4. DoD, China Military Power Report 2002.
5. Janes Strategic Weapon Systems, http://www.janes.com/articles/Janes-Strategic-Weapon-Systems/Tien-Kung-1-23-Sky-Bow-Taiwan.html.
6. The U.S. has no legal or treaty obligation to come to Taiwan's defense in the event of a military attack by China, but since the U.S. formally recognized the PRC and derecognized Taiwan in December 1979 the U.S. has maintained the sale of defense articles and services to the Taiwan armed forces, and it has maintained operational plans to come to Taiwan's defense should it be necessary and ordered by the President of the United States.
7. James Dunnigan, "Chinese Stealth Fighter Sighted," StrategyPage.com, January 20, 2011, http://www.strategypage.com/dls/articles/Chinese-Stealth-Fighter-Sighted-1-20-2011.asp.
8. It is extremely unlikely that China would arm missiles fired at Taiwan with chemical or biological warheads; and the effects of convention explosive warheads are no different than equivalent-sized bombs dropped from aircraft.
9. Patriot PAC-3 missiles are manufactured by the Lockheed Martin Corporation.
10. Patriot PAC-2 Guidance Enhanced Missiles are manufactured by the Raytheon Corporation.
11. The ranges of Patriot radars are classified. Open source information varies, but not much. AN/MPQ-53/65 multifunction phased array radar Patriot MIM-104, http://www.armyrecognition.com/patriot_mim-104_vehicles_systems_us_army_uk/an_mpq-53_patriot_radar_search_detection_illumination_data_sheet_specifications_information_uk.html.
12. As the Principle Director for Operations in the Defense Security Cooperation Agency the author over saw all U.S. Foreign Military Sales programs to Taiwan, travelled to Taiwan frequently and visiting the Patriot sites.
13. Defense Security Cooperation Agency, 36(b) Major Arms Sales, Press Release, October 3, 2008, http://www.dsca.osd.mil/PressReleases/36-b/2008/Taiwan_08-56.pdf.
14. Defense Security Cooperation Agency, 36(b) Major Arms Sales, Press Release, January 29, 2010, http://www.dsca.osd.mil/PressReleases/36-b/2010/Taiwan_09-75.pdf.
15. Taiwan Air-Defense Overview, GlobalSecurity.org http://www.globalsecurity.org/military/world/taiwan/air-defense-over.htm.
16. Syun An, originally known as the Po Sheng C4ISR FMS Program, is the name Taiwan gave to the data-link (TADLS) program when, in 2002, it combined data-link with the Taiwan Command and Control System (TCCS) recommended in DSCA C4ISR Architecture Study, it became synonymous with Taiwan's overall C4ISR efforts.
17. Syun An, provides Taiwan with several operational advantages. It distributes near real-time common tactical picture. It provides commanders accurate, timely information for improved situational awareness. It maximizes unit, sensor and weapon employment. It optimizes weapon-target pairing for layered defense. And its automation increases operator efficiencies, reduces errors. However, numerous platforms have not yet been equipped with data-link terminals. Improving Taiwan's Military Capabilities, C4ISR Integration, by Edward W. Ross, U.S.-Taiwan Business Council Defense Conference 2009, September 27-29, 2009 Boars Head Inn Charlottesville, Virginia, http://ewrossinternational.com/taiwan_c4isr.pdf .
18. "Shared Early Warning System Begins Mission at Peterson," June 22, 2003, http://www.spacewar.com/reports/Shared_Early_Warning_System_Begins_Mission_At_Peterson.html.

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Satellites Support Growing PLA Maritime Monitoring and Targeting Capabilities

By Andrew S. Erickson

New satellites are enhancing Chinese command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) capabilities. These systems will enable the Chinese military to strengthen cueing, reconnaissance, communications, and data relay for maritime monitoring and targeting. The successful achievement of high quality real time satellite imagery, target-locating data and fusion, as well as reliable indigenous satellite navigation and positioning would facilitate holding enemy vessels at risk via devastating multi-axis strikes involving precision-guided ballistic and cruise missiles. Emerging space-based C4ISR capabilities could thus greatly increase China's capability to use military means to assert its interests along its contested maritime periphery.

