace Machinery and Electronics Corporation*). In addition to formation of two new academies, CASIC organized itself into four business departments [事业部] centered on four academies:

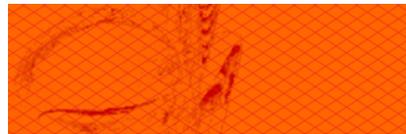
- The First Business Department: CASIC R&D Center [航天科工集团公司研究开发中心], First Academy, 719 Factory, 068 Base, Control Company, and Yunnan Space Corp.
- The Second Business Department: Second Academy; 061 Base, and 801 Factory
- The Third Business Department: Third Academy and 111 Factory
- The Fourth Business Department: Fourth Academy, 066 Base, and Henan Space Office

Director:

- **Xu Dazhe.** Born in 1956 and with roots in the CASC First Academy's 15th Research Institute and 211 Factory, Xu moved up the chain within the First Academy and CASC. He was appointed as head of the First Academy in 2,000. In 2007, senior industry leadership promoted him to CASIC to assume the senior position.
- **Assistant to the Director** [总经理助理]: Xie Lianggui [谢良贵], former Second Academy Director.

Other Corporate-Level Leadership:

- **Gao Hongwei.** Deputy Director. Born in 1956 and with roots in the 066 Base and



Third Academy (cruise missiles).

- **Cheng Wen** [承文]. Born in July 1952, Cheng Wen has roots in the Third Academy's 31st Research Institute. In 1996, he was appointed as Third Academy Deputy Director.
- **Fang Xiangming** [方向明].
- **Li Yue** [李跃]. Born in 1959, Li's rose through the ranks of the Second Academy. He also served as head of the newly formed Fourth Academy, and served as program manager [总指挥] of at least one major weapon system.
- **Cao Jianguo** [曹建国]. Born in August 1963, Cao rose through the Third Academy's design department ranks, and eventually served as Third Academy Deputy Director.

CASIC S&T Committee [中国航天科工集团公司科技委]

Chairman [主任]: Xia Guohong.

Vice Chairman: Hua Lusen [花禄森], former director of the 066 Base.

Senior S&T advisors are mostly senior retired aerospace engineers, including Huang Weilu [黄纬禄], Chen Minxiong [陈敬熊], Zhong Shan [钟山], Li Bohu [李伯虎], Yu Benshui [于本水], Huang Peikang [黄培康], Liu Xingzhou [刘兴洲], and Huang Ruisong [黄瑞松].

Contact Info:

Address: 8 Fucheng Road, Haidian District, Beijing.

Tel: (8610) 6837-0296.

Website: <http://www.casic.com.cn>.

FIRST ACADEMY

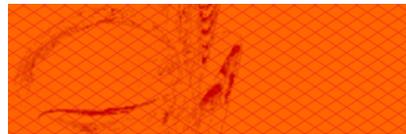
Academy of Aerospace Information Technology

中国航天科工信息技术研究院

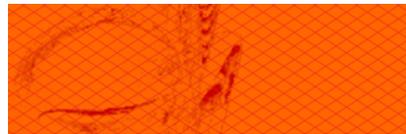
航天科工一院

Established on July 1, 2002 as part of a CASIC reorganization, CASIC First Academy is involved in a range of civilian and military-related products and services. Its primary business lines include microsatellites, satellite applications, GPS, and GPS/inertial guidance units. Its most prominent product is the Qinghua-1 (HT-1) 50kg microsatellite that operates in a sun synchronous orbit; and the 25kg NS-1 microsatellite, which is characterized by its MEMS-based guidance and navigation system. The satellite designer was You Zheng [尤政].

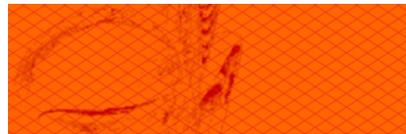
The CASIC First Academy R&D Center [航天科工一院研究开发中] consists of the Space Technology R&D Department [宇航技术研究部], Information Technology R&D Department [信息技术研究部], Tracking Technology Sub-Center [测控技术分中心], and the Satellite Communications Technology Center [卫星通信技术分中心].



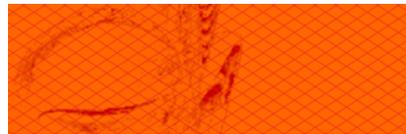
<p>Director [院长]:</p> <ul style="list-style-type: none"> • Yu Liang [於亮]. Born in October 1963, Yu has roots in the CASIC Second Academy's 706th and 204th Research Institutes. Yu's relatively young age (46 years old) as a senior industry executive reflects a general trend within the aerospace industry. Deputy Directors include Yang Yiwei [杨嘉伟] and Meng Bo [孟波]. <p>Contact Info: Address: 8 Fucheng Road 9F, Haidian District, Beijing. Tel: (8610) 6837-1164. Website: http://www.casic-it.cn.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>8511 Research Institute <i>Nanjing Institute of Electronic Equipment</i> 南京电子设备研究所</p>	<p>Formed in 1978 in Nanjing, the 8511 Institute is the aerospace industry's main electronic and infrared countermeasures entity. It manages an integrated test and manufacturing facility in the Jiangning Science Park [江宁科学园].</p> <p>Contact Info: Address: 35 Houbiaoying Road, Baixia District, Nanjing City. Tel: (8625) 8463-8536.</p>
<p>Beijing Aerospace Measurement & Control Technology Development Co 北京航天测控技术开发公司</p>	<p>Established in 1982, the company produces automated measurement and control systems for satellites, missile, launch vehicles, engines, radars, and aircraft. Among other activities, the company has done work on GPS Real Time Kinematic (RTK) quality positioning, using known surface points to refine the satellite positioning information.</p> <p>Contact Info: Address: 3 Shixing East Road, Tracking Technology Industry Park, Shijingshan District, Beijing. Tel: (8610) 8879-6066. Website: www.casic-amc.com.</p>
<p>CASIC Satellite Technology, Ltd 航天科工卫星技术有限公司</p>	<p>Established in June 2,000, the company designs and manufactures microsatellites and associated payloads. It was formerly known as the Qinghua Satellite Corporation (航天清华卫星公司) and is jointly invested by CASIC, Tsinghua Tongfang Co., Ltd [同方股份有限公司] and China Silver Tie Holdings Ltd (China Yintai Holdings; [中国银泰投资公司]).</p>



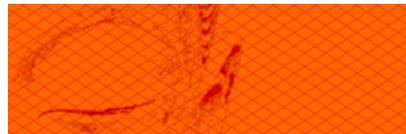
	<p>The company has developed and manufactured five small satellites: Hangtian Tsinghua 1 microsatellite, three payload satellites: KT-1PS/PS2/PS3, and a nanosatellite NS-1 (Naxing-1), a 25kg spacecraft first launched in April 2004 from Taiyuan Space Launch Center.</p> <p>Director: Zhai Yutao [翟昱涛].</p> <p>Contact Info: Address: 7 Huayuan Road, Xinshi Building, 6F, Haidian District, Beijing. Tel: (8610) 8280-3250. Website: www.casic-sat.com.cn.</p>
<p>Aerospace Computer Corporation 航天计算机集团公司</p>	<p>Aerospace Computer Corporation (ASCC) was founded in 1994 and develops automation solutions for public security, traffic management, finance, medical treatment, sanitation, electric power and other government institutions. Subsidiaries include Beijing Orient Space Computer Corp [北京东方航天计算机集团]; Shenzhen Oastar Electronic Ltd [深圳奥士达电子有限公司]; Putian System Integration Co., Ltd; Huadi Computer Co., Ltd. [华迪计算机公司航天信息公司]; Beijing Orient Space Electronics Co., Ltd; Riso Technology Zhuhai Co. [珠海理想科学工业有限公司], Ltd; Zhuhai Jinfeng Electronics Co., Ltd.</p> <p>Contact Info: Address: 9 Nanda Street, 17/F Science & Technology Tower, Zhongguancun, Haidian District, Beijing. Tel: (8610) 6891-0001. Website: www.aerospaceit.com.</p>
<p>Beijing Changfeng Century Satellite Technology Co., Ltd 世纪卫星科技有限公司</p>	<p>Established in 2000, Beijing Century Satellite Technology, Ltd designs and develops satellite communication and navigation equipment. Its main shareholders are CASIC and the Second Academy (Changfeng Group). Its primary focus has been very small aperture satellite (VSAT) and emergency satellite communication technology in China.</p> <p>Contact Info: Address: 188 South Fourth Ring West Road, Building 5-10, Beijing. Tel: (8610) 6370-2888. Website: www.bcs.net.cn.</p>



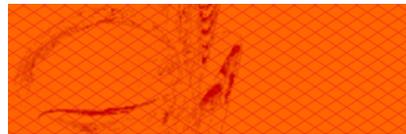
<p>China Systems Engineering Co., Ltd 中国航天系统工程公司</p>	<p>The company was founded in honor of Qian Xuesen, father of China's space and missile program in the 1950s and 1960s. It provides systems engineering and other services.</p>
<p>SECOND ACADEMY Changfeng Electromechanical Technology Academy 中国航天科工防御技术研究院 中国长峰机电技术研究设计院 中国航天二院</p>	
<p>Established in 1961 as a branch academy, the Second Academy is China's main designer and producer of air and space defense systems. With a growing emphasis on integrated air and space defense [空天立体防御], it consists of a design department, 10 specialized research institutes, a simulation center, three factories, and nine independent commercial enterprises. Its most prominent defense products include the ground and ship-launched HQ-9 and HQ-16 air defense systems, including the missile, radar, and associated ground equipment. The Second Academy also likely designed, developed, and produced the direct ascent kinetic kill vehicle (KKV) anti-satellite (ASAT) system that was tested in January 2007.</p> <p>The Second Academy currently has 13,000 employees, of which about 7500 are engineers and other technicians. Prominent political leaders who have roots in the Second Academy include Zeng Qinghong and Song Jian. Its declared capital value is U.S. \$730 million (RMB 5 billion). The Second Academy also is known as Changfeng Corporation. The Second Academy's research institutes and manufacturing facilities are clustered in a complex in western Beijing, along with other specialized guidance, navigation, and control R&D centers of other CASIC and CASC academies.</p>	
<p>Director [院长]:</p> <ul style="list-style-type: none"> • Song Qin [宋欣], as of 15 Jul 09 (<i>China Space News</i>). He had previously been reflected as director of the Third Academy. Song replaced Xie Lianggui [谢良贵], who moved to become assistant to the CASIC Director. Born in March 1964, Xie came up through the Second Academy ranks and served as 23rd Research Institute director for seven years. 	
<p>Deputy Directors [副院长]: Wei Zhiping [韩志平]; and Quan Chunlai [全春来]. Born in 1959, Quan's background is in the 23rd Research Institute.</p>	
<p>Contact Info: Address: 52 Yongding Road, Haidian District, Beijing. Tel: (861) 6838-5399.</p>	



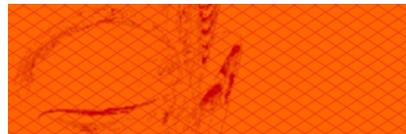
Important departments, institutes, and factories:	
<p>Second Design Department <i>Beijing Institute of Electronic Systems Engineering</i> 第二总体设计部;or 二院二部;or 北京电子工程总体研究所</p>	<p>Established in 1958, the Second Academy's 2nd Department is responsible for design and project management functions associated with surface to air missile and space interceptor systems.</p> <p>Director: Zheng Huanmin [郑焕敏].</p> <p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-5551.</p>
<p>23rd Research Institute (23所) <i>Beijing Institute of Radio Measurement (BIRM)</i> 北京无线电测量研究所</p>	<p>Established in November 1958 and employing 1800 people, the 23rd Research Institute designs, develops, and manufactures air defense-related radar and communication systems. It also has weather radar products. It may be synonymous with the 203rd RI, or at least closely affiliated.</p> <p>Institute Director [所长]: Cheng Zhen [程臻].</p> <p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-5603. Website: www.casic23.com.cn.</p>
<p>25th Research Institute <i>Beijing Institute of Remote Sensing Equipment</i> 北京遥感设备研究所</p>	<p>Established in October 1965, the 25th Research Institute is responsible for radar and optical terminal guidance systems.</p> <p>Director: Liu Chuping [刘著平].</p> <p>Contact Info: Address: 58 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-6115.</p>
<p>201 Research Institute 航天科工防御技术研究试验中心</p>	<p>Serves as the Second Academy's primary simulation center, and focuses on quality assurance of components and assemblies, destructive physical analysis (DPA), failure analysis, and non-destructive testing.</p> <p>Director: Ao Gang [敖刚].</p>



	<p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 8852-7201. Website: http://www.ht201.com.</p>
<p>203rd Research Institute <i>Beijing Institute of Radio Measurement</i> 北京无线电计量测试研究所</p>	<p>Established in November 1958, the 203rd Research Institute conducts RF measurement and testing. It may be synonymous with the 23rd RI, or at least closely affiliated.</p> <p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-8203. Website: http://www.casic203.com.</p>
<p>204th Research Institute (now 706th Research) 北京计算机应用和仿真技术研究所</p>	<p>Established in 1988, the 706th RI (previously 206th RI) specializes in computer hardware and software, as well as electromagnetic interference. It manages an electromagnetic compatibility (EMC) center. Also manages a business enterprise Beijing Aiwei Electronic Technology Co [北京爱威电子技术公司].</p> <p>Contact Info: Address: 51 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-5534. Website: http://www.emi-filter.com.</p>
<p>206th Research Institute <i>Beijing Institute of Mechanical Equipment</i> 北京机械设备研究所</p>	<p>The 206th RI designs and develops air defense launchers and other ground equipment, as well as flight control actuators.</p> <p>Contact Info: Address: 52 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-8512.</p>
<p>207th Research Institute <i>Beijing Guangda Opto-Electronic Co, Ltd</i> 北京环境特性研究所 北京光达光电公司</p>	<p>The 207th RI is a key laboratory for environmental testing of a range of RF systems.</p> <p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 6876-2815. Website: http://www.gdgd.com.</p>



<p>208th Research Institute 北京电子文献服务中心</p>	<p>The 208th Research Institute serves as the Second Academy's information collection and dissemination entity.</p> <p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-5191.</p>
<p>210th Research Institute - <i>Xian Changfeng Electro-Mechanical Institute</i> 西安长峰机电研究所</p>	<p>With at least 1,300 employees, the 210th RI designs and develops solid motors for air defense interceptors.</p> <p>Contact Info: Address: 90 Dianzi Road, Section One, Xian.</p>
<p>283 Factory (283 厂) - <i>Beijing Xinfeng Machinery Factory</i> 北京新风机械厂</p>	<p>The 283 Factory is the Second Academy's primary assembly facility for missile systems. The factory has 90,000m² of work space, more than 800 employees, and RMB 80 million in fixed capital assets. One source claims that the 283 Factory was established in April 1983. Others discuss a symbiotic relationship between the 283 Factory and the neighboring 284 and 699 Factories since the 1960s.</p> <p>Director: Ma Jie [马杰].</p> <p>Contact Info: Address: 52 Yongding Road, Beijing. Tel: (010) 6838-7892.</p>
<p>284 Factory - <i>Beijing Changfeng Machinery Factory</i> 北京长峰机械动力厂</p>	<p>The 284 Factory has been involved in manufacturing of missile control system hardware.</p> <p>Contact Info: Address: 51 Yongdong Road.</p>
<p>699 Factory - <i>Beijing Xinli Machinery Factory</i> 北京新立机械厂</p>	<p>General missile Transporter Erector Launcher assembly.</p> <p>Director: Huang Yunhai [黄云海].</p> <p>Contact Info: Address: 50 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-8181.</p>
<p>THIRD ACADEMY</p>	



第三研究院

海鹰公司

The Third Academy was formed in Beijing in September 1961. Its most prominent product is the DH-10 (东海-10) land attack cruise missile (LACM). According to the 2009 *DoD Report to Congress on PRC Military Power*, at least 150-350 DH-10s with a range of at least 1500 km and 500kg warhead are in the PLA inventory, along with 40-55 launchers. It also produces the YJ-62 ground and ship-launched anti-ship cruise missile; YJ-82 submarine-launched ASCM; YJ-83 ship-launched ASCM; YJ-63 air-launched LACM; and YJ-91 high speed anti-radiation missile. A 4,000 kilometer variant of the DH-10 is said to be in development. The Third Academy's capitalized value is RMB 4.5 billion.

Employing an estimated 13,000 people (6,000 of which are technicians and 2,000 mid-level and senior engineers), the Third Academy has assets valued at U.S. \$2.5 billion (RMB 17.3 billion) in 2007, revenue of \$1.08 billion (RMB 7.4 billion), and net profit [净利润] of \$351 million (RMB 2.4 billion).

Director:

- Liu Erqi [刘尔琦]. Formerly Deputy Director of the Second Academy, Liu replaced Song Qin [宋欣], who appears to have moved laterally to head up the Second Academy. Liu served as program manager [总指挥] for two systems, and is the deputy chief of an unidentified GAD Technical Working Group [总装备部某技术专业组副组长].

Deputy Directors:

- Huang Xingdong [黄兴东]. Formerly director of the Third Academy's 3rd Design Department.
- Liu Depei [刘德培].
- Shi Xinxing [史新兴].
- Wei Yiyin [魏毅寅].

Contact Info:

Address: 1 Xili Road, Yungang North District, Beijing.

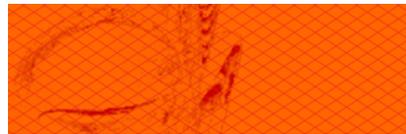
Tel: (8610) 8853-9267.

Important departments, institutes, and factories:

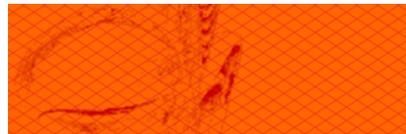
3rd Design Department

北京机电工程研究所
三院三部

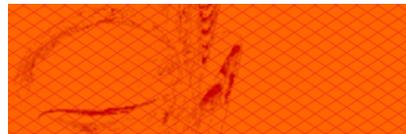
Established in 1960, the 3rd Design Department does general cruise missile industrial planning, as well as conceptual design and preliminary research. It has at least 14 offices dedicated toward various specialties.



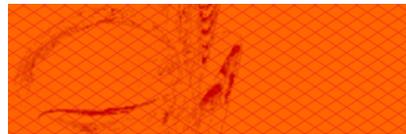
	<p>Director: Gao Wenkun [高文坤], as of July 2009.</p> <p>Contact Info: Tel: (8610) 6837-7435.</p>
<p>31st Research Institute <i>Beijing Institute of Propulsion Machinery</i> 北京动力机械研究所</p>	<p>Established in 1957, the 31st RI designs and develops cruise missile engines.</p> <p>Director [所长]: Xue Liang [薛亮].</p> <p>Contact Info: Address: 17 Yungang West Road, Fengtai District, Beijing. Tel: (8610) 8853-6939.</p>
<p>33rd Research Institute <i>Beijing Institute of Automated Control Equipment</i> 北京自动化控制设备研究所</p>	<p>Established in 1965, the institute designs, develops, and tests cruise missile-related navigation, guidance, and control systems.</p> <p>Director: Cui Yuping [崔玉平].</p> <p>Contact Info: Address: 1 Xili Road, Yungang North District, Beijing.</p>
<p>35th Research Institute <i>Beijing Huahang Radio Measurement Institute</i> 北京华航无线电测量研究所</p>	<p>Established in April 1986 and located adjacent to the Third Academy 239 Factory, the 35th RI specializes in radar and electro-optical seekers and image processing equipment.</p> <p>Contact Info: Address: 3 Hepingli East Road, Dongcheng District, Beijing. Tel: (8610) 6837-3481.</p>
<p>303rd Research Institute 北京振兴计量测试研究所</p>	<p>Responsible for testing and standardization of components and sub-assemblies used in Third Academy cruise missile products.</p>
<p>304th Research Institute 北京京航计算通讯研究所</p>	<p>Established in 1987, the 304th Research Institute is the Third Academy's primary information systems management organization, including software development.</p> <p>Contact Info: Address: 1 Xili Road, Yungang North District, Beijing. Tel: (8610) 6837-6187.</p>



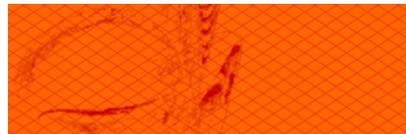
<p>306th Research Institute <i>Beijing Institute of Special Materials and Applications</i> 北京特种材料及应用研究所</p>	<p>The 306th Research Institute was established in June 2002, primarily to support the Third Design Department and the 159 Factory. With more than 150 employees, the institute specializes in structural composite materials, and was recently awarded contract as consult and/or supplier for COMAC's large commercial aircraft program.</p> <p>Director: Ma Rongping [马荣萍].</p> <p>Contact Info: Address: Yungang, Fengtai District, Beijing.</p>
<p>310th Research Institute 北京海鹰科技情报研究所</p>	<p>Provides research, analysis, and publication services to Third Academy entities.</p>
<p>8357 Research Institute <i>Jinhang Institute of Computers and Communications</i> 津航计算机通讯研究所</p>	<p>With 420 employees and located in Tianjin, the 8357th Research Institute was established in 1966. It develops automated control systems, on-board computers, and automated target recognition (ATR) systems.</p> <p>Contact Info: Address: 162 Wuma Road, Tianjin City North District. Tel: (022) 2621-1392.</p>
<p>8358 Research Institute <i>Tianjin Jinhang Institute of Technical Physics</i> 天津津航技术物理研究所</p>	<p>The 8358 Institute conducts opto-electronics-related R&D, including infrared and laser-related guidance, as well as ATR processing technology.</p> <p>Director: Wu Zhixin [吴志新].</p> <p>Contact Info: Address: 58 Hongqi Road, Aerospace Way, Nankai District, Tianjin City.</p>
<p>8359 Research Institute <i>Beijing Institute of Special Machinery</i> 北京特种机械研究所</p>	<p>Develops missile launchers. Civil products include vehicles.</p> <p>Director: Chen Denggao [陈登高].</p> <p>Contact Info: Address: 61 Wukesong Road, Haidian District, Beijing.</p>
<p>159 Factory</p>	<p>Established in April 1960, the 159 Factory is China's final</p>



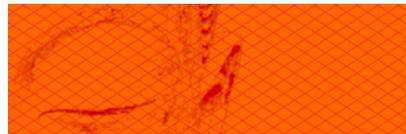
<p><i>Beijing Xinghang Electro-mechanical Equipment Factory</i> 北京星航机电设备厂</p>	<p>assembly facility for the DH-10 and other land attack and anti-ship cruise missiles. The factory is said to be 32.5 square meters in area, and has at least seven “sub-factories” [分厂] and three manufacturing-related R&D centers.</p> <p>Director: Ni Shumin [倪树敏].</p> <p>Contact Info: Address: 9 Dongwangzuo North Road, Fengtai District, Beijing. Tel: (010) 6837-5855 or 6837-4413.</p>
<p>239 Factory <i>Beijing Hangxing Manufacturing Corporation</i> 北京航星机器制造公司</p>	<p>Hangxing is a first class facility for testing and manufacturing, of electro-mechanical and electronic products, including wireless technology and attitude control systems.</p> <p>Director: Lu Yuguo [卢宇国].</p> <p>Contact Info: Address: 11 Hepingli East Road, Dongcheng District, Beijing. Tel: (8610) 422-1131.</p>
<p>FOURTH ACADEMY 中国航天科工运载技术研究院 中国航天科工四院</p>	
<p>Established on July 1, 2002, the CASIC Fourth Academy is primarily a systems integration organization focused on medium range ballistic missiles and solid fueled launch vehicles. The Fourth Academy likely is the lead systems integrator for China's anti-ship ballistic missile (ASBM) program.</p> <p>In 2008, the CASIC Fourth Academy earned U.S. \$264 million (RMB 1.8 billion) in revenue from civilian products, and in 2009 it expects to have a 1:1 ratio in its civil and military business. By the end of 2010, the Fourth Academy's annual goal is earn U.S. \$2.9 billion (RMB 20 billion) in revenue, with a profit of \$87.9 million (RMB 600 million).</p> <p>Academy Leadership: Director: Pan Xudong [潘旭东]. Born in 1965, Pan Xudong is a systems engineering simulation specialist formerly with the CASIC Second Academy. He replaced Shen Weiwei [沈维伟], who previously served as the Third Academy's Deputy Director.</p> <p>Deputy Directors: Yang Xiling [杨西玲], Yang Shaohua [杨少华], and Liu Wenjun [刘文军]. Xu</p>	



<p>Bo [许波] is the academy's S&T Committee Chairman.</p> <p>Contact Info: Address: 8 Fucheng Road, Aerospace Building, Room 710, Haidian District, Beijing.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>4th Design Department 四院四部</p>	<p>With a staff of more than 520 employees, the 4th Design Department main products and services include the design and program management of solid fueled satellite launch vehicles and missiles. The Fourth Academy's design house began preliminary research on the first conventionally armed, terminal guidance variant of the DF-21 (the DF-21C) as early as 1995.</p> <p>The Fourth Design Department was formed in 1965, under what is now the CASC Fourth Academy, in order to lead the design work for the JL-1/DF-21 MRBM. It was transferred to the First Academy (China Academy of Launch Technology) in 1970, then to the Second Academy in 1979.</p> <p>The chief designer and systems integration staff for the ASBM program likely resides within the 4th Design Department, where they coordinate with other research institutes and factories from throughout CASIC, its sister organization CASC, and other entities.</p> <p>Located in western Beijing, the 4th Department has at least seven divisions. The First Office is responsible for general flight vehicle and warhead design. The Second Office manages launcher and missile body structure, while the Third handles electronic systems, such as antennas. The Fourth Office is dedicated towards preliminary research projects. The Fifth Office is primarily responsible for aerodynamic flight controls, such as rudders, wings, elevators, etc; the Sixth manages guidance systems; and the Seventh is responsible for fuses.</p> <p>Director: Liu Wenjun [刘文军]; Deputy Director is Zhang Demin [张德民].</p> <p>Contact Info: Address: 51 Yongding Road, Haidian District, Beijing. Tel: (8610) 6876-3824.</p>
<p>17th Research</p>	<p>Established in 1968, the 17th Research Institute is responsible for</p>



<p>Institute <i>Beijing Institute of Control and Electronic Technology</i> 北京控制与电子技术研究所</p>	<p>solid fuelled ballistic missile guidance, navigation, and control systems. In 2007, it opened a C⁴ISR Key Laboratory [国防重点实验室]. It likely has the lead for systems integration work on the ASBM guidance, navigation, and control sub-system, including software development. It occupies a space of almost 15,000m² in the Muxidi area of western Beijing, near the Second Academy complex.</p> <p>Director [所长]: Song Zhaolong [宋兆龙].</p> <p>Contact Info: Address: 51 Muxidi Beilijia, Chaoyang District, Beijing. Tel: (8610) 6326-3311.</p>
<p>307th Factory <i>Nanjing Chenguang Factory</i> 南京晨光集团有限责任公司</p>	<p>Overseeing 4566 employees, the 307 Factory is the final assembly plant for DF-21 ballistic missiles and associated variants, and where the final assembly of ASBM systems would take place. On July 8, 2002, immediately following the formation of the Fourth Academy, the 307 Factory began the initial phase of a program to expand its manufacturing area. Chenguang's website claims the company's manufacturing space is now 720,000m². In effect, the expansion would almost double the 307 Factory's production area. The factory, which also does contract manufacturing of civilian products, has a number of sub-factories, perhaps best described as production lines. At least one of these is the general assembly line [总装分厂].</p> <p>Director: Yang Shaohua [杨少华], who also serves as the Fourth Academy's second deputy director.</p> <p>Contact Info: Address: 1 Zhengxue Road, Nanjing City. Tel: (8625) 5282-2245. Website: http://www.cacgg.com.</p>
<p>SIXTH ACADEMY 航天科工集团第六研究院 中国航天科工动力技术研究院 Also - the Hexi Machinery Corporation (中国河西化工机械公)</p>	
<p>The Sixth Academy is CASIC's primary business division dedicated toward design, development, and manufacturing of solid rocket motors. It has roots dating back to October 1956, when Qian Xuesen proposed development of solid propelled missile systems.</p>	



Employing 5000 in four research institutes and two factories, the CASIC Sixth Academy is situated in Hohhot, Inner Mongolia. With R&D commencing in 1965, its primary product has been 1.4 meter diameter motors for the DF-21/JL-1 medium range ballistic missile. The CASIC Sixth Academy is developing the solid rocket motors for the DF-21D ASBM.

