China's Navigation in Space

By Andrew Erickson and Amy Chang

What new approaches will China's space tracking take?

The People's Republic of China's "Long View" space-tracking and telemetry system enhances space situational awareness and operations while offering military potential. Yet this sea-based approach suffers from inherent dependencies and liabilities. The program appears at a crossroads, with the development of additional overseas ground stations a tempting alternative. How Beijing proceeds will shape its capabilities critically; the United States should monitor related developments closely.

AP PHOTO (VINCENT YU)

A fundamental element of the Chinese space program, space-tracking *Yuanwang* vessels provide ship-based C4ISR and can also track information and guidance for foreign satellite data. Here, the *Yuanwang* 6 docks in Hong Kong after tracking and remotely controlling the *Shenzhou* 7 spacecraft in 2008.

China relies on space-event support ships far more than does any other power today—its fleet is rivaled only by that of the United States. But in contrast to the United States, Russia, and other modern global military powers, a regionally focused China has no overseas military bases and only limited space and domestic ground-based assets on which to rely. The country's *Yuanwang* (Long View) ships fill this void by performing a variety of useful roles in peacetime, including monitoring and tracking space vehicles such as rockets, spacecraft, and missiles; as well as communicating and coordinating with ground assets.

China's diverse, rapidly evolving, interactive command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) architecture remains different from that of the United States even as it increases in coverage and sophistication. In the event of conflict, mobile ship-based C4ISR could have significant advantages over fixed ground installations, from providing tracking information and guidance for missiles to intercepting foreign satellite data. Yet no English-language study to date has covered the *Yuanwang* vessels in depth, let alone explored their possible military applications.

Global Context

The United States is China's only peer in ship-based space tracking. The U.S. Military Sealift Command, founded in 1958, has a Special Mission Program that currently includes 25 ships supporting military and government tasks. It operates three active instrumentation ships, the USNS *Observation Island* (T-AGM-23), *Invincible* (T-AGM-24), and *Howard O. Lorenzen* (T-AGM-25), which "provide platforms for monitoring missile launches and collecting data that can be used to improve missile efficiency and accuracy." The *Observation Island* is fitted with Cobra Judy (AN/SPQ-11), a passive electronically scanned array radar that supports space and ballistic-missile tracking as well as other instrumentation. It is linked to two types of non-maritime radars: the ground-based Cobra Dane (AN/FPS-108) in Shemya, Alaska; and three Cobra Ball (RC-135S) aircraft. As part of the U.S. ballistic-missile defense system, the Military Sealift Command operates the Sea-based X-band Radar Platform (SBX-1).

These assets represent parts of a larger U.S. surveillance network that includes such allied land-based components as the ballistic-missile detection radars at Fylingdales, U.K.; and Thule, Greenland. With its global ground- and space-based C4ISR, the United States is far less reliant than China on this sea-based approach. Few other countries even have space-event support ships. Russia today operates only the *Akademik Sergei Korolev*, and France the *Monge*. No other country maintains a significant presence in this field.

Birth of a Space-Tracking Program

First conceived in 1965 by Premier Zhou Enlai, Beijing's concept for space-tracking ships was further developed under Project 718 in the 1970s.[1] The *Yuanwang* program was launched to support Chinese intercontinental ballistic-missile (ICBM) sea tests. These were approved as early as the mid-1960s, but were apparently delayed by the Cultural Revolution. China's Commission of Science and Technology for National Defense tasked the design departments of the Seventh Ministry of Machine Building, the Seventh Academy of the Sixth Ministry of Machine Building, and its own test bases with organizing a concept-study team.

Design and development began in 1974; construction in 1975. Following the resolution of numerous technical problems by the many organizations assigned to participate, Jiangnan Shipyard completed the first vessels in the late 1970s; they subsequently underwent debugging and sea trials. A total of six *Yuanwang* ships have been built, though only three are operational today.

On 26 April 1980, an 18-ship task group including both warships and *Yuanwang* vessels sailed from Shanghai. This was the first major instance of Chinese maritime power projection since Ming Dynasty Admiral Zheng He's AD 1405–33 voyages, and the first ever into the western Pacific. On 18 May, in a previously surveyed area near Fiji, the task force retrieved the instrument package from China's first successful DF-5/CSS-4 ICBM test, demonstrating the ability to successfully exploit sea-based tracking.

