CHINA AEROSPACE STUDIES INSTITUTE

China's Ground Segment
Building the Pillars of a Great Space Power

A BluePath Labs Report by

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China Aerospace Studies Institute

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China Aerospace Studies Institute

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Abbreviations

AIRCAS	Aerospace Information Research Institute of the Chinese Academy of Sciences
AR	Autonomous Region
AVIC	Aviation Industry Corporation of China
BITTT	Beijing Tracking and Communication Technology Research Institute
BS EDI	Beijing Special Engineering Design and Research Institute
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CAAA	China Academy of Aerospace Aerodynamics
CAS	China Academy of Sciences
CASC	China Aerospace Science and Technology
CASIC	China Aerospace Science & Industry Corporation Limited
CAST	China Academy of Space Technology
CBERS	
CCP	Chinese Communist Party
CETC	China Electronics Technology Company
CFOSAT	China-France Ocean Satellite
CHEOS	China High-Resolution Earth Observation System
CLTC	China Launch and Tracking Control
CMC	Central Military Commission
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Administration
CRESDA	China Centre for Resources Satellite Data and Application
EDD	Equipment Development Department
ELINT	Electronic Intelligence
ESA	European Space Agency
EW	Early Warning
FYP	Five Year Plans
GAD	General Armament Department
GWIC	China Great Wall Industry Corporation
IRST	Infrared search and tracking system
ISR	Intelligence, Surveillance, and Reconnaissance
JIDS	Joint Integrated Data Link
JSLC	Jiuquan Satellite Launch Center
LPAR	Large Phased Array Radars
MCF	Military-Civilian Fusion
MIIT	Ministry of Industry and Information Technology
MOST	Ministry of Science and Technology
MUCD	Military Unit Cover Designation
NASA	National Aeronautics and Space Administration
NDU	National Defense University
NDRC	National Development and Reform Commission
PLA	People's Liberation Army
PLAAF	People's Liberation Army Air Force
PLAN	People's Liberation Army Navy
PNT	Positioning, Navigation and Timing
PRC	People's Republic of China
RADI	Institute of Remote Sensing and Digital Earth
RMB	Renminbi
SSA	Space Situational Awareness
SASTIND	State Administration for Science, Technology and Industry for National Defense
TSLC	Taiyuan Satellite Launch Center
VLBI	Very Long Baseline Interferometry
XSCC	Xi'an Satellite Control Center
XSLC	Xichang Satellite Launch Center

Key Findings

CHINA HAS GRAND AMBITIONS FOR SPACE INFRASTRUCTURE

- While China has not released its Space Great Power Strategy, projects such as the *National Civil Space Infrastructure Mid- and Long-Term Development Plan* and the Space-Earth Integrated Information Network Mega Project point toward a resilient system of systems that will allow data sharing between space, air, sea and ground assets, including unmanned vehicles for economic and defense purposes.

THE GROUND SEGMENT IS LARGELY OPERATED BY THE CHINESE MILITARY

- The PLA and specifically the Strategic Support Force's Space Systems Department play a major role in launch, tracking, command and long term operations of China's growing constellations of satellites. As the Chinese military continues to modernize on its path toward informatization and eventually intelligentization, space systems will play an even greater role, necessitating the PLA's continued involvement in defense and civilian space infrastructure programs.

THE GROUND SEGMENT FOR CHINA'S SPACE PROGRAMS HAS EXPANDED DRAMATICALLY

- The last ten years have seen remarkable growth in the number and sophistication of ground stations to support China's scientific and defense related space programs. Examination of commercial satellite imagery of stations built prior to that period saw expansion of their capabilities through addition of antennas and other infrastructure. New stations have been set up and existing stations expanded. Based on public plans this momentum is likely to continue.

COMMERCIAL APPLICATIONS AND OPERATORS WILL PLAY A GREATER ROLE IN GROUND SEGMENT OPERATIONS

- The Chinese government, specifically the PLA and Chinese Academy of Sciences, have been the main developers of space infrastructure. However, the commercial market, encouraged by government initiatives, is seeing rapid growth. Space services, including TT&C operations, equipment, though disentangling true private companies from thinly-masked subsidiaries of SOEs remains a challenge.

THE UNITED STATES REMAINS AHEAD IN SPACE INFRASTRUCTURE

- While China's deployment of multiple constellations of satellites and development of an extensive space ground segment is notable, it does not approach the technological sophistication or size of many of the systems deployed by the United States. In many cases what appears to be novel in a Chinese context proved to be emulating programs that have been underway in the United States for decades.

Introduction

Space operations are not just a matter of rockets and satellites: ground stations, commonly recognized by their large satellite dishes, play an invaluable role in operating satellites and other spacecraft. Communicating with satellites and other spacecraft, downloading the data they collect and other operations requires multiple networks of sophisticated processing centers and receiving and monitoring stations.

Ground Segment Station Responsibilities	
Telemetry [遥测]	Data regarding a space object's position and velocity
Remote Control [遥控]	The ability to issue commands to a space object
Communications [通信]	Bi-directional exchange of data, including downlink

The ground segment, particularly Telemetry, Tracking and Command (TT&C) stations, provide a vital service in downlinking data and monitoring satellites' orbits. These stations and the control centers also help satellites respond to emergencies such as solar events (which can harm satellites or degrade communications with their ground stations) or regain control if they fall out of communication.

China's network of ground stations domestically and abroad and its fleet of space tracking and military support vessels are a less obvious but important player supporting the launches of new satellites, maintaining the accuracy of its PNT constellations and downlinking data from its growing constellations of remote sensing satellites.[i]

This study is meant to provide a background on the development of this system, the various technological hurdles that have been overcome, its capabilities and their implications for the United States.

This study provides an overview of China's ground segment, its satellite telemetry, tracking and command (TT&C) ground stations, military early warning radars, Satellite Laser Ranging (SLR) stations and supporting radio and optical observatories.

TT&C stations ensure proper operation of satellites by receiving data, sending new commands, observing orbital position and watching for debris. These stations are typically large permanent facilities, but because they require line of sight to operate, road-mobile systems and specially-equipped ships are used to ensure continuous contact with a satellite throughout its orbit. Countries frequently lease or build stations outside their territory to provide coverage.

Lasers installed in permanent or mobile laser stations can bounce light off objects in orbit and observe the reflections to determine position and range. Large scale radio antennas, sometimes networked together with other installations around the globe can be used to pick up and enhance faint radio emissions. These stations can engage in science projects, listening to natural radio waves from distant stars and galaxies, or assist in maintaining connections with exploratory probes operating near the moon or on their way to other planets.

While there are civilian uses for these facilities, their implications for China's ability to conduct campaigns in space and support its armed forces should not be understated. Ground segments also play a crucial role in modern military applications, controlling and downlinking data from remote sensing Intelligence, Surveillance, and Reconnaissance (ISR) satellites, and maintaining operation of Positioning, Navigation, and Timing (PNT) satellites, which make up Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS), Galileo, GLONASS or Beidou.

[i] As will be detailed in a later section, space is playing a rising role in China's diplomacy and global economic strategies through the "Going Out" Strategy and Belt and Road Initiative See Section 3

Many components of this ground segment are involved in providing Space Situational Awareness (SSA). From avoiding detection by enemy satellites to maintaining communications with key data-relay satellites, SSA will be an important factor in a country's ability to prosecute and win wars in the future. Military early warning radars which scan the skies for incoming missiles also provide information on objects in low earth orbit such as satellites and debris.

Proper assessment of both China's plans to become a scientific great power and the capability of the Chinese Armed Forces must factor in the ground segment of its space infrastructure.

Scope Note

While the United States, Russia and European Space Agency have well known ground segments, but less has been written on China's.

This study will attempt to fill this gap in the literature, examining the permanent and mobile TT&C stations, TT&C ships and stations established outside of China.

Note that while many Chinese commercial and state operated satellite constellations are touched upon in this study, the focus here is on the ground segment and related organizations.

Organization of this Report

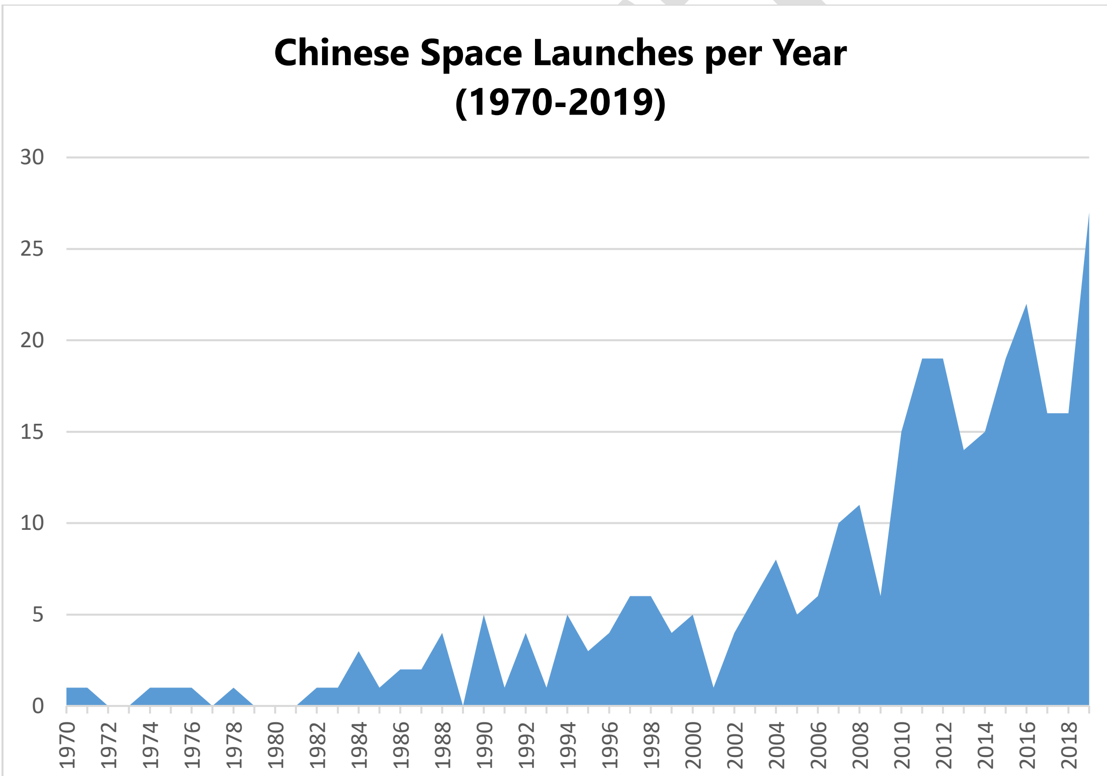
Section 1 first explains China's national plans for space exploration and development of space infrastructure, before turning to examine specific application and strategic plans for China's ground segment. It then provides an overview of the history of China's space program development, and outlines the types of systems involved and their applications. Section 2 profiles the specific organizations and stations that make up the ground segment within China. Section 3 first discusses the drivers of China's development of ground segment stations abroad, and the roles space play in economic plans and international scientific cooperation.

1. China's Ambitions for Space

This section first outlines China's broader ambitions in space, then explores how the ground segment fits into the bigger picture through an analysis of its applications.

1.1 Strategic Plans for Space

China's space ambitions are no secret: with over 250 active satellites in orbit and ambitious scientific exploration programs it has emerged as a major space power. Since 2009 China has consistently launched more than ten rockets a year, reaching an all-time high of 27 in 2019.[1][ii]



China is determined to become what it calls a "Space Great Power" [航天强国], and this rapid launch tempo reflects a series of milestones for scientific exploration and space infrastructure project set by Chinese leadership to achieve that goal. Li Guoping [李国平], spokesperson for CNSA and director of its systems engineering department has described China's three-phase plan for space with major milestones in 2020, 2030 and 2050:[2]

[ii] Launch tempo is an important indicator of a countries space capabilities. The frequency of launches, and the orbits to which satellites or spacecraft needed to add new capabilities, create redundancy in case of technical failure or enemy action or to replace satellites which have run out of fuel and have or will deorbit. However, new technologies are being explored to refuel satellites. Northrup Grumman for example successfully refueled a satellite using its Mission Extension Vehicle on 25 February 2020. See: "Mission Extension Vehicle," Northrup Grumman, https://www.northropgrumman.com/space/space-logistics-services/mission-extension-vehicle/

Milestones for Chinese Space Programs		
2020	"Make major breakthroughs in key points and enter the ranks of Space Great Powers" [重点突破, 进入航天强国行列]	• Complete Beidou GNSS • Launch China's Mars Mission (Tianwen-1) • Complete the "China High-Resolution Earth Observation System" • Lunar sample return mission (Chang'e 5) • Begin construction of a long-term space station (completion expected 2022)

~2030	"Make comprehensive improvements, join the front rank of global Space Great Powers"
	[整体跃升, 跻身世界航天强国的前列]
		• Complete first flight of heavy launch vehicle (expected 2028)
		• Establish orbital service and maintenance system
		  ○ autonomous orbital refueling
		  ○ Automated maintenance of spacecraft in orbit
		  ○ Automated space debris removal
		• Establish the "Space-Earth Integrated Information Network"
		  ○ Complete national civil space infrastructure (2025)
		• Manned Lunar landing

2050	"Take the lead, Comprehensively Become a Space Great Power" [超越引领，全面建成航天强国]	• Manned mission to Mars • Establish long-term base on the moon • Deep space exploration including visiting the edge of the solar system • Creation of low-cost, reusable spacecraft transportation system

While parts of the programs listed above will be touched upon in later sections, two major efforts are playing an outsize role in defining the development of China's ground segment.

National Civil Space Infrastructure

In October 2015, NDRC, Ministry of Finance, and SASTIND jointly issued the *National Civil Space Infrastructure Medium- to Long-Term Plan* (2015-2025) [国家民用空间基础设施中长期发展规划].[3]

According to the Plan, civil space infrastructure refers to space-earth integrated engineering facilities that provide users with remote sensing, communications, broadcasting, navigation and positioning, and other products and services using space resources.[4]

The Plan proposed a phased approach to developing China's civil space infrastructure, divided among China's Five Year Plans (FYP):

Phase	Objectives
12th FYP Period (2011–2015)	Establish the backbone of the national civil space infrastructure; Build a satellite development model and service support mechanisms; Formulate data sharing policies.
13th FYP Period (2016–2020)	Form three major systems including satellite remote sensing, satellite communications and broadcasting, and satellite navigation and positioning; Basically complete the national civil space infrastructure; Create a commercialization model; Be capable of providing international services.
14th FYP Period (2021-2025)	Build a technologically advanced, highly efficient national civil space infrastructure system with global coverage that supports economic and social development domestically and globally.

Construction and development of the three major systems of satellite remote sensing, communication and broadcasting, and navigation and positioning are central to the success of the Plan. Each of these three systems can be divided into the space component and the ground component.

For the satellite remote sensing system, the space component mainly consists of the land, ocean, and atmospheric observation satellite series. The ground component mainly includes a network of remote sensing satellite receiving stations, data center(s), general application support platform(s), and a shared network platform. The Plan noted a need to coordinate the construction of ground facilities such as receiving stations, to expand the construction of overseas stations, to realize the coordinated operation of multiple stations, and to coordinate the services of land, sea, and meteorological satellite data centers.