Beijing's satellite capabilities, while still far from cutting-edge in many respects, are improving rapidly. China today has only a fraction of the overall space capability of the United States, retains major gaps in coverage in every satellite application, and relies to a considerable extent on technology acquired through non-military programs with foreign companies and governments. Beijing will likely purchase supplementary "high-resolution, electro-optical and synthetic aperture radar commercial imagery," according to the U.S. Department of Defense (DoD), until it is able to deploy a more advanced set of reconnaissance satellites in the coming decade. The current sources of Chinese space imagery include "all of the major providers including Spot Image (Europe), Infoterra (Europe), MDA (Canada), Antrix (India), GeoEye (United States), and Digital Globe (United States)" [1].

Yet, Beijing is combining foreign knowledge with increasingly robust indigenous capabilities to produce significant advances in maritime C4ISR. High-resolution satellites, launchers, and launch infrastructure are prioritized. China is developing and acquiring relevant technologies via all available means, with satellite-specific "thermal insulation blankets" and "traveling wave tubes" cited by DoD as particular areas of foreign collection [2]. Chinese satellite developers are implementing a competitive workplace culture that emphasizes modern management, standardization, quality control (including ISO 9000 management initiatives) and emerging mass production ability—part of a larger trend in China's dual-use military-technological projects [3]. China's in-orbit assets are growing rapidly. Near/real-time C4ISR is facilitated increasingly by China's integrated *Qu Dian* system and related networks and data links, which include secure People's Liberation Army (PLA) voice/data communications provided by *Fenghuo/Zhongxing/Shentong* comsats [4].

Detection and Targeting from Space

These advances are greatly improving China's ability to monitor and threaten force deployments on its periphery. According to VADM David Dorsett, Deputy Chief of Naval Operations (CNO) for Information Dominance, "Ten years ago if you looked at their C4ISR capabilities they did not have an over-the-horizon radar. They had virtually […] no ISR satellites. They now have a competent capability in ISR and over-the-horizon radars, but the years from now we expect a much greater increase in the numbers of satellites they have in orbit and their capability to fuse information" [5]. Specifically, DoD added that: "The PLA Navy is improving its over-the-horizon (OTH) targeting capability with Sky Wave and Surface Wave OTH radars. OTH radars could be used in conjunction with imagery satellites to assist in locating targets at great distances from PRC shores to support long range precision strikes, including by anti-ship ballistic missiles" (ASBM) [6]. A wide range of Chinese technical sources concur with the DoD's assessment. According to two researchers affiliated with the PLA Navy Aviation Engineering Academy: "Through the integration of the data obtained via a number of different satellites, and with the addition of processing and data fusion, [one could] guarantee missile guidance requirements for all types of target information for a long-range ASBM strike" [7].

Satellites are already a key emerging link in ISR architecture that the PLA needs to detect, track, and—in a worst-case scenario—strike foreign surface vessels on its contested maritime periphery. China is developing a wide variety of precision weapons, including the initial operational capability-equivalent (IOC) DF-21D ASBM, which would benefit greatly from improved ISR capabilities. According to VADM Dorsett, while data fusion probably remains a challenge and China's ASBM has yet to be tested against sea-based maneuvering targets, "China likely has the space based intelligence, surveillance and reconnaissance (ISR), command and control structure, and ground processing capabilities necessary to support DF-21D employment. China operates a wide spectrum of satellites, which can provide data useful for targeting within its maritime region." Moreover, "China's non-space based ISR could provide the necessary information to support DF-21D employment. This includes aircraft, UAVs, fishing boats, and over-the-horizon radar for ocean surveillance and targeting" [8]. This is significant, as many previous Chinese and foreign open source assessments claimed that the lack of satellite/C4ISR infrastructure precluded effective ASBM employment. Demonstrated Chinese ASBM capability to strike a moving maritime target would not only suggest the potency of a new, unique weapons system, but also serve as a bellwether of emerging C4ISR-supported anti-access/area denial (A2/AD) capabilities.

China's ~15 reconnaissance-capable satellites include electro-optical, multi- and hyper-spectral, and radar, especially synthetic aperture radar (SAR). Several satellite series are particularly relevant to maritime monitoring.

Haiyang and *Huanjing*: Pioneering Ocean Surveillance

Maritime surveillance, a significant focus of PRC satellite development, has been prioritized at the national level as one of eight key areas specified by China's 863 State High-Technology Development Plan [9]. China's first series of dedicated maritime monitoring satellites is designed and developed by China Academy of Space Technology (CAST) and administered by the State Oceanic Administration (SOA).