In theory, its main competitor would be its former parent organization - the CASC's Fourth Academy based in Xian. Its entities focus on casings, nozzles, grains, and igniters.

Academy Leadership:

Director: Zhang Yufeng [张玉峰].

Deputy Directors: 窦生刚.

Party Chairperson is Wang Zhongmin [王忠民].

Contact Info:

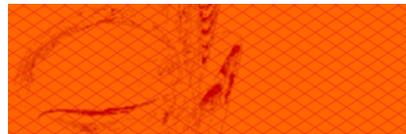
Address: 65 Xinhua East Road, Xincheng District, Hohhot City, Inner Mongolia.

Tel: (0471) 494-4023.

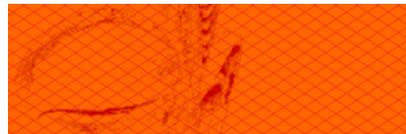
Website: <http://www.zghx.com.cn/gaikuang.htm>.

Important departments, institutes, and factories:

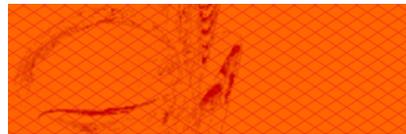
<p>41st Research Institute (41所)</p>	<p>The 41st Research Institute serves as the Sixth Academy's main solid motor design department and has a close working relationship with the Northwest Polytechnical University in Xian. Having long been China's primary design house for solid motors, there are conflicting reports as to its subordination. Some refer to the 41st RI as under the CASC Fourth Academy and others under the CASIC Sixth Academy. One possibility is that the CASC Fourth Academy established an R&D center and assigned personnel from the 41st RI, then re-subordinated the remaining assets of the 41st RI to CASIC. Among its many projects include a hybrid solid-liquid propulsion system for a microsatellite that was first tested in July 2007.</p> <p>Also designs wind power engines. Its offices are numbered 101 through at least 108. In 2007, the institute director was Jin Shixue [金世学].</p>
<p>46th Research Institute 内蒙古合成化工研究所</p>	<p>Established in 1975, the institute's 300 employees are focused motor propellant-related research and development. It has at least seven subordinate offices, numbered 601-607.</p>



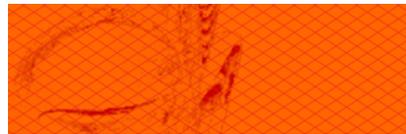
	<p>Contact Info: Tel: (0471) 494-4097.</p>
<p>601st Research Institute</p>	<p>The 601st RI is the Sixth Academy's main testing facility for solid rocket motors. Among its recent projects includes a second stage solid rocket motor.</p> <p>Contact Info: Address: Located in the Hohhot area. Tel: (0471) 494-5428.</p>
<p>602nd Research Institute</p>	<p>A fairly new institute that appears to be the Sixth Academy's information collection and dissemination organization.</p>
<p>359 Factory <i>Honggang Mechanical Factory</i> 红岗机械厂</p>	<p>Established in 1965 and employing more than 1,000 people, the Honggang Factory is the primary assembly facility for DF-21 solid rocket motors. In 2009, it was constructing a new facility for the manufacturing of solid rocket motors for the DF-21D. It also manufactures motors for use in China's QW shoulder-launched air defense system.</p> <p>It also manufactures steel casings and other solid motor assemblies. It occupies 560,000 m² of space in the Hohhot area.</p> <p>Contact Info: Address: Huanghe Shao Zhen (Nandi), Saihan District, Hohhot City, Inner Mongolia. Tel: (0471) 494-5401.</p>
<p>389 Factory <i>Hongfeng Chemical Factory</i> 红峡化工厂</p>	<p>Established in June 1964, the Hongfeng Factory manufactures propellant materials for solid rocket motors.</p> <p>Contact Info: Address: Huanghe Shao Zhen (Nandi), Saihan District, Hohhot City, Inner Mongolia. Tel: (0471) 494-5261.</p>
<p>Inner Mongolia Aerospace Yijiu S&T Co. 内蒙古航天亿久科技发展 有限责任公司</p>	<p>Involved in the development of wind power systems and other civilian products.</p> <p>Contact Info: Tel: (0471) 494-7797.</p>



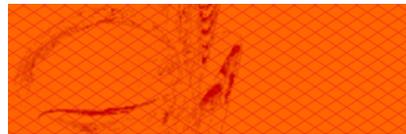
<p>Inner Mongolia Jingang Heavy Machinery Co. 内蒙古金岗重工有限公司</p>	<p>Company is affiliated with the Honggang Factory.</p> <p>Contact Info: Address: Huanghe Shao Zhen (Nandi), Saihan District, Hohhot City, Inner Mongolia. Tel: (0471) 494-7074.</p>
<p>NINTH ACADEMY Sanjiang Aerospace Group 066 BASE 三江集团</p>	
<p>The 066 Base was created in August 1969 as a third line industry, specifically supplying the Third Academy with cruise missile components. Its most prominent product is the DF-11 (NATO Designation: CSS-7) short range ballistic missile. Based on a 1993 decision, 066 Base began work on an extended range variant – the DF-11A – with the goal being to double the range but keep the same accuracy. The motor was viewed as the key sub-system. An initial static test of a new motor on February 24, 1995 resulted in a failure. A second test in June 1995 based on an adjustment to the motor design succeeded. An initial design concept flight test [方案试验] was conducted on August 28, 1996. After a successful test on October 6, 1997, another test a few days later encountered problems. Another test on June 24, 1998 discovered a problem with the warhead. However, the missile was successful in its flight test on August 15, 1998.</p> <p>Its design institute supports a range of national-level basic research projects. According to the 2009 DoD Report to Congress on PRC Military Power, 700-750 DF-11s were in operation with PLA, along with 120-140 launchers.</p> <p>With 16,000 employees (6,000 technicians), the group has capital assets valued at RMB 15 billion (about U.S. \$2.2 billion). Its revenue in 2007 was over RMB 5 billion with a margin of RMB 280 million. Its goal is to have well over half of its revenue (RMB 3.5 billion) come from the sale of civilian products. Group headquarters is in Xiaogan, just north of Wuhan in Hubei province. Most of its production facilities are in Yuan'an. Prominent former figures include Tang Kehui [汤克辉], a chief designer of the DF-11 and Wang Zhenhua [王振华], chief designer of the DF-11A. Liu Shiquan was the deputy chief designer of the DF-11A.</p> <p>Director:</p> <ul style="list-style-type: none"> Feng Zhigao [冯志高]. Born in 1962, Feng is a missile designer who has worked his way up the 066 Base chain of command. He is dual-hatted as CASIC Deputy Director. Deputy Directors include Dai Chuanbo and Xu Tao [徐涛]. 	



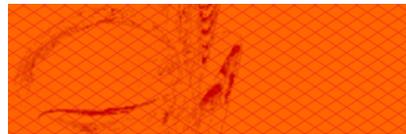
<p>Contact Info:</p> <p>Address: 45 Qingnian Road, Wuhan City, Hubei province. Tel: 027-83562456. Website: www.cssg.com.cn.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>Sanjiang Group Design Institute 三江集团设计所</p>	<p>Established in October 1975, the Sanjiang Design Institute, also known as the Ninth Department, is responsible for design and program management of missiles and related sub-systems, sub-assemblies, and components. Its main product is the DF-11. It also carries out basic research on a range of national-level aerospace programs. It has at least eight offices [室].</p> <p>Director: Yang Yibing [汤亦兵] since 2004. He was born in April 1962. He replaced Xiong Wei (熊玮), who served as chief designer [总设计师] of a major weapon system (NFI).</p> <p>Contact Info: Address: Qiaokou District, Jitian Road, Sec 2, Aerospace City.</p>
<p>Hongyang Machinery Factory 红阳机械厂</p>	<p>Established in 1969 and originally based in Yuan'an, Hongyang is said to be the 066 Base's final assembly plant. It also produces boats, composite materials, and machine tools. It oversees subsidiaries producing civil products, including motorboats.</p> <p>Contact Info: Address: Mail Box 2, Xiaogan City, Hubei, 432100, China. Tel: (86712) 235-7186. Website: http://www.hy-cssg.com.</p>
<p>Jiangbei Machinery Factory 三江集团江北机械厂</p>	<p>Jiangbei is said to manufacture solid fueled motor casings and other high pressure vessels. Includes a research institute for development of high performance composite materials.</p> <p>Contact Info: Address: 6 Beijing Road, Xiaogan City, Hubei, China. Tel: (86712) 235-6038.</p>



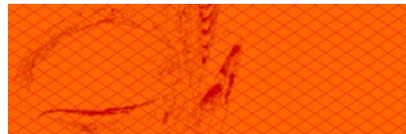
	Website: www.cssg-jbc.com .
<p>Hongfeng Machinery Factory 三江集团红峰机械厂 自动控制技术应用研究所)</p>	<p>Hongfeng is the 066 Base's primary navigation, guidance, and control R&D and production facility. Opened in 1970 and based in Xiaogan, Hongfeng employs 1,108 people. With RMB 280 million in capitalized investment, its manufacturing area is 25,000m², and in 2006 it began a 13,400m² expansion.</p>
<p>Xianfeng Mechanical Factory 三江集团险峰机器厂 -- 电子技术研究所</p>	<p>Located in Yuan'an, Xianfeng was established in 1970. Xianfeng reportedly manufactures missile-borne radar systems for guidance.</p> <p>Contact Info: Address: 55 Beijing Road, Xiaogan City, Hubei, China. Tel: (86712) 235-7741.</p>
<p>Honglin Mechanical Factory -- 三江集团红林机械厂 -- 探测与控制技术研究所</p>	<p>Among other products, Honglin is said to produce missile-related fuses.</p>
<p>Wanfeng Antenna Factory - 三江集团万峰无线电厂 - 测控技术研究所)</p>	<p>Located in Xiaogan, Wanfeng occupies 11,000m² of factory space and employs 2,260 people. It is said to manufacture missile-associated ground equipment.</p> <p>Contact Info: Tel: 0712-2959520.</p>
<p>Jianghe Chemical Factory -三江集团江河化工厂</p>	<p>Jianghe is the 066 Base's solid motor design and manufacturing facility. Has a cooperative relationship with Huazhong S&T University. Its commercial affiliate is the Wuhan Sanjiang Space Gude Biotech Co., Ltd.</p> <p>Jianghe has a working relationship with the CASC 42nd Research Institute, also known as the Hongxing (Redstar) Chemical Institute [湖北航天化学动力总公司].</p> <p>Contact Info: Address: Located in Yuan'an.</p>
<p>Wanshan Special Vehicle Corporation -- 湖北三江航天万山特种车辆有限公司</p>	<p>Manufactures missile launchers.</p> <p>Director/CEO: Cao Jingwu [曹敬武].</p>



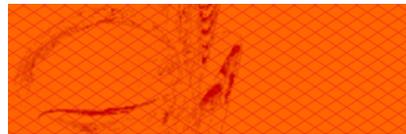
	<p>Contact Info: Address: 69 Beijing Road, Xiaogan City, Hubei, China. Tel: (86712) 295-0356. Website: http://www.wstech.com.</p>
<p>Sanjiang Import & Export Co, Ltd</p>	<p>Serves as Sanjiang's export management company.</p> <p>Contact Info: Address: 45 Changqing Road, Jiangnan, Wuhan City, Hubei, China. Tel: (8627) 8356-2460.</p>
<p>061 BASE Jiangnan Aerospace Group 中国江南航天工业集团公司</p>	
<p>Founded in 1964, the 061 Base employs more than 6,000, of which 650 are technicians. Located in Guizhou, it oversees 20 subsidiaries. The organization serves as a source for a range of components rather than as a supplier of end products. The 061 Base saw a profit [利润总额] of RMB 500 million in 2008.</p> <p>Deputy Director: Shao Jin [邵进].</p> <p>Contact Info: Address: 7 Honghe Road, Xiaohe District, Guiyang City. Tel: (0851) 869-6061. Website: http://www.cjspace.com.cn.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>Guizhou Aerospace Equipment Manufacturing Co. 贵州航天设备制造有限公司</p>	<p>The company is the 061 Base's primary development center.</p>
<p>3297 Factory <i>Guizhou Xinli Castings and Forgings Co, Ltd</i> 贵州航天新力铸锻有限责任公司</p>	<p>Located in Zunyi, Xinli has 700 employees engaged in manufacturing of castings and forgings. Precision castings likely will become more important for missile technology since castings reduce the number of parts, thus reducing overall cost.</p> <p>Contact Info:</p>



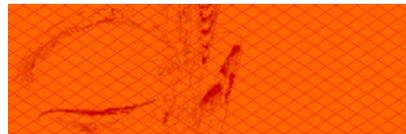
	<p>Address: High Tech Industry Park, Zunyi City. Tel: (0852) 869-0138. Website: http://www.gzhtxl.com.cn.</p>
<p>3405 Factory <i>Guizhou Aerospace Control Technology Co, Ltd</i> 贵州航天控制技术有限公司</p>	<p>The factory focuses on air defense-related flight control actuators and inertial instruments, such as gyroscopes, autopilot systems, and fuel gauges. It has 1,000 employees.</p> <p>Contact Info: Address: Guiyang City, Economic Development and Technology Zone. Tel: (0852) 861-5005.</p>
<p>3408 Factory <i>Guizhou Aerospace Kaihong S&T Co.,Ltd</i> 贵州航天凯宏科技有限责任公司</p>	<p>Kaihong employs 680 people for manufacturing of auto-related products and satellite communications assemblies.</p> <p>Contact Info: Address: 20 Dalian Road, Zunyi City, Guizhou (Aerospace High Science & Technology Industrial Park). Tel: (0852) 869-4310. Website: www.gzhtkh.com.</p>
<p>3531 Factory <i>Fenghua Machinery Factory</i> 贵州航天风华精密设备有限公司</p>	<p>Established in 1965, the factory specializes in metal work, including aluminum and composite materials.</p> <p>Contact Info: Address: Zunyi City, Suiyang County, Fenghua Township.</p>
<p>3536 Factory <i>Guizhou Aerospace Precision Products, Co.</i> 贵州航天精工制造有限公司</p>	<p>The 3536 Factory is a leading producer of aerospace fasteners. It employs 441 people.</p> <p>Contact Info: Address: Kaishan, Guizhou province. Tel: (0852) 869-3536. Website: www.app536.com.</p>
<p>3653 Factory <i>Guizhou Space Wujiang Machine and Equipment Co., Ltd.</i> 贵州航天乌江机电设备有限责任公司</p>	<p>The factory focuses on aluminum-based technologies and supercritical CO₂ extraction equipment. As a side note, supercritical CO₂ washers are inherently dual use, used not only for washing gyros and other precision instruments but also for the semiconductor rinsing process as a substitute for water. It also has uses in environmentally friendly dry cleaning.</p>



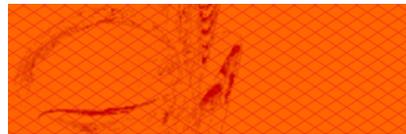
	<p>Contact Info: Address: 20-5 Dalian Road, Zunyi City, Guizhou.</p>
<p>3655 Factory 贵州航天地面设备制造有限公司</p>	<p>Manufactures aerospace system ground equipment. Employs over 1,000 people.</p> <p>Contact Info: Address: Located in Zunyi. Tel: (0852) 861-2655.</p>
<p>3656 Factory 江南航天机电工业公司</p>	<p>The 3656 Factory manufacturers special vehicle-related assemblies and also appears to be a depot repair facility.</p> <p>Contact Info: Tel: (0852) 6626-2335.</p>
<p>3658 Factory <i>Guizhou Aerospace Equipment Manufacturing Co. Ltd.</i> 贵州航天天马机电科技有限公司</p>	<p>The company manufactures hydraulic machinery and other parts.</p>
<p>Linquan Motor Factory 林泉电机厂 贵州林泉微电机有限公司</p>	<p>Established in 1998, the factory employs 710 personnel and focuses on micro-motors [微特电机].</p> <p>Contact Info: Address: 28 Sanqiaoxin Road, Guiyang City. Tel: (0851) 484-2907.</p>
<p>Guizhou Qunjian Precision Machinery Co., Ltd 贵州群建精密机械有限公司</p>	<p>Employing 764 people, the company's specialty is manufacturing of high precision gears [高精度齿轮]. Previously known as the 3247 Factory.</p>
<p>Guizhou WinStar Hydraulic Transmission Machinery Co., Ltd 贵州凯星液力传动机械有限公司</p>	<p>The company supplies speed variators for the hydraulic machines.</p> <p>Contact Info: Address: Located in the Guizhou Aerospace High and New Technology Industry Zone (Dalian Road) in Zunyi.</p>
<p>Zunyi Meiling Battery Co. 遵义梅岭锌空电池有限责</p>	<p>The Meiling Factory supplies specialized batteries to a broad range of customers throughout China.</p>



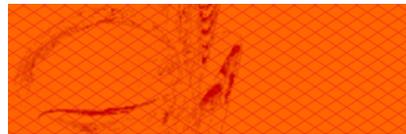
任公司	<p>Contact Info: Address: 705 Zhonghua Road, Honghuagang, Zunyi, Guizhou province.</p>
<p>Hongguang Machine Manufacturing Co., Ltd 贵州航天红光机械制造有限公司</p>	<p>It has 631 employees engaged in manufacturing of aerospace components and automotive products.</p> <p>Contact Info: Address: Guizhou Aerospace Technology Park, Zunyi City. Tel: (0852) 869-3133.</p>
<p>Guizhou Aerospace Nanotechnology, Ltd 贵州航天纳米科技有限责任公司</p>	<p>The company designs, develops, and manufactures nano-carbon products.</p> <p>Contact Info: Address: 26 Yushui Road, Zunyi City, Guizhou. Tel: (0852) 892-8641.</p>
<p>Guizhou Space Appliance Co., Ltd 贵州航天电器股份有限公司</p>	<p>Established in December 2001, the Guizhou Space Appliance Co. pools the resources of a number of entities under the 061 Base.</p> <p>Contact Info: Tel: (0851) 869-7419. Website: http://www.gzhtdq.com.cn.</p>
<p>068 BASE Hunan Space Bureau 湖南航天管理局 中国航天科工集团 68 基地</p>	
<p>The 068 Base was established in 1970 as a Third Line production complex. With 6,000 employees, its assets total U.S. \$293 million (RMB 2 billion). Its revenue from civilian products was U.S. \$146 million in 2008 (RMB 1 billion). Its core competencies include near space flight vehicle design, development, and manufacturing; production of missile control system components; and various ground system components and sub-systems.</p> <p>Director [主任 or 局长]:</p> <ul style="list-style-type: none"> Wu Qing [伍青]. Deputy Directors include Zhang Guanxiong [张冠雄], Liao Fengbin [廖丰湘], Luo Chuanyong [罗传勇], and Bao Dingchao [鲍定超]. <p>Contact Info:</p>	



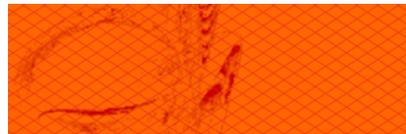
<p>Tel: (0731) 814-6528. Website: www.xn--6kr68kvyufes.com.</p>	
<p>7801 Research Institute 湖南航天机电设备与特种材料研究所</p>	<p>Established in 1992, the institute designs and develops test and calibration equipment for inertial navigation systems, and a range of guidance, navigation, and control components. The 7801 Research Institute also may host the 068 Base's Advanced Materials and Equipment Development Center [高新材料与装备技术研发中心], which opened on June 1, 2009.</p> <p>Contact Info: Address: 217 Fenglin Road, Sec 3, Yuelu District, Changsha.</p>
<p>Near Space Flight Vehicle Development Center 近空间飞行器研发中心</p>	<p>Established in 2005, the center serves as CASIC's only entity dedicated toward design and development of flight vehicles leveraging the characteristics of near space. Among its projects include JK-5, JK-12, and JKZ -20 airships (飞艇).</p> <p>Contact Info: Address: 217 Fenglin Road, Sec 3, Yuelu District, Changsha. Tel: (0731) 814-9382.</p>
<p>Hunan Space Magnet Co., Ltd 湖南航天磁电有限责任公司</p>	<p>Established in 1995, the Space Magnet company develops and produces advanced magnets and magnetic materials for use on satellites and flight vehicles. Specialties include ferrite and bonded/sintered NdFeB magnets. Magnetic materials are used for inductors.</p> <p>Contact Info: Address: Aerospace City, Yuelu District, Changsha. Tel: (0731) 814-9982. Website: http://www.spacemagnets.com.</p>
<p>7803 Factory <i>Hunan Taishan Mechanical Factory</i> 湖南泰山机械厂</p>	<p>Established in 1970, the 7803 Factory specializes in diamond-based materials.</p> <p>Contact Info: Address: 631 Fenglin Road, Sec 3, Yuelu District, Changsha. Tel: (0731) 881-5385.</p>
<p>7804 Factory <i>Huaxing Electromechanical</i></p>	<p>Among other things, this factory produces auto components.</p>



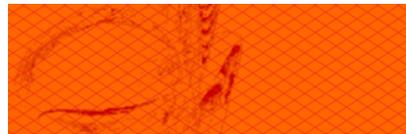
<p><i>Instruments Factory</i> 湖南航天华星机电仪器总厂</p>	<p>Contact Info: Tel: (0731) 814-9548.</p>
<p>7807 Factory</p>	<p>No details available at current time.</p>
<p>7809 Factory 湖南航天长宇机电总厂 邵阳特种车辆厂</p>	<p>Established in 1970, the 7809 Factory manufactures specialized vehicles.</p>
<p>7861 Factory <i>Zhujiang Instrument Factory</i> 湖南航天珠江仪器厂 <i>Hunan Space Satellite Communication Co .Ltd</i> 湖南航天卫星通信科技有限公司</p>	<p>Established in 1986, the 7861 Factory manufactures a range of electronic products, including antenna systems.</p> <p>Contact Info: Tel: (86731) 8149-294.</p>
<p>Hunan Aerospace Information Co, Ltd 湖南航天信息有限公司</p>	<p>Established in 2,000, Hunan Aerospace Information produces a range of information technology products, including electronic tax collection and anti-counterfeiting systems.</p> <p>Director: Luo Chuanyong [罗传勇].</p> <p>Contact Info: Address: 800 Wuyi Blvd, Changsha, Hunan province. Tel: (0731) 488-5666. Website: http://www.hnhtxx.com.cn/index.asp.</p>
<p>CHINA PRECISION MACHINERY IMPORT-EXPORT COMPANY (CPMIEC) 中国精密机械进出口总公司 (精密公司)</p>	
<p>CPMIEC is the primary international business development division of CASIC. It may have changed its name to the CASIC Foreign Trade Company [中国航天科工集团公司外贸公司; or 航天科工外贸公司 for short].</p> <p>Leadership: Its general representative [总裁] is Ji Yanshu [纪彦蜀], who replaced Wang Bingyan [王丙炎].</p>	
<p>SHENZHEN AEROSPACE 航天科工深圳 (集团) 有限公司</p>	
<p>Shenzhen Aerospace is a CASIC subsidiary with investment from the Third Academy, the 061 Base, the Second Academy, and the Tiantong Computer Center. It supports international</p>	



trade development.	
Contact Info:	
Address: 4019 Shenzhen South Dadao, Aerospace Building B, 5F, Futian District, Shenzhen City.	
Tel: (0755) 88266100.	
Email: contact@szaerospace.com .	
OTHER DIRECT REPORTING INSTITUTES, FACTORIES, AND ENTERPRISES	
Fenghua Machinery Factory 风华机器厂	Located in Harbin.
259 Factory	Located in Shenyang, the factory produces components for missile terminal guidance systems. It was involved in 1970s program to develop seeker and inertial guidance devices for an air launched anti-radiation missile (风雷 7 号).
111 Factory <i>Shenyang Aerospace Xinguang Group</i> 沈阳航天新光集团有限公司	The Xinguang Factory has origins in the early 1950s as an aircraft engine overhaul facility. Today, it develops and manufactures engine-related liquid nitrogen containers. Employs 3400 people, including 1400 technicians and engineers. Contact Info: Address: 3 Dongta Road, Dadong District, Shenyang City. Tel: (8624) 2433-8738. Website: http://www.dwrq.com.cn .
694 Factory <i>Xinyang Aerospace Fastener Co, Ltd</i> 信阳航天标准件厂	Formed in 1978, the 694 Factory specializes in aerospace fasteners. Media reporting notes advances in titanium alloy (钛合金) technology. Contact Info: Address: 108 Chang'an Road, Xinyang City, Henan province. Tel: (0376) 632-0694. Website: http://www.casic694.com .
Shenyang Aerospace Xinxing Company/Factory 沈阳航天新星机电有限责任公司	Produces a range of fuel pump-related products. Previously referred to as the 139 or 119 Factory. Contact Info: Address: 1 Yangshan Road, Huanggu District, Shenyang City.