For the communication and broadcasting system, the space component includes fixed and mobile communication broadcasting satellite series. When it comes to the ground component, the Plan proposed to both upgrade existing facilities and to build new ones including TT&C stations, gateway stations, uplink stations and calibration fields for communication satellites.[5]

The Plan noted that the development of the navigation and positioning system has been incorporated into the unified planning and implementation of China's second-generation satellite navigation system national S&T mega project [中国第二代卫星导航系统国家科技重大专项].

The first phases of this plan, between 2011-2019 saw rapid growth in space infrastructure, expanding networks of ground stations, and a high tempo of satellite launches to deploy communications and remote sensing satellites. Other goals appear to have been met, with significant commercialization of China's space sector. Between 2016-2020, for example, China launched satellites for Algeria, Argentina, Belarus, Ethiopia, Indonesia, Pakistan, and Saudi Arabia. Additional developments in this area will be discussed in greater detail in Section 3.

While the plan is framed in civilian terms, each leg of the three systems will of course have strong potential for use in military operations as well as civilian applications. There do not appear to be public details about a military analog to this Plan, as will be discussed in greater detail in subsequent sections, the Chinese military oversees large swathes of China's ground segment and space programs.

However, a second effort, described in a separate set of plans, is explicitly meant to unify both civil and military capabilities.

The Space-Earth Integrated Information Network Mega Project

Launched in early 2017, the Space-Earth Integrated Information Network Mega Project [国家天地一体化信息网络重大工程], managed by the Ministry of Science and Technology (MOST) and led by China Electronics Technology Company (CETC), is intended to achieve the comprehensive integration of a space-based information network, future internet, and mobile communication network.[67] [iii] Put another way, the megaproject is designed for the purpose of "providing information network coverage wherever [China has] national interests" [国家利益到哪里, 信息网络覆盖到哪里].[8] According to China Academy of Sciences (CAS) Academician and CMC Equipment Development Department (EDD) researcher Yin Hao [尹浩], the information network, when completed, will consist of various types of satellite systems (reconnaissance and surveillance satellites, communication satellites, navigation and positioning satellites, early-warning satellites, meteorological satellites, etc.) on different orbits, supplemented by land-, sea-, and space-based information systems and application terminals to form an organic, intelligent, distributed, space-earth integrated global information network system.[9] This integrated network will support four application areas: spacecraft, guided missile and space launch centers, near space[iv] flight vehicles and unmanned aircraft (UAVs).

The Mega Project has already met some of its milestones. In April 2018, CETC announced its "first major achievement" since project inception: a "ground information port" [地面信息港] that "integrates information network, remote sensing, geographic information, positioning and navigation and other information to connect information resources and user needs."[10]

China's Military-Civil Fusion (MCF) strategy will play an important role in this Mega Project. In a journal article published in August 2017, CAS and CAE Academician, Wuhan University Professor Li Deren [李德仁] highlighted the dual-use characteristic of the space-based information network, noting that the development of a positioning, navigation, timing, remote sensing, communication (PNTRC) network can significantly advance the MCF initiative. Li underscored the project's enormous economic potential and national security implications, but also noted that as a first step, much work is needed to promote the integration of the communication, navigation, and remote sensing satellite systems between military and civilian sectors.

Importantly, this Mega Project gives an indication of the ultimate goal for space infrastructure: to reduce reliance on a ground segment. Writing in the *ZTE Technology Journal* in August 2016, a group of researchers from the Harbin Institute of Technology and Nanjing University argued that the design of the space-sky-earth integrated information network architecture should aim to downplay the role played by ground stations.[11] They indicated a need to "achieve uninterrupted space-based wide-area data acquisition, processing, and transmission functions without the need to establish a dedicated ground station network globally."

[iii] The *National Science and Technology Innovation Plan for the 13th Five Year Period*, released by the State Council in July 2016, announced plans to launch a group of national S&T R&D megaprojects called titled *S&T Innovation 2030*, which includes the Space-Earth Integrated Information Network Mega Project. These megaprojects are designed to "reflect national strategic intentions" [体现国家战略意图], and, as the name suggests, seek to achieve significant breakthroughs by 2030. See: "Notice by the State Council on Releasing the National Science and Technology Innovation Plan for the 13th Five Year Period" [国务院关于印发"十三五"国家科技创新规划的通知], Gov.cn, 8 August 2016, http://www.gov.cn/zhengce/content/2016-08/08/content_5098072.htm.

[iv] Near space is defined as the upper atmosphere above 20km and reaching to the "Karman Line" at 100km typically used to define the beginning of space.

But what are these plans intended to accomplish? The following section will briefly touch upon some of the key applications for the ground segment.

1.2 Composition and Applications of China's Ground Segment

Space Situational Awareness

A fundamental reason for China's ground segment is to help China maintain Space Situational Awareness (SSA), that is, the ability to detect, track, and identify objects in orbit. Satellites can be tracked through a number of means, including radar, optical telescopes, lasers and radio receiving stations.

Space Situational Awareness Network

It is important to note that the U.S. operates a global network of ground based radars and telescopes which in various incarnations has been in operation since the late 1950s. Russia and France also operate similar systems. The most recent version of the U.S. system, called "Space Fence" was declared operational in March 2020. The U.S. Space Force Space Surveillance Network already tracks some 26,000 objects and is capable of tracking objects ten centimeters across. The system is composed of an operations center at Redstone Arsenal, in Alabama, and radars on Kwajalein Atoll in the Marshall Islands

Space tracking is also important due to the rising risk of collision between satellites or from space debris. Debris from antisatellite (ASAT) missile tests by China in 2007 and India in 2019 have generated significant amounts of debris that are still in orbit. In 2009, Kosmos 2251, a Russian military communications satellite collided with Iridium 33, a commercial communications satellite. The event generated significant debris, further illustrating the necessity of precision tracking of active and defunct satellites and responsible operation to ensure they do not harm other spacecraft after their mission ends.

SSA also has military implications. Identifying a reconnaissance satellite's orbit, for example, can provide sufficient time to take measures to conceal sensitive systems or for personnel to camouflage themselves from visual, infrared or radar sensors. Most worryingly, precise characterization of an orbit is also vital to conducting attacks against a satellite, whether a direct kinetic attack (kinetic, low-power dazzling or high-power laser) or a jamming attack. Access to ground stations also offers the potential for hacking attacks through the connections used to control the satellite. Networked databases of imagery and other data collected from satellites by ground stations are also vulnerable. [12] As one article described it, SSA is "continuous preparation of the battlespace in order to fight and win a war in space" or simply "Space Battle Management."[13]

As technology improves and especially high quality optics and more powerful lasers become cheaper, there is likely to be a shift in the shape of China's space infrastructure. Worldwide there is an ongoing shift away from large expensive stations as networks of small, but cheap optical and radar satellite tracking stations become more popular.[14] These stations will not reduce the need for large installations necessary for deep space missions, but it will mean that China can easily build redundant and highly accurate systems to track satellites and space debris.

SSA of course is not the only military application for ground segment operations.

Ground Segment Military Applications

Modern warfare requires the use of space for intelligence collection, communications and early warning. Ground segment infrastructure is an essential part of getting this data from satellite, to receiving dish, to headquarters or units in the field. The PLA relies on an extensive ground network to collect data gathered from reconnaissance, weather or early-warning satellites, determine unit locations through Beidou, or maintain communications with far distant units via intermediary relay satellites. Maintaining communication with more than 200 satellites, and downlinking their data for commercial and military purposes, including a nascent space-based early warning system and a communications network that will increasingly be vital for China's modernizing force. As will be discussed in subsequent sections, much of China's ground segment is operated by the PLA, or organizations with close links and data-sharing agreements.

As China completes its transition to an informatized force and looks ahead toward intelligent warfare [智能化战争], these ground based links will become even more important in handling larger bandwidth and acting as redundancies combating jamming or degradation of satellite constellations.

Chinese sources make it clear that likely adversaries' reliance on space makes space targets and supporting infrastructure an important target in a conflict. The 2000 edition of *Science of Campaigns* (2000), a textbook published by the Academy of Military Sciences concludes "to cripple or destroy the enemy's information system would drastically degrade the enemy's combat capabilities by making it blind, deaf or paralyzed."[15] Developing the capability to degrade enemy reconnaissance capabilities in the early stages of a conflict appears to be a major priority for Chinese military planners. This will rely on precise tracking of enemy satellites. China's ground segment and particularly the space situational awareness component will play a vital role in Chinese military space operations.

As a result, there has been major investment in both the ability to field satellites with military applications, and develop countermeasures to deny the use of space to China's adversaries. As noted in the unclassified summary of the *U.S. Space Strategy* released in June 2020: "[China has] weaponized space as a means to reduce U.S. and allied military effectiveness and challenge our freedom of operation in space."[16]

To attack enemy space assets China has developed a number of ground-based dazzling systems (which interfere with optics), or other high powered lasers, jamming systems and most famously direct-ascent anti-satellite missiles. In 2019, Acting Defense Secretary Patrick Shanahan stated that "China is deploying (counter space) directed energy weapons," confirming what had been widely speculated for more than a decade.[17][18]

Two additional areas are worth touching upon briefly as background: datalinks and strategic early warning systems.

Datalinks and Communications

Since the 1990s China has been working on an automated theater-level C4ISR system called Qu Dian [区电].[19] The system was intended to link together airborne sensors with satellites, buried fiber optic cable networks and microwave transmission nodes.[20]

The PLA Navy began building satellite datalinks in the 1980s, but practical a satellite internet network for its ships and outposts, called the BlueNet Project [蓝网工程], (such as those in the South China Sea) appear to have only taken shape in the mid-2000s.[21] While reporting on this system focuses on media and information streaming (providing sailors and marines access to digital publications for example) through a digital portal the system presumably involves high-bandwidth connections for other purposes.[22]

In the early 2010s, China appears to have begun work to develop a tactical data sharing and cooperative engagement capability, through the "Joint Integrated Data Link (JIDS) [全军综合数据链] linking ships, aircraft, and ballistic missiles.[23] The Space-Earth Integrated Information Network Mega Project is likely part of an effort to ensure reliable and redundant links between sensors and forces in support of battle networks like JIDS.[24][25]

Strategic Early Early Warning

The Chinese military uses a network of large phased array radars (LPAR) for early warning. This network, which appears to have been in place by the early 2000s, represent a modernization of the first early warning network of 7010 and 110 radars set up in the late 1960s to assist with missile instrumentation and space tracking. As with the other components of its ground segment, China appears to be moving toward space-based platforms. Russia has recently committed to supporting Chinese modernization of this system.[26] In 2016 *S&T Daily* confirmed that China had built space-based constellation of infrared early warning satellites called the "Outpost" [前哨].[27]

China's views of space as a strategic domain are not restricted to military applications. Space, especially space based services, are expected to be a major driver of economic growth.

Economic Development as Driver of Space Applications

China hopes that these satellite services will bolster the domestic economy, generating high-value jobs in advanced manufacturing, and generating revenues through space services such as communication ground stations and PNT-related applications. China is expected to build a national civil space infrastructure system by 2025, provide continuous and stable business services, improve data sharing service mechanisms, form a commercial development model, and have international service capabilities.

Chinese analysts note that the global space industry is estimated to reach $485 billion in 2020. China's market for launch vehicles, satellite applications and satellite broadband internet will be worth over $114 billion.[28] In 2018, for example, Beidou and related satellite navigation applications was supported by a workforce of roughly half a million people.[29]

Another example of the envisioned satellite-enabled "internet of things" is smart ships: largely autonomous cargo and other vessels linked to a global network of sensors, GNSS, and weather data. In November of 2018, a Chinese company tested the world's first "intelligent" cargo ship, Pacific Vision [明远], a 362-meter long Very Large Ore Carrier (VLOC).[30] Chinese companies see fleets of similarly-equipped ships as the future of maritime cargo shipping.

The Chinese government began actively encouraging greater investment in space in 2014 and as of 2020 there are over 100 'private' companies involved in space, though disentangling which are still largely part of the established SOEs working in the sector remains a challenge.[31]

As will be seen in later sections, these types of emerging sectors are driving the growth of ground segments within China and abroad.

1.3 Historical Overview of China's Ground Segment

China's ground segment has undergone a series of spurts of growth, related to national defense and civilian scientific projects. This section will initially address that history, charting the initial drive to develop infrastructure to support ballistic missile testing, communications satellites and reconnaissance satellites, and the faster expansion to first support manned space missions and later deep space programs, while accelerating development of civil space infrastructure such as earth observation, communications and GNSS satellites.

Origins of China's Ground Segment

What would become the foundations of China's space tracking and control system dates to the creation of China's first missile test range in the 1950s. In 1956, Chinese scientists founded the Northwest Comprehensive Missile Testing Facility [西北综合导弹试验基地], later to become the Jiuquan Satellite Launch Center with the aid of Soviet technicians and R-2 missiles provided by Moscow.[32]

After the launch of the Sputnik and Explorer satellites by the Soviet Union and United States in October 1957 and February 1958, the PRC leadership initially set its sights on launching a satellite by 1960. The program, codenamed Project 581 [581 工程] was quickly cancelled as the difficulty of the project became clear.

In 1960, with the withdrawal of Soviet advisors, Chinese leaders tasked the Chinese Academy of Sciences' Changchun Optical Machinery Institute with developing optical tracking systems under the code-named Project 150 [150 工程]. This program and others developing support infrastructure for missile testing would lay the foundations for China's space ground infrastructure.

In June 1967 China established a Satellite Ground Measurement Department [卫星地面测量部] in Qiaonan [桥南], outside Weinan [渭南], in the east central Shaanxi province, to administer a network of TT&C stations for its space program.

By the beginning of 1970, an initial satellite TT&C network, consisting of stations in Guangxi, Hainan, Hunan, Shandong, Xinjiang, and Yunnan was complete, and tested by tracking U.S. Explorer satellites.[33] This network played an important role in the launches of the Dongfanghong-1 satellite and the return-type remote sensing satellite.

In 1972 China took the first steps toward building a satellite communications ground station, using equipment donated by the Nixon administration after it was used to transmit coverage of his visit to television audiences in the United States.[34]

To further support development of domestic satellite communications capabilities work began on the requisite ground segment infrastructure. In 1974, the 7th Ministry of Machine Building [第七机械工业部], predecessor to the China National Space Administration (CNSA), China Aerospace Science and Technology Corporation (CASC), and China Aerospace Science & Industry Corporation Limited (CASIC), launched the 450 Project [450 工程], a system of tracking and measurement radars for the Dongfanghong-2, China's geostationary communication test satellite.[35] The first Dongfanghong 2 mission in January 1984 failed to achieve geostationary orbit, but a second test satellite, launched in April of that year, was successful. In the early 1970s China developed early warning and missile tracking radars, including the large-scale 7010 radar (also called the Xuanhua Radar Station [宣化雷达站]), built into the side of a mountain in Hebei, and the Type 110 radar in Zhanyi, Yunnan.[36] The stations were used to track foreign satellites, including the Soviet Kosmos-1402. They subsequently supported tests of the DF-3 and DF-5 in 1979 and 1980.

In September 1977, the CMC approved the *Three Grasps* [三抓], three major technological development programs: intermediate-range and intercontinental ballistic missiles, submarine-launched ballistic missiles, and geosynchronous communications satellites. While these programs were initiated in the 1950s and 1960s, they were delayed due to a combination of the withdrawal of Soviet assistance, the Great Leap Forward and the Cultural Revolution.