China launched its first maritime observation satellite, *Haiyang*-1A, on 15 May 2002. This satellite, which monitored ocean water color and temperature, had military applications; an official publication states that 12 percent of *Haiyang*-1A's 2003 "satellite data distribution" was "military." HY-1B, with a 3X faster ocean color scanner (permitting a one day revisit period), was launched in April 2007 to survey China's maritime periphery, including the East and South China seas. Fully operational versions are scheduled to follow: HY-1C, -1D, and -2A in 2011, and HY-3 in 2012 [10].

A total of 15 further *Haiyang* ocean monitoring satellites are planned, in three sets. The HY-1 series will monitor ocean color with an optical radiometer and sea surface temperature with a medium spatial resolution optical sensor. Eight satellites, designated HY-1C –J, will be launched in pairs every three years between 2011 and 2019. Four satellites, HY-2A –D, will be launched every three years over the same period. The HY-3 series will use synthetic aperture radar (SAR) sensors with 1-10 m resolution and X-band radar to monitor maritime resources, pollution, and coastal zones. Three satellites will be launched in 2012, 2017, and 2022 respectively.

Likewise relevant to maritime surveillance will be China's *Huanjing* disaster/environmental monitoring constellation, envisioned to contain eleven satellites capable of visible, IR, multi-spectral, and SAR imaging. Two initial satellites in the series, *Huanjing*-1A and -1B, provide real time multi- and hyper-spectral imaging respectively, to a resolution of 30 m. *Huanjing*-1C and -1D are reportedly scheduled for launch in 2011. The full constellation is designed to form a complete image on China every 12 hours [11].

Yaogan: Opening Sharper Eyes for ISR

China's *Yaogan* series of advanced SAR and electro-optical remote sensing satellites, while officially civilian in mission, operate from "similar, near-polar, Sun-synchronous orbits," suggesting that they "provide multi-wavelength, overlapping, continuous medium resolution, global imagery of military targets" [12]. It may build on the *Ziyuan*/*Jianbing* series, China's equivalent of the China-Brazil Earth Resources series, which conducts real time digital photoreconnaissance. It may also be related to the *Tianhui*-1 stereotopographic mapping satellite.

Yaogan 1, launched on 27 April 2006, has since completed its mission. *Yaogan* 2-11 were launched between 25 May 2007 and 22 September 2010, for a total of 12 satellites currently operational in orbit. The rapid pace of recent launches (7 since 9 December 2009) suggests that this is a particularly high priority for China. *Yaogan* 12 is reportedly scheduled for launch in March 2011; further launches could rapidly consolidate coverage of China's maritime periphery. Table 1 details *Yaogan* satellites launched to date.

Of particular interest with respect to potential for cueing of ASBMs and other precision weapons is the launch of *Yaogan* 9A, B, and C together on March 5, 2010 to coincide with the first day of China's National People's Congress. These satellites fly in triangular formation in similar orbits at identical inclination, apparently as a type of Naval Ocean Surveillance System (NOSS). According to *Jane's*, "Yaogan-9 reportedly carries millimetre-wave [*sic*] radar to help the trio stay in close orbital formation, infra-red sensors to detect ships, and antennas to pick up electronic emissions. They are thought to be able to find and track major Western warships, providing accurate positional data for targeting by land-based [ASBM] systems" [13]. The U.S. Navy reportedly deployed such a system, White Cloud, beginning in the early 1970s, apparently to detect surface vessels by sensing their electronic emissions and locating them using time distance of arrival [14].

China uses a variety of other satellites to link these sensors to shooters, and support related network functions. Its first data relay satellite, *Tianlian*-1, facilitates near-real-time communication between satellites and ground control, complementing China's > 10 ground stations and 4 operating *Yuanwang* space event support ships. *Tianlian*-2 will reportedly be launched in June 2011. To enhance weapons guidance accuracy, China's *Beidou*-2/Compass navigation/positioning system will distribute positional data [15].

Compass: Providing Positioning and Communications

A central challenge for Chinese weapons employment is guaranteeing access to global positioning information without depending on the U.S. Global Positioning System (GPS) constellation, the signals of which Beijing fears the United States might restrict during wartime. A retired senior PLA official alleges that PLA analysis concluded that unexpected GPS disruption likely caused the PLA to lose track of the second and third missiles of a three-missile salvo being fired into the East China Sea 18.5 km from Taiwan's Keelung naval port in March 1996, as part of a larger effort to deter what Beijing perceived to be pro-Taiwan independence moves. "It was a great shame for the PLA ... an unforgettable humiliation. That's how we made up our mind to develop our own global [satellite] navigation and positioning system, no matter how huge the cost. "Beidou is a must for us. We learned it the hard way." Retired PLA general Xu Guangyu adds that China's *Beidou* and *Yuanwang* systems guarantee that "There is no chance now for the US to use its GPS to interfere in our operations at all" [16].