	<p>Tel: (8624) 8652-1804. Website: http://www.sytaikong.com.</p>
<p>Aisino Corporation 航天信息公司</p>	<p>Aisino is engaged in the development, production, system integration and promotion of various computer system applications. It provides information security technology solutions and related services to its clients. The company is also deals with the manufacture and distribution of bill printers, digital set top boxes, fiscal cash registers, integrated circuit (IC) cards and tax control point of sale (POS) machines.</p> <p>On July 11th of 2003, it was listed in Shanghai Stock Exchange, and now it has 4 subsidiaries, 33 holding subsidiaries and 13 joint-stock subsidiaries. It supposedly was a major contractor for the Golden Tax Project, Golden Card Project and Golden-shield Projects. It concluded an agreement with IBM for an innovation center in 2008.</p> <p>CEO/Director: Liu Zhennan [刘振南], former Second Academy Deputy Director</p> <p>Contact Info: Address: 18A Xingshikou Road, Haidian District, Beijing.</p>
<p>Aerospace Hi-Tech Holding Group Co. Ltd 航天科技控股集团股份有限公司</p>	<p>Contact Info: Currently unavailable.</p>



APPENDIX TWO

CHINA AEROSPACE SCIENCE AND TECHNOLOGY CORPORATION (CASC)

中國航天科技集團公司

The China Aerospace Science and Technology Corporation (CASC) is one of China's most prominent aerospace and defense enterprises. Its primary products and services include launch vehicles, satellites, ballistic missiles, and a range of other space systems.

CASC is organized in a manner similar to U.S. defense corporations, with a corporate-level structure and various business divisions (academies). Like U.S. defense enterprises, each academy focuses on a specific core competency. However, while U.S. defense companies tend to be differentiated into further specializations within a business division, CASC academies are organized in R&D and/or design departments, research institutes focusing on specific sub-systems, sub-assemblies, components, or materials; and then testing and manufacturing facilities.

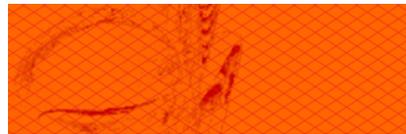
CASC assets [资产总额] as of 2008 totaled U.S. \$20.4 billion (RMB 139.2 billion), up from \$11.7 billion (RMB 80 billion) in 2005. By comparison, Boeing had U.S. \$53 billion in fixed assets in 2008, Lockheed Martin had \$33.4 billion, Northrop Grumman had \$30.2 billion, General Dynamics had \$28.4 billion, and Raytheon \$23.3 billion. CASC revenue [营业收入] amounted to U.S. \$6.9 billion (RMB 47 billion) in 2007, up from \$4.5 billion (RMB 30.9 billion) in 2005. Its profit was U.S. \$776 million (RMB 5.3 billion) in 2007, up significantly from \$278 million (RMB 1.9 billion) in 2005.

Director [总经理]:

- **Ma Xingrui [马兴瑞]**. Born in October 1959, Ma Xingrui leads one of China's largest and technologically advanced aerospace technology enterprises. After almost 10 years at Harbin Institute of Technology, Ma has a satellite background. He was promoted to become the Fifth Academy (China Academy of Space Technology) Deputy Director. In that position, he was the senior director [总指挥] and chief designer [总设计师] of the SJ-5 satellite. After the successful launch of the satellite in May 1999, he was promoted to become CASC Deputy Director. He was appointed as CASC Director in August 2007.

Deputy Directors:

- **Wu Zhuo [吴卓]**. Born in 1950, he is one of CASC's older leaders. Wu has roots in CASC's Chenguang Factory and in the Second Academy Fourth Department (now



CASIC Fourth Academy Fourth Department).

- **Rui Xiaowu** [芮晓武]. Born in 1959, he spent more than 15 years in the First Academy's 710th Research Institute and then in the corporate commercial enterprise business area. On the board of the directors for a number of CASC commercial enterprises, including Sino Satellite Communications Company Limited, China Spacesat Company Limited, Chairman of China Aerospace International Holdings Limited and CASIL Telecommunications Holdings Limited.
- **Lei Fanpei** [雷凡培]. Born in May 1963, Lei has roots in the 067 Base's 11th Research Institute. He was appointed to his current position in 2005.
- **Wu Yansheng** [吴燕生]. Born in July 1963, Wu served for many years in the First Academy's First Design Department.
- **Yuan Jiajun** [袁家军]. Born in September 1962, Yuan joined CASC in 1987 after graduating from BUAA. He previously served in the Fifth Academy and worked for many years in CAST's 501st Design Department, and promoted to become executive assistant to the CAST Director, Deputy Director (November 2007), and then Director, CAST. He is dual-hatted in that position now.
- **Yuan Jie** [袁洁]. Born in August 1965, Yuan has roots in the Shanghai aerospace industry, specifically the 805th Research Institute.

S&T Committee

- Wang Liheng [王礼恒]. CASC S&T Committee Director
- Zhou Xiaofei [周晓飞]. CASC S&T Committee Secretary General.
- Wu Yanhua [吴艳华]. Senior designer.
- Huang Chunping [黄春平]. Deputy Chief designer of the LM-2F.

Contact Info:

Address: 16 Fucheng Road, Haidian District, Beijing

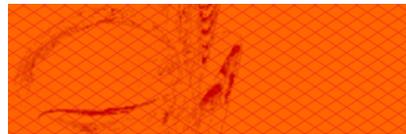
Tel: (8610) 6837-0043

Website: www.spacechina.com.

FIRST ACADEMY

China Academy Of Launch Technology (CALT)

中国运载火箭技术研究院



中国航天科技一院

Established on November 16, 1957, the CASC First Academy is first organization dedicated toward the design, development, and manufacturing of ballistic missile and space launch vehicle systems. Among its products are China's entire inventory of liquid fuelled ballistic missiles, including the DF-4 (CSS-3) and silo-based DF-5 (CSS-4) intercontinental ballistic missile (ICBM), and solid fuelled systems, such as the DF-15 (CSS-6) short range ballistic missile and DF-31/DF-31A intercontinental ballistic missile (ICBM).¹⁸⁷ The CASC First Academy is also a leading organization in China's manned space program.

Among the programs currently under development are said to the LM-5 and possibly the DF-41. The LM-5 is said to be designed to lift a 25 ton payload to low earth orbit (LEO), or a 14 ton payload into geostationary transfer orbit (GTO). New facilities are said to be under construction in the Tianjin area in order to transport the vehicle to its new launch site on Hainan Island.

Director [院长]:

- Li Hong [李洪]. Born in May 1964 in Shenyang, Li Hong has risen through First Academy ranks as a systems designer. In 2007, he replaced Wu Yansheng, who currently serves as CASC Deputy Director.

Deputy Directors:

- Liang Xiaohong [梁小虹]; Wu Zhuo [卓超]; Wang Sainan [王塞南]; and Yang Shuangjin [杨双进] who previously served as assistant to CALT Director.

Contact Info:

Address: 1 Dahongmen Road, Fengtai District, Beijing

Tel: (8610) 6838-3526

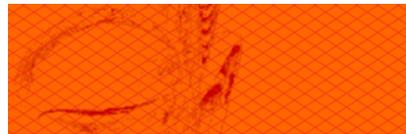
Website: www.calt.com.

Important departments, institutes, and factories:

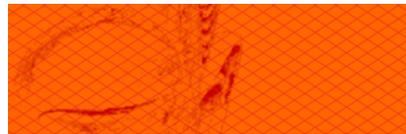
CALT Research and Development (R&D) Center

--中国运载火箭技术研究院研发中心

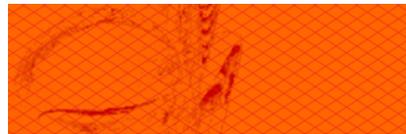
Established in July 2002, the CALT R&D Center is focused on research and development of key strategic aerospace and defense technologies and new concepts. It employs nearly 100 engineers and support personnel.



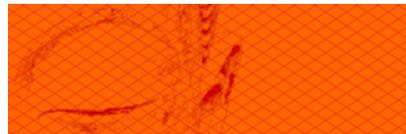
	<p>Director: Hu Defeng [胡德风] (as of 2007)</p> <p>Contact Info:</p> <p>Address: 1 Dahongmen, Donggaodi, Fengtai District, Beijing.</p> <p>Tel: (8610) 8853-7150.</p>
<p>1st Design Department</p> <ul style="list-style-type: none"> - 中国运载火箭技术研究院总体设计部 - 北京宇航系统工程研究所 - 第一总体设计部 	<p>Established in April 1958, the First Academy First Design Department employs 600 people for the purpose of designing satellite launch vehicles, ballistic missiles, and other flight vehicles.</p> <p>Director [主任]: Wang Xiaojun [王小军]</p> <p>Contact Info:</p> <p>Address: 1 Dahongmen Road, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-1929.</p>
<p>10th Research Institute</p> <p><i>Beijing Institute of Near Space Flight Vehicle Systems Engineering</i></p> <p>北京临近空间飞行器系统工程研究所</p>	<p>Established on October 22, 2008, the 10th Research Institute is one of the First Academy's newest entities. Its main mission is design and development of near space flight vehicles. Its CASIC counterpart is the 068 Base's Near Space Flight Vehicle Research Institute in Hunan.</p> <p>Director [所长]: Bao Weimin [包为民]. Born in March 1960, Bao is concurrently chief designer of a major weapon system, First Academy S&T Committee Director, and Deputy Director of the CASC S&T Committee. He was formerly deputy director of the First Academy's 12th Research Institute. He also sits on three PLA General Armaments Department (GAD) committees: Member, GAD S&T Committee [总装备部科技委], Director, GAD S&T Committee General Missile Technology Expert Group [总装备部导弹总体技术专业组], and Deputy Director, GAD S&T Committee Precision Guidance Expert Group [总装备部精确制导专业组].</p>



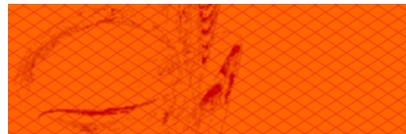
	<p>Contact Info:</p> <p>Address: 1 Dahongmen Road, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-0809.</p>
<p>12th Research Institute</p> <p><i>Beijing Aerospace Automatic Control Institute</i></p> <p>北京航天自动控制研究所</p>	<p>Established in April 1958, the 12th Research Institute is China's oldest missile-related navigation, guidance, and control institute. It also does software design as well as simulation. Included in its list of research activities is on-board SAR imaging technology and DSP/FGPA design. Located in the Beijing's Yongding missile R&D complex, the institute employs more than 700 people. It also hosts a national defense laboratory for guidance and control technology [制导与控制技术国防科技重点实验室] that was opened in 2006.</p> <p>Director: Song Zhengyu [宋征宇], who replaced Liu Jizhong [刘继忠]. Born in June 1970, Song was the deputy chief designer [副总设计师] of the LM-2F launch vehicle.</p> <p>Contact Info:</p> <p>Address: 50 Yongding Road, Haidian District, Beijing.</p> <p>Tel: (8610) 6838-6949.</p>
<p>14th Research Institute</p> <p>- <i>Beijing Institute of Space Long March Technology</i></p> <p>- <i>Beijing Institute of Special Electro-Mechanics</i></p> <p>北京特殊机电研究所</p>	<p>Established in February 1971, the 14th Research Institute is the aerospace industry's leading entity for the design, and development of re-entry vehicles and warheads. More specifically, it specializes in re-entry vehicle structural design, aerodynamics, re-entry maneuvering capabilities. With more than 500 employees (200 of which technicians and engineers), it manages assets valued at RMB 150 million and 80,000 m² of manufacturing space in the First Academy's main R&D and manufacturing complex near Nanyuan Airport.</p> <p>Deputy Director is Lu Jisan [吕级三].</p> <p>Contact Info:</p>



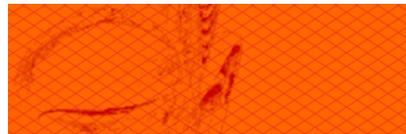
	<p>Address: 1 Dahongmen Road, Gaotiandi South, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-2256.</p>
<p>15th Research Institute 北京航天发射技术研究所</p>	<p>With over 1,000 employees, the 15th Research Institute designs and develops launch systems and ground equipment for ballistic and space launch vehicles. It has a close relationship with the 519 Factory (Changzhi Qinghua Machinery Factory) and the Tai'an Special Vehicle Corp in Shandong province. Engineers also have examined concepts associated with underground missile launch complexes.</p> <p>Contact Info:</p> <p>Address: 1 Dahongmen, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-2725.</p> <p>Website: http://www.casv.com.cn.</p>
<p>18th Research Institute <i>- Beijing Research Institute of Precise Mechatronic Controls</i> 北京精密机电控制设备研究所</p>	<p>Established in 1995, the 18th Research Institute employs 1,000 people for design of precision parts for control systems.</p> <p>Director: Zhu Chenglin [朱成林].</p> <p>Contact Info:</p> <p>Address: 1 Dahongmen, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-2903; 8852-0128.</p> <p>Website: www.calt-18.com.</p>
<p>19th Research Institute <i>Beijing Institute of Aerospace Information</i> 北京航天信息情报研究所</p>	<p>Established in 1984, the 19th RI is CALT's primary entity for specialized information and data services.</p> <p>Contact Info:</p> <p>Address: 1 Dahongmen, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-3353.</p>



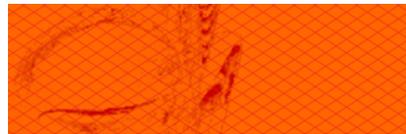
<p>102nd Research Institute - <i>Beijing Aerospace Institute for Metrology and Measurement Testing</i> 中国航天科技集团公司第一计量测试研究所</p>	<p>The 102 Research Institute is CALT's primary entity for standardization and certification.</p> <p>Contact Info: Address: 1 Dahongmen Road, Gaotiandi South, Fengtai District, Beijing. Tel: (8610) 6838-3632. Website: www.102.com.cn.</p>
<p>702nd Research Institute - <i>Beijing Institute of Structure and Environment Engineering</i> 北京环境强度研究所</p>	<p>Established in November 1956, the 702nd Research Institute employs 600 for structural and environmental engineering.</p> <p>Contact Info: Address: 1 Dahongmen Road, Gaotiandi South, Fengtai District, Beijing. Tel: (8610) 6838-3158.</p>
<p>703rd Research Institute - <i>Aerospace Research Institute of Materials and Processing Technology (ARIMT)</i> 航天材料及工艺研究所</p>	<p>Established in 1957, the 703rd RI designs and develops space and missile materials, and hosts the GAD National Key Laboratory for Advanced Functional Composite Materials [先进功能复合材料技术国防科技重点实验室].</p> <p>Contact Info: Address: 1 Dahongmen Road, Gaotiandi South, Fengtai District, Beijing. Tel: 6838-3608; 6875-7501. Website: http://www.arimt.com/cn/index.asp.</p>
<p>211 Factory - <i>Capital Aerospace Machinery Company</i> - 首都机械厂</p>	<p>With over 4200 employees, the 211 Factory is believed to be the assembly and integration facility for liquid fueled launch vehicles and missiles, as well as the DF-31. It was formerly an aircraft overhaul plant until its conversion in the 1960s. Its website asserts that factory space is 100,000 m², about 1/3 the size of the CASIC 307 Factory.</p>



<p>- 首都航天机械公司</p>	<p>In 2004, the 211 Factory enjoyed gross assets [总资产] totaling RMB 2.15 billion, revenue [总收入] of RMB 2 billion, and a profit [利润] of RMB 273 million.</p> <p>Current factory Director [厂长]: Zhang Weimin [张为民]. Previous Director was 郭玉明. Another name mentioned as 211 Factory director is 郭凤仁.</p> <p>Contact Info:</p> <p>Address: 2 Jingbei East Road, Nanyuan, Fengtai District, Beijing.</p> <p>Tel: (8610) 6875-0017.</p>
<p>811 Factory</p> <p>- Changzheng Aerospace Control Engineering Co.</p> <p>长征航天控制工程公司</p>	<p>Manufactures precision parts for control systems. Its corporate name represents a joint venture together with the 18th Research Institute.</p> <p>Contact Info:</p> <p>Address: 1 Dahongmen, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-2905.</p>
<p>China Long March Vehicle Corp (Rocket Stock)</p> <p>长征火箭技术股份有限公司</p>	<p>Has 400 employees. Directed by Wang Zongyin, who also serves as the General Manager of China Aerospace Times Corporation The company's products and services include tracking systems, electronic countermeasures, guidance systems, and electronic components.</p> <p>It has six specialized laboratories and R&D centers including an antenna lab, microwave lab, satellite navigation lab, telemetry, control and telecommunication lab, satellite and spaceship application lab and integrated circuit lab. In September 02, it established a satellite navigation engineering research center. Aerospace Long March Launch Vehicle Technology Co. Ltd; Guilin Aerospace Technologies Co, Ltd; Shanghai Astronaut Electronic Co; Hangzhou Aerospace Electronic Co. Ltd; Zhengzhou Aerospace Electronic Co., Ltd; Tianhe Navigation and Telecommunication Technology Co., Ltd; Beijing Jintaixing Telemetry Co., Ltd; Beijing Long March</p>



	<p>Launch Vehicle Machinery and Electronic Co. Ltd.</p> <p>Contact Info: Address: 188 West Fourth Ring Road, District 15, Building 7, Beijing Tel: (8610) 8853-0300 Website: http://www.rocketstock.com.cn.</p>
<p>FOURTH ACADEMY</p> <p>Academy of Aerospace Propulsion Technology</p> <p>航天动力技术研究院 中国航天科技集团公司第四研究院</p>	
<p>Established in 1962, the Fourth Academy is responsible for solid motor research, development, and manufacturing. With over 7,000 employees and also known as the Academy of Aerospace Solid Propulsion Technology, the CASC Fourth Academy has five research institutes and three production facilities involved in all aspects of solid rocket motors. In addition to R&D on solid motors for the DF-31, DF-31A, JL-2, and possibly the DF-41, the Fourth Academy may be design, developing, and producing motors -- casings, nozzles, grains, and igniters -- for use on larger solid fueled launch vehicles. Some sources indicate work on a 2.5 meter diameter motor, either 350 or 500 tons. Studies indicate significant work into high energy composite (HEC) propellants.</p> <p>The academy is based in Xian, and with fixed assets totaling U.S. \$805 million (RMB 5.5 billion), its revenue in 2008 amounted to US \$658 million (RMB 4.5 billion). The Fourth Academy would be roughly analogous to Aerojet or Alliant Techsystems (ATK) Space Systems. Starting salary for CASC Fourth Academy engineers with PhDs is RMB 5,000 a month; RMB 3,000 for master's degree holders, and RMB 1500 for undergraduates.</p> <p>The solid motor community's founding fathers include Cui Guoliang [崔国良], Xing Qiuhen [邢球痕], and Ye Dingyou [叶定友].</p> <p>Leadership</p> <ul style="list-style-type: none"> • Director: Zhou Weimin [周为民] • Deputy Director: Hou Shao [侯晓]. Born in November 1963, Hou is a solid motor designer with roots in the 41st Research Institute. He lead system integration efforts on three different rocket motor programs. Other deputy directors include Wang 	



Jinglin [王景林]; Zhang Xinming [张新明]; and Tian Weiping [田维平].

Planning Department Deputy Director: Ren Quanbin [任全彬]. Chief designer of the expendable solid motors [逃逸固体火箭发动机] used on the Shenzhou manned space vehicles.

Contact Info:

Address: 1 Tianwang Road, Baqiao District, Xian City.

Tel: (8629) 8360-5564.

Website: www.sunvalor-casc.com.

Important departments, institutes, and factories:

CASC Fourth Academy Design Department

陕西动力机械研究所
中国航天科技集团公司四院设计部

Established in 1964 and employing 225 engineers and other personnel, the Fourth Academy's solid motor design department hosts a GAD National Key Laboratory [国防科技重点实验室]. Its offices [室] are number in the 101, 102, 103, 104, etc.

Director: Gao Bo [高波]. Born in July 1968 in Hangzhou, the 41st Research Institute director is Gao Bo. Assistant to the director and a senior designer is 甘晓松.

Contact Info:

Address: 1 Tianwang Road, Baqiao District, Xian City.

42nd Research Institute

Hongxing (Redstar) Chemical Institute

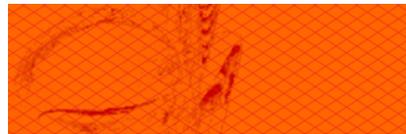
湖北航天化学动力总公司

Established in 1965 and employing over 1,000 personnel, the 42nd RI designs and develops propellant materials for use in solid motors.

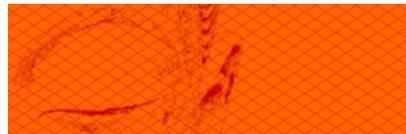
Director: Zhang Xiaoping [张小平], as of Spring 2009.

Contact Info:

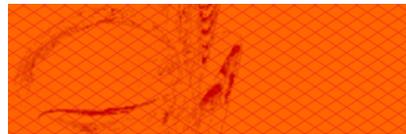
Address: 1 Chunyuan Road (and/or 58 Qinghe Road),



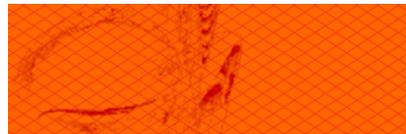
	<p>Xiangfan City, Hubei province.</p> <p>Tel: (8671) 382-0378.</p> <p>Website: www.casc42.com.</p>
<p>43rd Research Institute</p> <p><i>Xian Aerospace Composite Materials Research Institute</i></p> <p>西安航天复合材料研究所</p>	<p>Established in May 1970 and employing more than 1300 personnel, the 43rd RI designs and develops composite materials for solid motors.</p> <p>Contact Info:</p> <p>Address: 17 Tianwang Xiangyang Road, Dongjiao, Xian City.</p> <p>Tel: (8629) 8360-1606.</p>
<p>44th Research Institute</p> <p>陕西电器研究所</p>	<p>The 44th RI designs and develops a range of gauges and sensors for solid motors and other systems.</p> <p>Contact Info:</p> <p>Address: 1 Tianwang Road, Baqiao District, Xian City.</p> <p>Tel: (8629) 8360-6672.</p> <p>Website: www.casc44.com.</p>
<p>47th Research Institute</p> <p>陕西向阳化工机械公司科技信息研究所</p>	<p>The 47th RI serves as the Fourth Academy's main information gathering and dissemination entity.</p> <p>Contact Info:</p> <p>Tel: (8629) 8360-3077.</p>
<p>401st Research Institute</p> <p>西安航天动力测控技术研究所</p>	<p>Employing 700 people and established in 1966, the 401st RI is said to be China's largest solid motor testing facility.</p> <p>Contact Info:</p> <p>Address: 1 Tianwang Road, Baqiao District, Xian City.</p> <p>Tel: (8629) 8360-7536.</p>
<p>7414 Factory</p>	<p>The 7414 Factory manufactures solid motor assemblies and components. Employing 1600 personnel, the 7104 Factory</p>



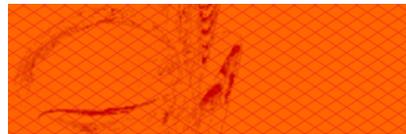
<p><i>Xian Aerospace Motor Machine Factory</i> 西安航天动力机械厂</p>	<p>has more than 170,000 m² of space.</p> <p>Contact Info:</p> <p>Address: 1 Tianwang Road, Baqiao District, Xian City. Tel: (8629) 8360-7296. Website: www.aerospacemotor.com.</p>
<p>7416 Factory <i>Xian Aerospace Chemical Power Factory</i> 西安航天化学动力厂</p>	<p>Established in June 1966 and employing 1300 personnel, the 7416 Factory is the Fourth Academy's main solid motor propellant production and general assembly facility. Presumably, its products would include larger solid motors, such as those used with the DF-31 and JL-2, as well as satellite kick motors.</p> <p>Director: Wang Shiyong [王世英], as of 2008.</p> <p>Contact Info:</p> <p>Address: 16 Hongqing Xiangyang South Road, Xian City. Tel: (8629) 8360-8878. Website: www.spacepower.com.cn.</p>
<p>7424 Factory</p>	<p>Since 1993, the factory has engaged in an unknown facet of solid rocket motor manufacturing.</p> <p>Contact Info:</p> <p>Address: 24 Changping Road, Lantian County, Xian City.</p>
<p>Shaanxi Space S&T Co, Ltd 陕西宇航科技工业公司</p>	<p>Established in 2002 and employing 2350 people, Shaanxi Space S&T Company offers a variety of electronic and chemical products.</p> <p>Contact Info:</p> <p>Address: 1 Tianwang Road, Baqiao District, Xian City.</p>



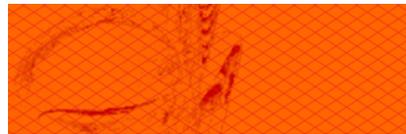
Website: http://sxyhthhg.cn.alibaba.com .	
<p>FIFTH ACADEMY</p> <p>China Academy of Space Technology</p> <p>中国空间技术研究院</p>	
<p>Established in February 1968, the Fifth Academy, or China Academy of Space Technology (CAST), is China's primary organization engaged in satellite design, development, and manufacturing.</p> <p>Leadership</p> <p>Director [院长]: Yang Baohua [杨保华]. Appointed as CAST Director in 2007, Yang has a background in CAST's 502nd Research Institute.</p> <p>Deputy Directors: Li Kaimin [李开民]; Liu Fang [刘方]; Yang Mengfei [杨孟飞]; Shi Junjie [史俊杰]; Zhang Hongtai [张洪太]; Song Liding [宋黎定], Li Ming [李明], Dai Shoulun [代守仑], Liu Xudong [刘旭东], and Li Zhongbao [李忠宝].</p> <p>Contact Info:</p> <p>Address: 31 Zhongguancun South Boulevard, Haidian District, Beijing.</p> <p>Tel: (8610) 6819-7121.</p> <p>Website: www.cast.cn.</p>	
Important departments, institutes, and factories:	
<p>Fifth Design Department</p> <p>501st Research Institute</p> <p>中国空间技术研究院总体部</p>	<p>With 900 employees, the Fifth Design Department is responsible for satellite R&D, design, and systems integration.</p> <p>Contact Info:</p> <p>Address: Tangjialing Space City, Haidian District, Beijing.</p>
<p>502nd Research Institute</p> <p><i>Beijing Institute of Control Engineering (BICE)</i></p>	<p>Established in 1975, BICE designs, researches and develops satellite attitude and orbit control systems, including jet propulsion and various guidance, navigation and control sub-systems. Employs 1200 engineers and workers.</p>