Developing the necessary supporting technologies, which ranged from computers to lasers, also required immense effort—and widespread adaption of foreign technologies. China's limited access to computers was a major limiting factor. When China launched its first satellite in April 1970, for example, the control center in Shaanxi had very limited technologies including a Doppler radar and single Type 717 computer, and technicians involved frequently had to resort to manual calculations and slide rules.[37] The now-expanded network of ground stations needed specialized ships to support tests of missiles fire. The China Satellite Maritime Tracking and Control Department was founded in June 1968, but construction of the Yuanwang ships, which used some of China's early computers such as the Type 151 and Type 260, were not commissioned until 1978.[38] These ships played a key role in tests of China's first ICBM in the South Pacific in May 1980, and of the Julang-1 submarine-launched ballistic missile in October 1982.

In 1986, the China Launch and Tracking Control (CLTC) [中国卫星发射测控系统部] was established to manage China's network of TT&C stations.[39] In December of the same year the China Remote Sensing Satellite Ground Station was founded to administer scientific earth observation ground stations under the Chinese Academy of Sciences. As will be discussed in greater detail in Section 2, CLTC and its subordinate organizations, are staffed by members of the PLA and an integral part of China's military space operations.

Shenzhou: China's Manned Space Program

Perhaps the highest-profile component of China's space program is the Shenzhou [神舟] manned space program. China first initiated a manned space program in April 1971, the 714 Project [714 工程], but the project was canceled due to the lack of necessary supporting technologies and infrastructure. Just over twenty years later, and having laid the groundwork for a robust space program, Chinese leaders began a new program. In 1992 the Manned Space Program (Project 921) was established. However, the complexity of spaceflight operations and necessity of maintaining communications, particularly during reentry, appears to have required Chinese government to begin making arrangements to build or lease ground stations outside China's borders.[40] The TT&C and communication system designed for the manned space program is the largest one to date, incorporating a much more comprehensive set of functions and the most advanced technologies.

Agreements were signed and construction begun in Africa, South America and South Asia. These facilities in Chile, Kenya, Kiribati, Namibia, and Pakistan were used to support a series of missions in the early 2000s, culminating with the October 2003 launch of Shenzhou 5, China's first crewed spaceflight mission. Manned spaceflights are planned for later in 2020, and China plans to complete construction of the 66 ton-Tiangong-3 space station by 2022.

Lunar and Mars Exploration

As outlined in section 1, China has set major milestones for exploration of the Moon and Mars.

The lunar exploration program (CLEP) was begun in 2003, and is divided into three major stages: orbiting, landing and sample return. The first lunar probe, Chang'e 1, was successfully launched in 2007, marking an important breakthrough in China's deep space TT&C capabilities. Chang'e 2, launched in 2010, went beyond lunar space to intercept an asteroid, required a more powerful TT&C network. The last of these initial stages of lunar exploration, the Chang'e 5 lunar sample return mission, is scheduled for late 2020.[41]

In July 2020, China launched its second mission to Mars, consisting of the Tianwen-1 Spacecraft and a lander and rover.[42] The first mission Yinghuo-1 [萤火一号], was intended to be China's first probe to visit Mars. However, the joint effort with Russia, and launched with the Fobos-Grunt sample-return probe ended in failure in November 2011, after the Russian deep space network lost contact with Yinghuo-1 and Fobos-Grunt.[43] Perhaps reflecting China's drive for self-reliance and the memories of that failed program, China's deep space and VLBI networks have been expanded to support the Tianwen-1 mission, which will arrive at Mars and land in April 2021.[44]

These programs, which require significantly larger antennae arrays, have been a driver of the growth of China's TT&C network domestically and abroad. Stations in Beijing, Jiamusi, Kashgar, Kunming, Shanghai and Urumqi, when networked with stations in Namibia, Argentina or elsewhere provide a much more powerful capability than if the domestic network alone was used.[45] As a result, China has built or established partnerships to establish a Very-Long-Baseline Interferometry (VLBI) network, which combines observations from several distant points for greater resolution.

China began work on large radio telescopes capable of deep space communications and VLBI projects in 1987 with the construction of the 25-m Sheshan observatory outside Shanghai.[46] The Nanshan 25-meter radio telescope outside Urumqi followed in 1993. The China Academy of Sciences China National Astronomy Observatory, found in April 2001 through the merger of Beijing, Xinjiang and Yunnan Observatories, the Changchun Satellite Observation Station, and other related organizations, operates many of these stations.

Ground stations in Australia (New Norcia), Chile (Santiago), Spain (Maspalomas) have also provided support to China's lunar Chang'e missions.[47] In 2006, deep space network facilities in Miyun, Beijing, and Kunming, Yunnan were completed to support the Chang'e 1 lunar mission. However, in 2007, Chinese authorities noted that they needed these stations as China did not have sufficiently large deep space tracking network of its own, especially to support the Chang'e 1 lunar mission.[48] Kouru and Maspalomas have continued to support these missions including Chang'e 5.[49] After completing its primary mission in lunar orbit, Chang'e 2, launched in 2010, visited the L2 Lagrange point between the earth and the sun and began interception of 4179 Toutatis, an asteroid.

China has also launched a deep space communications relay satellite, Queqiao [鹊桥], to support operations on the far side of the moon. Launched in 2018, it was positioned beyond the moon in the L2 Lagrange point.[v] Transmissions received the satellite outside of the moon's "shadow" could then be relayed on to the Chang'e lander and Yu'tu rover.

[v] Lagrange points are areas of space where gravity from different bodies largely cancel each other out, allowing objects to remain in stable positions

The Future: Space-Based TT&C

While the development of a global network of ground stations has opened doors for international cooperation, it does not come without risks. Access to stations abroad is contingent upon host-nations' permission, and often features language restricting their use for military purposes. In a conflict, China can expect access to these stations be further restricted, either by the host country or due to international pressure. Therefore, while these stations offer important new capabilities and flexibility, they do not resolve the longer issue of reliable access. As a result, China is investing heavily in communications and relay satellites as well as a large network of domestic and international ground stations.

The most important of these is the Tianlian [天链] series of data-relay satellites, which China has launched in part to help improve communications and reduce reliance on foreign tracking stations.[50]

The first satellite in the constellation was launched in January 2003. The second was launched d in 2008, with the system reaching initial global coverage with the launch of a third in 2012.[51] The second generation of the system, Tianlian 2, was launched in 2019. The satellites sit geostationary orbit (36,000km) and can operate similarly to ground stations, though they offer significantly better coverage. The new system features an extended mission lifespan, up to 12 years, and has higher bandwidth transmission.[52]

Another leg of the space-based infrastructure is a space-based Internet of Things (IoT). On May 12, 2020, China launched the latest group of satellites of the Xingyun or "Moving Cloud" Project [行云工程], a planned constellation of 80 communication satellites in low earth orbit that will provide global IoT connectivity.[53] The two satellites Xingyun 2-01 and Xingyun 2-02, are testing inter-satellite laser communications as well as ground-connections with IoT devices. In August 2020, the first two satellites of the Xinyun-2 Internet-of-things project successfully conducted inter-satellite laser datalink.[54]

At the same time, other smaller constellations of large high-throughput satellites (HTS) such as the SJ-20 [实践二十号] testbed launched in December.[55] HTS Satellites offer significant increases in transmission capacity compared to other communication satellites.[vi,56]

In the near future these services will increasingly be distributed. In 2018, Guan Hui [关晖], CEO of commercial operator Space Wisdom [宇航智科] proposed a new decentralized "Three Nos" [三无] model of satellite management: "No Stations, No Control Center, No Frequency" ["无测站、无中心、无频率"] which will treat satellites like cloud IT applications.[57]

There are additional, physical reasons to move components of the ground segment into space. Space-based SSA offers several important advantages compared to ground-based systems. While satellite Laser Ranging (SLR) and optical systems used to identify debris are restricted to hours when the sun can reflect off the objects, but the sky is dark enough to image effectively.[58] Optical and laser systems in orbit can operate 24/7. As a result, this appears to be the direction that both the United States and China have identified as optimal for space tracking duties. It is worth noting that while China has yet to field such a system, Boeing launched the first component of the Space-Based Space Surveillance (SBSS), which tracks space objects from deep space to low Earth orbit in 2010.[59] The US Air Force declared the SBSS fully operational in April 2013.[60]

[vi] HTS satellites are able to transmit at greater than 100 Gigabits/second, whereas conventional communication satellites' typically transmit at 10 Gigabits/second or less.

Space-based communication and SSA represent the ultimate goals of China's space infrastructure, but the road to get there has not been easy. The next section examines the history of China's space programs more generally with a focus on how ground segment networks have been built to support space operations.

2.1 China's Domestic Ground Segment

The preceding sections provided an overview of the trajectory of the development of China's ground segment. In this section, the organizations responsible for operating the ground segment, and to the greatest degree possible, the specific stations themselves, are profiled. Stations located outside China's borders those stations are covered in Section 3.[vii]

2.1 PLA Strategic Support Force Space Systems Department

The organization with the most responsibility for China's ground segment is actually a service under the People's Liberation Army. At the end of 2015, the PLA underwent significant reorganization, including the creation of a new service, the PLA Strategic Support Force (PLASSF) [解放军战略支援部队]. The service is intended to act as an "information umbrella" and provide advantages to the PLA in aerospace, space, cyber and electromagnetic domains.[61] This will include involvement in PLA information operations, electronic warfare, and cyberattacks, with the latter organized under its Network Systems Department [网络系统部].

Most relevant for this study is the creation of the Space Systems Department (SSD) [航天系统部] which has taken on many of the space launch, tracking, early warning and reconnaissance duties that had previously been allocated among the General Armaments Department and the components of the General Staff Department's 2nd, 3rd, and 4th Departments. As examined below, there is clear evidence showing that much of China's ground segment is now operated by the SSD. This includes much of China's SSA, space launch, and missile instrumentation infrastructure.[62]

Other areas with less clarity include the operations of China's constellations of spy satellites. China began launching photographic and electronic reconnaissance satellites (publically referred to as technology demonstration satellites [技术试验卫星]) in the early 1970s.[viii][63]

The PLA's current constellation of earth observation satellites designated Jianbing [尖兵] but launched under civilian designations, likely consists of the Yaogan 8, 15, 19, 22, and 27 satellites.[64] Elements of the Yaogan system may be similar to the U.S. Naval Ocean Surveillance System (NOSS) SIGINT satellites.[65] These are most likely subordinate to the Aerospace Reconnaissance Bureau [航天侦察局], formerly under the General Staff Department's Second Department (Intelligence).

The structure of satellite development programs and frequent exchanges or connections between the SSF and the various organizations charged with downlinking data from China's other satellites strongly suggest SSF involvement in those programs.

The SSD almost certainly plays a hand in another component of the PLA's ground segment: operations of its communications satellites. China launched a series of communications satellites divided into two groups: Fenghuo [烽火], first launched in 2000, believed to be dedicated military tactical communications, and Shentong [神通], first launched in 2003 for strategic communications.[66] At least six of these satellites (four Shentong, two Fenghuo) appear to be active as of writing.[67]

The former General Staff Department included a number of regional satellite communication stations [卫星通信地球站] which have subordinate numbered communications regiments [XX 通信团]. The 2nd Satellite Ground Station, for example, is based in Xi'an and uses the MUCD 61068.

[vii] The geographic coordinates of individual stations and areas of interest are provided in Appendix 2

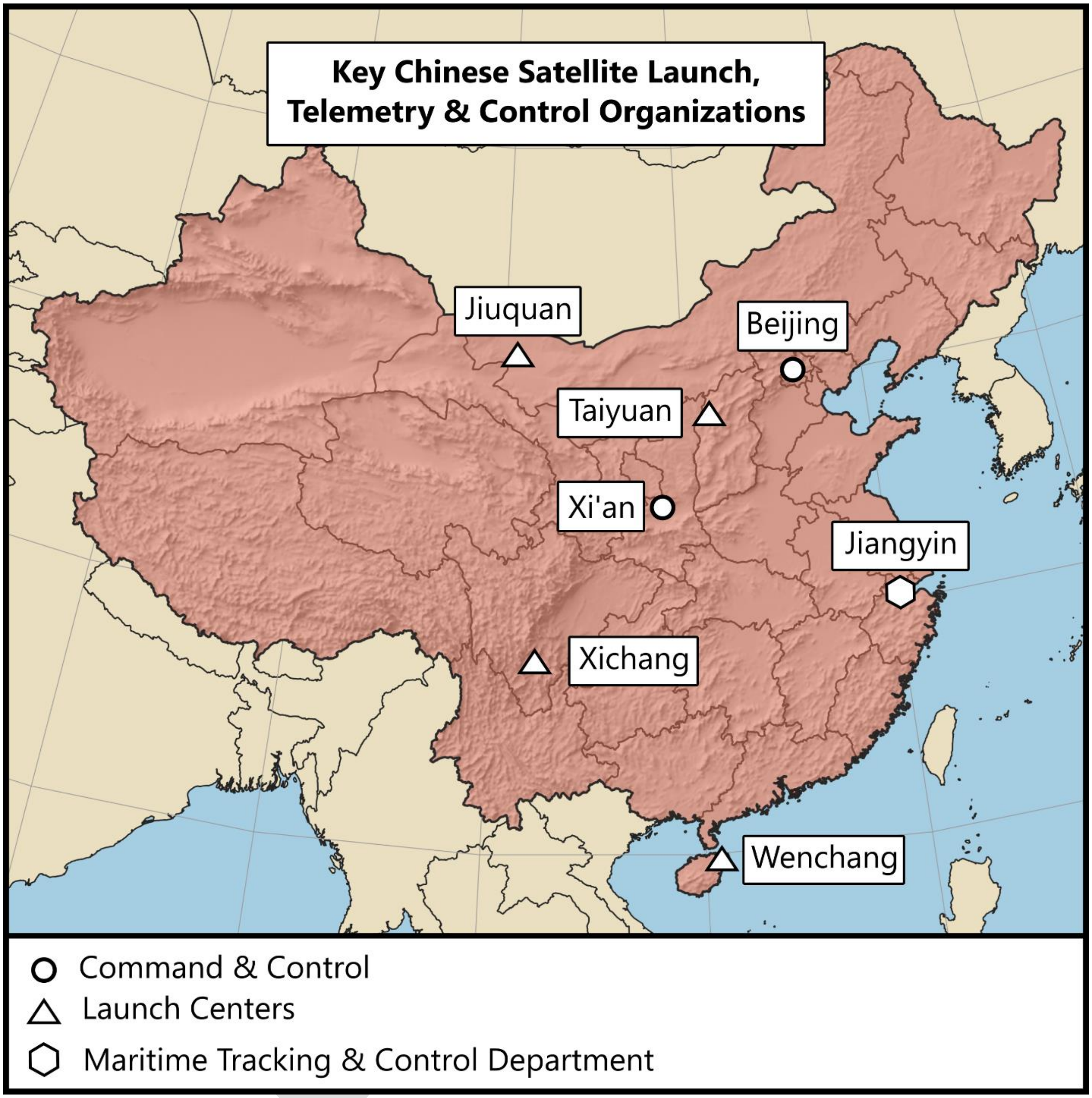
[viii] The first two missions of the Changkong [长空] series electronic reconnaissance satellites in 1973 and 1974 both failed shortly after launch. The first successful launch achieved low earth orbit in 1975.