Satellite navigation facilitates the monitoring of friendly forces and the targeting of enemy forces by offering reliable positioning signals. It supports command and control by providing basic communications functions. At present, China uses the U.S. GPS and Russia's GLONASS satellite navigation systems as well as its own indigenous *Beidou* satellite navigation system [17]. Beijing has had only limited access to receiver technology and was denied access to the military mode of Europe's nascent Galileo system, apparently intensifying existing Chinese efforts to develop *Beidou* further [18].

China deployed its own three-satellite *Beidou*-1 navigation constellation in 2007, but it is limited to providing service from 70 to 140 degrees east longitude and from 5 to 55 degrees north latitude and navigation coverage accurate to within ~20 m. This enables *Beidou*-1 to support operations on China's immediate maritime periphery, but not further afield. To ensure reliable independent access in the future, and to support broader operations, China is deploying a 35-satellite (5 geostationary, 30 medium earth orbit) constellation—called *Beidou*-2/Compass—that would provide much-improved accuracy, with regional navigation and communications coverage anticipated by 2011 and global navigation and communications coverage by 2015-20 [19]. Seven satellites have been launched thus far; four remain fully operational. Table 2 details *Beidou* satellites launched to date.

Conclusion

With China's rapid progress in independent systems, or "hardware," the biggest limitations on Chinese maritime surveillance and targeting lie in systems integration and "software." As Admiral Dorsett states, "They don't have a great ISR, integrated ISR capability. [...] They don't demonstrate a level of sophistication and joint warfighting. [...] while they're delivering technology and capabilities, they are at the early stages of operational proficiency across the board" [20]. Integration challenges involving software processing and data management and transfer reportedly plagued the PLA following Sichuan's 2008 Wenchuan Earthquake, although its response to the 2010 Yushu Earthquake—which relied in part on satellites, e.g., *Beijing 1*—reflected significant "lessons learned."

The sprawling, stovepiped nature of the many military services and organizations that control satellite/C4ISR architecture further complicates the horizontal/vertical inter-service, inter-level, military-civilian bureaucratic coordination necessary for real time data fusion to support kinetic operations. Institutional wrangling for control of China's space assets continues among such organizations as the General Armaments Department, the General Staff Department, and PLA Air Force—and even the Second Artillery and PLA Navy to some extent. GAD controls all orbital satellite operations, yet lacks a combat role. The PLAAF has developed extensive space-related theoretical research and has an officially approved doctrine of "integrated air and space, using both offense and defense"

[21], yet currently is not known to control any space assets. There are additionally rumors of a future Space Force [22]. Ownership and operational control of some satellites and applications are divided among more than a dozen governmental, university, and civil organizations, with 75 percent of satellites normally run by nonmilitary organizations and peacetime/wartime authority transfer dynamics remain unclear [23].

Despite these ongoing challenges, however, China's surveillance satellites—together with the supporting infrastructure, human and otherwise—is improving rapidly. Beijing has a clear strategic rationale to master the relevant capabilities, particularly for A2/AD operations in its Near Seas (Yellow, East, and South) and their approaches. Doing so could finally enable the PLA to translate its traditional approach of achieving military superiority in a specific time and area even in a context of overall inferiority (*yilie shengyou*) into the maritime dimension.

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Notes:

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8. N2/N6 Public Affairs Office, January 3, 2011.
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10. For all launch schedule predictions, see "Chinese Launch Record," http://www.sworld.com.au/steven/space/china-rec.txt; www.forum.nasaspaceflight.com.
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21. "China's PLA Eyes Future in Space and Air: Air Force Commander," People's Daily Online, http://english.peopledaily.com.cn/90001/90776/90786/6799960.html.
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Table 1: YaoganSatellites Launched to Date—Notional Specifications