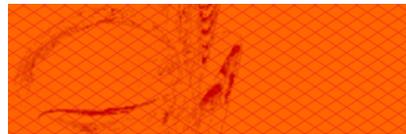
<p>北京控制工程研究所</p>	<p>Director: Bian Bingxiu [边炳秀]</p> <p>Contact Info:</p> <p>Address: Zhongguancun South Road, Section 3, Haidian District, Beijing.</p>
<p>503rd Research Institute <i>Beijing Institute of Satellite Information Engineering</i> 北京卫星信息工程研究所</p>	<p>The 503rd Research Institute develops satellite tracking and telemetry and other ground equipment.</p> <p>Contact Info:</p> <p>Address: 75 Zhichun Road, Haidian District, Beijing. Tel: (8610) 6837-8212.</p>
<p>504th Research Institute <i>Xian Institute of Space Radio Technology</i> 西安空间无线电技术研究所 中国空间技术研究院西安分院</p>	<p>Established in 1968, the 504th RI designs, researches and develops space-based communications and remote sensing sub-systems. Electronic products include traveling wave tube amplifiers (TWTs; [行波管]), other amplifiers [功率], charged coupled device (CCD) cameras, microwave data links, and antennas. The 504th Institute also is known as the CAST Xian Sub-Academy. The 504th Research Institute also has focused on specialized components, such as X-Band monolithic microwave integrated circuits (MMICs; [微波单片集成电路]).</p> <p>Contact Info:</p> <p>Address: 150 Weiqu West Road, Chang'an District, Xian City. Tel: (8629) 8561-3114. Website: www.cast504.com.</p>
<p>508th Research Institute <i>Beijing Institute Of Space Mechanics & Electronics</i> 北京空间机电研究所</p>	<p>Established in August 1958, the 508th Research Institute designs and develops electro-optical and other satellite sensors.</p> <p>Contact Info:</p> <p>Address: 1 Daohongmen Road, Fengtai District, Beijing.</p>



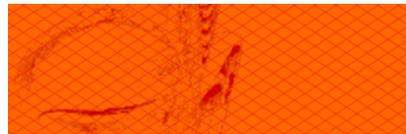
	Tel: (8610) 6838-2824.
<p>510th Research Institute <i>Lanzhou Institute of Physics</i> 兰州物理研究所</p>	<p>With 600 employees and located in the Lanzhou Aerospace Science and Technology Park, the Lanzhou Institute of Physics conducts space environmental studies, including vacuum and cryogenic technology development. It was established in April 1968.</p> <p>Contact Info: Address: 105 Weiyuan Road, Lanzhou City. Tel: (86931) 826-4461. Website: www.lipcast.cn.</p>
<p>511th Research Institute 北京卫星环境工程研究所</p>	<p>Established in August 1958, the 511th Research Institute provides simulation and testing services for satellite development programs.</p> <p>Contact Info: Address: 5 Minzuyuan Road, Chaoyang District, Beijing. Tel: (8610) 6837-9960.</p>
<p>512th Research Institute 北京空间科技信息研究所</p>	<p>The 512th Research Institute is the Fifth Academy's primary information collection and dissemination organization.</p>
<p>513th Research Institute 山东航天电子技术研究所</p>	<p>Established in 1966 and moved to Yantai in 1987, the 513th RI designs and develops satellite-related communications and other electronic equipment. It also has had contracts related to encryption for missile systems. The 513th Institute hosted the visit of Russian Space Agency Director, Anatoly Perminov, in June 2009.</p> <p>Contact Info: Address: 2 Fuyuan Road, Yantai City, Shandong province. Tel: (0535) 684-7911.</p>
<p>514th Research Institute</p>	<p>Established in 1963, the 514th Research Institute is the Fifth Academy's primary entity for measurement and</p>



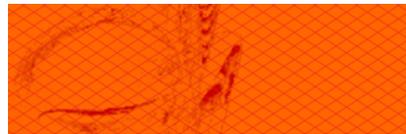
<p>北京东方计量测试研究所</p>	<p>standardization.</p> <p>Contact Info:</p> <p>Address: 61 Zhichun Road, Haidian District, Beijing.</p> <p>Tel: (8610) 6837-9008.</p>
<p>515th Research Institute 汕头电子技术研究所</p>	<p>The 515th Research Institute is responsible for satellite antennas and other components.</p> <p>Contact Info:</p> <p>Address: 6 Keji West Road, Gaoxin District, Shantou City, Guangdong province.</p>
<p>518th Research Institute 山西航天机电设备研究所</p>	<p>Established in 1966, the 518th RI designs and develops satellite-related ground systems.</p> <p>Contact Info:</p> <p>Address: 133 Xinjian Road, Taigu County, Shanxi province.</p> <p>Tel: (0354) 622-3282.</p>
<p>529 Factory 北京卫星制造厂</p>	<p>The 529 Factory is the Fifth Academy's general assembly facility.</p> <p>Director: Wang Zhongyang [王中阳].</p> <p>Contact Info:</p> <p>Address: 63 Zhichun Road, Haidian District, Beijing.</p>
<p>Dongfanghong Satellite Co, Ltd - 中国东方红卫星股份有限公司 - 中国卫星</p>	<p>The enterprise is publicly traded company that offers satellite-related solutions to military and civil users. Its activities include manufacturing of satellite ground equipment, and satellite services, such as satellite integrated applications, satellite navigation, satellite remote sensing and image transmission, satellite communication, television broadcasting, etc. It has eight subsidiaries,</p>



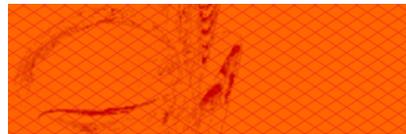
	<p>including ones in Xiamen, Yungang, and Xian.</p> <p>CEO: Li Kaimin [李开民].</p> <p>Contact Info:</p> <p>Address: Haidian District, Beijing.</p> <p>Website: www.spacesat.com.cn.</p>
<p>Space Star Technology Co., Ltd</p> <p>航天恒星科技股份有限公司</p>	<p>Space Star operates as a subsidiary of Dongfanghong.</p> <p>Contact Info:</p> <p>Address: 82 Zhichun Road, Haidian District, Beijing.</p> <p>Tel: (8610) 6837-9103.</p> <p>Website: http://www.spacestar.com.cn/en/index.asp.</p>
<p>SIXTH ACADEMY</p> <p>067 Base</p> <p>Academy of Space Propellant Technology</p> <p>航天推进技术研究院</p> <p>中国航天科技六院</p>	
<p>With roots dating back to 1965 and established in its current form on April 26, 2002, the Sixth Academy is China's primary organization engaged in research, development, and production of liquid fueled propulsion systems. The 067 Base was originally a Third Line complex centered in Fengxian, outside Xian. It Now employs around 10,000 people in four research institutes and one factory, and is headquartered in Xian.</p> <p>Among its more recent products is the YF-77 and YF-100, currently China's most powerful LOX & kerosene rocket engine. The LM-5 rocket is due to be first launched in 2014 from Wenchang Satellite Launch Center on Hainan island.</p> <p>Director: Tan Yonghua [谭永华].</p>	



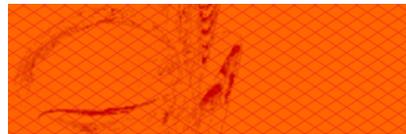
<p>Contact Info:</p> <p>Address: 26 Yuhang Road, Chang'an County, Weiqu Village, Xian City.</p> <p>Tel: (8629) 8520-8114.</p> <p>Website: www.aalpt.com.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>11th Research Institute</p> <p><i>Xian Aerospace Propulsion Institute</i></p> <p>西安航天动力研究所</p> <p>(previously 陕西动力机械设计研究所)</p>	<p>Established in 1958 under the First Academy, the 11th Research Institute is located in Fengxian, near Xian. Employing more than 1,000, it is one of CASC's primary design organizations for liquid fueled propulsion systems.</p> <p>Contact Info:</p> <p>Address: 18 Yuhang Road, Chang'an County, Weiqu Village, Xian City.</p> <p>Tel: (8629) 8520-8114.</p> <p>Beijing Branch; [北京航天动力研究所]:</p> <p>Address: 1 Daohongmen Road, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-2112.</p> <p>Website: http://www.calt11.com.</p>
<p>101 Research Institute</p> <p>- <i>Beijing Institute of Aerospace Testing Technology</i></p> <p>北京航天试验技术研究所</p>	<p>Established in April 1958, the 101st RI is one of China's first space and missile testing facilities. Its engine test stand is a prominent feature in the Yungang area, southwest of Beijing.</p> <p>Contact Info:</p> <p>Address: 1 Tiancheng Zhongli, Fengtai District, Yungang, Beijing.</p> <p>Tel: (8610) 6837-5354.</p>
<p>165 Research Institute</p> <p>陕西动力试验技术研究所</p>	<p>Employing more than 1500 people, the 165 Research Institute is China's largest liquid engine test facility.</p>



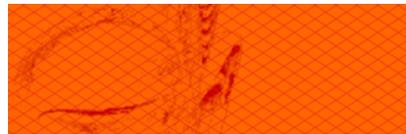
	<p>Director: Shi Fengzhang [史峰章].</p> <p>Contact Info:</p> <p>Address: 18 Yuhang Road, Chang'an County, Weiqu Village, Xian City.</p> <p>Tel: (8629) 8520-6446.</p> <p>Website: http://www.tzhg165.cn.</p>
<p>801st Research Institute <i>Shanghai Institute of Space Propulsion</i> 上海空间推进研究所</p>	<p>Formed after the spinning off and transfer of the Second Academy's 21st Research Institute in the mid-1960s, the 801st RI focuses on launch vehicle and missile engine design and development. Before January 2007, it was referred to as the Shanghai Propulsion Machinery Institute (上海航天动力机械研究所).</p> <p>Deputy Director: Dai Dehai [戴德海].</p> <p>Contact Info</p> <p>Address: 31F, 680 Guiping Road, Xuhui District, Shanghai City.</p> <p>Tel: (8621) 6485-2789.</p>
<p>7103 Factory 西安航天发动机厂</p>	<p>Established in May 1975, the 7103 Factory employs more than 3,000 personnel and occupies 297,000 m² of space. It is China's primary manufacturer of large liquid-fueled engines for the Long March launch vehicles and associated derivatives.</p> <p>Director: 尹宝宜.</p> <p>Contact Info:</p> <p>Address: Yuhang Road, Chang'an County, Weiqu Village, Xian City.</p> <p>Tel: (8629) 8520-6198.</p>



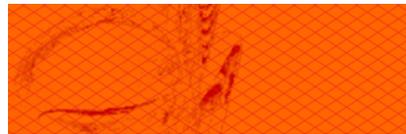
<p>7414 Factory <i>Xian Hangxing Factory</i> 西安航兴动力厂</p>	<p>Established in 1996, the 7414 Factory employs more than 700 people.</p> <p>Contact Info: Tel: (8629) 8520-6031.</p>
<p>Xian Aerospace Measurement and Test Center 西安航天计量测试研究所</p>	<p>Established in 1987, the center is a main measurement and test center for the CASC Sixth Academy</p> <p>Contact Info: Tel: (8629) 8520-7667.</p>
<p>SEVENTH ACADEMY SICHUAN ACADEMY OF AEROSPACE TECHNOLOGY Sichuan Aerospace Industry Corporation 062 BASE 四川航天技术研究院 四川航天工业总公司</p>	
<p>Established in 1965, Sichuan's aerospace industry employees 15,000 people. Its main products include components and sub-assemblies for space and missile systems, as well as the 100 kilometer range WS-1 and 200 kilometer range WS-2 multiple launch rocket systems.</p> <p>Its declared assets amount to U.S. \$791 million (RMB 5.4 billion), and its revenue in 2008 amounted to RMB 2.2 billion</p> <p>Director: Gong Bo [龚波] Deputy Director: Fan Weimin [范维民]</p> <p>Contact Info: Address: Aerospace North Road, Longquanyi District, Chengdu City. Tel: (8628) 8480-7062.</p>	



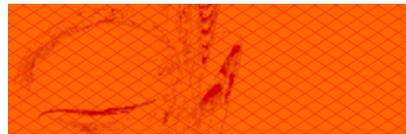
Website: www.scaic.com.cn .	
Important departments, institutes, and factories:	
<p>Seventh Academy R&D Center 七研究院研发中心</p>	<p>Employing 270 people, the Seventh Academy R&D Center engages in a range of aerospace design and systems integration work.</p> <p>Contact Info: Address: Aerospace North Road, Longquanyi District, Chengdu City. Tel: (8628) 8480-3337.</p>
<p>7102 Factory (7102 厂) <i>Long March Machinery Factory</i> 长征机械厂</p>	<p>At one time, located in Wanyuan City. However, it appears the factory is located in Longquanyi District. The factory recently opened an Advanced Manufacturing Technology Center [先进制造技术研发中心]. One specific technology is a special welding [<i>hanjie</i>] system.</p> <p>Contact Info: Address: Aerospace North Road, Longquanyi District, Chengdu City. Tel (8628) 8480-7102.</p>
<p>7105 Factory - <i>Liaoyuan Radio Factory</i> - <i>Sichuan Institute of Aerospace Electronic Equipment</i> 燎原无线电厂 四川航天电子设备研究所</p>	<p>Employing 5,000, the Liaoyuan Factory is an integrated R&D and manufacturing entity focused on navigation, guidance, and control technology, with a special interest on terminal guidance radar systems (including MMW radar seekers) and associated RF circuits.</p> <p>Although its roots go back to 1966, the current organization was formed in July 1992 after the integration of the 7301 and 7306 Research Institutes. It is located in the Longquanyi District Economic and Technological Development Zone.</p>



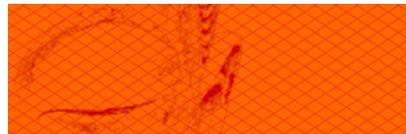
	<p>Contact Info:</p> <p>Address: 105 Yidu Middle Road, Longquanyi District, Chengdu.</p> <p>Tel: (8628) 8480-5365.</p>
<p>7111 Factory</p> <p>- Fenghuo Machinery Factory</p> <p>- Sichuan Institute of Aerospace Electro-Mechanical Engineering</p> <p>烽火机械厂</p> <p>四川航天机电工程研究所</p>	<p>Established in 1966, the factory has more than RMB 500 million in fixed assets.</p> <p>Director: Yi Huachang [易华昌].</p> <p>Contact Info:</p> <p>Address: 198 Changan Road, Chengdu City, Sichuan province.</p>
<p>692 Factory</p> <p>Chuannan Machinery Factory</p> <p>川南机械厂</p> <p>火工技术研究所</p>	<p>The 692 Factory had been involved in production of solid motor ignitors.</p> <p>Director: Wu Huiguo [吴惠国]</p> <p>Contact Info:</p> <p>Address: Luzhou City, Sichuan province.</p> <p>Tel: 0830-279-0593.</p>
<p>7301 Factory</p> <p>Pingjiang Instruments Factory</p> <p>平江仪表厂</p>	<p>No details available at the current time.</p> <p>Contact Info:</p> <p>Address: Aerospace North Road, Longquanyi District, Chengdu City.</p>
<p>7303 Factory</p> <p>Tongjiang Machinery Factory</p> <p>铜江机械厂</p>	<p>Involved in near space UAV propulsion systems.</p> <p>Director: Ran Zhoubing [冉周兵]</p>
<p>7304 Factory</p>	<p>With 300 employees, 7304 Factory is focused on turbojet and other engine component design,</p>



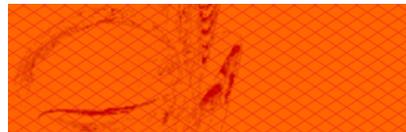
<p>四川达宇特种车辆制造厂 四川航天特种动力研究所</p>	<p>development, manufacturing, and testing. Also referred to as the Mingjiang Machinery Factory [明江机械厂]. The 7304 factory has been engaged in R&D on near space flight vehicle propulsion.</p> <p>Contact Info:</p> <p>Address: 118 Aerospace North Road, Longquanyi District, Chengdu.</p> <p>Tel: (8628) 8480-7080.</p>
<p>7306 Factory <i>Zhujiang Machinery Factory</i> 竹江机械厂</p>	<p>No details available at the current time.</p>
<p>Chengdu Aerospace Wanxin S&T Co, Ltd 成都航天万欣科技有限责任公司</p>	<p>Wanxin is the Seventh Academy's primary standardization and testing enterprise.</p> <p>Contact Info:</p> <p>Tel: (8628) 8480-7903.</p>
<p>Chongqing Academy of Electromechanical Design 重庆航天机电设计院</p>	<p>Established in 1984, the organization has 300 employees focused on fire control and engine control systems.</p> <p>Contact Info:</p> <p>Address: 60 Yuchuan Road, Shiqiaopu High Technology Development Zone.</p> <p>Tel: (8623) 6879-0016.</p>
<p>Sichuan Sunkun Co, Ltd 四川神坤装备股份有限公司</p>	<p>Sunkun Co specializes in hydraulic control systems, with most of its revenue coming from civilian clients.</p> <p>Contact Info:</p> <p>Address: Hangtian Road, Longquanyi District, Chengdu City, Sichuan.</p>



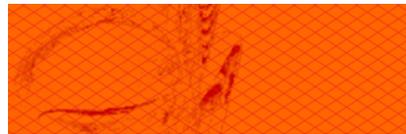
	<p>Tel: (8628) 8480-4200.</p> <p>Website: www.sunkun.com.cn.</p>
<p>Sichuan Aerospace Shidu Guidance Co, Ltd</p> <p>四川航天世都制导有限公司</p>	<p>The entity specializes in aerospace-related laser guidance technology</p> <p>Contact Info:</p> <p>Address: Aerospace North Road, Longquanyi District, Chengdu.</p> <p>Tel: (8628) 8480-6086.</p> <p>Website: http://www.schtlaser.com.</p>
<p>EIGHTH ACADEMY</p> <p>SHANGHAI ACADEMY OF SPACE TECHNOLOGY</p> <p>上海航天技术研究院</p>	
<p>Established in August 1961, the Eight Academy is the space and missile industry's largest and most diverse business division. Employing around 16,800 people, the Shanghai space industry was in large part formed with the transfer of several research institutes (20, 21, 22, 24, and 27 RIs) from the Second Academy in the mid-1960s. With assets totaling US \$2.5 billion (RMB 17.1 billion), the Eighth Academy's revenue [总收入] was U.S. \$1.8 billion (RMB 12.5 billion).</p> <p>Leadership</p> <p>Director: Zhu Zhisong [朱芝松]. Born in 1969, Zhu rose through the ranks of the Shanghai space academy and was appointed director in late 2008, replacing Yuan Jie [袁洁]. Deputy Directors include Qu Ya [曲雁] and Wang Haoping [汪浩平].</p> <p>Contact Info:</p> <p>Address: 222 Caoxi Road, Aerospace Building, Shanghai.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>Eighth Design Department</p> <p><i>Shanghai Institute of Electro-Mechanical Engineering</i></p>	<p>Employing 478 people, the Eighth Design Department carries out systems engineering services and design work on various aerospace systems.</p>



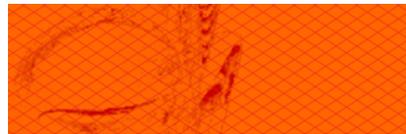
<p>上海机电工程研究所 第八设计部</p>	<p>Contact Info: Address: 412 Guilin Road, Xuhui District, Shanghai. Tel: (8621) 439-1460.</p>
<p>509th Research Institute (509 所) <i>Shanghai Institute of Satellite Engineering (SISE)</i> 上海卫星工程研究所</p>	<p>Established in December 1969, the 509th Research Institute is Shanghai's primary satellite design, research, and development organization. Its main products would include weather and synthetic aperture radar (SAR) satellites, and possibly electronic intelligence systems.</p> <p>Contact Info: Address: 251 Huayin Road, Minhang District, Shanghai. Tel: (8621) 6430-1091.</p>
<p>800th Research Institute <i>Shanghai Institute of Precision Machinery</i> 上海航天精密机械研究所</p>	<p>The 800th Research Institute designs, develops launch vehicles. Presumably, products include vehicles in the Long March 4 (LM-4) series.</p> <p>Contact Info: Address: 76 Gui'de Road, Songjiang District, Shanghai. Tel: (8621) 5773-3685.</p>
<p>802nd Research Institute <i>Shanghai Institute of Radio Equipment</i> 上海无线电设备研究所</p>	<p>The 802nd Research Institute focuses on missile-related precision radar guidance systems and fuses, especially radar precision guidance and transmission systems. The institute has six offices for R&D and five component manufacturing centers. It publishes the journal <i>Guidance and Fuse</i>. Employing about 800 personnel, the institute manages assets valued at RMB 400 million.</p> <p>Contact Info Address: 201 Liping Road, Yangpu district, Shanghai.</p>



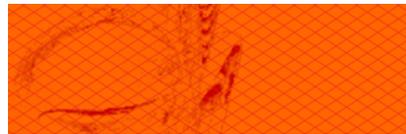
	Tel: (8621) 6519-6883.
<p>803rd Research Institute <i>Shanghai Xinyue Instrument Factory</i> 上海新跃仪表厂</p>	<p>The Xinyue Factory develops and manufactures guidance, navigation, and control systems assemblies and components, with a specialized focus on infrared terminal guidance. Its 1400 employees occupy 74,000 m² of workspace.</p> <p>Contact Info: Address: 710 Yishan Road, Shanghai. Tel: (8621) 5464-0241. Website: www.aeroxy.com.</p>
<p>804th Research Institute <i>Shanghai Institute of Electronic and Communications Equipment</i> 上海航天电子通讯设备研究所</p>	<p>Responsible for radar ground stations and satellite applications.</p> <p>Contact Info: Address: 76 Qiqihar Road, Shanghai. Tel: (8621) 5521-7601.</p>
<p>805th Research Institute <i>Shanghai Institute of Space Systems Engineering</i> 上海宇航系统工程研究所</p>	<p>The 805th Institute is Shanghai's primary systems design institute for space launch vehicles and satellite applications.</p> <p>Director: Zhang Yuhua [张玉花].</p> <p>Contact Info: Address: 3805 Jindu Road, Minhang District, Shanghai. Tel: (8621) 5442-0565.</p>
<p>806th Research Institute 上海航天化工应用研究所</p>	<p>Carries out R&D into space power sources, such as batteries.</p> <p>Contact Info:</p>



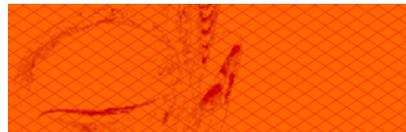
	Address: Huzhou.
<p>807th Research Institute</p>	<p>Established in 1980, the 807th Institute functions as the 8th Academy's information collection and dissemination group.</p> <p>Contact Info:</p> <p>Address: 408 Guilin Road, Shanghai.</p>
<p>808th Research Institute</p> <p>上海精密计量测试研究所</p>	<p>The 808th Research Institute conducts testing and certification of components.</p> <p>Contact Info:</p> <p>Address: 570 Yongjia Road, Shanghai.</p> <p>Tel: (8621) 6433-1840.</p>
<p>809th Research Institute</p>	<p>LV and tactical weapons computer automation launch control systems design and satellite control computers. Established in 1979.</p> <p>Contact Info:</p> <p>Address: 492 Anbei Road, Changning District, Shanghai.</p>
<p>810th Research Institute</p> <p><i>Shanghai Xinli Power Equipment Institute</i></p> <p>上海新力动力设备研究所</p>	<p>Designs and develops solid motors.</p> <p>Contact Info:</p> <p>Address: 3333 Dongfang Road, New Pudong District, Shanghai.</p>
<p>811th Research Institute</p> <p><i>Shanghai Institute of Space Power Sources</i></p> <p>上海空间电源研究所</p>	<p>Employing over 500 people, the 811th Research Institute develops power sources for a range of flight vehicles.</p> <p>Contact Info:</p>



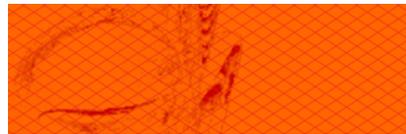
	Address: 388 Cangwu Rd, Shanghai.
<p>812nd Research Institute <i>Shanghai Institute of Control Engineering</i> 上海航天控制工程研究所</p>	<p>Designs and develops space vehicle control systems. Cooperative relationship on civil-military integration with the Shanghai Aerospace Automobile Electromechanical Company.</p> <p>Contact Info: Address: 130 Tianlin Road, Shanghai. Tel: (8621) 6483-7779.</p>
<p>813th Research Institute 上海航天测控通信研究所</p>	<p>The 813th RI's 400 employees design and develop tracking and communications systems for missiles, launch vehicles, and satellites.</p> <p>Contact Info: Address: 881 Tianbao Road, Shanghai. Tel: (8621) 6503-7797.</p>
<p>814th Research Institute <i>Xinguang Communications Factory</i> 新光电讯厂</p>	<p>Conducts R&D and manufacturing of a wide range of telecommunications systems.</p> <p>Contact Info: Address: 1200 Zhongshan North Road One, Shanghai.</p>
<p>Shanghai Xinxin Machinery Factory 上海新新机器厂</p>	<p>Established in 1961, Xinxin has been focused on engines and other aerospace systems.</p> <p>Factory Director: Qiao Ruiyi [乔瑞毅]</p> <p>Contact Info: Address: 111 Chenpu Road, Pudong District, Shanghai. Tel: (8621) 5844-1661, 5891-0540.</p>