Yuanwang vessels would subsequently be deployed to support a wide variety of military and civilian space launches, a practice that continues today. In April 1984, the fleet successfully tracked China's first geostationary experimental communications satellite. The role of the ships positioned in distant oceans had been critical for satellite launches to geosynchronous transfer orbit when existing ground stations could only track limited distances along certain lines of sight.

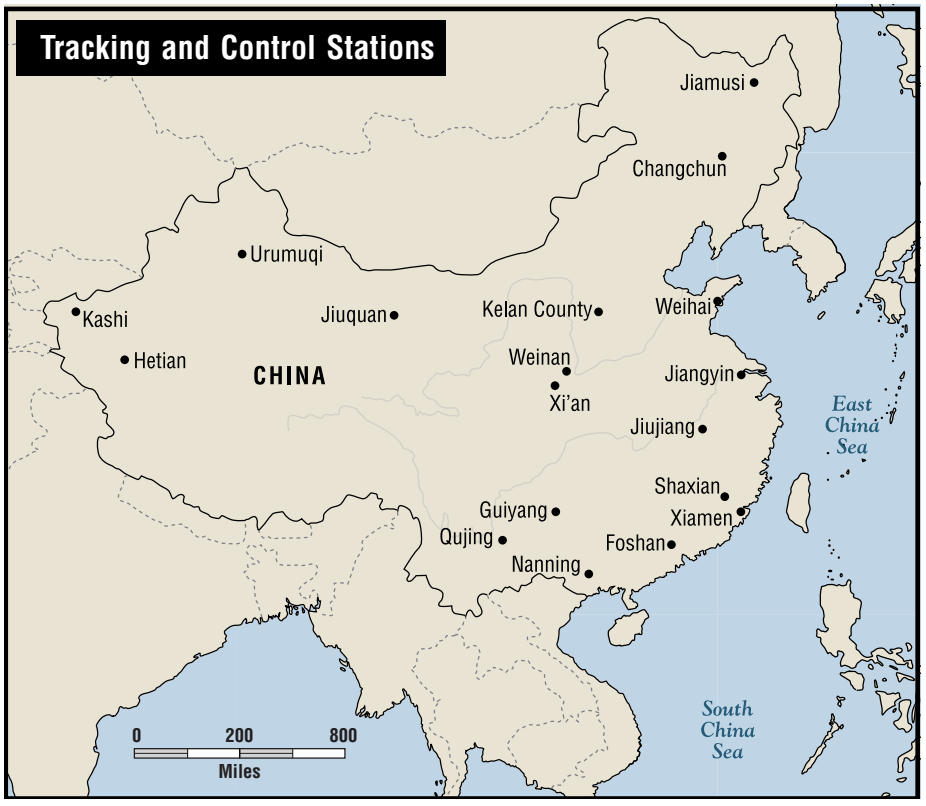
Between the 1980s and 2000s, the *Yuanwang* fleet has made significant progress in technological advances and capabilities. Beginning in 1981, improvements in the ships' tracking system permitted coverage to 24,855 miles above Earth. This subsequently advanced to more than 248,550 miles. In April 1984, the *Yuanwang* fleet successfully tracked China's first geostationary communications satellite. Today, the ships still play an essential role in such operations.

In May–June 1997, they demonstrated comprehensive tracking capability by monitoring the *Dongfanghong-3* and *Fengyun-2* satellites. Since late 1999, *Yuanwang* ships have tracked *Shenzhou* spacecraft, indicating the ability to follow manned space flights. In late 2007, the fleet's space-tracking distance expanded from 43,496 to 248,550 miles during the *Chang'e*-1 lunar mission.

China's *Yuanwang* space-event support ships complement its numerous ground stations and two *Tianlian* data-relay satellites, which facilitate communications with these stations and other satellites. The country's network of ground- and sea-based stations provides tracking data and support for ballistic-missile tests and space launches.