It is likely subordinate to the SSF. Each PLA service is believed to operate its own central satellite communication station [通信总站]. Provincial-level Military Districts [军区] also appear to have dedicated satellite ground stations as well.

The SSD also appears to have taken over roles such as operations of Beidou and other navigation systems for the PLA, such as the CMC Joint Staff Department Navigation Bureau [联合参谋部导航局] and its Central Satellite Navigation Station [卫星导航定位总站], (Unit 61081, an SSF unit), which is responsible for the Beidou navigation system.[68]

Perhaps indicating the overall importance of space operations to the service and the PLA as a whole, the SSF's senior leadership, as of writing Lt. General Shang Hong [尚宏] (left), is believed to be the commander of the Space Systems Department. He previously served as chief of staff for the former General Armament Department (GAD), Chairman of the China Satellite Launch and Tracking General (CLTC), and commander of the Jiuquan Satellite Launch Center.[69] Hao Weizhong [郝卫中] deputy commander of the space systems department, formerly served as commander of Taiyuan Space Launch Center.[70] Fei Jiabing [费加兵], who serves as chief of staff, previously commanded the China Satellite Maritime Tracking and Control Department, which operates China's fleet of shipborne TT&C stations.[71]

2.2 Commanding and Supporting Organizations



China Launch and Tracking Control (CLTC)

The organization believed to operate the majority of China's space ground infrastructure is the China Satellite Launch and Tracking General (CLTC) [中国卫星发射测控系统部] (lit. China Satellite Launch & Tracing Systems Department). Established in 1986, it manages China's space tracking network and space launch centers.[72]

While outwardly portrayed as an independent civilian organization, there are strong indications that is a major component—or potentially synonymous with—the PLA Strategic Support Force Space Systems Department.[73] Its subordinate components are identified as PLASSF SSD units, and its current and former leadership includes PLASSF personnel. The Chief of Staff of the former General Armaments Department (Headquarters Department) [总装备部 (司令部) 参谋长] has historically concurrently occupied the role of CLTC chairman [中国卫星发射测控系统部主席].[74] A *China Youth Daily* article in 2011, for example, noted that it obeys the commands of the PLA General Armaments Department (GAD).[75]

CLTC's scope of responsibilities has been described as includes providing launch and tracking measurement and control services for domestic and foreign satellites, designing and producing satellite tracking, measurement and control, and demonstration equipment, and launch site construction.[76] CLTC consists of the following entities: Xi'an Satellite Control Center (XSCC), Xichang Satellite Launch Center (XSLC), Jiuquan Satellite Launch Center (JSLC), Taiyuan Satellite Launch Center (TSLC), Beijing Tracking and Communication Technology Research Institute (BITTT) and Beijing Special Engineering Design and Research Institute (BS EDI).[ix]

CLTC is heavily involved in China's space cooperation efforts globally, building stations in Chile and Argentina, among others. It provides services for many different nations, and its International Cooperation Department frequently holds outreach events promoting international space cooperation.[77] China Great Wall Industry Corporation (CGWIC), the government-owned commercial space service provider, for example, identifies CLTC as one of its primary subcontractors.[78]

Another organization under CLTC but which appears to have limited direct role in space tracking is the Beijing Special Engineering Design, and Research Institute (BS EDI) [北京特种工程设计研究院/北京特工院] is responsible for the overall design of China's spacecraft launch sites (Jiuquan, Xichang, Taiyuan, Wenchang).[79]

Beijing Tracking and Communication Technology Research Institute (BITTT)

Established in 1965, the Beijing Institute of Tracking and Telecommunications Technology [北京跟踪与通信技术研究所] (BITTT) leads the design of TT&C communication systems for China's space programs, including the construction of TT&C stations abroad. The Director of BITTT also sits on a panel of space experts convened by the CMC S&T Committee.[80]

BITTT is responsible for the design of both the TT&C system as well as the landing site system for China's manned spaceflight project. A May 2005 article in *PLA Daily* noted that BITTT is the only organization [总师单位] that undertakes the design of two subsystems out of the seven major manned spaceflight systems in China.[81] BITTT's central task, as of 2016, was supporting China's manned space and lunar exploration programs, building on its previous experience participating in major space missions in the following capacity:[82]

- TT&C and recovery tasks of four unmanned flights and three manned flights under the Shenzhou program;
- TT&C tasks for flight tests of launch vehicles and satellites;

[ix] While analysis of the specific equipment types used in ground segment operations is beyond the scope of this study, it should be noted that China Electronic Technology Group Corporation's (CETC) [中国电子科技集团公司] 54th Research Institute appears to be the main contractor for China's ground segment, producing "Over 90% of communication & 30% of TT&C equipment" for China's manned space program. It also produces equipment for Deep Space and VLBI stations, Yuanwang ships and Beidou ground stations. See: "The 54th Research Institute of China Electronic Technology Group Corporation," CETC, 25 November 2017.

- The design of the TT&C systems for all satellite control centers, TT&C stations, and the Yuanwang fleet;
- The demonstration verification test of the Beidou Satellite's rapid positioning system;
- The Chang'e-2 mission.

In its capacity operating as a general contractor of TT&C systems, BITTT has undertaken and completed the construction of ground TT&C systems for Nigerian satellites, Venezuelan satellites, and SinoSat, as well as the construction of foreign TT&C stations in Chile and Kiribati. As of 2016, R&D for the ground application and data receiving system for the Chang'e-3 lunar orbiter was underway at BITTT.

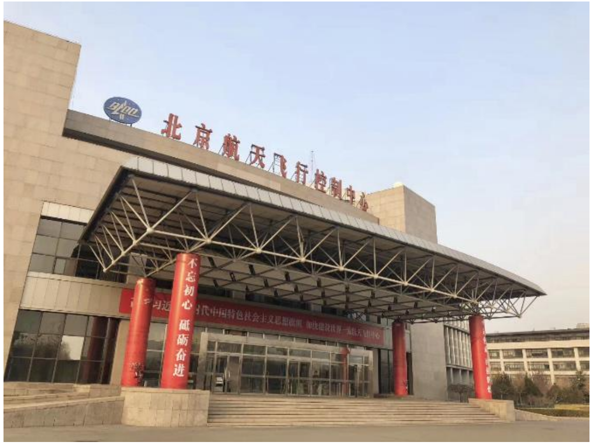
While the organization was previously identified as subordinate to CLTC, there are indications that it has been reorganized.

A study in 2020 for the U.S. China Economic and Security Commission suggests that BITTT, previously an organization under CLTC, is now subordinated to the PLASSF Space Systems Department.[83] This is supported by the fact that Dong Guangliang [董光亮], a senior engineer who sits on a panel of space experts convened by the CMC S&T Committee [中央军委科技委航天领域专家委员会], was identified as the director of BITTT in an article from November 2017.[84]

Dong previously served as the chief designer of the TT&C systems that supported the manned space program, phase three of the lunar exploration program, and the high-resolution earth observation system [高分]. He also served as a deputy chief designer of the Chang'e 4 and Mars Exploration missions.

According to information from 2016, BITTT is located in Beijing Space City [中国北京航天城] in Haidian District and employs over 500 people. It has more than ten subordinate laboratories and offers graduate programs and post-doctoral research positions to civilian as well as active-duty military personnel.[85]

Beijing Aerospace Flight Control Center
[北京航天飞行控制中心]



The Beijing Aerospace Flight Control Center [北京航天飞行控制中心], a component of the PLASSF SSD, serves as the command and control center for China's manned space, lunar exploration, and Mars exploration programs.[86]

Established in 1996, it is China's first modern flight control center capable of performing tasks such as transparent control, visual TT&C support, high-precision real-time orbit determination, high-speed data processing, and clear image transmission.[87] While launch phase operations are handled by the respective launch centers, the control center receives data from the Xi'an Control center and relays commands throughout the remainder of a mission.

During the July 2020 Tianwen-1 Mars exploration mission, for example, the Center took on a myriad of functions, including command and control, computing, data processing, information exchange, and long-term aircraft management.[88] As the mission flight control center, this center is also responsible for Earth-Mars transfer orbit control, Mars orbit capture control, Mars surface teleoperation control, and orbiter operation management.

Li Jian [李剑] (left) was appointed Director of the Center in 2016.[89]

2.3 China Xi’an Satellite Control Center

[中国西安卫星测控中心]
Xi’an, Shaanxi Province

The headquarters of China’s Satellite Monitoring and Control Network [中国卫星测控网] is the Xi’an Satellite Control Center. It is also formerly known as the 26th Testing and Training Base [总装第 26 试验训练基地] of the General Armament Department (GAD). The Center remains part of the PLA, though it is now subordinate to the PLA Strategic Support Force. Yu Peijun [余培军] has served as Director and Qi Yahu [祁亚虎] as Party Secretary since 2017.[90] In 2017, Qi was identified as a member of the Strategic Support Force during his participation as a delegate to the CCP’s 19th Party Congress, and he is believed to hold rank above Major General.[91]

Its primary roles are satellite tracking, data transmission information processing, monitoring, and control. Spacecraft launched from China’s launch centers are controlled from the Xi’an Center, with the participation of their subordinate TT&C infrastructure. Data from satellites and spacecraft is received and processed at the center, and then passed to the Beijing Aerospace Control Center.

The Xi’an Center has major responsibility for tracking and reentry missions for China’s crewed space program, which are handled by a combination of stations abroad, including the Swakopmund, Namibia station, and the Third Mobile Station in Inner Mongolia (both profiled in later sections).[92] The Shenzhou 1 mission in 1999, for example, involved three coordinating centers, 11 ground within China and abroad, and four maritime TT&C ships.[93]

The Center has multiple subordinate large ground stations and controls mobile stations. Some of these ground stations also have subordinate sub-stations [分站].

Under the Xi’an Center, the Xi’an Measurement and Control Technology Department [西安测控技术部] is the organization directly responsible for administering stationary and mobile TT&C stations.

History

The predecessor to the Xi’an Center, the Satellite Ground Tracking Department [卫星地面测量部] was established in Qiaonan [桥南], outside Weinan, Shaanxi Province on June 23, 1967. Initially, the Weinan department was subordinate to the 20th Base (Jiuquan).

The department played an important role in all three of the “Three Grasps,” providing TT&C support to the Dongfanghong communications satellite and missile tests. China’s early warning radar network built during the early 1970s, including the 7010 radar or Xuanhua Radar Station [宣化雷达站] and Type 110 radar in Zhanyi, Yunnan, were operated by the Department. As part of the expansion of tracking infrastructure ahead of ICBM and SLBM testing in the early 80s, the organization was upgraded to a Center that was formally established in September 1975. The current form of the organization was created in 1987 when it moved from Weian to Xi’an in 1987 to accommodate the requirements of its expanding size.[94]

In the 1980s and 1990s, the core aerospace launch and TT&C network [航天测控网] was composed of the three launch sites: Jiuquan, Taiyuan, and Xichang, supported by command and control sites in Xi’an and Beijing and assisted with data from ground stations in Changchun, Lingshui, Kashgar, Nanning, Weinan, Xiamen, and the fleet of Yuanwang ships in Jiangyin, Wuxi.

Ground Stations

The following ground stations are identified as subordinate to the Xi'an Satellite Control Center. While their personnel do not necessarily wear military uniforms, it is clear that these are units of the PLA Strategic Support Force.

Changchun Station

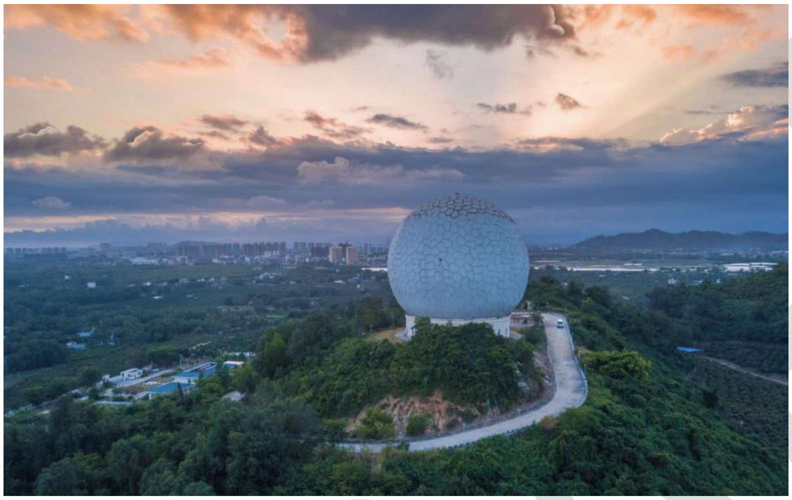
The Changchun Satellite Tracking & Control station [长春测控站] was established in 1968 and is located in Liming Village [黎明村], outside Changchun, Jilin. It has been identified as subordinate to the PLASSF and is believed to use the MUCD 63759.[95] It is equipped with a 154-IIB monopulse radar, and may also be a sub-station of the Jiamusi Satellite Tracking & Control station, which is part of the Deep Space Network.[96]

Kashgar Station

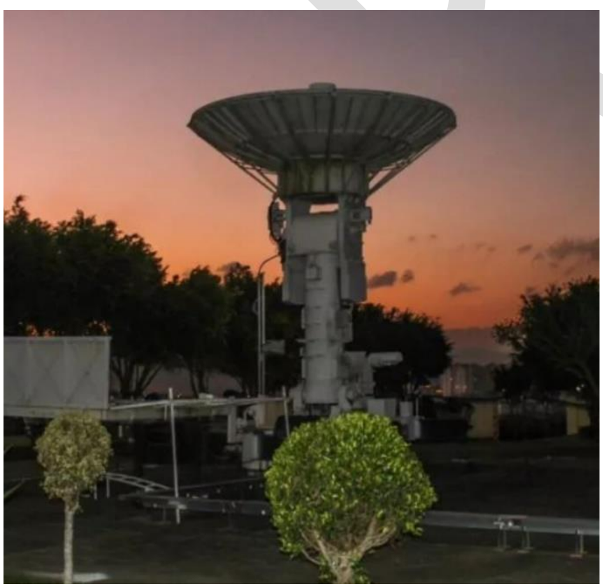
Kashgar (or Kashi) in Western Xinjiang AR is home to several TT&C stations, including China's first space TT&C station, established in 1968.[97] It appears to have been subordinated under the Base 26 of the General Armament Department until the military reorganization in 2016 when it was transferred over to the PLASSF. It uses the MUCD 63783.[98]

Lingshui (Hainan) Station

[陵水测控站]



One of several space tracking and downlink facilities based in Hainan is the Lingshui Control Station. The station began operations in April 2008.[99] It has been involved in tracking experimental SJ-series satellites.[100] While few details are available, commercial imagery indicates the facility was built in 2012 and features a 40m radome. The National Satellite Ocean Application Service [国家卫星海洋应用中心] operates a ground station 8km to the Northeast.[101]



Menghai Station

[勐海测控站]

A station appears to have been built in Menghai County, Xishuangbanna, Yunnan Province, sometime in early 2019. The Menghai station, identified as supporting the Xi'an center, has apparently supported the Jilin-1 Gaofen-02A [吉林一号高分 02A 卫星], and possibly the Ningxia-1 [宁夏一号卫星], satellite launches in November 2019.[102]

It also carried out tracking for a Jielong-1 carrier rocket [捷龙一号运载火箭] launch with three satellites in August 2019. While there does not appear to be a previous mention of the station in Chinese news media, a review of commercial satellite imagery suggests it has existed since at least 2010, had satellite dishes since at least 2012, and doubled in size between 2012 and 2016.[103] It may be a sub-station of the Nanning Station.[104]

Minxi Station

[闽西测控站]

Minxi station was originally founded as the Minxi Observatory in October 1967. It provided tracking support to the failed launch of the Changkong-1 [长空一号] electronic reconnaissance satellite in July 1974.[105]

In 1975, the station was expanded to house the 450 Project, the microwave measurement and control system for experimental Dongfanghong 2 communication satellite development program, also called the 331 Project.[106] The Dongfanghong 2 satellites were launched on 29 January and 8 April of 1984, the former failing to achieve the desired orbit.[107] After the end of the Dongfanghong 2 program the station was apparently closed, and a new station opened in Xiamen, Fujian.