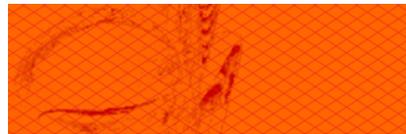
	Website: http://www.xxjq.com.cn .
<p>149th Factory 上海航天设备制造总厂</p>	<p>The factory is the primary assembly facility for launchers for air defense systems developed by the Eighth Academy.</p> <p>Contact Info: Address: 100 Huayu Road, Minhang District, Shanghai. Tel: (8621) 6430-1161.</p>
<p>223 Factory <i>Shanghai Xinli Machinery Factory</i> 上海新力机器厂</p>	<p>The Xinli Factory has manufactured tactical missile engines and motors.</p> <p>Contact Info: Address: 3333 Dongfang Road, Pudong District, Shanghai.</p>
<p>244 Factory <i>Shanghai Xinyu Factory</i> 上海新宇电源厂</p>	<p>The Xinyu Factory has produced batteries for a range of aerospace applications.</p> <p>Contact Info: Address: 165 Laohumin Road, Shanghai. Tel: (8621) 5816-0680. Website: http://www.sh-xinyu.com.</p>
<p>Shanghai Xinzhonghua Factory 上海新中华机器厂</p>	<p>The Xinzhonghua Factory is the Shanghai aerospace industry's primary launch vehicle systems integration factory.</p> <p>Contact Info: Address: 110 Huayin Road, Minhang District, Shanghai.</p>
<p>NINTH ACADEMY CHINA AERSOPACE TIMES ELECTRONICS CORPORATION</p>	



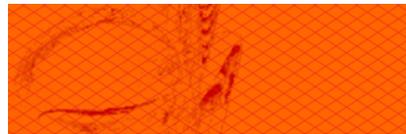
<p>(CATEC) 中国航天时代电子公司</p>	
<p>The Ninth Academy, formed in part on the basis of China Aerospace Times Electronics Corporation, was created in March 2003 and (again in February 2009) and marks the consolidation of research and manufacturing entities involved in electronic components, on-board computers, and inertial guidance systems. Most had been subordinated to the CASC First Academy (CALT). It employs 15,000 personnel.</p> <p>Director: Liu Meixuan [刘眉玄].</p> <p>Contact Info: Address: 188 North Fourth Ring Road West, Fengtai District, Beijing. Tel: (010) 8853-0118.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>13th Research Institute <i>Beijing Institute of Control Devices</i> 北京控制仪器研究所</p>	<p>China's primary designer and developer of inertial instruments, with a special focus on strap down inertial guidance systems. Located in the Second Academy complex in western Beijing, it has more than 800 employees.</p> <p>Contact Info: Address: 52 Yongding Road, Haidian District, Beijing. Tel: (8610) 6838-8949.</p>
<p>16th Research Institute 西安航天精密机电研究所</p>	<p>Established in 1966 and with more than 1400 employees, the 16th Research Institute focuses on inertial navigation components. It originally was subordinated to the CASIC Second Academy. It has a close relationship with the 7171 Factory, and both are located in what appears to be new facilities in Xian's southern suburbs (Chang'an District's "Aerospace City").</p> <p>Contact Info:</p>



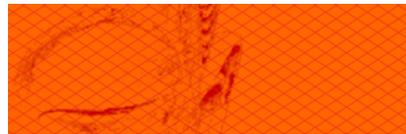
	Tel: (8629) 8561-9614.
<p>704 Research Institute <i>Beijing Institute of Telemetry (BRIT)</i> 北京遥测技术研究所</p>	<p>Established in 1957, the institute has 1400 employees designing and developing navigation, control, and attitude control systems and components, including satellite navigation, tracking and telemetry, MEMS, radar signal processing, and others. Its commercial name is the Aerospace Long March Rocket Technology Company [航天长征火箭技术有限公司].</p> <p>Director [所长]: Li Yanhua [李艳华].</p> <p>Contact Info: Address: 1 Dahongmen, Donggaodi South, Fengtai District, Beijing. Tel: (8610) 6875-0851.</p>
<p>771 Research Institute 西安微电子技术研究所</p>	<p>Originally established in Beijing in 1965, the 771st RI is now situated in Xian, one of China's centers for advanced microelectronics R&D. It engages in R&D in military-grade integrated circuits and on-board computers. It also has developed amplifiers [功率], including those used for civilian light emitting diodes.</p> <p>Director: Zhang Junchao [张俊超]</p> <p>Contact Info: Address: 189 Taiyi Road, Xian City. Tel: (8629) 8226-2655. Website: http://www.lishan.net.cn.</p>
<p>772 Research Institute <i>Beijing Microelectronic Technology Institute (BMTI)</i> 北京微电子技术研究所</p>	<p>Established in 1994 with more than 400 employees, the 772 RI specializes in design and development of military-standard very large scale integrated circuit (VLSIC) ceramic packaging and mounting technology. This includes radiation-hardened ICs, system on chip, digital signal processors, and analog to digital and</p>



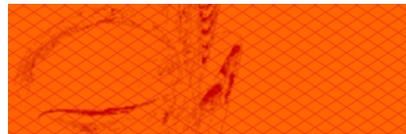
	<p>digital to analogue converters. Receives an annual government grant of \$8.8 million for R&D research.</p> <p>Its commercial alter ego is MXTronics Corporation [时代民芯], which was established in 2005. Its 2008 revenue was \$365 million and its target for 2009 is \$482 million.</p> <p>Contact Info:</p> <p>Address: No. 2 North Road, Siyingmen Donggaodi, Fengtai District, Beijing.</p> <p>Tel: (8610) 6838-4700.</p>
<p>165 Factory <i>Guilin Space Components Co.</i> 桂林航天电器公司</p>	<p>Manufactures electronic components.</p> <p>Contact Info:</p> <p>Tel: 0773-3866680.</p> <p>Website: http://www.gatechcorp.com/gs/fzlc.htm.</p>
<p>Aerospace Times Opto-Electronic Technology Company 航天时代光电科技有限公司</p>	<p>Engaged in design and development of fiber optic gyros. Received patent from an unknown Ukrainian organization for gyro production.</p> <p>Director: Wang Wei [王巍]</p>
<p>200 Factory <i>Beijing Guanghua Factory</i> 北京光华无线电厂</p>	<p>Established in 1965, the 200 Factory manufactures guidance and attitude control-related electronic sub-assemblies. With over 1,000 employees, the factory is collocated in CASIC Second Academy complex in western Beijing. It has a commercial subsidiary, the Beijing Guanghua Electronic Technology Company [北京航天光华电子技术有限公司].</p> <p>Director: Wang Dongqiang [王东强]</p>



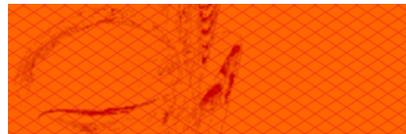
	<p>Contact Info:</p> <p>Address: 50 Yongding Road, Beijing.</p> <p>Tel: (010) 6838-8686.</p>
<p>230 Factory</p> <p><i>Beijing Xinghua Machinery Factory</i></p> <p>北京兴华机械厂</p>	<p>Employing more than 1,000 and with registered capital of RMB 100 million, the 230 Factory is a key manufacturer of precision inertial guidance instruments. The factory is collocated in CASIC Second Academy complex in western Beijing. It was formerly under the First Academy until its re-subordination in 2005. With the 7171 and 7107 Factories supposedly modeled after the 230 Factory, the relationship between these three manufacturing facilities is unknown at the current time.</p> <p>Contact Info:</p> <p>Address: 52 Yongding Road, Haidian District.</p>
<p>289 Factory</p> <p><i>Chongqing Bashan Instrument Factory</i></p> <p>重庆巴山仪器厂</p>	<p>Since 1965, Bashan has been a primary manufacturer of satellite communications and telemetry systems. Employing 500 (290 technical), it's a key organization for collection of data during missile tests.</p> <p>Director: Zhang Po [张波].</p> <p>Contact Info:</p> <p>Address: 85-1, Shixin Road, Shiqiaopu, Jiulongpo, Chongqing.</p> <p>Tel: (8623) 6846-3088.</p> <p>Website: http://www.ht289.com/index.asp.</p>
<p>539 Factory</p> <p>- <i>Shanghai Institute of Space Electronic Equipment</i></p> <p>- <i>Shanghai Aerospace Electronics Company</i></p>	<p>Employing more than 700 personnel, the 539 Factory designs and develops satellite communications components. It was previously known as the Shanghai Scientific Instruments Factory [上海科学仪器厂].</p>



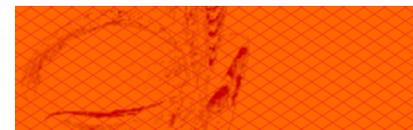
<p>上海空间电子设备研究所</p>	<p>Contact Info: Tel: (8621) 5992-5678.</p>
<p>693 Factory <i>Zhengzhou Aerospace Electronics Technology Company</i> 郑州航天电子技术有限公司</p>	<p>The 693 Factory produces microelectronic components and employs 790 personnel. Located in the Zhengzhou new high technology zone, it is a subsidiary of Rocketstock [长征火箭股份].</p> <p>Contact Info: Address: 102 Guangming Road, Zhumadian, Henan Province. Tel: (8639) 6382-1408; (86371) 6799-1062. Website: http://www.ht693.com.</p>
<p>825 Factory <i>Hangzhou Aerospace Electronic Co, Ltd</i> 杭州航天电子技术有限公司 (泰兴分厂)</p>	<p>The 825 Factory manufactures electronic connectors for the aerospace industry.</p> <p>Contact Info: Address: 968 Shangtang Road, Hangzhou. Tel: (86571) 8801-2825. Website: www.hzconnector.cn.</p>
<p>7107 Factory</p>	<p>Established in May 1968 as a Third Line factory, the 7107 Factory manufactures inertial guidance components, such as accelerometers, for missiles, launch vehicles, and manned space vehicles. It is located in Baoji, has 300 employees, and assets valued at RMB 430 million. Its commercial name is the Shaanxi Aerospace Navigation Equipment Company (SANEC; [陕西航天导航设备有限公司]).</p> <p>Contact Info: Address: 43 Baoguang Road, Baoji City, Shanxi Province. Tel: (8691) 7336-2092.</p>



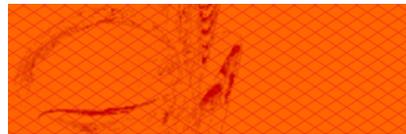
<p>7171 Factory 陕西苍松机械厂</p>	<p>Established in May 1968 as a Third Line factory, the 7171 Factory manufactures inertial guidance components, such as gyroscopes, for missiles, launch vehicles, and manned space vehicles. It has 1432 employees.</p> <p>Contact Info: Tel: (8629) 8561-9614.</p>
<p>ELEVENTH ACADEMY China Academy of Aerospace Aerodynamics (CAAA) 航空气动力技术研究院</p>	
<p>The Eleventh Academy was formed on the basis of the 701st Research Institute, or the Beijing Institute of Aerodynamics (BIA; [北京空气动力研究所]). Employing around 1,000 people, its primary function is aerodynamic testing, but it also designs, develops, and produces a range of components.</p> <p>Director: Li Feng [李锋].</p> <p>Contact Info: Address: 17 Yungang West Road, Fengtai District, Beijing. Tel: (8610) 8853-9794. Website: http://www.sensor701.com.</p>	
<p>Important departments, institutes, and factories:</p>	
<p>701st Research Institute Beijing Institute of Aerodynamics</p>	<p>BIA was founded in 1956 as China's first large scale aerodynamic R&D base.</p> <p>Contact Info: Address: 17 Yungang West Road, Fengtai District, Beijing. Tel: (8610) 6874-3294. Website: www.bia701.com.</p>



<p>707th Research Institute 信息咨询研究中心</p>	<p>The 707th Research Institute provides engineering consulting services.</p> <p>Contact Info: Website: http://www.caecc.com.</p>
<p>708th Research Institute 中国航天标准化研究所</p>	<p>Established in 1965, the 708th Research Institute specializes in standardization and testing.</p> <p>Contact Info: Address: 89 Xiaotun Road, Fengtai District, Beijing. Tel: (8610) 8810-8023.</p>
<p>710th Research Institute 北京信息控制研究所</p>	<p>The 710th Research Institute specializes in software engineering.</p> <p>Contact Info: Tel: (8610) 6837-2493.</p>
<p>Shenzhen Academy of Aerospace Technology 深圳航天科技创新研究院</p>	
<p>Established in 2000, the Shenzhen Academy of Aerospace Technology is a joint venture between CASC, the Shenzhen City government, and Harbin Institute of Technology. It specializes in radio frequency identification (RFID), digital trunking communication systems, GPS vehicle location, radio frequency monitoring systems, as well as systems integration services. It has a relationship with a number of organizations, including the Bauman Institute in Russia, Samara State Aerospace University (SSAU), Russian Academy of Sciences (Far East Branch), Far East Technical University, Novosibirsk State Technical University, National Technical University of Ukraine, and Saint Petersburg Electrotechnical University.</p> <p>Director: Zhang Hua [张华].</p> <p>Contact Info: Address: 10 Keiji South Road, High-Tech Zone, Nanshan Dist, Shenzhen.</p>	

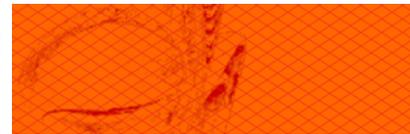


<p>Tel: (86755) 2672-7074.</p> <p>Website: http://www.szaat.com.</p>	
<p>Shenzhen Aerospace Spacesat Co., Ltd</p>	<p>The enterprise was jointly founded by China Spacesat Co. Ltd., Harbin Institute of Technology and Shenzhen Academy of Aerospace Technology. It will be part of a research, development and manufacturing base for the aerospace industry in Shenzhen, and is expected to develop six to eight types of satellites and produce four to five satellites every year. The satellites (probably Compass program systems) will be used for global navigation, telecommunications, remote sensing and space exploration.</p> <p>An unnamed CASC research institute is also said to be moving into the base in Shenzhen. The facilities are to be based in the Shenzhen Hi-Tech Industrial Park.</p>
<p>China Aerospace International Holdings Limited (CASIL)</p> <p>中國航天國際控股有限公司 (航天控股)</p>	
<p>China Aerospace International Holdings Limited, together with its subsidiaries, manufactures and sells plastic injection products, intelligent chargers, liquid crystal displays, and printed circuit boards. It offers printed circuit boards; electronic products, including AC/DC adapters, AC/DC switching adapters, cigarette light adapters, laptop AC adapters, plug adapters, portable intruder alarms, remote controls, standard battery chargers, and switching power supplies; and plastic products and moulds, polyfoam packing materials, and rechargeable batteries. The company also engages in the assembly of various plastic, metal, and electrical components; and the electroplating of plastic products. China Aerospace International Holdings sells its products in the Americas, Europe, Asia, Mid East/Africa, and Australasia.</p> <p>Leadership:</p> <p>CASC Deputy Director Wu Zhuo serves as Chairman of the Board.</p> <p>Mr. Zhao Liqiang serves as Executive Director and President.</p> <p>Contact Info:</p> <p>Address: Room 1103-1107A, 11/F, One Harbourfront, 18 Tak Fung Street, Hunghom, Kowloon, Hong Kong.</p> <p>Tel: (852) 2193 8888.</p>	



Acknowledgements:

The author would like to express appreciation to Andrew Erickson (Naval War College), Paul Giarra (Global Strategies & Transformation) and William S. Murray (Naval War College), and others on a non-attribution basis for reviewing previous drafts and offering thoughtful comments.



¹ Military Power of the People's Republic of China 2009, Annual Report to Congress, *Pursuant to the National Defense Authorization Act, Fiscal Year 2000*, March 2008, p. 21. Also see Norman Friedman, "China Working on Anti-Ship Ballistic Missiles," *Naval Institute Proceedings*, July 2006, pp. 90-91. Dr. Jeffrey Lewis from the New America Foundation was one of the first to identify the specific variant as the DF-21D in October 2008. This was confirmed by a DoD spokesperson in March 2009.

² Wang Zaigang, "The Nemesis of Super Aircraft Carrier Battle Groups" [超级航母编队的克星], *Naval and Merchant Ships [Jianchuan zhishi]*, January 5, 2005, pp. 24-27.

³ Near space is the region of [Earth's atmosphere](#) that lies between 20 and 100 km (65,000 to 325,000 feet). In simple terms, near space is the domain above where a commercial [airliner](#) flies but below the realm of an orbiting [satellite](#). An airship is a lighter-than-air aircraft having propulsion and steering systems. Chinese research and development on near space airships and other flight vehicles is discussed later

⁴ Andrew Erickson and David Yang, "On the Verge of a Game-Changer: A Chinese Antiship Ballistic Missile Could Alter the Rules in the Pacific and Place U.S. Navy Carrier Strike Groups in Jeopardy," *U.S. Naval Institute Proceedings*, Vol. 135, No. 3, (May 2009), pp. 26-32. Also see Andrew S. Erickson, "Chinese ASBM Development: Knowns and Unknowns," Jamestown Foundation *China Brief*, Vol. 9, Issue 13. For a broader summary, see Andrew S. Erickson and David D. Yang, "Using The Land To Control The Sea?: Chinese Analysts Consider the Antiship Ballistic Missile," *Naval War College Review*, Autumn 2009, Vol. 62, No. 4, pp. 53-86.

⁵ The shift in the DDG-1000 program was addressed in U.S. Navy testimony before the Senate Armed Forces Committee in June 2009. For the transcript, see <http://armed-services.senate.gov/Transcripts/2009/06%20June/09-40%20-%206-4-09.pdf>.

⁶ Christopher P. Cavas, "Missile Threat Helped Drive DDG Cut," *Defense News*, August 4, 2008.

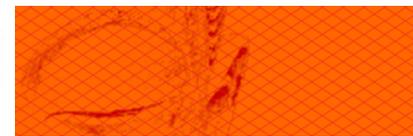
⁷ From Beijing's perspective, Taiwan is an inalienable part of China and has been since ancient times. Chinese on both sides of the Taiwan Strait carried out a prolonged, unremitting struggle against foreign invasion and occupation of Taiwan. Beijing also believes that the international community has acknowledged the fact that Taiwan belongs to China, despite the temporary division. More importantly, China has its own "domino theory" – if Taiwan moves toward independence, separatist activities in Xinjiang, Tibet, and other parts of China would be encouraged. It also claims that no political leader would be able to survive the splitting of the Chinese nation, and therefore Taiwan is a regime survival issue.

⁸ According to the March 2009 DoD Report to Congress on PRC Military Capabilities, "China has expanded the force opposite Taiwan to seven brigades with a total of 1,050-1,150 missiles, and is augmenting these forces with conventional medium-range ballistic missile (MRBM) systems, such as the anti-ship ballistic missile, and at least two land attack cruise missile (LACM) variants capable of ground or air launch."

⁹ For a detailed account of the exercises and their implications, see Robert S. Ross, "The 1995-1996 Taiwan Strait Confrontation: Coercion, Credibility, and Use of Force," *International Security* 25:2 (Fall 2000), pp.87-123. Also see John W. Garver, *Face Off: China, the United States, and Taiwan's Democratization*, (Seattle: University of Washington Press, 1997). The United States acknowledges Beijing's position that there is but one China, and Taiwan is part of China. However, it has not acquiesced to or accepted Beijing's position. Nor has the U.S. attempted to define "One China." While not stating so publicly, Taiwan's international status remains undetermined, and differences between the two sides of the Taiwan Strait should be worked out in a peaceful manner. The agreement in 1979 to abrogate the U.S.-ROC Mutual Defense Treaty and switch diplomatic ties to Beijing rested upon the assumption that Beijing's approach would be peaceful. At the same time, Congress enacted legislation in 1979 – the Taiwan Relations Act – that calls for the United States to maintain the capacity to respond to use of force and other forms of coercion.

¹⁰ See Dennis J. Blasko, "The Pentagon-PLA Disconnect: China's Self Assessments of Its Military Capabilities," *China Brief*, Volume 8, Issue 14, July 3, 2009.

¹¹ See China's Defense White Paper (*China's National Defense in 2008*), January 20, 2009, at http://news.xinhuanet.com/english/2009-01/20/content_10688124_1.htm, accessed on August 29, 2009.



¹² For example, a casual May 2009 search on China's Google search engine using the term "counter aircraft carrier ballistic missile [反航母弹道导弹] can generate more than 7000 results, "ballistic missile striking aircraft carrier" [弹道导弹打航母] generates more than 10,000 hits, and "anti-ship ballistic missile" [反舰弹道导弹] generates 37,000 hits. In contrast, a U.S. Google search using the search term "anti-ship ballistic missile" generates less than 4000 hits.

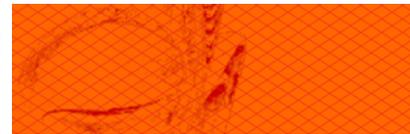
¹³ The best sources include Qiu Weizhen and Long Haiyan, "China's Anti-Ship Ballistic Missile" [中国反舰弹道导弹], *Modern Ships [Xiandai jianchuan]*, 2006 Issue 12(B); and Qiu Weizhen and Long Haiyan, "930 Seconds – A Discussion on China's Development of an Anti-Ship Ballistic Missile (Operational Scenario)" [930秒——中国反舰弹道导弹发展探讨 (作战假想)], *Modern Ships*, 2007 Issue 01(B); and "A Discussion of China's Development of an Anti-Ship Ballistic Missile" February 21, 2008, at <http://blog.huanqiu.com/?uid-6885-action-view-space-itemid-2009>. Also see KKT, "China's Concept Establishing a Theater Conventional Strike Capability," [我国区域常规打击力量建设设想], April 15, 2009, *Military Forum* (Bulletin Board Site), at <http://top81.ws/show.php?f=1&t=795524&m=5199452>, accessed on June 12, 2009. KKT is a popular technical bulletin board commentator on Chinese missile issues, especially with regard to solid rocket motor technology.

¹⁴ Yi Ming, "Secret Nemesis of the US Aircraft Carrier: 1996 Concept for Countering Aircraft Carriers," *Military World* [Lianyungang], <http://gsj.lyg.gov.cn/www/ShowArticle.asp?ArticleID=128630>, August 28, 2008, accessed on January 3, 2009 (now a broken link, perhaps due to its status as a government website). "Yi Ming" is an anonymous pseudonym. Also see a Taiwanese analysis, "Secret Aircraft Killer Weapon? Technical Analysis of the Anti-Ship Ballistic Missile," *Defense Technology Monthly*, July 2007. The analysis is discussed in Chang Litian, "Taiwan Media Reveals Three Secret Technologies for China's Aircraft Carrier Killers," *Zhonghua Network*, August 4, 2008, at <http://www.u-chinese.com/2008-08-04-00-36-28/402-3.html>. These and other popular articles refer to a 1000 kilometer range DF-15 SRBM, a 1500-2000 kilometer range DF-21 MRBM, and a 3000 kilometer range DF-25B MRBM. A 1000 kilometer range DF-15 ASBM variant is possible, as is development of a 3000-kilometer range ASBM variant. However, the DF-25 designation is questionable. The DF-25 was a conceptual 1700 kilometer range system from the 1980s. The aerospace industry advocated PLA Second Artillery procurement of the missile system to use in the South China Sea for extended range fire support for the PLA Navy. While similar in range to the DF-21, the DF-25 adopted the first and a modified second stage of the DF-31 ICBM. The DF-25 payload was said to be 2000 kilograms (kg), much larger than the earlier DF-21 variant's 600 kg warhead. While unclear, the program is said to have been terminated in 1996. See John Wilson Lewis and Hua Di, "China's Ballistic Missile Programs: Technologies, Strategies, and Goals," *International Security*, Fall 1992, (Vol 17, No. 2), pp. 5-40.

¹⁵ For an overview of the technological imperative theory, see Barry Buzan and Eric Herring, *The Arms Dynamic in World Politics*, (Boulder: Lynne Rienner, 1998). Also see Hasan Ozbekhan, "The Triumph of Technology: 'Can Implies Ought'," in Joseph P. Martino (ed.), *An Introduction to Technological Forecasting*, (New York: Gordon and Breach, 1972), pp. 83-92.

¹⁶ One shouldn't be surprised to start seeing China's space and missile industry patenting key defense technologies. In addition, the push to publish S&T papers may account for the number of ASBM and other conventional strategic strike articles that appear in peer-reviewed journals. For assessments of China's R&D and industrial capacity, see Zhang Hong, Miao Jiansong, Qi Zaikang, and Liu Xiongfei, "Research on Terminal Guidance Precision of Tactical Ballistic Missile Striking Aircraft Carriers" [战术弹道导弹打击航母的末制导精度研究], *Journal of Projectiles, Rockets, Missiles, and Guidance [Danjian yu zhidao xueba]*, October 2008, pp. 2-4. The authors are from the Beijing Institute of Technology. On specialized bulletin board sites, however, some technical aspects of an ASBM program are questioned. For example, commentators on a radar specialty site viewed missile-borne synthetic aperture radar (SAR) for mid-course or terminal guidance as particularly difficult.

¹⁷ *China Science & Technology Statistics Data Book* (2007), Ministry of Science and Technology Of The People's Republic Of China. As of 2006, China's GERD amounted to more than US \$43.89 billion (RMB \$300 billion). China's R&D expenditures have targeted five areas: 1) aerospace (both aviation and space); 2) computers and office automation; 3) electronic and communication technology; 4) medical equipment; and 5) pharmaceuticals. Aerospace R&D investment in 2007 totaled U.S. \$483 million (RMB 3.33 billion).



¹⁸ For a good overview of the 15-year plan, Cong Cao, Richard P. Suttmeier, and Denis Fred Simon, "China's 15-year Science and Technology Plan," *Physics Today*, December 2006.

¹⁹ The Precision Guidance Expert Group has been headed by Chen Dingchang, former CASIC Second Academy Director. See "Introduction to Chen Dingchang, at <http://www.casic.com.cn/n16/n1250/n10984/n17506/17672.html>. Bao Weimin [包为民], director of the CASC First Academy's new 10th Research Institute, serves as deputy. Other key players in this group include Yao Yu [姚郁], head of the Harbin Institute of Technology; Yin Xinliang, former Second Academy Director, CASIC Director, and currently Deputy Chairman of CASIC's S&T Advisory Group; Zhang Tianxu [张天序] an automatic target recognition expert from Huazhong S&T University's Institute for Pattern Recognition and Artificial Intelligence; and Zeng Guangshang [曾广商] from the CASC First Academy's 18th Research Institute. The 863-801 program appears to be aligned with the GAD Precision Guidance Experts Group, with Yao Yu for example serving on both the 863-801 and Precision Guidance Expert Groups. Another expert, Long Teng [龙腾] from Beijing Institute of Technology, also has been on the 863-801 expert group and also sits on the GAD Radar Surveillance Experts Group [总装备部雷达探测专业组] and Satellite Application Expert Group [总装备部卫星应用专业组]. He Songhua [何松华] from Hunan University has been on a number of GAD Committees, with a particular focus on millimeter wave seeker technology, and also was a consultant to the CASIC Second Academy's Second Design Department.