Domestic Ground Stations

China has three satellite launch centers and stations: Jiuquan (also known as Base 20 and Dongfeng Space City), Xichang (Base 27), and Taiyuan (Base 25). The country is currently constructing a station in Wenchang (also known as Wenchang Space City and Wenchang Satellite Launch Center), which should be operational in 2013. Additionally, it has two control facilities: an Aerospace Command and Control Center in Beijing and a Satellite Monitor and Control Center in Xi'an (also known as Base 26). The Aerospace Telemetry Oceanic Ship Base is a crucial ground station, as it tracks *Yuanwang* data on both commercial satellites and spacecraft. Established in 1978 in Jiangyin, Jiangsu Province, the base sends the ships it operates primarily to the Pacific and Indian Oceans. China operates three integrated land-based space-monitoring and control network stations in Kashi, Jiamusi, and Sanya.



The country's tracking and control-station network includes, but may not be limited to:

Changchun Tracking & Control Station (Changchun, Jilin)
Dongfeng Tracking & Control Station (Jiuquan, Gansu)
Guiyang Tracking Station (Guiyang, Guizhou)
Hetian Tracking & Control Station (Hetian, Xinjiang)
Jiamusi Tracking & Control Station (Jiamusi, Heilongjiang)
Kashi Tracking & Control Station (Kashi, Xinjiang)
Lushan Tracking & Control Station (Jiujiang, Jiangxi)
Lvliang Command Post (Lvliang, Shanxi)
Minxi Tracking & Congrol Station (Shaxian, Fujian)
Nanhai Tracking & Control Station (Foshan, Guangdong)
Nanning Tracking & Control Station (Nanning, Guangxi)
Qingdao Tracking & Control Station (Weihai, Shandong)
Sanya Tracking & Control Station (Sanya, Hainan)
Taiyuan Tracking & Control Station (also known as Taiyuan Satellite Launch Center) (Kelan County, Shanxi)
Tianshan Tracking & Control Station (Urumuqi, Xinjiang)
Weinan Tracking & Control Station (Weinan, Shaanxi)
Xiamen Tracking & Control Station (Xiamen, Fujian)
Xi'an Satellite Control Center (Xi'an, Shaanxi)
Zhanyi Tracking & Control Station (Qujing, Yunnan)

Foreign Ground Stations

China has overseas tracking stations in Karachi, Pakistan; Malindi, Kenya; and Swakopmund, Namibia. The Malindi station, in an Indian Ocean coastal town, became operational in July 2005 to support the *Shenzhou* 6 mission. In Swakopmund, the station works in conjunction with *Yuanwang* 3 to provide telemetry, tracking and command (TT&C) support during *Shenzhou* spacecraft landings.[2] China also had a ground station in Tarawa, Kiribati; but it was dismantled in 2003 after Kiribati recognized Taiwan. Beijing plans to construct three ground-control stations in South America by 2016 for deep-space network support. Additionally, China reportedly shares space-tracking facilities with France, Sweden, and Australia.[3]

Yuanwang Space Tracking, Telemetry, and Control Ships

As of June 2008, the *Yuanwang* fleet completed 68 maritime space-tracking missions, sailed more than 1.4 million nautical miles safely, and performed more than 7,600 days of operations at sea. Space-event ships have

subsequently played a larger role in space operations. During 2011–12, *Yuanwang* ships 3, 5, and 6 completed a cumulative 120,000-nautical-mile, 539-day trip to provide space-tracking and control support for the docking of the *Tiangong*-1 space-lab module and *Shenzhou*-8 spacecraft. This mission set a new record for China's maritime tracking operations, including the most missions per ship in a year and the longest span of time in one voyage.

The three operational *Yuanwang* ships are hull numbers 3, 5, and 6. *Yuanwang* 1 completed construction in August 1977, was commissioned in 1978, and was decommissioned in October 2010. *Yuanwang* 2, launched in September 1978, has been decommissioned, though the date is unknown. *Yuanwang* 3 was launched on 26 April 1994 and commissioned 28 May 1995. *Yuanwang* 5 was commissioned in September 2007; *Yuanwang* 6 in April 2008. *Yuanwang* 6's maiden voyage occurred in September 2008, when she provided tracking for the *Shenzhou*-7 mission.