Nanning Station

[南宁站]

Nanning Station was established in 1967 as part of the original space tracking network.[x] It is located in the Xixiangtang District [西乡塘区], of Nanning, in the Guangxi Autonomous Region.[108] Since its establishment, it has been involved in numerous launches, including the Shenzhou-7.[109] It also has a sub-station [分站] in Yao'an, Yunnan Province that was involved in a 2014 experimental launch as part of atmospheric reentry tests for the Chang'e-5 mission.[110] It uses an S-band tracking and control system and has been used for international tracking & control missions, including with France.**Error! Bookmark not defined.**

It is identified as a PLASSF unit and uses the MUCD 63760.[111][112] As of 2019, the unit commander is Zhang Wuzhan [张武战].[113]

Qingdao Station

[青岛测控站]

Located in Qingdao's Chengyang District [城阳区], it is affiliated with Xi'an Satellite Control Center and was established to support China's manned spacecraft program. It is sometimes referred to as the Bohai Station [渤海站]. The station has 18-meter and 10-meter receiving dishes. The larger of these was added around 2007, and the station has roughly doubled in size since 2006. It has successfully supported the Shenzhou missions and received an award for "outstanding contribution for its participation in Shenzhou 1 test in 1999, the first step in China's manned space mission program from the General Armament Department.[114] It appears to be the successor to an earlier station established to support the ICBM, SLBM, and communication satellite tests in the 1980s.

[x] Elements of the Xiangxi /Western Hunan Station [湘西观测站], one of China's first TT&C stations, may have moved to Nanning after it was shut down and the network reorganized around 1987.

Xiamen Station
[厦门测控站]

In 1991 construction of a second station began in Xiamen, Fujian province to support the Shenzhou, and later Beidou programs. It began operations in 1994.[115]

Satellite imagery indicates that Xiamen station underwent a major upgrade of its equipment in 2014.[116] It uses the MUCD 63758.[117]

At least one mobile satellite tracking support unit of the Xi'an Center's Mobile Support Department [活动测控部] is based in Xiamen (left).[118][119]

Weinan station
[渭南测控站]

Located just an hour's drive to the east of downtown of Xi'an, Weinan was the original home for China's Space Tracking Network. After the Xi'an Center was established, it remained involved a subordinate TT&C station and participates in long-term management of over 100 satellites and spacecraft.[120]

It is also home to a PLASSF unit with the MUCD 63752, which is described as a comprehensive control station [综合性测控站]. As of 2020, the director of the Weinan Station is Wei Hui [尉辉].[121]

Xiangxi (Western Hunan) Station
[湘西站]

Located in Xinhua County, Hunan Province [湖南省新化县], this station is was originally part of China's first TT&C network. Construction of the station was approved in 1967, and equipment was installed in 1968. The completed station featured a Type 154 monopulse radar and Type 717 computer.[122] The unit was given the MUCD 89756. The station supported the launch of the Dongfanghong-1 and other launches but was ultimately closed in 1987 due to the reorganization of the TT&C network.

Zhanyi Station

[沾益测控站]

One of the earliest stations involved in satellite tracking and missile instrumentation is the Type 110 radar in Zhanyi.[123] It began trial operations in 1971 and worked in conjunction with the 7010 Radar in Hebei in tracking various domestic and foreign satellites and supported missile testing of the DF-3 and DF-5. The station has a Type 110 tracking radar, can identify targets up to 1,700 kilometers away, and track up to 1,200 kilometers away.[124,125]

As of writing it appears to be active, with multiple upgrades to the power infrastructure and barracks areas around it in recent years.

Mobile Tracking Stations
[活动测控站]

Mobile tracking stations provide flexible support to space launches, maintaining contact with satellites as they move out of line of sight with permanent ground stations.

Three mobile tracking stations are subordinate to the XSCC Mobile Tracking & Recovery Department [西安卫星测控中心活动测控回收部] (Unit 63762), which is located in Weinan, Shaanxi Province [陕西渭南].[126,127]

The first station is also located in Weinan, while the second (at least partially) is based in Hetian, Xinjiang AR (aka Hetian Station [和田站]).[128] The third is located in Siziwang, Inner Mongolia AR.

The first two provide mobile spacecraft (satellite and manned spacecraft) tracking, while the third provides tracking for reentry of spacecraft. All have been involved in various Shenzhou manned spacecraft missions.

First Mobile Station, Weinan, Shaanxi

Few details appear to be available about this organization, but it is known that the station was established in 1969.[129] One or more sub-stations are also present nearby.[130] It is believed to use the MUCD 63771.

Second Mobile Station, Hetian, Xinjiang

The Hetian (also spelled Hotan/Khotan) Station, located in Xinjiang, supports the Xi'an Satellite Control Center. The Hetian station was established around 1970.[131] It appears to have at least one antenna that is 5-meters tall.[132] One or more of the stations may have a 4.2-meter antenna.[133]

As of 2018, the Director of the 2nd Mobile Ground Station is Chen Songming [陈松明] (inset).[134] It may have the MUCD 63772.[135]

Third Mobile Station – Main Landing Station, Inner Mongolia

The third station is the "Main landing station" [着陆场站] for satellites and China's Shenzhou manned space missions.[136] The predecessor of these stations was involved in China's first recoverable satellite mission in 1975.[137] It appears to be also be known as the main station [主场站], short for main landing station [主着陆场站]. Also known as the Recovery Tracking Station [回收测量站], it has a search-and-rescue and recovery team [搜救回收队] composed of ground vehicles and helicopters.[138] Jiuquan Satellite Launch Center personnel may also be involved. It is located in Honggor Sum, Inner Mongolia [红格尔苏木]. There is also a secondary landing site [副着陆场] at the Jiuquan SLC. This may be the Dongfeng Landing Station [东风着陆场], which is involved in testing and recovery of a new reusable crewed spacecraft for that will be used to transport astronauts to China's future space stations.[139]

Deep Space Network

China has also built a Deep Space Network [深空网络] of large radio dishes to communicate with its manned space missions and lunar and mars space exploration missions.

The network is primarily composed of three dishes in Kashgar, Jiamusi, and Neuquén, Argentina, and is subordinate to CLTC through the Xi'an Satellite Control Center.[140] The network was expanded and upgraded to support the "Chang'e-3" and "Chang'e-4" missions.[141] The stations also contributed to European and U.S. space missions, with Jiamusi providing support to ESA's Cassini Saturn probe and NASA Juno probe missions. Other stations abroad have supported Chinese space missions, including a station in Malargue (Argentina) New Norcia (Australia) and Cebreros (Spain).

Kashgar Deep Space TT&C Station
[喀什深空测控站]

Kashgar's 35m deep space TT&C station [35 米深空测控站] was designed and built by a team from the 54th Research Institute of CETC [中国电子科技集团公司第五十四研究所], a certified primary contractor for the PLA. The project was initiated in 2008 and completed at the end of 2012.[142] It is roughly situated about 160km south of Kashgar in a part of the desert referred to as the Heizi Gobi [黑孜戈壁].

The Kashgar station was designed and built by a team from the 54th Research Institute of CETC [中国电子科技集团公司第五十四研究所], a certified primary contractor for the PLA, and represents a major improvement in the Institutes' development of VLBI (Very Long Baseline Interferometry) technology. The Kashgar 35-meter deep-space measurement and control station, along with a 65-meter radio telescope antenna in Sheshan, Shanghai, and a 50-meter radio telescope antenna in Beijing, form a VLBI network that has increased the accuracy of the ground station's angle measurement of deep-space targets by nearly three orders of magnitude.

The Kashgar deep space Tracking station includes three 35-meter receivers. Construction began in August 2011, with a single antenna completed by 2013. Two additional receivers were added in 2020. The station participates in the Chang'e 4 mission, communicating with the lunar orbiter and Yutu-2 rover on the surface of the moon.

The station appears to be a subordinate sub-station of the Kashgar TT&C station.[143]

Jiamusi Deep Space TT&C Station

The Jiamusi station is located in northeastern China in Heilongjiang province.[xi] Completed in 2012, the 66-m radio telescope is used to study pulsars but is equipped with transmitters as well as receivers allow it to act as command and control for deep space missions.

Director as of 2019 is Han Lei [韩雷].[144] One article describing cooperation between Jiamusi Deep Space Station and the National Astronomical Observatory of China [国家天文台] described their cooperation as "joint military-civil cooperation that achieved 'win-win' results [军地联合科研取得了双赢的效果]."[145] In 2018 the station successfully made contact with the Queqiao [鹊桥] relay satellite, allowing China to control the Chang'e 4 lander and lunar rover on the far side of the moon. The stations are also involved in maintaining communications with the Tianwen 1 [天问一号], China's Mars spacecraft mission launched in July 2020.[146]

[xi] The station is also sometimes called Linhai [林海]

Neuquén, Argentina

The Neuquén Deep Space Station [内乌肯深空站], also called Zapala station, is located in central Argentina.

Neuquén is crucial to the operation of China's Deep Space Network, filling the gap in global coverage between the Kashgar and Jiamusi stations to provide support to deep space missions, including the Tianwen Mars exploration mission launched in 2020.[147] It is also involved in lunar missions, maintaining communication with the Queqiao relay satellite in the L2 Lagrange point, which allows data to be transmitted to probes on the other side of the moon.[148]

The station is the result of an agreement signed in 2015 by then-President Cristina Fernández de Kirchner and Xi Jinping. Controversially, the agreement granted China 50 years full sovereignty over a site with an area of almost a square mile (200 hectares) in Bajada del Agrio, Neuquén province, and exemption from taxes.

The station, which features a 35-meter receiver weighing 450 tons, was completed in 2017. Experts from the Xi'an Satellite Control Center helped manage the project and construction was handled by China Harbour Engineering Company [中国港湾工程有限责任公司].[149]

China and Argentina are "Comprehensive Strategic Partners," and the Neuquén station is one of a raft of joint projects including dams, a nuclear power plant, and modernization of a railway.[150] Construction was expected to bring in 300 million pesos ($37.5 million USD at the time) and then-Ambassador to Argentina Yan Wanming said the facility would help create 1,500 jobs in Argentina.[151,152]

However, the station attracted controversy due to the station's links to the PLA through CLTC.[153] Others objected to legal exemptions given to the station and other restrictions. Entry to the facility is also controlled by Chinese personnel.[154] Chinese employees at the station work under Chinese labor law, not Argentina's, and Argentina's space agency, Comisión Nacional de Actividades Espaciales (CONAE), only has access to the station 10 percent of the time.[155]

While the station's stated purpose is to "promote activities such as interplanetary exploration, astronomic observation and to follow and control orbiting satellites and data acquisition," President Macri, who assumed office later in 2015, requested an annex to the agreement prohibiting military use of the station.

While its status remains controversial, it is an integral component of China's Deep Space Network and will be important to the completion of China's planned lunar and Mars exploration missions.

2.4 Launch Centers

While most components of the space tracking network fall under the Xi'an Satellite Control Center, each of China's Satellite Launch Centers and Sites has its own group of subordinate stations and substations. The Satellite Control Center is responsible for long-term monitoring and tracking of satellites, but for the launch phase of space missions or during missile testing, the launch centers appear to have lead responsibility.

Jiuquan Satellite Launch Center (JSLC)
[酒泉卫星发射中心]

The birthplace of modern Chinese rocketry and China's space program, the Jiuquan Satellite Launch Center was established in 1958 as the Northwest Comprehensive Missile Testing Facility [西北综合导弹试验基地].[169] The center is located Buge Yin'a Rila, in the western part of Inner Mongolia [布格音阿日拉].[156]

The Center has also been known as the 20th (Testing and Training) Base [第 20 (试验训练) 基地], Dongfeng Aerospace City [东风航天城], and in the West as the Shuang Cheng-Tzu Missile Test Center. [157] The Center is subordinate to the PLA SSF Space Systems Department and uses the MUCD 63600.[158] As of April 2020 its commander is Zhang Zhifen [张志芬], and political commissar is Ji Duo [纪多] (both as of April 2020).[159]

Jiuquan specializes in placing satellites in medium, low earth orbit and high inclination orbits, as well as scientific and experimental and recoverable satellite launches.[172]

The Center mainly launches CZ-2C/D, CZ-4B/C, and CZ-11 Long March rockets, and has thus far been the country's only launch center for the manned spaceflight (Shenzhou) program.[160] The Center has carried out all Shenzhou [神舟] manned spacecraft and both Tiangong [天宫] space station program launches, all Tianhui-1 [天绘一号] and several recoverable satellites, Shijian [实践], Yunhai [云海], Gaofen [高分], Zhuhai-1 [珠海一号], Yaogan [遥感], Jilin-1 [吉林一号], LKW [陆地勘查],[161] satellite launches, among others.[173] China has launched four since March 2017.[162]

Continuing its historical role, the Center also carries out short-range ballistic missile, land-attack cruise missile, and space intercept testing.[163]

While there is little information about it, some sources reference a Jiuquan Comprehensive Tracking Station [酒泉综合测控站], which may include space- and missile-related tracking stations in the area.[164] This may be related to the JSLC launch test station [酒泉卫星发射中心发射测试站], but it is unclear. There are several tracking facilities in and around the grounds of the Center that appear to be part of this organization: the Dashuli Radar Tracking Station [大树里雷达测量站], an optical tracking station [光学测量站点] to the northeast of the Center, and just above the North Technical Center a telemetry station.[165]

The Dong Feng Control Station [东风测控站] is part of the Jiuquan Satellite Launch Center [中国酒泉卫星发射中心] and has been involved in the launches of various spacecraft, including the Shenzhou-7.[166] It also features a 68-meter calibration tower [标校塔] there.[167]

The JSLC also has a network of large phased array radars (LPAR) in the following locations: Korla area, Xinjiang AR [新疆库尔勒市开发区]; Huanan County, Heilongjiang Province [桦南县]; Yiyuan County, Shandong Province [山东淄博市沂源县]; Longgangzhen, Zhejiang [龙井桥乡]; and possibly a fifth in Hui'an, Fujian Province [福建省泉州市惠安县].[168] While their focus is detecting incoming threats, their historical predecessors (the 110 and 7010 radars) participated in space tracking and missile instrumentation missions.