²⁰ Among various sources, see Dr. Tai Ming Cheung, "The Remaking of the Chinese Defense Industry and the Rise of the Dual-Use Economy," Testimony Before the US-China Economic and Security Review Commission, Hearing on China's Proliferation and the Impact of Trade Policy on Defense Industries in the United States and China, July 13 2007. For another good overview of China's defense industrial reforms, see Evan S. Medeiros, Roger Cliff, Keith Crane, James C. Mulvenon, *A New Direction for China's Defense Industry*, RAND Corporation, 2005.

²¹ One could argue that China and the United States are already competing in the area of extended range anti-ship missiles. In July 2009, DARPA announced the second contract for development of a long range anti-ship missile (LRASM) similar to developments in China. Consistent with DARPA's mission to prevent technological surprise, the LRASM concept is designed to "reduce dependence on precision intelligence, surveillance and reconnaissance sources, data links, and GPS by demonstrating advanced onboard sensing and processing capabilities. The unprecedented capabilities will allow precision engagement of moving ships based only on coarse, initial target cueing, even in extremely hostile environments." See <http://www.darpa.mil/news/2009/LRASM2.pdf>.

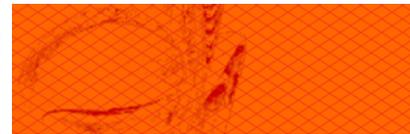
²² The term "aerospace" [航天] is used to describe China's space and missile industry, which is separate and distinct from the aviation [航空] sector.

²³ Military Power of the People's Republic of China 2009, Annual Report to Congress.

²⁴ See "Extreme Urgency: The Fourth Academy Succeeds in Finalizing Design of a Key Conventional Program Within Two Years" [十万火急：航天四院重点常规型号两年实现定型], *China Space News*, May 27, 2006. The new ballistic missile R&D effort was under the leadership of the Fourth Design Department director and chief designer Hou Shiming [侯世明] and with the newly assigned Fourth Academy Director Li Yue serving as test site commander. Born in November 1937, Hou had previously served under Huang Weilu as deputy chief designer of the JL-1 sea-launched ballistic missile. He became head of the Fourth Department in 1993. See "Space Personalities," Hou Shiming, at <http://www.54sh.com/special/universe/hangtianrenwu3.html>, accessed on May 2, 2009.

²⁵ Ibid. Also see "CASIC Fourth Academy Success in Certain Key Program's Flight Test," *China Space News*, August 20, 2003. A key senior designer inside the Fourth Department is Zhong Shiyong [钟世勇]. Janes reported that a DF-21 test involving missile defense countermeasures took place in July 2002. The ASBM variant would be expected to have a similar supply chain, or perhaps even more complex if the CASIC Fourth Academy also assumes responsibility for development of a tailored ASBM sensor fusion center for the Second Artillery.

²⁶ KKT, "China's Development Concept for Theater Missile Strike Power," April 2009. The article was published at http://blog.sina.com.cn/s/blog_596bff040100d5rd.html, but has been removed. According to



KKTT's analysis, three systems under development are: the DF-25; the DF-26; and the DF-27. . KKTT further claims that all four systems are supposed to be tested and fielded before 2015. One other commentator of unknown reliability notes that the DF-26 and DF-27 are being developed separately by CASIC and CASC and only one will be downselected.

²⁷ "Regulations for Contracting Defense S&T Preliminary Research Projects," COSTIND announcement, May 17, 1989. .

²⁸ *China Today: Defense Science and Technology*, Beijing: National Defense Industry Press, 1993, pp. 155-156.

²⁹ See General Work Regulations on Weapons Systems R&D Designer System and Program Management System [武器装备研制设计师系统和行政指挥系统工作条例]. The regulations have been in place since 1984, and unlikely to have changed since then.

³⁰ The latter is the National Basic Research Program and is affiliated with the National Nature Science Foundation. Both have military set asides [known as *junkou*; 军口]. The 863 Program was scheduled for completion in 2000. However, in 2002, a second phase was extended out to 2017. For an excellent overview of the 863 Program, see Evan A. Feigenbaum, "Who's Behind China's High-Technology 'Revolution'?", *International Security*, 24 (1), Summer 1999. For a general idea on spending levels, the 863 Program was allocated RMB 11 billion 2004, 5.5 billion for the 973 Program, and 1.5 billion for the Key Technologies R & D Program.

³¹ ASBM, ASAT, and missile defense kill vehicles all operate at extremely high speeds, are compact, and share common terminal guidance technologies.

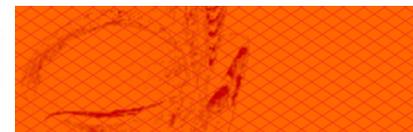
³² For example, Zhejiang University has been actively involved in two related basic research programs, the 863-801 and 863-805 programs.

³³ Feng Jing, "863 Program Spurs Science and Technology," *Beijing Review*, March 29, 2001. Another initiative with possible relevance is the defense portion of the 973 Program (National Security Basic Research; [国家安全重大基础研究]). The 973 Program was launched in 1998,

³⁴ See "Qi Faren: Anti-Satellite Technology Can Be Used to Attack Aircraft Carrier," *Ming Pao*, March 5, 2007, p. A4.

³⁵ The specific 863 designation that appears to cover aerospace and aviation technology is the 863-7 area [领域]. ASAT technologies appear to have been developed under the 863-4 area (Advanced Defense; [先进防御]), specifically the 863-409 topic. Among the research entities involved during the initial R&D on an ASAT kinetic kill vehicle -- euphemistically referred to as a space interceptor [空间拦截器] -- was the Harbin Institute of Technology. Key 863-409 group members include Chen Dingchang [陈定昌], Huang Chunping [黄春平] from Harbin Institute of Technology, Yang Guoguang [杨国光] from Zhejiang University, and Xiao Wen [肖文] from the CASC First Academy, who served as deputy designer of the 409 KKV. Others include Shi Xiaoping [史小平] from Harbin Institute of Technology, Lin Xiangdi [林祥棣] from the Southwest University of Science and Technology, Wan Ziming [万自明] from the Second Academy Second Design Department, Zhou Jun [周军] from Northwest Polytechnical University, who played a leading role in establishing his university's Opto-Electronic and Imaging Precision Guidance Lab [光电和图像精确制导实验室]. Among various sources, see "Report on Recent Research Advances in Micro-Optics" ["微光学的应用及其最新研究进展'学术报告], Announcement, China Jiliang University College of Information Engineering, September 11, 2006, at <http://xxgxcxy.cjlu.edu.cn/ReadNews.asp?NewsID=609>, accessed on June 20, 2009. Chinese engineers on technical bulletin board sites indicate that the KKV "space interceptor" may have been a 35kg microsatellite equipped with experimental imaging infrared and millimeter wave terminal homing package.

³⁶ The Precision Guidance Expert Group has been headed by Chen Dingchang, former CASIC Second Academy Director. See "Introduction to Comrade Chen Dingchang," China Aerospace Science and Industry Corporation, September 20, 2008 at <http://www.casic.com.cn/n16/n1250/n10984/n17506/17672.html>. Bao Weimin [包为民], director of the CASC First Academy's new 10th Research Institute (Near Space Flight Vehicle Institute), serves as deputy. The 863-801 program appears to be aligned with the GAD Precision Guidance Experts Group.



³⁷ “Regulations for Leaders of Key National Defense S&T Labs,” July 11, 2008 and Management Methodology for Key National Defense S&T Labs, July 11, 2008, COSTIND announcements.

³⁸ For an excellent overview of the potential shortcomings of a space-based maritime surveillance architecture, see Eric Hagt and Matthew Durnin, “China’s Antiship Ballistic Missile: Developments and Missing Links,” *Naval War College Review*, Autumn 2009, Vol. 62, No. 4, pp. 87-115.

³⁹ Chen Haidong, Yu Menglun, Xin Wanqing, Li Junhui, Zeng Qingxiang, “Study for the Guidance Scheme of Re-entry Vehicles Attacking Slowly Moving Targets” ([再入飞行器攻击慢速活动目标的制导方案研究]) *Missiles and Space Vehicles (daodan yu hangtian yunzai jishu)*, No. 6, 2000. Also She Eryong, Ma Hongmei, Ding Yuzheng, Xu Xuewen, “Design of Midcourse Surveillance and Tracking Simulation System for Ballistic Missile” [弹道导弹中段监视与跟踪仿真系统设计] *Aerospace Control*, Issue 2, 2007, pp. 68-72. The Beijing Special Electromechanical Institute (First Academy’s 14th Research Institute) is responsible for re-entry vehicle design and R&D.

⁴⁰ The most likely candidates would be one of the organizations that GAD certified as “key defense C4ISR laboratories” (C4ISR[国防重点实验室]). Only a handful of these offices have been established. – the National University of Defense Technology (NUDT), the China Electronics Technology Corporation 28th Research Institute in Nanjing, and the CASIC Fourth Academy’s 17th Research Institute. Of these three, a reasonable assumption would be that the CASIC Fourth Academy would not only serve as the lead systems integrator for the missile but also for the ground segment as well. As an aside, at least some funding for preliminary research on remote sensing appears to have been covered under at least two 863 Programs -- 863-708 and 863-315.

⁴¹ AIS uses a commercial VHF line-of-site transceiver to connects vessels and shore sites that purchase the capability. The network shares hull, location, deployment, and other information. The International Maritime Organization established guidance on the mandatory carriage of AIS transceivers aboard merchant shipping of a certain tonnage.

⁴² Lt Col Ed “Mel” Tomme and Col Sigfred J. “Ziggy” Dahl, “Balloons in Today’s Military? An Introduction to the Near-Space Concept,” *Air & Space Power Journal*, Winter 2005. Also see Lt Col Edward B. Tomme, “The Paradigm Shift to Effects-Based Space: Near-Space as a Combat Space Effects Enabler,” *Airpower Research Institute Research Paper*, 2005-01. For a general Chinese analysis, see Wang Shengkai, Quan Shouwen, Li Binhua, and Ma Qin, “Near Space and Near Space Flight Vehicles” [临近空间和临近空间飞行器], *CONMILIT*, [Xindai junshi], 2007(7), pp. 36-39.

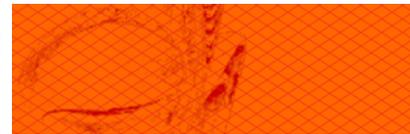
⁴³ Major Andrew J. Knoedler (USAF), “Lowering the High Ground: Using Near-Space Vehicles for Persistent ISR, paper presented to Center for Strategy and Technology, Air War College, November 2005, p. 107.

⁴⁴ For a representative Second Artillery overview, see Li Chao, Luo Chuanyong, and Wang Hongli, “Research into Near Space Flight Vehicle Applications for the Second Artillery” [Jinkongjian feixingqi zai dierpaobing budui de yingyong yanjiu]; Tang Jiapeng, Guan Shixi, Ling Guilong, and Duan Na, “Study on Propulsion System of Near Space Vehicles,” *Journal of Projectiles, Rockets, Missiles, and Guidance*, June 2009, pp. 145-148. Also see Li Zhen, Li Haiyang, and Yong En’mi, “Analysis of Trajectory Characteristics of Near Space Kinetic Weapons,” *Journal of Projectiles, Rockets, Missiles, and Guidance*, June 2009, pp. 183-185. At least some near space flight vehicle research is funded by the 863-705 program.

⁴⁵ Wang Wenqin, Cai Jingye Cai, and Peng Qicong, “Conceptual Design Of Near-Space Synthetic Aperture Radar For High-Resolution And Wide-Swath Imaging,” *Aerospace Science and Technology* (2009), pp. 1-8. Wang is from the University of Electronic Science and Technology of China (UESTC) and claims to be a leading advocate within China of near space SAR remote sensing.

⁴⁶ See Duan Dongbei, “Airship R&D and Application in Aeronautics and Astronautics in China,” Briefing, VEATAL Airship Conference, Beijing, April 24-26, 2008. Duan is from the CASIC 068 Base.

⁴⁷ Yang Jian, “CASC First Academy 10th Research Institute Established” [航天一院 10 所揭牌成立], *China Space News*, October 24, 2008 (in Chinese), at <http://www.china-spacenews.com/n435777/n435778/n435783/49822.html>; Zhan Shige and Meng Qingguo, “Conference Held in Beijing on Developmental Prospects for Near Space Flight Vehicles,” *Bulletin of National Natural Science*



Foundation, May 12, 2006, http://www.nsf.gov.cn/Portal0/InfoModule_375/1111.htm. The establishment of a research institute and its place in the number scheme (“10th” Research Institute) within the CASC First Academy connotes the relatively high priority being placed on near space flight vehicles.

⁴⁸ “A Certain CASC 7304 Factory Engine Moves into the High Altitude, Long Endurance Domain” [航天 7304 厂某发动机迈向无人机中高空长航时领域], *China Space News*, June 22, 2009.

⁴⁹ For a good overview of this thesis, see Gregory Kulacki and Jeffrey G. Lewis, *A Place for One's Mat: China's Space Program, 1956–2003*, (Cambridge, MA: American Academy of Arts and Sciences, 2009).

⁵⁰ For one widely cited article published 10 years ago, see Ma Genhai, “Considerations Regarding China's Military Use Satellite System Entering the Next Century,” *Journal of the Institute of Command and Control Technology* [Zhihui jishu xueyuan xuebao], 1999, Vol. 10, No. 6. Also see Zhu Bin and Chen Xuan, “A Space-Based Electronic Information System for Long Range Precision Strike,” *Aerospace China*, 2007, Issue 3.

⁵¹ Qiu and Long assert that a program to deploy a space-based reconnaissance architecture, programmed under the 863 program for 2015–2020, was accelerated in 2004. The total scope of the space architecture is unknown at the current time. However, in their 2006/7 *Modern Ships* article, Qiu and Long assess that during a crisis, 24 satellites could be available, including six EO satellites, 10 radar reconnaissance satellites, two maritime satellites, and six electronic reconnaissance satellites with a visit rate of 40 minutes. For emergencies, microsats, with a life of 1–2 weeks, can augment large ones and be launched from mobile platforms within 12 hours of an order.

⁵² “China Blasts Off First Data Relay Satellite,” *Xinhua News Agency*, April 26, 2008. For an example of the data relay satellite being used for missile guidance, see Chen Lihu, Wang Shilian, Zhang Eryang, “Modeling And Simulation Of Missile Satellite-Missile Link Channel In Flying-Control Data-Link” [基于卫星中继的导弹飞控数据链路分析], *Systems Engineering And Electronics*, 29(6), 2007. The chief designer of the satellite was Ye Peijian (叶培建).

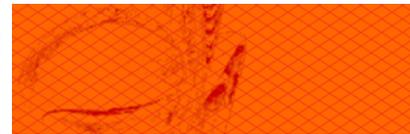
⁵³ Wu Ting-yong, Wu Shi-qi, Ling Xiang, “A MEO Tracking and Data Relay Satellite System Constellation Scheme for China,” *Journal of Electronic Science and Technology of China*, December 2005.

⁵⁴ Chen Deyuan and Tu Guofang, “SAR Image Enhancement Using Multi-scale Products for Targets Detection,” *Remote Sensing Journal* [Yaogan xuebao], March 2007, pp. 185–192. Authors are from the Institute of Electronics, Chinese Academy of Sciences.

⁵⁵ While not 100% certain, the lead systems integrator for SAR satellites appears to be the Shanghai Academy of Space Technology. The SAR package likely is the responsibility of the China Academy of Sciences Institute of Electronics. Shanghai also designed, developed, and manufactured the LM-4 series of launch vehicles, which generally are used for sun synchronous orbit satellites and launched from the Taiyuan Space Launch Center. The LM-4B program manager was Li Xiangrong [李相荣]. For an early discussion on the dual nature aspects of SAR satellites, see Huang Weiken, Zhou Changbao, “Outlook and Requirements for China's Maritime SAR Satellites,” *China Aerospace* [Zhongguo hangtian], 1997(12).

⁵⁶ Guo Huadong, “Spaceborne and Airborne SAR for Target Detection and Flood Monitoring,” *Photogrammetric Engineering and Remote Sensing*, May 2000 (in English). The lead organization for basic research and developmental work is said to be the China Academy of Sciences Institute of Electronics. Also see Zhu Minhui and Wu Yirong, “Extend Progresses in Synthetic Aperture Radar Technology,” paper presented at the Asian Conference on Remote Sensing 1999 (in English). The on-board SAR processor was said to be a joint project between the Beijing Remote Sensing Institute and the Radar Systemtechnik (RST) in Switzerland.

⁵⁷ With cooperation in the area of SAR satellites having been initiated as far back as 1989, the antenna was a topic of discussion during the visit of China Academy of Sciences President to Moscow in 2004. Another topic of the meeting was results of Russian Venus observation mission. Venus observation was used by the Russians in the 1970s and 1980s as a platform for testing RORSAT capabilities. See “Chinese Academy of Sciences Delegation's Trip to Russia is a Success,” *China Academy of Sciences New Release*, July 16, 2004. The specific type of is described as a “net shaped” antenna [合成孔径雷达系统网状抛物面天线].



⁵⁸ The dimensions of the SAR satellite are 1.2m x 1.1m x 3.0 meters. The antenna is 6m x 2.8m. Its ground resolution is 20 meters, although this presumably depends on a range of factors. Its maximum resolution is said to be 5 meters.

⁵⁹ Eventually, the constellation would grow to six and five respectively. "China to Set Up World's First Satellite Constellation for Disaster Monitoring," *People's Daily*, June 25, 2004. Also see Xingling Wang, Gang Wang, Yan Guan, Quan Chen & Lianru Gao, "Small Satellite Constellation for Disaster Monitoring in China," Geoscience and Remote Sensing Symposium, 2005. IGARSS Proceedings, 2005, IEEE International, Vol 1, Issue , 25-29 July 2005, p. 3 (in English). The SAR satellites would operate in the S-Band portion of the frequency spectrum.

⁶⁰ Space industry publications highlighted the chief designer, program manager, and senior engineer for both the 2006 and 2009 after the launches. All are from the CASC Eighth Academy and have been associated with SAR satellite R&D.

⁶¹ Jiang Xingwei, Lin Mingsen, and Tang Junwu, "The Programs of China Ocean Observation Satellites and Applications," National Satellite Ocean Application Service briefing, February 26, 2008 (in English). China launched its first ocean survey satellite, Haiyang-1A, in May 2002. In April 2007, the second ocean survey satellite, Haiyang-1B, was launched. Both were ocean color remote sensing satellites.

⁶² *Defense Science Board Task Force on the Future Of The Aircraft Carrier*, OSD/AT&L, October 2002, pp. 52-53.

⁶³ The GSD ECM and Radar Department (GSD Fourth Department) has the (ELINT) portfolio within the PLA's SIGINT apparatus. This department is responsible for electronic countermeasures, requiring them to collect and maintain data bases on electronic signals. ELINT receivers are the responsibility of the Southwest Institute of Electronic Equipment (SWIEE). The GSD 54th Research Institute supports the ECM Department in development of digital ELINT signal processors to analyze parameters of radar pulses. See Ping Kefu, "Capabilities of The GSD Third Department in Technical Intelligence," *East Asian Diplomacy and Defense Review*, 96 (5), p. 6. Information on China's SIGINT apparatus drawn from Desmond Ball, "Signals Intelligence in China," *Jane's Intelligence Review*, August 1, 1995, pp. 365-375; and Robert Karniol, "China Sets Up Border SIGINT Bases In Laos," *Jane's Defense Weekly*, November 19, 1994, p. 5. The first Chinese ELINT satellite was launched from Jiuquan in July 1975 on the FB-1 launch vehicle which was specifically designed to meet the weight and orbital accuracy requirements of ELINT platforms. The FB-1 launched two more experimental ELINT satellites in December 1975 and August 1976.

⁶⁴ Also see Yuan Xiaokang, "Satellite Electronic Reconnaissance, Antijamming," *Shanghai Hangtian*, October 9, 1996, pp. 32-37, in *FBIS-CST-97-011*; and Yuan Xiaokang, "Some Problems of Space Electronic Reconnaissance," *Hangtian Dianzi Duikang*, March 1996, pp. 1-5, in *CAMA*, Vol. 3, No. 4. Yuan is a key engineer involved space-based antenna systems design, including both ELINT and SAR, from the SAST 509th Research Institute (Shanghai Institute of Satellite Engineering).

⁶⁵ See Appendix One.

⁶⁶ Greg Kulacki should be credited with highlighting the private nature of initial KT funding. Chinese references back up his assertions, and there appears to be a growing trend of initiatives being funded through venture capital.

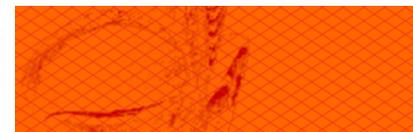
⁶⁷ "China's First Four-Stage Solid Fuelled Launch Vehicle "KT-1" A Success" (*woguo diyixing siji quanguti yunzai huojian "kaituozhe yihao feixing shiyan rongde chengong*), *China Space News*, September 19, 2003.

⁶⁸ Shi Fashu, "Kaituozhe-1 Solid Launch Vehicle Development Planning and Implementation," *China Aerospace (zhongguo hangtian)*, August 2003, pp. 13-16.

⁶⁹ Gu Ti, "Kaituozhe: New Choice for Small Satellite Launches," *Aerospace China*, November 2002, p. 2. There are indications that the KT-2 has been re-designated as the KT-1B.

⁷⁰ See Sean O'Connor's excellent summary of the ASBM and OTH-B programs at <http://geimint.blogspot.com/2008/11/oth-radar-and-asbm-threat.html>.

⁷¹ Another type of OTH radar – a surface wave system -- also operates in the HF band, and relies on "electromagnetic coupling" of the HF waves to the sea surface. This coupling provides a means to detect



targets over the horizon beyond the line-of-sight limit experienced by conventional microwave radar systems. Surface wave systems usually have a surveillance range no more than 400km. Therefore, they are mostly used for local area defense against low-flying missiles and also for some monitoring of ship traffic. Surface wave radars are large and require sophisticated frequency management systems in order to operate via the ever-changing ionosphere.

⁷² See Tang Xiaodong, Han Yunjie, and Zhou Wenyu, "Skywave Over the Horizon Backscatter Radar," 2001 CIE International Radar Conference Proceedings, January 2, 2001. Authors are from the Nanjing Research Institute of Electronic Technology. In a bi-static system, a typical transmitting site, however, can be about 1/6th the size of the receiver.

⁷³ Xin Guo, Ni Jin-Lin, Liu Guo-Sui, "Ship Detection with Short Coherent Integration Time in Over-the-Horizon Radar," Conference Paper, International Conference on Radar (RADAR 2003), Adelaide, Australia on 3-5 September 2003. The three are from the 14th Research Institute and the Research Center of Electronic Engineering Technology, Nanjing University of Science & Technology. For an excellent Western analysis of Chinese OTH-B radar development, see Sean O'Connor, "OTH Radar and ASBM Threat, *IMINT and Analysis*, November 11, 2008 at <http://geimint.blogspot.com/2008/11/oth-radar-and-asbm-threat.html>.

⁷⁴ See Zhang Zhe, "Development of Over-the-Horizon Sensor Technology," *Zhongguo Hangtian*, August 1991.

⁷⁵ Li Le-wei, "High Frequency and Over the Horizon Ionospheric Backscatter Studies in China," *Radio Science*, Volume 33, No. 5, September-October 1998, pp. 1445-1458.

⁷⁶ *Aircraft Carrier (In) Vulnerability: What it Takes to Successfully Attack an American Aircraft Carrier*, Lexington Institute Naval Strike Forum, August 2001.

⁷⁷ The organization most likely responsible for developing the radar architecture for ocean surveillance, including an OTH capability, is the China Electronics Technology Group Corporation (CETC). As a state owned corporation formed in 2002, CETC oversees some 46 research institutes specializing in electronic technology and 26 other high-tech companies.⁷⁷ Two key CETC entities responsible for developing and operating an OTH network includes the Nanjing Nriet Industrial Corporation, a spin off of the Nanjing Research Institute of Electronics Technology (14th Research Institute). Another is Qingdao's China Research Institute of Radiowave Propagation (CETC 22nd Research Institute) also has played a role. It also has a production facility in Xinxiang.

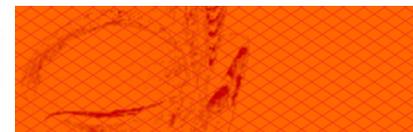
⁷⁸ See Appendix Two.

⁷⁹ "The Dragon Soars to the Ninth Heaven - China's "Soaring Dragon" High Altitude Long Endurance Unmanned Aerial Vehicle," *Xiandai Bingqi*, March 1, 2007, pp 4-8, in OSC CPP20070507436001.

⁸⁰ Some of the initial publications regarding use of ballistic missiles against aircraft carriers, and prioritizing millimeter wave terminal guidance, emerged in 1997. See for example, Xu Minfei, Zhu Zili, and Li Yong, "Feasibility of Technologies for Use of Ballistic missiles to Counter Aircraft Carriers," [*Guofang Keji Cankao*], 1997, 18(4), pp. 126-130, summarized in CAMA. Also see Feng Jianbao, "Feasibility Study of Conventional Ballistic Missiles Attacking Aircraft Carriers," paper presented at the Annual China Astronautics Society UAV Specialists Conference, April 1998, summarized in *Chinese Astronautics and Missilery Abstracts (CAMA)*, Vol. 6, No. 1. Doctrinal writings regarding the applying ballistic missiles in a maritime blockade emerged around the same time. See for example Hu Wenlong (ed), *Study on Joint Blockade Operations [Lianhe fengsuozhan yanjiu]*, Beijing: National Defense University Press, 1999.