Satellite	Military Designation	NORAD ID	Int'l Code	Contractor	Launch Date (UT)	Launch Site	Launch Vehicle	Orbit (Perigree X Apogeekm, inclination)	Type
*Yaogan*1	JB-5-1	29092	2006-015A	SAST	2006.04.26	Taiyuan	CZ-4B	634 X 636, 97.9° (since decayed)	SAR
*Yaogan*2	JB-6-1	31490	2007-019A	CAST	2007.05.25	Jiuquan	CZ-2D	640 X 669, 97.9°	EO
*Yaogan*3	JB-5-2	32289	2007-055A	SAST	2007.11.11	Taiyuan	CZ-4C	634 X 637, 97.8°	SAR
*Yaogan*4	JB-6-2	33446	2008-061A	CAST	2008.12.01	Jiuquan	CZ-2D	643 X 666, 97.8°	EO
*Yaogan*5	JB-8-1?	33456	2008-064A	CAST	2008.12.15	Taiyuan	CZ-4B	478 X 498, 97.3°	SAR
*Yaogan*6	JB-7-1?	34839	2009-021A	SAST	2009.04.22	Taiyuan	CZ-2C	514 X 517, 97.6°	SAR
*Yaogan*7	JB-6-3	36110	2009-069A	CAST	2009.12.09	Jiuquan	CZ-2D	635 X 674, 97.9°	EO
*Yaogan*8	JB-7-2?	36121	2009-072A	SAST	2009.12.15	Taiyuan	CZ-4C	1200 X 1212, 100.4°	SAR
*Yaogan*9 A/B/C	?	36413, 36414, 36415	2010-009A, 2010-009B, 2010-009C	CAST	2010.03.05	Jiuquan	CZ-4C	1068 X 1127, 63.4°	ELINT
Yaogan 10	JB-5/7-3?	36834	2010-038A	SAST	2010.08.09	Taiyuan	CZ-4C	634 X 637, 97.8°	SAR
Yaogan 11	JB-6-4?	37165	2010-047A	CAST	2010.09.22	Jiuquan	CZ-2D	633 X 676, 98.0°	EO

Sources: "Real Time Satellite Tracking," http://www.n2yo.com; "Yaogan (Jianbing 5/6/7)," www.sinodefence.com/space/military/yaogan.asp.

Table 2: Beidou/Compass Satellites Launched to Date—Notional Specifications

Satellite	NORAD ID	Int'l Code	Contractor	Launch Date (UT)	Launch Site	Launch Vehicle	Orbit	Status
Beidou-1A	26599	2000-069A	CAST/CASC	2000.10.30	Xichang	CZ-3A	GEO, 140°E è 58.7°E (as of 2010.11.28)	Usefulness Uncertain
Beidou-1B	26643	2000-082A	CAST/CASC	2000.12.20	Xichang	CZ-3A	GEO 80.5°E	Operational
Beidou-1C	27813	2003-021A	CAST/CASC	2003.05.24	Xichang	CZ-3A	GEO 110.5°E	Operational
Beidou-1D	30323	2007-003A	CAST/CASC	2007.02.02	Xichang	CZ-3A	GEO 58.75° è Disposal Obit (as of 2009.02.18)	Not Operational
Beidou-2/ *Compass*-M1	31115	2007-011A	CAST/CASC	2007.04.13	Xichang	CZ-3A	MEO, period 1.289 hours	Experimental
Beidou-2B/ *Compass*-G2	34779	2009-018A	CAST/CASC	2009.04.14	Xichang	CZ-3C	GEO drifting; 84.5°E è Librating ~ 75°E libration point (as of shortly after launch)	Not Operational
Beidou-2C/ *Compass*-G1	36287	2010-001A	CAST/CASC	2010.01.16	Xichang	CZ-3C	GEO 160.0°E è144.5°E (as of 2010.02.22)	Operational
Beidou-2D/ *Compass*-G3	36590	2010-024A	CAST/CASC	2010.06.02	Xichang	CZ-3C	GEO 84°E	Operational
Beidou-2/ *Compass*-IGSO-1	36828	2010-036A	CAST/CASC	2010.07.31	Xichang	CZ-3A	IGSO 118°E, 55.0°E incl.	Operational
Beidou-2E/ *Compass*-G4	37210	2010-057A	CAST/CASC	2010.10.31	Xichang	CZ-3C	GEO 160°E	Operational
Beidou-2/ *Compass*-IGSO-2	37256	2010-068A	CAST/CASC	2010.12.17	Xichang	CZ-3A	GEO	Operational

Sources: "Real Time Satellite Tracking," http://www.n2yo.com; NASA, http://nssdc.gsfc.nasa.gov/nmc/SpacecraftQuery.jsp; www.gpsworld.com.

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