In 1998, an oceanographic survey ship that had been constructed in the 1970s to support China's ICBM test program, *Xiangyanghong* 10, was converted into a space-tracking ship and renamed *Yuanwang* 4. Technological modifications included the addition of a "large-scale remote monitoring equipment with new frequency bands on the vessel, upgrad[ing] the vessel's communications and computer facilities, and adjust[ing] antennas and equipment on the deck through a combination of technical upgrade and replacement to create a more rational layout and further improve the vessel's stability."[4] On 5 August 2007, the ship was damaged in a collision with a coal tanker and suffered extensive fire damage, ending her service life. She was decommissioned on 14 December 2011, after 36 years of service. In 12 voyages totaling more than 1,000 days at sea, she had covered 180,000 nautical miles' maritime TT&C for the trial flights of launch vehicles and *Shenzhou* spacecraft, as well as the *Beidou-1-04* satellite.

REUTERS/CHINA DAILY INFORMATION CORPS)

Nations sending astronauts into space have since 2003 included China, whose program aims to establish a permanent space station around 2020. The unmanned *Shenzhou* 8 (carried by a Long March CZ-2F rocket) blasted off on 1 November 2011, heading for a successful docking with the space lab *Tiangong* 1 that makes China the third nation to have completed such maneuvers in space.

Yuanwang's Capabilities

China's earliest TT&C system, based on very high-frequency radio, was inaccurate and easily disrupted. China proceeded to build C-band radars in the 1970s to support geosynchronous-orbit launch missions and S-band radars in the 1990s to support the Project 921 manned spaceflight program. The S-band radars combined tracking and ranging, command, audio, and video links unified into a single antenna, thereby vastly improving China's tracking and communication systems.

To ensure the accuracy of missile, satellite, and spacecraft measurements, *Yuanwang* 1, 2, 3, 5, and 6 possess (or possessed) C- and S-band monopulse tracking radar; cinetheodolite laser ranging and tracking systems;

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China's network of domestic ground stations includes the Jiuquan Satellite Launch Center in the northwest, here with researchers at work during the November 2011 launch of *Shenzhou* 8.

velocimetry systems; onboard computers to track and control spacecraft; and inertial, satellite, and stellar navigation and positioning approaches. HF, ULF, UHF, and SATCOM communications operate via secure telephone, radio, fax and data link. Equipped with meteorological instruments and able to download weather satellite images, the vessels can operate in any maritime domain except polar zones.

These technologies enable *Yuanwang* ships to complete operational missions that include monitoring and tracking space vehicles such as rockets, spacecraft, "launch vehicles, satellites, and aircraft over water, and communicating with mission centers in real time."[5] Their spacecraft-control technology, including the Tracking and Data Relay Satellite System, is modeled on U.S. and Soviet systems.

Unlike her peers, *Yuanwang* 4 lacked the ability to control spacecraft, serving mainly in tracking and communications relay roles. *Yuanwang* 5 and 6, with more advanced technologies than their predecessors, have onboard optical fiber cables networked to share resources and quickly transmit data to other assets such as mission centers. *Yuanwang* 6 is "equipped with hi-tech antennas that can transmit signals within a 400,000 km [248,550-mile] radius of the Earth."[6]

Future *Yuanwang* Fleet Developments

Over the past few years, Chinese researchers have been analyzing the feasibility of using Tracking and Data Relay Satellite System technology as a high-speed data-relay platform for TT&C ships, which would allow for faster data transfer and more accurate tracking.[7] This technology would supplement China's existing TT&C network for future spaceflight missions.

There has been speculation in Chinese-language media about the construction of another sister ship. In 2009, *Yuanwang* 6 chief engineer Liu Yong spoke of a *Yuanwang* 7 in pre-research stages, noting her potential operational role in deep-space exploration missions.[8]

Military Utility

In the past, *Yuanwang* ships have been sent to designated areas in the Pacific, Indian, and Atlantic Oceans to survey and track *Shenzhou* spaceship missions. Conclusive open-source data on the *Yuanwang* ships' military applications remain unavailable, but the vessels could conceivably support novel operational approaches and provide unique, useful information to China's C4ISR infrastructure.