Taiyuan Satellite Launch Center (TSLC) [太原卫星发射中心]

Kelan County, Xinzhou, Shanxi [山西忻州岢岚县]

Established in 1967, the Taiyuan Center is also known as the 25th Testing and Training Base [第 25 试验训练基地].[169] While referred to in English and Chinese as Taiyuan, it is located over 150km away from Taiyuan, the provincial capital of Shanxi. Historically it has been referred to as the Wuzhai Space and Missile Test Center by Western analysts after the county to the Northeast. The Center is subordinate to the PLA SSF Space Systems Department [航天系统部], and has an assigned MUCD of 63710. As of December 2019 its commander is Yu Zhijian [于志坚],[170] and political commissar is Wan Minggui [万明贵] (October 2019).[171]

It has launched various Long March rockets, Dongfeng missiles, and a range of satellites,[169] specializing in low earth orbit and sun-synchronous orbit satellites.[172]

Civilian rocket launches from the center include CZ-2C/D, CZ-4B/C, and CZ-6 Long March rockets, and a range of satellites, in particular the Gaofen [高分], Haiyang [海洋], Yaogan [遥感], Gaojing [高景], Ziyuan [资源], Fengyun [风云], and Shijian [实践] series.[173]

The Center is also thought to test medium- and intermediate-range ballistic missiles like the Dongfeng [东风] series.[174]

Befitting these roles it has extensive TT&C infrastructure. There is a telemetry station on the grounds of the TSLC which may be the same as the TSLC tracking & control station [太原卫星发射中心测控站]. [175176] The Center has eight tracking stations, including one main radar tracking station [雷达测量站] at Yangqu, Shanxi Province [阳曲站] and three secondary stations at Lishi, Shanxi [山西离石], Yulin, Shaanxi [陕西榆林], and Hancheng, Shaanxi [陕西韩城]. [177178] All four are subordinate to the Lüliang Command Post [吕梁指挥所].[179] The Post is also known as the TSLC radar tracking station [太原卫星发射中心雷达测量站][180] and might also be known as the (Taiyuan) tracking & control center [(太原)测控中心], and is located in Taiyuan (apparently at the TSLC) and not Lüliang.**Error! Bookmark not defined.Error! Bookmark not defined.** The Yangqu Station has a vehicle-mounted radar tracking station, while the others' vehicle-mounted radar can only receive and not send signals.**Error! Bookmark not defined.** The remaining four stations appear to be optical tracking stations [光学测量站点].**Error! Bookmark not defined.** There is also a radar station , though this may just be one of the aforementioned tracking stations.**Error! Bookmark not defined.**

A mobile radar station located in Yinchuan, Ningxia AR [宁夏银川] is identified as subordinate to the TSLC and uses the MUCD 63726. The unit also has a radar tracking station in Wuwei, Gansu Province [甘肃武威市凉州区].

An additional station that participates in manned spacecraft tracking and control and is believed to be under the TLSC is Xingxian Station [兴县站]. This radar tracking & control station [雷达测控站] is located in Xingxian, near Lüliang.[181] As of 2018, the unit has been in Xingxian for over 40 years and had carried out six Shenzhou manned spacecraft and over 100 satellite tracking and measurement missions as of 2007. [182,183] It appears to be a PLASSF unit with the MUCD 63717and is described as subordinate to the Taiyuan tracking and control center [太原测控中心][xii] presumably under the Taiyuan Satellite Launch Center.[184,185]

Xichang Satellite Launch Center (XSLC)

The Xichang Satellite Launch Center [西昌卫星发射中心] is located in Mianning County, Liangshan Yi Autonomous Prefecture, in south-central Sichuan Province [四川省凉山彝族自治州冕宁县].[186]

[xii] This may also be known as the Lüliang Command Post [吕梁指挥所]

Established in 1970, the center was also known as the 27th Testing and Training Base [第 27 (试验训练)基地] under the General Armament Department. [187] As with the other centers it is now subordinate to the PLA SSF Space Systems Department [航天系统部] and uses the MUCD 63790.[188]

Zhang Xueyu [张学宇] (left) is the commander, and the political commissar is Dong Chongqing [董重庆] (both as of June 2020).[189] Li Shangfu [李尚福], current director of the CMC Equipment Development Department (EDD), previously served as director of the launch center.[190]

The Center launches mainly CZ-3A, CZ-3B (sometimes with Yuanzheng-1 [远征一号] upper stages), CZ-3C, and CZ-2C Long March rockets.[173] The Center has launched all of China's lunar exploration / Chang'e project spacecraft, all of the Beidou navigation, Tianlian-1 [天链一号], and communications technology test-series (TJS) [通信技术试验卫星] satellites, and several Apstar [亚太], ChinaSat [中星], Yaogan [遥感], Fengyun satellites, among others.[173] It focuses on geostationary orbit broadcast, communications and meteorological satellite launches.[172]

Xichang appears to still carry out more foreign commercial satellite launches than any other Chinese launch site, including satellites for Nigeria (2007), Venezuela (2008) and Indonesia (2009).[191] Xichang was also reportedly the site of an anti-satellite weapon launch in 2007.[192]

Supporting tracking stations include the XSLC Niutoushan tracking station [牛头山观测站] located to the southeast of the launch site.[193] Another tracking station is located just to the west of Xichang City.[194] The XSLC also includes a "launch test station" [发射测试站].[195]

An additional PLASSF Satellite Observation and Measurement Station under the Xichang Center located in Yibin [宜宾] in Sichuan province and is part of the Xichang Satellite Launch Center.[196] Built between 1976 and 1978, the station has participated in over 200 Chang'e, Beidou, Fengyun, and other satellite tracking and measurement missions from the Xichang, Jiuquan, and Taiyuan launch centers.[197]

The station has been identified as a PLA unit with the MUCD 63819.[198] As of June 2018, the station's commander was identified as Bao Zhenqing [鲍振轻], and its Party Committee Secretary was Tang Gang [唐刚].[199] Additional auxiliary satellite observation stations appear to be present in the Baita Mountain [白塔山] area, possibly built in 2020, and in the Xuzhou District [叙州区].[200,201]

Wenchang Spacecraft Launch Site
[文昌航天发射场]

China's newest launch site is located in Wenchang, Hainan Province [海南文昌]. Although sometimes referred to as the Wenchang Launch Center, as of 2020, it is still identified as subordinate to the Xichang Launch Center.[202] Due to its location closer to the equator, launches from this location require less energy or are capable of launching heavier loads, making it mainly responsible for geosynchronous satellites, polar-orbiting satellites, space stations, deep space probes.

Tracking and control duties during the launch phase are handled by Tongguling tracking station [铜鼓岭测控点] in Wenchang and the Paracel Islands tracking station [西沙测控站] on Duncan Island [琛航岛].

2.5 China Satellite Maritime Tracking and Control Department

[中国卫星海上测控部]

When spacecraft (or missiles undergoing testing) are over the ocean, specialized ships, typically called tracking or missile instrumentation ships, are necessary to collect data and send instructions. Equipped with satellite receiving dishes, radars, laser rangefinders, and optical telescopes, they remain in contact with satellites and monitor them for issues as the spacecraft passes out of line of sight with ground stations.

China operates two groups of ships involved in these duties. The first is a small fleet of space tracking and rocket transport ships designated, Yuanwang [远望], that are operated by the China Satellite Maritime Tracking and Control Department (Base 23) [中国卫星海上测控部] in Jiangyin, Wuxi [江阴, 无锡市, 江苏省], more than 100 kilometers up the Yangtze River.

These ships were built to act as both missile instrumentation and satellite tracking duties, and help maintain communications with satellites and ballistic missiles as orbits pass through areas outside the range of ground stations. While these ships allow China to conduct tracking missions in international waters, operating them is expensive, and while they operate for extended periods, the overall number of ships is limited compared to the demands for their support, as an individual launch can involve multiple ships. The fleet maintains a high tempo of operations, and as of June 2020, the Department has completed 200 tracking and control missions.[203]

Ship	Date Commissioned	Status	Mission
YW-1	1978	Museum Ship	Maritime TT&C
YW-2	September 1978	Museum Ship	Maritime TT&C
YW-3	May 1995	Active	Maritime TT&C
YW-4	October 1979	Destroyed in test	Maritime TT&C
YW-5	September 2007	Active	Maritime TT&C
YW-6	April 2008	Active	Maritime TT&C
YW-7	July 2016	Active	Maritime TT&C
YW-21	May 2013	Active	Rocket Transport
YW-22	June 2013	Active	Rocket Transport

History

In June 1968, Mao Zedong, Zhou Enlai, and the CMC approved a proposal from COSTIND [国防科委] regarding the development of far seas vessels including escort ships, logistics, survey and other 'special engineering' vessels [远洋特种工程船]. A central goal of this proposal was to assist in the development of ICBMs, which would need tracking and instrumentation ships downrange (in the south pacific) for testing.[204] The program was approved for inclusion in the state plan in December 1970 and established a leading small group for the development of maritime survey vessels [远洋测量船工程领导小组] under the State Council and CMC. The China Satellite Maritime Measurement and Control Department was established in April 1975.[205] In September 1977, the Party Center approved the "Three Grasps" [三抓] program to develop an ICBM, an SLBM, and a communication satellite, all of which would require maritime tracking and instrumentation support. In August and October 1977, China's first

20,000-ton space tracking ships were laid down. By 1980 the special engineering project had completed the Yuanwang 1 and 2, as well as the Xiangyanghong 10 and various other special support and rescue vessels.

The Department's first major mission in May 1980 was to participate in tracking of a test of the DF-5 intercontinental ballistic missile (ICBM), which targeted an empty patch of the south pacific 8,000 km away. Tests of the Julang-1 SLBM followed in 1982.

The fleet has been expanded and upgraded since 1986, but the two original two ships built in the 1970s have been retired while another was damaged beyond repair in an accident and used as a target in a missile test.[206] The Yuanwang Ship Detachment [远望号船队] is currently composed of four tracking ships and two rocket transport ships.

The Yuanwang ships are both physically large and built to withstand missions that can cover thousands of nautical miles lasting over 100 days away from home port. In 2019, for example, Yuanwang fleet, including transports, carried out 17 tracking and control missions, one rocket transport mission, and spent a cumulative 550 days at sea.[207] These ships regularly deploy to the Central Pacific or the Indian Ocean in support of satellite launches.[208]

While their hallmark is the massive radio dishes, they also carry sophisticated radars, laser satellite ranging, communication, and precision timing equipment.[209] The Xi'an satellite measurement and control center is connected to the Yuanwang ships via wired and satellite communications.[210]

The Yuanwang 21 and 22 are Rocket Transport Ships [火箭运输船]. All are homeported in Jiangyin, Wuxi, Jiangsu Province along the Yangtze River. February 2020 both ships Transported Long March 7 A and Long March 5 B rockets.[211]

Leadership

While the Department's activities are highly publicized as scientific missions, their leaders are rarely portrayed wearing uniforms.

However, its ties are clear both historically and based on contemporaneous evidence. The Maritime Tracking and Control Department was formerly the General Armament Department's 23rd Testing and Training Base [总装第 23 试验训练基地].[212] The Department is also assigned the MUCD 63680.[213]

As of 2019, Unit 63680 was commanded by Wu Jingao [吴锦高] (left). Wu Hexian [吴贺宪] (below) serves as commissar and Party Secretary.[214]

Intelligence, Space Tracking and Missile Instrumentation Ships

In addition to the Yuanwang ships under the China Satellite Maritime Tracking and Control Department, the PLA also operates at least six Auxiliary General Intelligence (AGI) ships that appear to be capable of space tracking and missile range instrumentation duties as well.

Range instrumentation ships can also be used to collect telemetry and other signals intelligence. Chinese AGI ships for example, were present near training areas for the Rim of the Pacific (RIMPAC) international naval exercises hosted by the United States in 2014 and 2018. [215]

These appear to be parceled out among operational support fleets [作战支援舰支队] with a mix of ships providing logistical and intelligence support functions (see chart). Of these, the ships with the designation Diao [调] series includes vessels engaged in satellite tracking support and maritime survey operations.

Given the sensitivity of their missions, few details about their roles appear to be available. In addition to missile testing, they are likely involved in missions related to military applications for Beidou or military communications systems.[216]

Pennant Number	Romanization	Chinese	Fleet
851	Beijixing	北极星	ESF
852	Haiwangxing	海王星	SSF
853	Tianwangxing	天王星	SSF
854	Tianlangxing	天狼星	NSF
855	Tianquanxing	天权星	ESF
856	Kaiyangxing	开阳星	NSF
857	Tianquxing	天枢星	SSF
858	Yuhengxing	玉衡星	ESF
859	Jinxing	金星	NSF
	Beidiao 900	北调 900	NSF

The ships' names are taken from the stars that make up the Big Dipper constellation.

Construction of these ships began in the early 1980s. The Type 814 Dadie Class "Xiangyanghong 28" geodetic intelligence ship Wuchang Shipyard officially started construction on December 22, 1983, and was launched on June 12, 1986. It was later renamed the Beidiao 900. completed in October of the same year, and conducted a sea trial in Qingdao on October 29.

2.6 Other Organizations involved in Space Asset Command, Tracking, and Management

In addition to the military-run organizations responsible for China's space programs, a number of other civilian agencies, observatories, and research institutes play supporting roles in China's space ground segment.

The Aerospace Information Research Institute (AIR)

The Chinese Academy of Sciences plays a prominent role in space infrastructure operations, in part through the recently formed Aerospace Information Research Institute under [中国科学院空天信息创新研究院]. It was created in July 2017 out of the merger and reorganization of three CAS research institutes:[217]

- *Institute of Electronics* [中国科学院电子学研究所/电子所], China's first comprehensive electronic and information science research institute established in 1956;
- *Institute of Remote Sensing and Digital Earth* (RADI) [中国科学院遥感与数字地球研究所], established in 2012 on the basis of the former Institute of Remote Sensing Applications (est. 1979) and the Earth Observation Center (2007).
- *Academy of Opto-Electronics* [中国科学院光电研究所]. Established in 2003, the Academy of Opto-electronics is a research unit with overall management and technical functions in three main areas: optoelectronic engineering, aerospace, and applied technology.

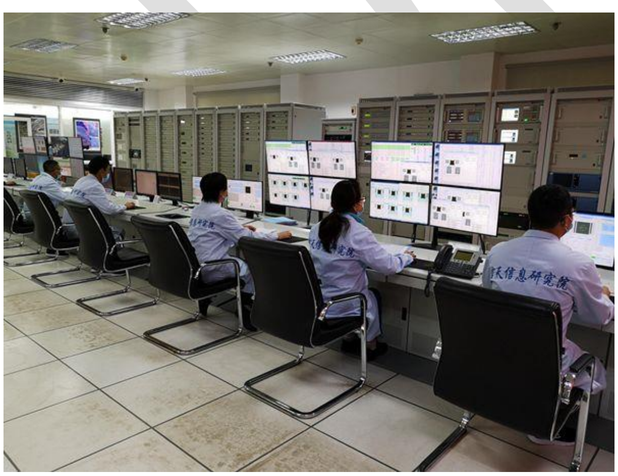
A *China Science Daily* article from August 2019 chronicled the merger, describing it as unprecedented in scale in CAS's history. It involved 2,800 employees and 1,800 students spread across 12 campuses.[218] CAS Academician Wu Yirong [吴一戎], director of the Institute of Electronics was appointed director of AIR in April 2018.