⁸¹ A series of meetings were held in the aftermath of the accidental bombing of the Chinese Embassy in Belgrade. A total of 15 programs were designated for acceleration. A CASC committee was formed to plan for the accelerated timeline. See "NATO Bombing: Accelerate Weapons R&D" [*Beiyue zhaxing: wuqi yanzhi jiasu*], China Space News [*Zhongguo hangtian bao*], May 12, 1999, p. 1. Attending the meetings were retired aerospace advisors, Xia Guohong (CAMEC/CASIC Director), Zheng Quanbao (CASC First Academy Deputy Party Chairman), Yin Xingliang (Second Academy Deputy Director), Huang Ruisong (Third Academy Deputy Director), Ye Peijian (Fifth Academy Chief Engineer), and Hua Linsen (066 Base Director).

⁸² "Aerospace First Academy Completes ASBM Proof of Concept Work" (航天一院完成弹道导弹攻击航母概念论证工作), *China Youth Daily* (online) as published by Hong Kong *Tom.com* in Chinese, April 30, 2006, at <http://news.tom.com/2006-04-30/004K/09548193.html> (link has been broken). The article claims that there



was a test of the missile, although few details were offered. As a missile designer, Xin worked in the CASC First Department's 10th Office.

⁸³ For background on CASIC and CASC, see Appendix One and Appendix Two.

⁸⁴ See "China Aerospace's 50-Year Sacred Journey: CASIC's Smelting of Its Strong Kaituoze Spear" [*Zhongguo hangtian 50nian xunli: kegong siyuan zhuzao changjian de jianqiang kaituoze*], *China Space News*, August 11, 2006. Also see <http://www.dolc.de/forum/archiver/?tid-354991.html> for further background.

⁸⁵ The conclusion that the CASIC Fourth Academy is the lead systems integrator is based on the assumption that the ASBM program is centered on the DF-21, and more specifically is an evolution of the DF-21C terminally guided ballistic missile. Jeffery Lewis from the New America Foundation first openly identified the first ASBM variant as the DF-21D, which was confirmed during a March 25, 2009 Pentagon press background brief. Responsible for solid motors less than 2 meters in diameter, CASIC's Sixth Academy has been specifically cited as developing and manufacturing the DF-21D solid rocket motor, as a major sub-system supplier to the CASIC Fourth Academy. The CASIC Fourth Academy should not be confused with the CASC Fourth Academy, which is responsible for large solid rocket motors used on the DF-31 and DF-41 ICBMs. Nor should the CASIC Sixth Academy be confused with the CASC Sixth Academy, which is responsible for liquid fueled propulsion systems. See Appendix One and Appendix Two for organizational details.

⁸⁶ See "Extreme Urgency: The Fourth Academy Succeeds in Finalizing Design of a Key Conventional Program Within Two Years."

⁸⁷ For a good U.S. discussion of the DF-15C, as well as a photo of a DF-15 with a biconic-shaped warhead, see Richard Fisher, "New Chinese Missiles Target the Greater Asian Region," International Assessment and Strategy Center, July 24, 2007.

⁸⁸ For a general survey of terminally guided ballistic missile guidance and navigation technical requirements, see Zhang Yiguang and Zhou Chengping, "Technological Trends Associated with Surface-to-Surface Ballistic Missile Precision Guidance" [*didi dandao daodan sixian yuancheng qingque daji de jishu qujing*], *Tactical Missile Control Technology* [*Zhanshu daodan kongzhi jishu*], 2004(4), pp. 58-60. The authors are from the 066 Base's design department and Huazhong University.

⁸⁹ For a general overview of guidance, navigation, and control technologies associated with an ASBM, see Wang Wei, "Can Ballistic Missiles Become Aircraft Carrier Killers?" [弹道导弹能成为航母克星吗?], *World Military Affairs* [*Shijie junshi*], 2006(4). Also see Qiu and Long, "A Discussion of China's Development of an Anti-Ship Ballistic Missile," *Modern Ships* [*Xiandai jianchuan*], 2006 Issue 12(B).

⁹⁰ See Appendix One and Appendix Two for organizational detail.

⁹¹ See China's Defense White Paper, published in January 2009.

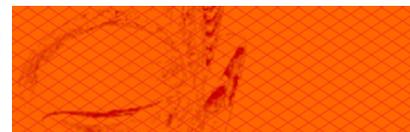
⁹² For a general overview, see Li Xianbin et al., "Microwave Power Module and its Application" [一种新型功率模块及其应用], *Application of Electronic Technique* [*Dianzi jishu yingyong*], 2005(31/11). The author is from the PLA Academy of Information Technology.

⁹³ "Xian Aerospace Base and Xidian University Open New Semiconductor R&D Center," *Xidian University News*, November 5, 2008, at <http://paper.xde6.net/html/xdpaper/20081105/xdpaper1867.html>, accessed on May 20, 2009.

⁹⁴ Use of gallium nitrite in military systems is a relatively recent trend. DARPA has a program to develop electronics based on gallium nitrite materials for integration into U.S. systems.

⁹⁵ Liu Junhu, Lu Jisan, and Wu Xuesen, Regarding DSPs for a New Type of Missile-Borne Control Computer, *Missiles and Space Vehicles*, 2002(1). Zeng Qingxiang has been a key figure in development of computer control systems.

⁹⁶ Zhu Jiang, He Zhiming, Zhou Bo, and Li Jianbin, "Real-time Signal Processing Implementation of the Missile-Borne SAR Using High Performance DSP" [弹载 SAR 实时信号处理研究], *Journal of Electronics and*



Information Technology [Dianzi yu xinxi xuebao], Vol. 30, No. 4, pp. 1011-1013. The authors are from the UESTC in Chengdu.

⁹⁷ Among various sources on the 863-801 focus area, see Zhang Lundong, "Design and Analysis of Pre-amplifier for Detection Circuit of Mechanically Dithered Ring Laser Gyroscope," *Optoelectronic Technology*, 2006, 26(2). 110-114.

⁹⁸ Deng Qiong, Liu Xiaoming, and Deng Bin, "A Design of Self-Adaptive Fuze System Based on MEMS" [基于MEMS的自适应钻地引信系统设计], *Journal of University of Electronic Science and Technology of China* (Dianzi keji daxue xuebao), Vol. 35, Vol. 6 (December 2006), 932-935.

⁹⁹ See Neil M. Barbour, "Inertial Navigation Sensors," The Charles Stark Draper Laboratory, Inc., NATO Paper (RTO-EN-SET-064).

¹⁰⁰ Chen Haidong, Yu Menglun, Xin Wanqing, Li Junhui, and Zeng Qingxiang, "Study for the Guidance Scheme of Re-entry Vehicles Attacking Slowly Moving Targets," *Missiles and Space Vehicles* [daodan yu hangtian yunzai jishu], No. 6, 2000.

¹⁰¹ Yang Zukuai and Liu Dingchen, "Requirements for Countering Aircraft Carriers with Precision Guided Sea-Launched Ballistic Missiles," [Jianchuan lunzheng cankao], March 2004, pp. 7-12. Liu Dingchen, Hu Hai, and Zhang Xing are from the Dalian Naval Academy's Operational Software Research Center.

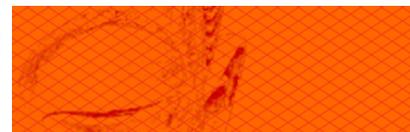
¹⁰² Lin Xinqi, Tan Shoulin, Li Hongxia, "Precaution Model and Simulation Actualization on Threat of Maneuver Target Group on the Sea," *Information Command Control System & Simulation Technology* [(Zhihui Kongzhi yu Fangzhen Jishu)], Vol. 27, No. 4 (August 2005), pp. 28-31. The study argues that the larger a carrier is, the less its turning ability. A 100,000-ton carrier supposedly can make a 90 degree turn in three minutes.

¹⁰³ For one of the best overviews, see Gao Feng, "The Application of Radar Homing Technology in Long Range Precision Guided Missiles" [雷达寻的技术在远程精确制导导弹中的应用] *Aerospace Shanghai* (Shanghai hangtian), 2004 (5), pp. 25-29. Gao is from the Shanghai Academy of Space Technology (CASC Eighth Academy) 802nd Research Institute. This organization specializes in missile guidance systems. Among other various sources, see Zou Weibao, Ren Sicong, and Li Zhilin, "Application of SAR in Combined Navigation System for Vehicle," *Aerospace Control*, Issue 1, 2002; Jiang Jinlong, Mu Rongjun, Cui Naigang, "Application of SAR in Terminal Guidance of Ballistic Missile," *Journal of Ballistics*, Issue 2, 2008; and Zhang Junchang, Hou Yibin, Zou Weibao, and Gao Shesheng, "Study of Tactical Ballistic Missile with Integrated Guidance System SINS/GNSS/SAR," *Journal of Projectiles, Rockets, Missiles and Guidance*, No. 4, 2000. For a design study associated with a DSP for SAR signal processing (TS203), see He Zhiming, Zhu Jiang, and Zhou Bo, "Research on Real Time Signal Processing of Missile-Borne SAR System," *Journal of Electronics and Information Technology*, April 2008, Vol. 30, Issue 4. The authors are from UESTC. CASIC's Third Academy 35th Research Institute also is said to be involved in missile-borne [弹载] SAR guidance R&D, as are engineers from the PLA Navy and PLA Air Force. For the aviation community, the Leihua Electronic Technology Research Institute in Wuxi appears to be doing work in use of SAR for air-to-air missiles.

¹⁰⁴ William H. Licata, "Missile Seekers for Strike Warfare Beyond the Year 2000," paper presented at the NATO Research and Technology Organization (RTO) SCI Lecture Series on "Technologies for Future Precision Strike Missile Systems," held in Tbilisi, Georgia, 18-19 June 2001; Bucharest, Romania, 21-22 June 2001; Madrid, Spain, 25-26 June 2001; Stockholm, Sweden, 28-29 June 2001, and published in RTO-EN-018.

¹⁰⁵ For general overviews, see Wang Qiang, Huang Jianchong, and Jiang Qiuxi, "The Chief Development Trends of Synthetic Aperture Radar" [合成孔径雷达的主要发展方向], *Modern Defense Technology*, April 2007, pp. 81-88. The authors are from the PLA's Institute of Electronic Engineering in Hefei, Anhui province. Also see Qin Yuliang, Wang Jiantao, Wang Hongqiang, and Li Xiang, "Overview of Missile-Borne Synthetic Aperture Radar" [弹载合成孔径雷达技术研究综述], *Signal Processing* (xinhao chuli), April 2009, pp. 630-635. The authors are from the National University of Defense Technology (NUDT), which hosts a National Laboratory for Precision Guidance and Automated Target Recognition [精确制导自动目标识别国家重点实验室].

¹⁰⁶ See for example Chen Haidong and Yu Menglun, "Concept for Maneuvering Re-Entry Vehicle Integrated Guidance" [机动再入飞行器的复合制导方案研究], *Journal of Astronautics* [Yuhang xuebao], Vol. 22, No. 5 (Sep 01), pp. 72.76.



¹⁰⁷ See Gao Feng, "The Application of Radar Homing Technology in Long Range Guided Missiles," *Aerospace Shanghai*, 2004 (5), pp. 25-29. Inertial navigation systems rely on gyros and accelerometers to calculate current position and velocity from a given starting position. On a missile, these components would be critical for stabilizing the SAR antenna.

¹⁰⁸ Zhang Hongrong, Tang Yuesheng, Wu Guan, and Long Sun, "SAR Deceptive Jamming Signal Simulation," conference paper presented at the 1st Asian and Pacific Conference on Synthetic Aperture Radar, 2007. APSAR 2007. Volume 5, Issue 9, pp. 61-64. The authors are from the East China Research Institute of Electronic Engineering in Hefei.

¹⁰⁹ In one Chinese analysis, the ASBM radar is viewed as sophisticated and costly as the AN/APG-77 active electronically scanned array (AESA) radar. With the radar accounting for about half, the authors estimate that the unit cost of an ASBM including the launcher would U.S. \$5-10.5 million. See Qiu and Long, "A Discussion of China's Development of an Anti-Ship Ballistic Missile," *Modern Ships [Xiandai jianchuan]*, 2006 Issue 12(B); and Qiu and Long, "930 Seconds – A Discussion on China's Development of an Anti-Ship Ballistic Missile (Operational Scenario)," *Modern Ships*, 2007 Issue 01(B).

¹¹⁰ Chen Haidong and Yu Menglun, "Concept for Maneuvering Re-Entry Vehicle Integrated Guidance," *Journal of Astronautics [Yuhang xuebao]*, Vol. 22, No. 5 (Sep 01), pp. 72.76.

¹¹¹ Chen Haidong, Yu Menglun, Xin Wanqing, Li Junhui, Zeng Qingxiang, "Study for the Guidance Scheme of Re-entry Vehicles Attacking Slowly Moving Targets," *Missiles and Space Vehicles [daodan yu hangtian yunzai jishu]*, No. 6, 2000.

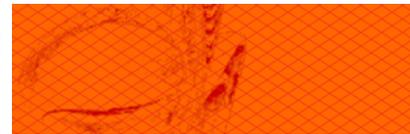
¹¹² See Huang Pinqiu, "Preliminary Analysis of Pershing-II Missile and Warhead" [*poxing-II daodan yu dantou de chubu fenxi*], *Missiles and Space Vehicles*, 1994(1). Huang was from the CASC First Academy's Beijing Institute of Special Electro-Mechanics, which is responsible for re-entry vehicle and warhead development.

¹¹³ See "Qi Faren: Anti-Satellite Technology Can Be Used to Attack Aircraft Carrier," *Ming Pao*, March 5, 2007, p. A4. CASIC – most likely the Second Academy – contracted with the GAD for the ASAT test. The missile was launched from Xichang Space Center and targeted an aging Feng Yun 1C (FY-1C) polar orbit satellite that had been launched in 1999. The successful test supposedly came after three misses on 30 November 2006, 20 April 2006, and 26 October 2005.

¹¹⁴ For an overview of China's ASAT program, see Ian Easton, "The Great Game in Space: China's Evolving ASAT Weapons Programs and Their Implications for Future U.S. Strategy," *Project 2049 Occasional Paper*, June 24, 2009. As a side note, diamond coatings and simulation were key research objectives of an 863-409 team that traveled to the United States for an SPIE conference in 1998. See Chen Dingchang, Wan Ziming, Lin Jin & Liu Decheng, "Key Technologies Introduced at U.S. SPIE'98 Aerodynamic Optics Association Meeting," *Dual Use Technologies & Products [Junmin liangyong jishu yu chanpin]*. While not confirmed, there are indications that the 863-401 KKV program morphed into the 863-801 focus area in the second phase of the 863 Program. Also see Wan Ziming, Chen Dingchang, Yin Xingliang, "Analysis of Key Problems for an Endo-Atmospheric KKV" [大气层内飞行的KKV关键技术分析综述], *Systems Engineering And Electronics [Xitong gongcheng yu dianzi jishu]*, 1999, Vol 21, No. 10. Authors are from CASIC Second Academy.

¹¹⁵ For an early reference to MMW terminal guidance for an ASBM, see Xu Minfei, Zhu Zili, and Li Yong, "Feasibility of Technologies for Use of Ballistic missiles to Counter Aircraft Carriers," [*Guofang Keji Cankao*], 1997, 18(4), pp. 126-130, summarized in CAMA.

¹¹⁶ MMW technology is a key research area under the 863 Program. The Center for Space Science and Applied Research within the China Academy of Sciences and Dongnan University hosts a key national laboratory for testing of MMW systems. For an example of one authoritative discussion of adapting air defense interceptor MMW terminal guidance to anti-ship missiles, see Xia Guifen, Su Hongyan, Ge Zhiqiang, and Huang Peikang, "Study on the High Frequency Resolution Technology on the MMW Radar Seeker," *Journal of Projectiles, Rockets, Missiles, and Guidance*, 2009, Vol. 29, No. 2, pp. 58-60. The authors are from the Beijing Institute of Remote Sensing Equipment (CASIC 25th Research Institute). For a general survey comparing MMW to other types of terminal guidance, see Yang Shuqian, "Development and Prospects of Precision Guidance Munitions," *Aerospace Control [Hangtian kongzhi]*, August 2004, pp. 17-20. Also see Xia Guifen, Zhu Huaicheng, et al., "Study on the Frequency Profile Modeling Technology of the MMW Radar Seeker," *Systems Engineering and*



Electronics [Xitong gongcheng yu dianzi jishu], 2008, Vol. 30, No.9. The authors are from the CASIC Second Academy's 25th Research Institute.

¹¹⁷ Wu Gang Gong Haihua Zhang Xiuhong, "Development of a Miniaturized Ka Band TWT," *Vacuum Electronics*, 2006(6). The authors are from the electronics industry's 12th Research Institute (Beijing Vacuum Electronics Research Institute).

¹¹⁸ Zhang Wei, Sun Houjun, Lu Xin, Hardware-in-the-Loop Simulation and Testing System for Millimeter-Wave Seeker, ,2008. ICMMT 2008. *International Conference on Microwave and Millimeter Wave Technology*, 21-24 April 2008, pp.:630–633. Also see Qin Yuliang, Zhu Sha, Wang Hongqiang, and Li Xiang, Characteristics and Potential Applications of Submillimeter Radar Seeker, *Modern Defense Technology [Xiandai fangyu jishu]*, 2008, Vol. 36, No. 6. The authors are from the National University of Defense Technology.

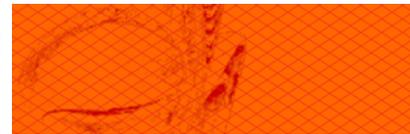
¹¹⁹ For example, see Lin Defu Qi Zaikang, and Wang Zhiwei, "Study on the System Technology of Multi-mode Seeker," *Tactical Missile Technology [Zhanshu daodan jishu]*, 2005(4). The authors are from Beijing Ligong University; and Hu Fuchang, "Improving the Penetrability of Antiship Missile with Multi-mode Composite Seeker," *Guidance and Fuse [Zhidao yu yinxin]*, 2003, Vol 24., No. 3. The author is from the CASC Eighth Academy's 802nd Research Institute, which has also done work on ballistic missile-related SAR guidance. Also see He Yimin and Zhou Jun, "Methods of Data Fusion Based on IR/MMW Dual Model Combined Guidance," *Journal of Projectiles, Rockets, Missiles, and Guidance*, February 2008 (Vol 28, No. 1), pp. 75-78. The authors are from the Northwest Polytechnical Institute's School of Astronautics. Another is Li Xiangping, Li Shizhong, Zhang Gang, and Li Yakun, "Passive Compound Guidance Detection Unit Design Study of Certain Mould Air to Ship Missile Seeker," *Modern Electronics Technology (Xiandai dianzi jishu)*, 2008, Vol. 31, No. 3. The authors, from the PLA Navy's discuss the guidance system in the context of a fast moving missile that acquires its target at a range of 100 km.

¹²⁰ For an earlier assessment, see Wu Guanghua, "Dual-Mode Millimeter Wave-IR Seeker for An Endo-Atmospheric Interceptor," *[Danjian jishu] (Projectile and Rocket Technology)*, Vol. 9, No. 3, 1996, pp. 15-20, in *FBIS-CHI-97-26* 1. The key component is a 35 GHz Ka-Band traveling wave tube amplifier. Chen Anhong, Cao Ju, Gao Xiaoying, & Du Chengqian, "Study on Key Technologies Associated with Surface to Surface Missile Imaging Infrared Terminal Guidance" *[didi daodan hongwai chengxiang mozhidaoo guanjian jishu yanjiu]*, Abstracts from the 2006 National Conference on Electro-Optical Technology in Chengdu. The authors are from the National Aerospace Intelligence Control Technology Laboratory [宇航智能控制技术国防科技重点实验室] in Beijing. Also see Zhang Yiguang, Ding Mingyue, Zhou Chengping, "Key Technologies for Ballistic Missile Infrared Imaging Guidance" [超高速导弹红外凝视成像导引头技术研究], *Journal Of Huazhong University Of Science And Technology [Huazhong keji daxue xuebao]*, Vol. 25, Issue 4 (April), 2004. The engineers are designers from the Sanjiang Space Group (066 Base, makers of the DF-11) and the Huazhong University of Science and Technology. Dong Chaoyang' Shi Xiaorong, and Xia Liancui, "A Fuzzy Adaptive Fusion Algorithm For Radar/Infrared Dual Mode Guidance," paper presented at the Sixth International Symposium on Instrumentation and Control Technology, 13-15 October, 2006, Beijing, China). Shi Xiaorong is from the CASIC Fourth Academy 17th Research Institute.

¹²¹ Liu Zhiguo, Wang Shicheng, Zhang Jinsheng, and Wang Shen, "The Research of Laser Seeker for Terminal Guidance of Ballistic Missile," *Journal of Projectiles, Rockets, Missiles and Guidance*, 25(1), 2005. Also see Min Haibo, Wang Shicheng, Deng Fanglin, Guo Yingran, "Attitude Control System for Laser Terminal Guided Ballistic Missile," *Aerospace Control*, Vol. 24, No. 4 (August 2006), pp. 13-19.

¹²² Xi Jianxing and Yang Bailong, "Application of CO₂ Laser Coherent Imaging Radar in the Navigation of Cruise Missiles and Terminal Guidance of Ballistic Missiles," *Microcomputer Information*, 2006(22). Also see Zeng Xianlin and Tian Xinwei, "CO₂ Laser Coherent Imaging Radar and Its Application Perspectives in Precision Guidance," *Infrared Technology*, 2000 22(4).

¹²³ For a discussion of the challenges associated with guidance systems and the blackout issue, see Wang Wei and Guan Yangze, "Discussion of the Blackout Problem," 863 Aerospace Technology Bulletin [863 航天技术通讯], 1999(6); and Gao Feng, "The Application of Radar Homing Technology in Long Range Guided Missiles," *Aerospace Shanghai*, 2004 (5), pp. 25-29.



¹²⁴ “Peng Xiangling: The Road to Tackling ‘Blackout’: Shenzhou-7 Limits to 11 Seconds,” *Renmin Wang*, July 2, 2009, at <http://scitech.people.com.cn/GB/9582714.html>.

¹²⁵ Terry H. Phillips (Shafer Corporation), *A Common Aero Vehicle (CAV) Model, Description, and Employment Guide*, 27 January 2003, unpublished paper for AFRL and AFSPC. This study asserts that modern thermal protection systems can only survive approximately 800 seconds in a high heat load environment. Much depends on the speed of re-entry. The temperature, measured in kelvins, is said to be equal to the re-entry speed measured in meters per second.

¹²⁶ The 703rd Research Institute also is known as the Aerospace Research Institute of Materials and Processing Technology; or [航天材料及工艺研究所]. The China Academy of Sciences Institute of Metal Research may also be contributing to the effort.

¹²⁷ “Technical Resolution of Thermal Protection for Certain System” [*jiejue moxinghao fang're jishu*], News Release of the Aerospace Research Institute of Materials and Processing Technology (703rd Research Institute), January 14, 2008. The 703rd Institute was founded in the 1950s and its first director was Dr. Yao Tongbin [姚桐斌]. Dr. Yao is considered a national hero not only due to his leading edge work early in China's missile program but also since he was a victim during the initial stages of the Cultural Revolution. His death prompted Zhou Enlai to declare the space and missile industry off-limits to the ravages of the Cultural Revolution.

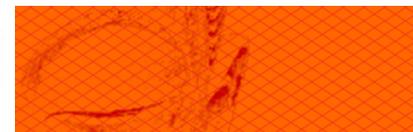
¹²⁸ See Zhang Zongqiang et.al., “Resin Composites on Long Time Ablation and Thermal Protection,” *Aerospace Materials Technology* [*Yuhang cailiao gongyi*], 2007, Vol. 37, Issue 6; Meng Songhe, Du Shanyi, and Han Jiecai, “Research Progress in Thermal Protection Systems and Materials,” paper for the 14th National Conference on Composite Materials, 2006; and Xu Zhenghui, Zhang Zhonghui, Wang Houshan, and Yang Shaoguang, “Study on Low Ablation Carbon Composites and Extended Time Counter Ablation Characteristics,” paper for the 14th National Conference on Composite Materials, 2006. For reference to a Ukrainian relationship on resolving heating problems, see the Academy of Sciences website at http://www.ipp.kiev.ua/about/conne_e.htm.

¹²⁹ Citing a Northwest Polytechnical University and other studies, Qiu and Long believe that the ASBM would adopt sophisticated missile defense countermeasures against U.S. sea-based missile defenses, including masking of the ASBM solid fueled motor's signature, mid-course maneuvering, decoys, coatings to reduce the warhead's radar cross section (RCS), and on-board jamming. Equipped with a hybrid solid and liquid fueled third stage, mid-course maneuvering would involve a boost-glide or hopping trajectory concept [跳跃式弹道方案]. In their detailed ASBM versus sea-based missile defense scenario, the analysis goes through the SBIRS alert process, arguing that SBIRS would not be able to establish an impact prediction point and thus could fail to provide cueing for sea-based missile defense radar systems. They make an argument that Ground Based Radar (GBR) systems in Korea and Japan likely would be unable to establish a track. The analysis also addresses possible attempts by the U.S. High Frequency Active Auroral Research Program (HAARP) in Alaska could fail to jam China's OTH-B system, implying the system has a military role. For an example of detailed analysis on U.S. missile defense systems, see Guo Xijian and Gao Guiqing, “Operational Effectiveness Study of the PAC-3 Missile Defense Systems [PAC-3 反导系统作战效能研究],” *Modern Defense Technology* [*Xiandai fangyu jishu*], 2007, Vol 37, no. 2 (April 2007). The authors are from the Second Artillery Engineering Academy.

¹³⁰ For a more detailed discussion on missile defense, see Mark Stokes, “Chinese Ballistic Missile Forces in the Age of Missile Global Defense: Challenges and Responses,” in *China's Growing Military Power: Perspectives On Security, Ballistic Missiles, And Conventional Capabilities*, edited by Andrew Scobell and Larry M. Wortzel, September 2002, pp. 107-168.

¹³¹ Zhou Yunwu, “Jamming Techniques for Cruise Missile Penetration,” *New Electronic Warfare Technology and Intelligence Reform Abstracts*, 1995 (10), pp. 143-147, in *CAMA* 1996, Vol 3, No. 6. Zhou is from the Third Academy's Beijing Institute of Electromechanical Engineering.