Given their strong sensing and data-relay capabilities, *Yuanwang* ships might be used to detect and track foreign satellites and to support operations that threaten them. The ships demonstrated the capability to locate and track foreign space objects when they tracked the U.S.-made, Chinese-launched *Asia*-1 satellite.

China has placed significant emphasis on developing ground-based kinetic and laser anti-satellite capabilities, in part because it believes this is one of the few effective ways to compensate for superior U.S. capabilities in other areas. There is no explicit evidence of ocean-surface surveillance and tracking ships supporting anti-satellite operations, nor of an intent to support such operations—but, based on the Chinese capabilities noted, *Yuanwang* ships might provide such a facilitating role. There has, likewise, been signifi-

cant Chinese research on ship-based multi-target simulators, designed for the tracking and control of satellite launches.[9] These might also be used to track and control missiles.

In any case, the People's Liberation Army (PLA) regards autonomous reliability in this area as vital. A retired senior military official alleges that PLA analysis concluded that unexpected GPS disruption probably caused the army to lose track of the second and third of a three-missile salvo fired in March 1996 into the East China Sea 11.5 miles from Taiwan's Keelung naval port. It was part of a larger effort to deter what Beijing perceived to be pro-Taiwan independence moves. Retired PLA General Xu Guangyu adds that China's indigenous navigation-satellite-system *Beidou* and *Yuanwang* ships guarantee "There is no chance now for the U.S. to use its GPS to interfere in our operations at all."[10]

Limitations

China's reliance on ships offers flexibility that fixed tracking stations do not, but it also imposes limitations. Operations and maintenance may be expensive and difficult. Lack of relevant engineers and equipment could complicate repairs during extended missions. Concentrated critical systems are deployed in vulnerable overseas areas in which Beijing lacks sovereignty. Their operation may also be affected by potential problems encountered by supporting vessels, such in the case of the *Yuanwang* 4 and her career-ending accident. Operations could even be disrupted by signals interference or maritime obstacles or exclusion zones that prevented vessels from maintaining a given track.

That *Yuanwang* ships' space tracking and control is conducted on water instead of land imposes challenges regarding bandwidth, inaccuracy and positioning; as well as ensuring efficacy and communication with other assets in uncertain meteorological conditions, with high sea states potentially halting operations. Yet architecture must be pristine and stable. Indeed, Chinese research on the vessels reveals scientists still grappling with stabilization and calibration issues, which could have strategic implications for operational scenarios. Articles and entire books have been dedicated to the science and technology of ship calibration.[11] Specific areas of focus include hull deformation, vibration and noise reduction, and experimental and long-range communication systems. The constantly changing and evolving aerospace and naval industries also make it difficult to meet increasingly high technological requirements.

The Long View

In relaying indispensable positioning information and controlling space assets overseas, the *Yuanwang* fleet represents a vital node in China's aerospace infrastructure. The construction and proliferation of these ships over the past four decades underscores their importance and utility to the country's space and military operations. Space-tracking vessels have successfully participated in full-range ICBM tests, submarine-to-shore guided-missile underwater-launch tests, communications-satellite launches, manned and unmanned space-vehicle launches, and an antarctic visit. They have played a significant role in the development and testing of technologies and weapons.

The status of the ships is at a critical juncture, with Chinese analysts differing concerning their utility. Rapid development of more comprehensive space assets and the country's gradual acquisition of overseas-facility access are supplementing its reliance on *Yuanwang* vessels. Yet Chinese research literature also points to a larger role for space TT&C ships as the nation's space operations continue to expand.

China will undoubtedly continue to develop capabilities and technologies that would be useful for *Yuanwang* space-tracking missions. It is prudent to watch for indications of future plans for space infrastructure, which can be ascertained through new technology such as the Tracking and Data Relay Satellite System, with which to equip existing *Yuanwang* vessels; the research, development, and designing of new *Yuanwang* vessels; and the acquisition of reliable overseas ground-based space facilities.

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