The creation of AIR is instructive because it reflects many of the larger issues that have slowed the development of China's ground segment in general. According to Wu Yirong, although China has managed to significantly increase the number of scientific papers and patents it produces, many areas remain reliant on foreign "chokehold" technologies. Many R&D projects are megaprojects by nature in the aerospace field, and institutional barriers prevented strategic decision-making at the national level. AIR Party Secretary Cai Rong [蔡榕] noted the same problem and pointed out that the merger is intended to facilitate the development of a "group army" [集团军] capable of shouldering big missions [大使命]. As the AIR website notes, AIR will pool together resources, take on interdisciplinary missions oriented toward meeting major national strategic needs.

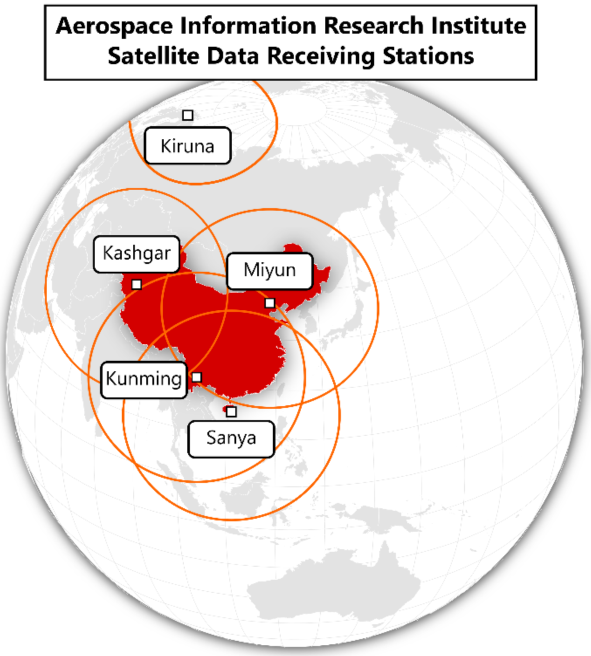
The merger officially began in April 2018 and as of late 2019, remained a work in progress. A total of 14 management departments have been set up within AIR and 20 research institutions have been created out of reorganizations. AIR operates campuses across China, including six in Beijing, and another six in Suzhou (Jiangsu), Sanya (Hainan), Kashgar (Xinjiang), Dorbod Banner (Inner Mongolia), Huailai (Hebei), and Yingkou (Liaoning).

According to *China Science Daily*, since its inception, AIR has taken part in multiple large-scale missions such as the development of the National Civil Space Infrastructure Data Receiving System [国家民用空间基础设施数据接收系统], a component of the project mentioned in the preceding sections, and has successfully completed 29 data receiving missions for earth observation and space science satellites at home and abroad. It has also been actively expanding its international "friend circle" through the promotion of international research personnel exchange, and two-way technology transfer programs [技术涉外推广与转移]. Specifically, AIR has participated in projects such as the "digital silk road," the Asia-Oceania GEOSS (AOGEOSS) GEO Initiative [亚洲大洋洲区域综合地球观测系统], and the BDS/GNSS Open Laboratory [北斗开放实验室].

China Remote Sensing Ground Station
[中国遥感卫星地面站]



The organization under AIR directly responsible for parts of China's ground segment is the China Remote Sensing Satellite Ground Station (RSGS) [中国遥感卫星地面站]. RSGS is an S&T organization [科技机构] composed of a central headquarters and a network of ground stations. It was established in December 1986, as part of the 1979 "Sino-US Scientific and Technological Cooperation Agreement" signed by Deng Xiaoping and President Carter, a national major S&T infrastructure initiative [国家重大科技基础设施]. Between 2007 and 2018, it operated under RADI until its consolidation into the Aerospace Information Research Institute.[219] Although the 2018 merger appears to yet to be fully completed, RSGS staff have been photographed wearing AIR work uniforms.



RSGS operates five ground stations globally. The Beijing headquarters is responsible for operation management and data processing and distribution, while its Miyun Station, Kashgar Station, Sanya Station, Kunming Station, and Arctic Station (Kiruna) [xiii] together form a data receiving network.

According to Huang Peng [黄鹏], deputy director of AIR RSGS, RSGS has the capability to receive satellite data in real-time covering the entire territory of China and 70% of the Asian landmass, as well as rapid downlink capability for satellite data from all over the world.[220]

RSGS is responsible for tracking most of China's earth observation satellites under the planned China High-Resolution Earth Observation System (CHEOS), including the natural disaster monitoring series, the resource series, the high-resolution series, and the electromagnetic monitoring test satellites. Several space science satellites such as the "Wukong," (which studies dark matter), "Micius" (part of quantum communications experiments)," and "Taiji-1" (gravitational wave detection) are also operated by RSGS ground stations.

Miyun Station, Beijing

Located in northeast Beijing, the Miyun facility is China's main earth observation satellite data archive. [221] It began operations in 1986, and has several large-diameter receiving antennas. Its reception area covers central and northern China as well as surrounding border areas.[222] Commercial satellite imagery shows that the Remote Sensing and Digital Earth (RADI) facility in Miyun has almost doubled in size and doubled the number of large scale dishes to ten since 2012.

[xiii] Detailed in section 3.2

Image Source: "China Remote Sensing Ground Stations" [中国遥感卫星地面站], Institute of Remote Sensing and Digital Earth [中国科学院遥感与数字地球研究所], Accessed February 2020], http://www.radi.cas.cn/jglb/kjtx/wxdmz/

Kashgar Station, Xinjiang

RADI's RSGS Kashgar Station [中国遥感卫星地面站喀什站] was officially unveiled on 28 January 2008.[223] The station covers Western China and neighboring areas in Central Asia.[224] It primarily serves as downlink station for a number of domestic constellations such as China's Disaster and environmental Satellites [环境减灾系列卫星, HJ-series], China-Brazil Earth Resources Satellite (CBERS) and Natural Resources [资源; ZY-series] satellites, SJ-9 test platform satellites as well as Gaofen optical earth observation satellites and international constellations such as the U.S. LANDSAT and French SPOT earth observation satellites.[225]

Kashgar Station Director Wang Jianping [王建平] told a reporter from *China Science News*: "Since its establishment, Kashgar Station has received data from more than 30 domestic and foreign satellites.[226] Since 2008, the facility has expanded from two 12m dishes to six 20m radomes, likely housing 12m dishes and a seventh 12m radome.

Sanya Station, Hainan

The RSGS station in Sanya began operations in 2010. With five 12-meter satellite data receiving antenna systems and supporting data receiving, recording, and data transmission equipment, it supports the operations of nearly 30 satellites.[227] The station is able to receive data from satellites over the South China Sea and neighboring countries in Southeast Asia.[228]

Kunming Station, Yunnan

The Kunming Satellite station began operations in May 2016. It consists of a single 7.3meter antennae.[229] Few other details appear to be available.

Beidou Navigation Satellite System

For commercial and military applications, perhaps no other space-based system is more important than global navigation satellite systems (GNSS). For these systems, which include the U.S. GPS, European Galileo, and Russian GLONASS constellations, their accuracy is contingent upon maintaining a precise fix on their location in space relative to the ground and to each other. This requires large networks of ground stations equipped with atomic clocks that monitor the satellites' locations to keep the system accurate.

Prior to Beidou, the PLA relied on radio navigation systems. Beginning in the mid-1960s the Central Military Commission and the Communist Party's National Defense Science and Technology Commission [国防科委][xiv] approved the development of intermediate and long-range wireless radio navigational systems. The resulting Changhe [长河] system, with short, intermediate, and long-range versions, were the first steps toward a comprehensive navigational system, and many of the research institutes involved in its production remain at the center of satellite navigation systems.[230]

Development of China's Beidou Navigation Satellite System has been a driver of Chinese space launches and development since the launch of its first satellites in 2000. The constellation expanded with Beidou-1 completed in May 2003, Beidou-2 in 2012, and finally, Beidou-3 in June 2020.[231] The system includes three main components: a space segment, with satellites in Geostationary Earth Orbit (GEO), Inclined Geo-Synchronous Orbit (IGSO) and Medium Earth Orbit (MEO), a user segment including various commercial receivers, chips and terminals, and most relevant for this study, a large ground segment.[232] The ground segment includes ground stations (including many of those profiled above) as well as master control stations, time synchronization/uplink stations, monitoring stations, and reference stations (also called fiducial stations) [基准站].

The latter are in a different category from space tracking stations but are of particular importance for GNSS. China has 150 national wide-area stations (RSs), 1200 regional RSs and has set up others in the Arctic and Antarctic.[xv] These stations along with the National BeiDou Ground-Based Augmentation System will help Beidou achieve "meter and decimeter level for wide area real-time services, centimeter-level for the areas within Beijing, millimeter level for postprocessing services" and "provide meter and decimeter level real-time location services for users in China, even centimeter-level service in some areas."[233] Beidou ground stations can also be used to augment the accuracy of the constellation or help compensate in the case of jamming or disabling of one or more of the constellation.

While earlier iterations of the system had limited capabilities, the expanded constellation appears to have entered widespread use in China. In terms of the BDS's civil applications, a December 2019 report by the China Satellite Navigation Office noted the BDS's application in a wide variety of fields including agriculture, transportation, forestry, fisheries, hydrological monitoring, meteorological forecasting, communication, power grid, disaster relief, public security, and others.[234] According to the report, by the end of 2019, more than 6.5 million road operating vehicles, 40 thousand postal and express delivery vehicles, 80 thousand buses in 36 central cities,

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[xiv] Predecessor to the Commission of Science, Technology, and Industry for National Defense (COSTIND)

[xv] For comparison, the U.S. GNSS fiducial station network has over 2000 stations

3.2 thousand inland navigation facilities, and 2.9 thousand marine navigation facilities, have adopted BDS, which forms the world's largest dynamic monitoring system for road operating vehicles. In the field of smartphones, mainstream chip manufacturers both at home and abroad have introduced integrated chips, which are compatible with BDS. By the third quarter of 2019, more than 400 models of smartphones sold in China are supporting positioning functions, among which about 300 models are supporting BDS.

While its prevalence among the PLA is unknown apart from scattered reporting on its use in exercises, reports from the China Satellite Navigation Office [中国卫星导航系统管理办公室] indicate widespread deployment of Beidou terminals. In January 2018, China Satellite Navigation Office Director Ran Chengqi [冉承其] told *China Youth Daily* that the BDS has become "standard issue" in fields related to national security.[235] In early 2020, Ran revealed that the BDS's high-precision positioning technology was widely utilized in support of the military parade to celebrate the 70th anniversary of the founding of PRC.[236] Other reports indicate that fishing boats and law enforcement vessels use 70,000 terminals, police 400,000, while municipal, provincial, and county-level emergency services use 45,000 Beidou terminals.[237] In 2019 it was reported that 70 percent of smartphones in China were compatible with Beidou.[238]

The growth of applications for the Beidou system likely indicates that the GNSS will remain a driver of ground segment infrastructure.

While no official government structure has been published, Beidou itself appears to be administered in part through four organizations. The China Satellite Navigation Committee [中国卫星导航系统委员会] appears to be a leading organization setting policy, establishing cooperative agreements and similar functions. It is led by Wang Zhaoyao [王兆耀] a PLA major general serving as deputy director of the CMC Equipment Development Department.[239]

An externally facing organization, China Satellite Navigation Office [中国卫星导航系统管理办公室], publishes information on the system through the website Beidou.gov.cn, and its Director Ran Chengqi [冉承其] also serves as its spokesperson. However, the website does not list an office address or any other details. The ground segment and other operations of Beidou system are likely be run through the Central Satellite Navigation Station [卫星导航定位总站], an SSF unit under the Joint Staff Department discussed in Section 2.1, and PLASSF 1st Navigation Base/ Base 35.

China Centre for Resources Satellite Data and Application (CRESDA)

China Centre for Resources Satellite Data and Application (CRESDA) is a research institute under the National Development and Reform Commission (NDRC) and China National Space Agency (CNSA) but administratively run by China Aerospace Science and Technology Corporation (CASC).[240]

CRESDA operates China's Natural Resources [Ziyuan; 资源] series of earth-observing satellites. The ZY satellites [ZY3-02] [资源三号 02 星], multi-spectral earth observing satellite of land surveying and mapping, resource survey and monitoring, disaster prevention and reduction, agricultural and forestry water conservancy, ecological environment, urban planning and construction, transportation and other fields.[241]

China National Space Administration [国家航天局]

China's national space agency, CNSA was founded in 1993 as part of the decision to split the former Ministry of Aerospace Industry [天工业部] into China Aerospace Science and Technology Corporation (CASC) [中国航天科技集团公司]. It is subordinate to State Administration for Science, Technology, and Industry for National Defense (SASTIND), which manages China's military and scientific R&D programs.[242]

While ostensibly responsible for China's manned space and lunar programs, these actually fall under the Central Military Commission's Equipment Development Department (EDD). China's Manned Space Office (921 Project Office) [中国载人航天工程办公室（921工程办公室）], for example, falls directly under the EDD and its current director, Hao Chun [郝淳], appears to be the first in that position who was not a uniformed officer since the office was established in 1992.[243] While sometimes described as having authority over China's launch centers, these in fact, fall under the PLA through the PLASSF SSD.

Overall CNSA appears to function much like the Chinese National Defense Ministry [国防部] under the State Council, which is headed by a member of the CMC and has a limited portfolio largely restricted to external [对外] responsibilities such as international exchanges and exercises.[244]

CNSA is currently led by Zhang Kejian [张克俭], who is concurrently deputy minister of the Ministry of Industry and Information Technology (MIIT) director and Party Secretary of SASTIND and director of China Atomic Energy Authority.[245]

In regards to China's ground segment, two organizations partially subordinate to CNSA play a role:

Space Debris Surveillance and Application Center [空间碎片监测与应用中心]

A growing danger for satellites or other spacecraft is space debris--the chips of paint, bolts, or even larger objects placed in orbit during the course of space launches, or created during anti-satellite missile tests. Space debris moves at 10km/s, so even small objects have the potential to cause serious damage. However, tracking the estimated 200,000+ objects between 1 and 10 centimeters is difficult. According to an article from 2015, China's 129 spacecraft in orbit experienced, on average, 30 close encounters (passing within 100 meters) with space debris each year.[246] As referenced in Section 1, Chinese planners have committed to building an automated space debris removal system in the next ten years, which will require extremely accurate and up-to-date data on space debris' orbits.

To mitigate the risk from this debris, in June 2015, the Chinese Academy of Sciences' National Astronomical Observatory and the China National Space Administration [国家航天局] established the Space Debris Monitoring and Application Center.[247] SASTIND (as the parent organization of CNSA) and CAS National Astronomical Observatory jointly manage the Center. The Center is believed to be the leading organization in charge of China's Space Debris Avoidance

System (SDAS).[248] The Center provides early warning and analysis for more than 100 of China's satellites, tracking space debris and maintaining an independent catalog of space debris.[249]

The announcement of the Center's establishment also noted that "can monitor not only debris, but also things much larger than debris, such as missiles, satellites, and high-speed aircraft. In other words, this Center has both civilian and military functions; in peacetime, it can provide early warning for Chinese aircraft in orbit; in wartime, it can provide early warning and coordinates for the People's Liberation Army to destroy enemy aircraft." The organization of the Center is unclear, but it appears to have begun receiving data from existing space debris tracking organizations. It is likely that the Changchun Observatory, which includes a space debris detection system [特大视场空间碎片探测系统], is involved.[250] As of 2018, a new component, a space debris monitoring base [空间碎片监测基地] is under construction in Bayingolin [巴音郭楞州],[251] Korla in Xinjiang.[252] The base was estimated to cost 200 million RMB ($28 million) and include large-aperture space telescopes, infrared optical sensors, and radars.[253]

The reference to its integration with missile and aircraft early warning systems suggests that the system is connected to China's network of missile early warning radars, believed to be operated by the PLASSF.