¹³² The primary organization responsible for missile-borne electronic countermeasures and satellite-based electronic support measures is the 8511 Research Institute in Nanjing (Nanjing Institute of Electronic Equipment). As a direct reporting entity under CASIC, it maintains a close relationship with the 29th Research Institute in Chengdu. Another organization possibly involved could be the Southwest Institute of Electronic Engineering (SWIEE), also known as the 29th Research Institute. It is located in Chengdu and is responsible for



radar reconnaissance and electronic countermeasures. The PLA General Staff Fourth Department [总参四部] is responsible for ECM operations. The Director is MG Wan Xiaoyuan.[万晓媛].

¹³³ Chinese testing has demonstrated that ballistic missiles can carry a significant amount of chaff that can affect a large volume of space. Development is focused in part on production of metallic strips that are 1.5 cm in length that can target radar systems that operate at 10 GHz (i.e., X-band radars).

¹³⁴ China has a long history of developing anti-radiation missiles. In the late 1970s, the PLA commissioned the aerospace industry to develop an air launched anti-radiation missile dubbed the Fenglei-7. With the Shenyang 259 Factory responsible for the seeker and inertial guidance package, the missile used a 10cm wide antenna and was tested at the 31 Base. For details, see "The PLA's First Air Launched Anti-Radiation Missile, the Fenglei 7," Nanjing University of Post and Telecommunications Military Update, at <http://www.njupt.edu.cn/pnjupt/org/bwc/ArmedForces/shjsh03.htm>, accessed on July 1, 2009.

¹³⁵ The 8511 Research Institute is said to have a new manufacturing and testing facility in Nanjing's Jiangning Science Park. See "The CASIC 8511 Institute Opens New Construction Project," Jiangsu Provincial Academy of Environmental Science News Release, June 1, 2008, at <http://74.125.47.132/search?q=cache:39y3yxPWKjKJ:www.jsaes.com/gongshi/ShowArticle.asp%3FArticleID%3D167+%22%E5%85%AB%E4%BA%94%E4%B8%80%E4%B8%80%E6%89%80%22&cd=4&hl=en&ct=clnk&gl=us>, accessed on July 1, 2009. For other background on the 8511 Institute, see <http://74.125.47.132/search?q=cache:b7lymKjRdsAJ:www.china-spaceneews.com/n435777/n435780/n435796/51003.html+%2214%E6%89%80%22+%22%E6%89%80%E9%95%BF%22+%E8%88%AA%E5%A4%A9&cd=4&hl=en&ct=clnk&gl=us>. Zhou Mingshan, Xu Ming, Li Chengjun, Wu Shiguo, "MMW Passive Countermeasures Technology and the Application of Expanded Graphite" [毫米波无源干扰技术及膨胀石墨在其中的应用], *Journal of Microwaves (Weibo xuebao)*, 2008 (24)1.

¹³⁶ Mark Stokes, "Chinese Ballistic Missile Forces in the Age of Missile Global Defense: Challenges and Responses," in *China's Growing Military Power: Perspectives On Security, Ballistic Missiles, And Conventional Capabilities*, edited by Andrew Scobell and Larry M. Wortzel, September 2002, pp. 107-168.

¹³⁷ Wang Wei, "Can Ballistic Missiles Become Aircraft Carrier Killers?" [弹道导弹能成为航母克星吗?], *World Military Affairs (Shijie junshi)*, 2006(4).

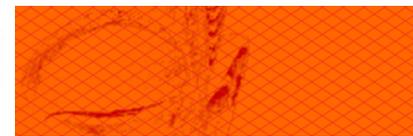
¹³⁸ See "CASIC's Successful Test of Key New Model of Solid Rocket Motor," *Qianlong Military Press*, May 22, 2006, <http://mil.eastday.com/eastday/mil/node62186/node62664/node62665/node136321/userobject1ai2053223.html>.

¹³⁹ "Fifth Announcement of 2009 for Completion and Acceptance of Construction Projects for Environmental Protection" [关于 2009 年第五批建设项目环境保护设施竣工验收公众参与的公示], Hohhot City Government Environmental Protection Bureau, August 20, 2009, accessed on 30 August 2009. The facility is 1780 m². The DF-21A has used the 1.4 meter diameter FG-05C solid rocket motor, while the FG-05D variant was developed for use on the KT-1, KT-409 (probable ASAT vehicle), and probably the DF-21C. As an aside, the 2 meter diameter FG-06 and FG-07 are the first and second stages on the DF-31. There are indications that a 1.7 meter solid rocket motor was developed for the KT-1B solid fueled launch vehicle.

¹⁴⁰ The business division under CASIC appears to focus on smaller diameter solid motors used in CASIC products, while the competing CASC business unit focuses on larger motors used on the DF-31/DF-31A ICBM, as well as for a possible new ICBM, the DF-41.

¹⁴¹ See for example Ye Dingyou and Zhang Dexiong, "Development of China Aerospace Solid Rocket Propulsion Technology," *China Aerospace [Zhongguo hangtian]*, 2002(12). Ye Dingyou is former head of the CASC Fourth Academy.

¹⁴² Aerospace 41st Research Institute Succeeds in Developing a Hybrid Small Satellite Solid-Liquid Propulsion System [航天 41 所研制成功小卫星固液混合动力系统], *China Space News*, March 21, 2008. The chief designer was Zhang Yongmei [张永梅].



¹⁴³ “Regulations for Leaders of Key National Defense S&T Labs,” July 11, 2008 and Management Methodology for Key National Defense S&T Labs, July 11, 2008, COSTIND announcements.

¹⁴⁴ The China Academy of Aerospace Aerodynamics [航天空气动力技术研究院] is an outgrowth of the 701st Research Institute, one of the first missile-related institutes established during the initial years of China’s space and missile program.

¹⁴⁵ For an example of a CARDC simulation of a biconical re-entry vehicle with flaps, see Tang Wei, Ma Qiang, Zhang Yong, and Li Weiji, “A Study On Conic Maneuverability Of A Biconic Vehicle With Flaps,” *Acta Aerodynamica Sinica* [空气动力学学报], March 2006; and Tang Wei and Gu Yawei, “Aerodynamic Analysis for a Re-entry Vehicle with Slice-Flaps,” *Acta Aerodynamica Sinica*, February 2009. The authors are from CARDC.

¹⁴⁶ Overseeing 4566 employees, the 307 Factory director is Yang Shaohua (杨少华), who also serves as the Fourth Academy’s second deputy director. The CASC First Academy’s 211 Factory, located in Beijing, also may play a role in manufacturing developing portions of the missile structure. The 211 Factory is known as the Capital Machinery Corporation.

¹⁴⁷ See “China Aerospace’s 50-Year Sacred Journey: CASIC’s Smelting of Its Strong Kaituoze Spear” (中国航天50年巡礼：科工四院 铸造长剑的坚强开拓者), *China Space News*, August 11, 2006. Also see <http://www.dolc.de/forum/archiver/?tid-354991.html> for further background. 688 mu is about 113 acres, 460,000 square meters, or 0.46 square km. Chenguang’s website claims the company’s manufacturing space is now 720,000 square meters. For the First Academy, the 211 Factory, located adjacent to Nanyuan Airfield south of Beijing, has generally been recognized as the primary assembly plant. For the Third Academy, it has been the 239 Factory (Beijing Hangxing Machinery Corporation).

¹⁴⁸ Qiu Zhenwei and Long Haiyan, “A Discussion of China’s Development of an Anti-Ship Ballistic Missile,” *Modern Ships*, 2006 Issue 12(B); and Qiu Zhenwei and Long Haiyan, “930 Seconds – A Discussion on China’s Development of an Anti-Ship Ballistic Missile (Operational Scenario)” (930秒——中国反舰弹道导弹发展探讨（作战假想）), *Modern Ships*, 2007 Issue 01(B); and “A Discussion of China’s Development of an Anti-Ship Ballistic Missile” February 21, 2008, at <http://blog.huanqiu.com/?uid-6885-action-viewspace-itemid-2009>.

¹⁴⁹ These are the 96163 Unit (811 Brigade) based in the Qimen area in Anhui; and the 96161 Unit (807 Brigade) in Chizhou area, also in Anhui province.

¹⁵⁰ It’s worth noting that it could be possible for an anti-ship guidance, navigation, and control package to be retrofitted onto the PLA Second Artillery’s existing inventory of SRBM and MRBMs.

¹⁵¹ For a detailed account of China’s aerospace campaign doctrine, see Mark Stokes, “The Chinese Joint Aerospace Campaign: Strategy, Doctrine, and Force Modernization.” In *China’s Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the Chinese People’s Liberation Army*. Edited by James Mulvenon and David Finklestein. The CNA Corporation, Virginia. December 2005, <http://www.cna.org/documents/DoctrineBook.pdf>.

¹⁵² Yu Jixun (ed.), *Second Artillery Campaign Science [dierpaobing zhanyixue]*, Beijing: National Defense University Press [jimi], 2004, pp. 159-168. LTG Yu Jixun is the senior Second Artillery Deputy Commander. The decision center would house the senior-most campaign commander [职首长], the political commissar, chief of general staff, and other senior command. The rear and front command centers would house deputy campaign commanders, deputy commissars, deputy chiefs of staff, etc.

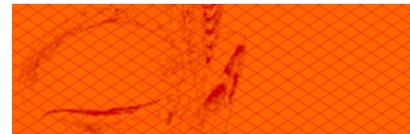
¹⁵³ Yu Jixun, p. 246.

¹⁵⁴ Yu Jixun, p. 149.

¹⁵⁵ Yu Jixun, p. 200. This issue also is discussed in See Hu Wenlong (ed), [Lianhe fengsuo zuozhan yanjiu] (Study on Joint Blockade Operations), Beijing: National Defense University Press, 1999.

¹⁵⁶ Yu Jixun, p. 292.

¹⁵⁷ Ma Bo and Liu Hong, “Consideration of Underground Railway Mobile Launch of Strategic Missiles” [Zhanlue daodan dixia tielu jidong fashe fangshi tansuo], *Missiles and Space Vehicles*, 2005 (2), pp.49-51. The authors



are from the CASC First Academy Institute of Space Launch Technology (15th Research Institute). In their concept, the central storage depot and launch preparation area would be approximately five km from each launch silo. Each launch silo would be separated by no less than 4.88 km, and the entire complex would be contained in a 75 square kilometer area.

¹⁵⁸ Shi Fashu, Yuan Bin, and Chen Shi'nian, "Developmental Prospects for China's Air-Launched Solid-Fuelled Launch Vehicles," *China Aerospace*, 2003(2). As a reference, the U.S. company Orbital Sciences offers air-launched services for placing small satellites in orbit using its Pegasus launch vehicle. It uses an L-1011 aircraft as the launch platform. Also see "Janes Defense Reveals China's Most Recent Aircraft Carrier Surgical Killer" [*jiandi fangfu bao zhongguo zuixin hangmu dashaqi waikeshuli*], August 26, 2008, at http://www.chnqiang.com/article/2008/0826/article_34759.shtml.

¹⁵⁹ See Gan Shaosong, Huang Zuyin, Ye Dingyou, and Gao Bo, "Concepts for Development of Our Country's Solid Launch Vehicles," undated and unsourced (likely 2005). The authors are from the CASC Fourth Academy, the primary competitors to the CASIC Sixth Academy.

¹⁶⁰ The three-stage launch vehicle has a weight of 13,000 kg. The launch vehicle separates from the aircraft at the altitude of 11,000 m and the airspeed of 206.93 m/s. Entering its "winged" flight mode, it accelerates to 2,250 m/s and reaches the altitude of 39,751 m. For Russian reporting, see Russia: Article on Chinese Aviation News CEP20070523322002 Moscow *Aviatsiya I Kosmonavtika* in Russian 28 Feb 07.

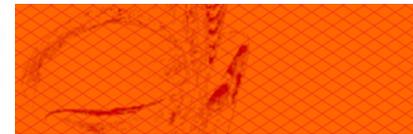
¹⁶¹ Yang Jian, Xu Cheng, Song Yang, and Shi Weiwei, "Analysis on Ability of Air-Launched Anti-Ship Ballistic Missile to Penetrate Close-In Weapon System" [机载弹道式反舰导弹突防"密集阵"能力分析], *Journal Of Naval Aeronautical And Astronautical University [Haijun hangkong gongcheng xueyuan xuebao]*, 2008, Issue 23, No. 5 (abstract only). The authors are from the PLA Naval Aviation Engineering Academy and PLA Navy Equipment Department.

¹⁶² Hu Hai, Zhang Xing, Liu Dingchen, "Transformation of Future Maritime Warfare Through Sea-Launched Precision Ballistic Missiles" [海射精确制导弹道导弹引发未来海战的深刻变革]; *Missiles and Space Vehicles*, 2006(4); and Yang Zukuai and Liu Dingchen, "Requirements for Countering Aircraft Carriers with Precision Guided Sea-Launched Ballistic Missiles" [反航母作战对海射精确制导弹道导弹的技战术需求], *Jianchuan lunzheng cankao*, March 2004, pp. 7-12. Liu Dingchen, Hu Hai, and Zhang Xing are from the Dalian Naval Academy's Operational Software Research Center. For a Chinese reference of unknown reliability regarding the DF-26 sea-launched variant of the ASBM, see "Janes Reveals New Chinese Secret Weapon to Counter Aircraft Carriers," *Qiangguo Network* (in Chinese), August 26, 2008, at http://www.chnqiang.com/article/2008/0826/article_34759.shtml. For another argument in favor of a submarine-launched ASBM, see Wang Zaigang, "The Nemesis of Super Aircraft Carrier Battle Groups" [*chaoji hangmu jiandui de xingke*], *Jianchuan Zhishi*, January 5, 2005, pp 24-27.

¹⁶³ See for example He Wentao and Wu Jiawu, "Study on Special Characteristics and Countermeasures for Aircraft Carrier Battle Groups" [航母编队特点及对策研究], *Modern Defense Technology [Xiandai fangwu jishu]*, Vol. 32, No. 5 (October 2004).

¹⁶⁴ Yan Zhongxin and Liu Dingchen, "Requirements and Development of Counter-Carrier 'Trump Card' Missile" [反航母"撒手锏"导弹的需求与发展探析], *Feihang daotan*, 2002(1), 6-8.

¹⁶⁵ Chen Hongbo and Yang Di, "Re-entry Maneuver Control Strategy Study of Common Aero Vehicle," *Systems and Control in Aerospace and Astronautics*, (Shenzhen ISSCAA 2006), 19-21 Jan. 2006, page(s): 638-642. The authors are from the Harbin Institute of Technology. Also see Zhai Hua and Zhou Bozhao, "Adjustable Range Trajectory Design with Multiple Constraints for Precision Guided Vehicles," *Systems and Control in Aerospace and Astronautics*, (ISSCAA 2006), 19-21 Jan. 2006, page(s): 1-4. The authors are from the National University of Defense Technology; and Zhou Wenya, Chen Hongbo, and Yang Di, "Entry Guidance for Common Aero Vehicle," *Systems and Control in Aerospace and Astronautics*, 2nd International Symposium on Systems and Control in Aerospace and Astronautics (ISSCAA), Shenzhen, China, 19-21 Jan. 2006, page(s): 4-6. Chen Hongbo is from CASC First Academy. Others are from the Harbin Institute of Technology. Another is Wang Yunliang, Tang Wei, Zhang Yong, and Li Weiji, "Aerodynamic Configuration Optimization of a Common Aero Vehicle," *Journal of Astronautics*, July 2006, funded by a Chinese Natural Sciences grant. Also see Zhao Ruian, "Concept of Orbital Ballistic Missiles," *Aerospace China*, Issue 1, 2004.



¹⁶⁶ The “skipping” also could involve energy management or “phugoid” porpoise-like measures in which the missile pitches up and climbs then pitches down and descends. Among various sources, see Li Yu, Yang Zhihong, and Cui Naigang, “Study on Optimal Trajectory for Boost-Glide Ballistic Missiles,” *Journal of Astronautics*, January 2008, Vol 29, No.1, pp. 66-71. Li Yu, Cui Naigang, and Guo Jifeng, “Development and Key Technology Analysis of Boost-Glide Missile,” *Tactical Missile Technology*, May 2008; and

¹⁶⁷ Guan Shiyi, “Regarding Qian Xuesen’s New Concept for Ballistic Trajectory,” *Winged Missiles Journal (feihang daodan)*, 2003, Issue 1, pp. 1-4. For an alternative concept, see Gu Liangxian, Gong Chunlin, and Wu Wuhua, “Design and Optimization of Wavy Trajectory for Ballistic Missiles,” *Acta Armamentarii*, Vol. 26, No. 3. May 2005, pp. 353-355.

¹⁶⁸ Xu Wei, Sun Pizhong, and Xia Zhixun, “Integration Design and Optimization for Boost Glide Missile” [助推-滑翔导弹总体一体化优化设计], *Journal of Solid Rocket Technology*, Vol 31, No. 4, 2008, p. 319.

¹⁶⁹ U.S. media reported the ASBM as having characteristics of a cruise missile. See Christopher P. Cavas, “Missile Threat Helped Drive DDG Cut,” *Defense News*, August 4, 2008. For references to the Qian Xuesen trajectory, see Gu Wenjin, Yu Jinyong, and Zhao Hongchao, “New Concept of M-Type Missile Trajectory,” *Journal of Naval Aviation Academy*, 2004, Vol. 19, No. 2. Also see Hu Zhengdong et.al., “Trajectory Performance Analysis and Optimization Design for Hypersonic Skip Vehicle,” *Journal of Astronautics*, 2008 (1), pp. 66-71.

¹⁷⁰ Xu Wei, Shen Pizhong, and Xia Zhixun, “Integrated Design and Optimization for Boost-Glide Missiles,” *Journal of Solid Rocket Technology*, Vol. 31 No. 4, pp. 317-320; Yang En’mi, Tang Guojin, and Chen Lei, “Schematic Study for Mid-Course Trajectories for Boost-Glide Missiles,” *Journal of National University of Defense Technology*, Vol 28, Issue 6, 2006; and Li Yu, Cui Naigang, Guo Jifeng, “Development and Key Technology Analysis of Boost-Glide Missile,” *Tactical Missile Technology*, 2008 (5); and Guo Xingling and Zhang Heng, “An Analysis of the Maximum Time Rates of Heat of Long-Range Boost Glide Flight,” *Journal of Astronautics*, 2008, 29(3), pp. 783-788. The U.S. Air Force’s Boost-Glide Re-entry Vehicle (BGRV) program investigated missile maneuvering at hypersonic speeds after re-entry into the atmosphere. Upon re-entry, flight control was achieved by using aft trim flares and a reaction jet system commanded from an onboard inertial guidance system. A BGRV was launched on Feb. 26, 1968, from Vandenberg Air Force Base by an Atlas F to the area of Wake Island in the Pacific, collecting data that proved valuable in developing later maneuvering re-entry vehicles.

¹⁷¹ For a good overview of the Prompt Global Strike program and more specifically the deployment of conventional ballistic missiles, see Bruce M. Sugden. “Speed Kills: Analyzing the Deployment of Conventional Ballistic Missiles,” *International Security* Volume 34, Issue 1 (2009), pp. 113-146.

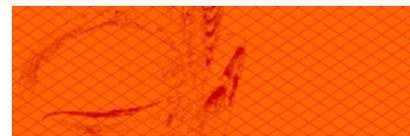
¹⁷² For a CASC First Academy assessment of the U.S. program, see Tong Xionghui, “Forecast and Analysis of USA’s Future Conventional Prompt Global Strike System” [美国未来全球快速精确打击体系预测分析], *Missiles and Space Vehicles*, May 2008. Also see Wang Yunliang, Tang Wei, Zhang Yong, Li Weiji, “Aerodynamic Configuration Optimization of a Common Aero Vehicle [通用航空飞行器气动布局设计优化],” *Journal of Astronautics*, [Yuhang xuebao], 2006, Volume 27, No. 4. The authors are from the Northwest Polytechny University and China Aerodynamics Research and Development Center (CARDC).

¹⁷³ Chen Xinmin and Yu Menglun, “Design Method of Missile Baseline Concept Based on Function Analysis” ([基于功能分析法的导弹基准方案设计方法]), *Missiles and Space Vehicles*, April 2008.

¹⁷⁴ Chen Hongbo and Yang Di, “Re-entry Maneuver Control Strategy Study of Common Aero Vehicle,” *Systems and Control in Aerospace and Astronautics*, (Shenzhen ISSCAA 2006), 19-21 Jan. 2006, page(s): 638-642.

¹⁷⁵ Yong En’mi, Tang Guojin, and Chen Lei, “Three-Dimensional Optimal Trajectory For Global Range Of CAV,” *Systems and Control in Aerospace and Astronautics*, (Shenzhen ISSCAA 2006), 19-21 Jan. 2006, pp. 1396-1400.

¹⁷⁶ In Joint Pub 1-02, DoD defines a cruise missile as “a guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity; depends on the dynamic reaction of air for lift and upon propulsion forces to balance drag.” The CASIC Third Academy classifies cruise missiles as short range (50km or less), medium range (50 to 120kms), medium-long range (120-500km), long range (500-5,000km), and very long range (5,000-8,000km), and intercontinental (above 8,000km). For a good overview



of global cruise missile developments, see Thomas G. Mahnken, *The Cruise Missile Challenge*, Center for Strategic and Budgetary Assessments, March 2005.

¹⁷⁷ See Guan Shiyi, Zhu Kun, and Song Fuzhi, "Some Issues Regarding Cruise Missile Systems" [关于飞航导弹体系的几个问题], *Tactical Missile Technology* ([*Zhanshu daodan jishu*], May 2004, pp. 1-10. The authors are all from the CASIC Third Academy's cruise missile design and systems engineering department.

¹⁷⁸ See Guan Shiyi, "Diversification of Cruise Missile Development" [向多极化发展的飞航导弹], *Missiles and Space Vehicles* (*daodan yu hangtian yunzai huojian*), June 2002, pp. 20-27; Guan Shiyi, "New Concept Cruise Missile Based on a Qian Xuesen Trajectory" [基于钱学森弹道的新概念飞航导弹] *Winged Missiles* [*feihang daodan*], 2003(1); Song Fuzhi, "Countering Aircraft Carriers: Cruise Missiles Better Than Ballistic Missiles" [对抗航母——巡航导弹优于弹道导弹], *Tactical Missile Technology*, April 2006. The authors are all from the CASIC Third Academy's cruise missile design and systems engineering department. For an argument against use of cruise missiles and in favor of sea-launched ballistic missiles to counter aircraft carriers, see Wang Zaigang, "The Nemesis of Super Aircraft Carrier Battle Groups" [*chaoji hangmu jiandui dekexing*], *Jianchuan Zhishi*, January 5, 2005, pp 24-27. Also see Li Benchang and Li Zhisheng, "Some Thoughts on Development of Our Country's Submarine Launched Cruise Missiles," *Missiles and Space Vehicles*, 2002(6).

¹⁷⁹ Among various sources, see Che Jing and Tang Shuo, "Research on Integrated Optimization Design of Hypersonic Cruise Vehicle," National Natural Science Foundation study, August 21, 2006. The authors are from the Northwest Polytechnical University's College of Astronautics, which hosts a GAD-funded laboratory on flight vehicles.

¹⁸⁰ Zhan Hao, Sun Dechuan, and Xia Lu, "Preliminary Design for Soaring Hypersonic Cruise Vehicle," *Journal of Solid Rocket Technology*, Vol. 30, No. 1, 2007. The authors are also from the Northwest Polytechnical University's College of Astronautics.

¹⁸¹ Chen Xiang, Chen Yuchun, Tu Qiuye, Zhang Hong, and Cai Yuanhu, "Research on Performance of Air-Turbo Rocket," *Journal of Projectiles, Rockets, Missiles, and Guidance*, 2009 (4), Vol. 29, No. 2, pp. 162-165. The authors are from the Northwest Polytechnological University's School of Power and Energy. Li Huifeng, Chen Jindong, Li Naying, "Research on Midcourse Navigation of Hypersonic Cruise Air Vehicles," *Modern Defense Technology*, 34(6). The authors are from the Beijing University of Aeronautics and Astronautics (BUAA) Space College.

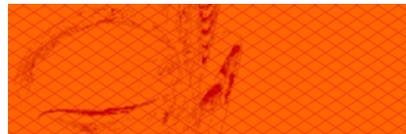
¹⁸² Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for a Carrier-Based Unmanned Combat Air System*, Center for Strategic and Budgetary Assessments, 2008, pp. 161-196.

¹⁸³ "Clinton Urges Broader China Approach," *International Herald Tribune*, January 28, 2009, at <http://www.ihf.com/articles/ap/2009/01/28/america/NA-US-China.php>.

¹⁸⁴ Andrew Erickson, "Facing A New Missile Threat From China," *CBS News*, May 28, 2009. It is worth noting that the INF Treaty excluded anti-ship cruise missiles.

¹⁸⁵ Extended range anti-ship missiles appear to be making a come back after an extended absence. In May 2009, an upgrade to the BGM/UGM-109E Tomahawk Block IV land-attack cruise missile was unveiled. The upgrade would have it a multirole weapon capable of hitting moving ships. The upgrades would include an active electronically scanned array, millimeter-wave seeker for target acquisition and homing; a passive electronic surveillance system is for long-range acquisition and identification. The system would have a 900 nautical mile range, or about 1450 km. See Bill Sweetman, "Antiship Missiles Engage Diverse Targets," *Defense Technology International*, May 6, 2009.

¹⁸⁶ A typical PhD would expect to have a basic monthly pay of around RMB 4000 a month, plus contingent bonus of upwards of RMB 1500 a month for a total of around RMB 5500 a month. Annual income is at least RMB 80,000 a year. A master's degree student would expect to have a starting salary of around RMB 2800 a month, contingent bonus of RMB 1400 a month for a total of RMB 4200 a month. Annual income is at least RMB 60,000 a year. Non-technical workers likely are paid around RMB 2000 a month, or RMB 30,000 a year with bonuses included. About half of all employees are "technical" personnel and presumably paid an annual



salary RMB 70,000, with the remainder being non-technical workers (RMB 30,000 a year). $50,000 \times 70,000 = 3.5$ billion for technical and $30,000 \times 50,000 = 1.5$ billion for non-technical.

¹⁸⁷ As many as 10 DF-31 7200+ kilometer range ICBMs have been produced for the Second Artillery, as well as one launcher per missile. A similar number of 11,200+ kilometer range DF-31A ICBMs have been produced as well. Sources of unknown reliability assert that the DF-31 is deployed to the Luoyang 54 Base's 813 Brigade (the 96265 unit) near Nanyang. One of the senior designers of the DF-31 was Liu Baoyong, who worked in the First Academy's First Design Department.