China also sees space debris as an area for international cooperation. It has participated in the Inter-Agency Space Debris Coordination Committee (IADC) since 1995 and regards the center as an opportunity to further cooperation in this field.[254]

Space Remote Sensing Demonstration Center [航天遥感论证中心]

This demonstration center, jointly operated with the China Academy of Sciences' Institute of Remote Sensing Applications [中国科学院遥感应用研究所], was established in January 2004.[255] It has participated in the calibration and testing of CBERS, Fengyun, and Huanjing series satellites.

A key focus of this organization appears to be the recruitment of foreign talent and access to remote sensing technology through international cooperation.[256] It has cooperated with more than ten countries, including Thailand, France, Egypt, Australia, the United Kingdom, Germany, the United States, and Hungary.[257]

China Satellite Laser Ranging Network [中国卫星激光测距网]

Satellites can also be accurately tracked with ground-based laser rangefinders. China has built a large network of observatories equipped with satellite laser ranging (SLR) equipment. Led by the Shanghai Astronomical Observatory [上海天文台], the network includes stations in Beijing, Changchun, Shanghai, Kunming and Wuhan, and at least two mobile stations.[258]

China's first SLR system began operations in 1972.[259] Most SLR systems are used to range objects in low earth orbit, but some of the larger stationary systems, such as the one on Changchun, are described as capable of ranging objects up to an altitude of 40,000km (which includes geostationary orbits) and giving a single-measurement-accuracy of less than 1.5cm.[260]

Chinese organizations, including the Network and mobile SLR stations under the Ministry of Natural Resources, participates in the International Laser Ranging Service (ILRS), which conducts various scientific experiments, including measuring tectonic plate shifts.[261]

As with other organizations profiled in this study, this network is believed to have strong ties with the Chinese military, though these are frequently obscured. However, some level of participation is identifiable, such as the participation of an unidentified PLA organization, Unit 61084, in SLR Network conferences. It may be an organization under the PLASSF 1st Navigation Base/ Base 35.[262]

While SLR has previously been restricted to periods of darkness, a study in 2020 determined that lasers can now be used to detect space debris during daylight hours, suggesting that SLR systems will continue to grow in utility.[263]

These stations undoubtedly are part of Space Situational Awareness for military and civilian purposes, but it is less likely that they are directly involved in offensive space operations. A study in 2009 assessed that "China's currently known SLR ranging stations should not be considered ASAT weapons due to the low probability of assured damage to a ground imaging satellite's imaging sensor." It went on to note that "the laser powers used for SLR are low enough that they would not interfere with satellites through heating effects or by causing physical damage to parts of satellites other than the sensors."[264] China is certainly capable of building more powerful lasers, and it is possible that the network has been involved in publicized "dazzling" or other anti-satellite laser attacks.

National Remote Sensing Center [国家遥感中心]

The main operator of civilian ground stations involved in remote sensing data in China appears to be the National Remote Sensing Center (NRSCC), which is subordinate to the Ministry of Science and Technology (MOST).

Established in 1981, the Center has subordinate specialized departments for aviation, environmental, maritime and metrological remote sensing, which are described as "affiliated" [依托] with relevant departments under other components of the state department, such as the National Satellite Ocean Application Service (under the Ministry of Natural Resources) and the National Satellite Meteorological Center [国家卫星气象中心], under the China Meteorological Administration.[265] The Center, therefore, appears to act as a coordinating umbrella organization for these specialized centers.

It is based in Beijing's Haidian District but has subordinate offices all over China. It appears to have some responsibility for GNSS system testing, and in addition to satellite data, it also collects information from UAVs and other aerial platforms and ground-based sensors.[266]

National Satellite Meteorological Center
[国家卫星气象中心]

China's weather satellite program has been a priority since the 1980s. The first "Fengyun" [风云; lit. "Wind and Clouds"] metrological satellite was launched in September 1988. China has launched 17 Fengyun satellites, and as of March 2020, nine active remain in orbit, with the most recent launched in June 2018.[267,xvi] Two additional launches are planned for launch in 2021.[268]

These satellites are administered by the National Satellite Meteorological Center [国家卫星气象中心] under the China Meteorological Administration [国家气象局].

Established in 1971, the National Satellite Meteorological Center is headquartered in Beijing's Haidian District.[269] The Center has weather satellite ground receiving stations [气象卫星地面接收站] in Beijing, Guangzhou, Jiamusi, and Urumqi, and Kiruna, Sweden.[270]

The Center also played a role in the development of ground systems, in-orbit testing, and receiving for the Gaofen [高分; lit. "High Resolution"] satellites and receives data and is involved in the operations of the series, which are believed to serve reconnaissance purposes. By 2012 the metrological center had archived 600TB of data, making it the largest digital remote sensing data center in China.[271]

The Fengyun program is also playing a role in China's outreach through the Belt and Road Initiative. Several Fengyun satellites have been repositioned and receiving stations set up to better provide coverage of areas along the Belt and Road.[272] A Fengyun receiving station was set up in Mozambique, for example, as part of BRI cooperation with the assistance of the National Satellite Meteorological Center.[273]

Beijing Weather Satellite Ground Station
[北京气象卫星地面站]

Built in 1985, the Beijing Weather Satellite Ground Station, located in Beijing's Haidian District, plays a role in daily operations of nearly 20 domestic and foreign satellites, including from U.S. National Oceanic and Atmospheric Administration (NOAA) and NASA Earth Observing System (EOA) satellites.[274275276] In total, the Station receives data from every day.[277] As of 2013, the Station had five satellite antennas: two 15-meter and one 13-meter satellite data receipt & launch antennas [卫星数据接收与发射天线], and two 7.3-meter antennas.[274]

Guangzhou Weather Satellite Ground Station
[广州气象卫星地面站]

Construction of the Guangzhou Weather Satellite Ground Station began in 1978, and it began operations in 1986.[278] It receives data and plays a role in the operations of the Fengyun series of weather satellites.[270] It also receives data from U.S. National Oceanic and Atmospheric Administration (NOAA) and NASA Earth Observing System (EOA), as well as Japan's Himawari/GMS satellites.[278] Its missions include satellite tracking, orbital testing, measurement & control, and data receipt, processing, storage, and forwarding.

The Station is under the dual administration of the National Satellite Meteorological Center and the Guangdong Meteorological Service [广东省气象局].[279280]

[xvi] FY-1C was destroyed in China's 2007 anti-satellite test

As of 2013, the Station had two satellite antennas: one 15-meter satellite data receipt & launch antennas [卫星数据接收与发射天线] and one 7.3-meter satellite distance-measurement antennas [卫星测距天线].[274]

It is at least partially open to the public and is located in Guangzhou's Tianhe District.[280]

There is a second site co-located with the Guangdong Weather Satellite Remote Sensing Center [广东省气象卫星遥感中心] that has seven satellite antennas.[281]

National Satellite Ocean Application Service Center
[国家卫星海洋应用中心]

Chinese Maritime Satellites
HY-2A[282]
HY-2B[283]
HY-1C[284]
China-France Ocean Satellite (CFOSAT)
HY-1A [285] (Inactive)
HY-1B[286]

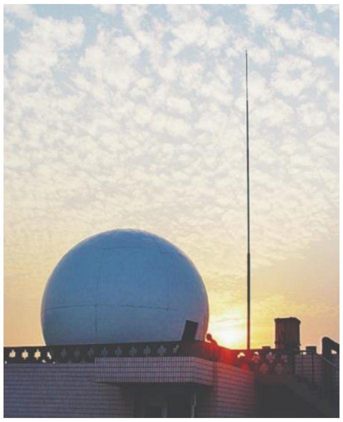
Another component of the National Civil Space Infrastructure project are constellations of maritime observation satellites. These satellites, which measure sea temperature, wave height, and other data, are administered by the National Satellite Ocean Application Service Center. The group of satellites includes a series designated HY for Haiyang (lit: ocean), and one co-developed with France, the China-France Ocean Satellite (CFOSAT). [287] The satellites will also play a role in fisheries management and ship tracking.[288]

The center is responsible for the planning and development of China's maritime remote sensing satellite programs as well as the construction and operation of ground stations to control and downlink data from the satellites.

The National Satellite Ocean Application Service has four main ground stations: Beijing, Hangzhou, Sanya, and Mudanjiang.[289]

As a central hub, the Beijing station not only receives, processes, and analyzes data but also distributes it. The Sanya and Mudanjiang stations are believed to be focused on data receiving.

The Miyun (Beijing), Kashgar and Sanya stations of the Institute of Remote Sensing and Digital Earth appear to work with the Ocean Application Service's dedicated stations to downlink and share data, including imagery that could be used for intelligence purposes, such as microwave remote sensing data from Gaofen-3.[290]



While subordinate to the Ministry of Natural Resources [自然资源部], the center shares data through an online portal and is affiliated with the National Remote Sensing Center.[291]

The maritime satellite project and applications [海洋卫星工程及卫星数据应用] has been a major means for diplomacy, with agreements set up with Peru, North Korea, France, Germany, and Spain, among others to exchange information. Exchange data under the World Meteorological Organization (WMO) [世界气象组织]. China-France Ocean Satellite (CFOSAT).

The first station was set up in 1988 in Hangzhou to receive data from China's first Fengyun weather satellite launched that year.[292] The Hangzhou station is affiliated with both the State Oceanic Administration and the Second Institute of Oceanography and is involved in real-time receiving, processing, archiving, and managing, as well as application and analysis.

In 2013, the Hangzhou ground station was incorporated into the national marine satellite ground application system business operation, and was renamed "National Marine Satellite Hangzhou Ground Station."

A second station in Hangzhou, the Yuhang [余杭] station (left), began in October 2008, and test operations began in August 2009.[293] It began formal operation in March 2011.[294] Since beginning operation, it has provided support to multiple maritime satellite missions such as the HY-2.

It appears to have served as a "backup" station [备份站] and administered by the Second Institute of Oceanography under the Department of Natural Resources [自然资源部第二海洋研究所].

Construction of the newest station in Mudanjiang in Heilongjiang province began in June 2009.[295] The organization has strong links to the Strategic Support Force.

National Satellite Marine Application Center Mudanjiang Receiving Station Staff with members of local PLA Strategic Support Force units.[296]

Quantum Satellite Experiment Ground Stations

An emerging role for satellite ground stations is quantum communications. China is engaged in a major research effort to develop a secure communication network using technologies based on quantum physics.[xvii] Led by physicist Pan Jianwei [潘建伟], an important component of this research effort is called the Quantum Experiments at Space Scale (QUESS), part of China's space science Strategic Priority Program. In August 2016, China launched its "quantum satellite," the Micius, to test long-distance quantum communications. According to Dr. Pan Jianwei, the main goals of the program are quantum key distribution from a satellite to ground station, a global-scale quantum communication network that uses satellites and fiber-optic cables, long-range entanglement testing involving two ground stations over 1,000 kilometers apart and a satellite, and ground-to satellite teleportation (sending quantum information from one location to another). In June 2017, China successfully entangled photons at two ground stations 1203 km apart, relayed through Micius.

The Chinese Academy of Sciences operates communication stations and observatories in Delingha, Qinghai Province, Nanshan, Xinjiang AR, Lijiang Yunnan Province, and now a mobile station in Shandong Province.[297] Successful links have also been established between Beijing and Austrian Scientists in Vienna and Graz (see inset).

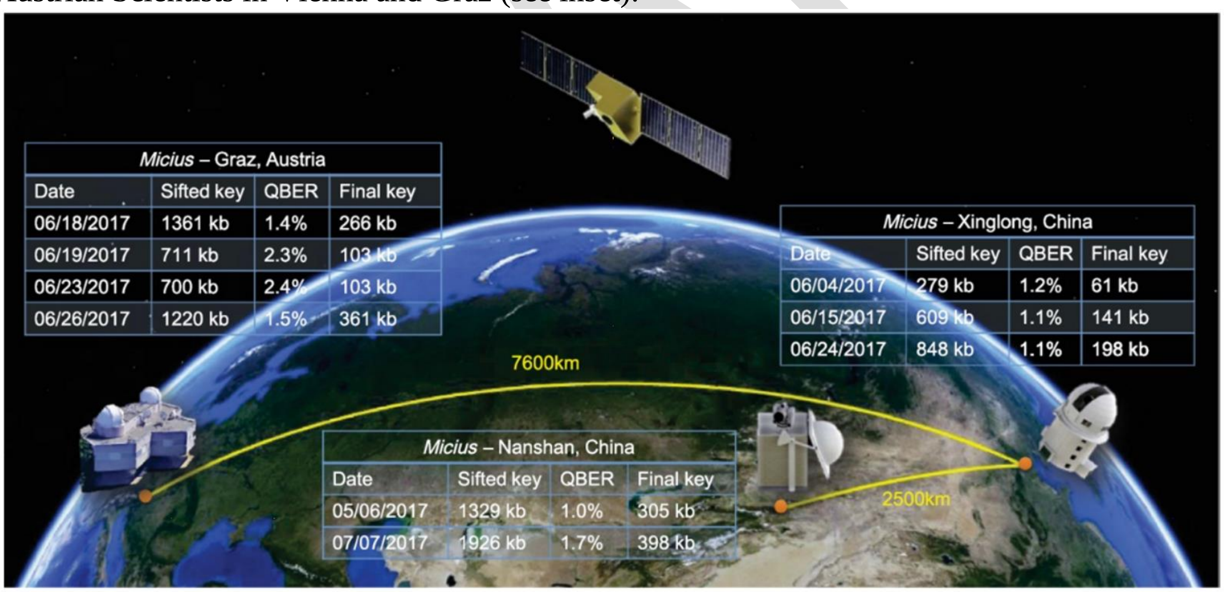


Fig. 7 Illustration of the three cooperating ground stations (Graz, Nanshan, and Xinglong). Listed are all paths used for key generation and the corresponding final key length

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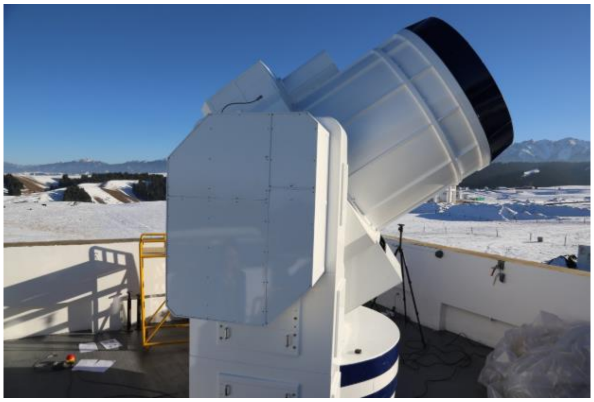
[xvii] For more on China's quantum technology projects see: Elsa Kania, John Costello, "Quantum Leap (Part 1): China's Advances in Quantum Information Science," China Brief, 5 December 2016. https://jamestown.org/program/quantum-leap-part-1-chinas-advances-quantum-information-science-elsa-kania-john-costello/ and Elsa Kania, John Costello, "Quantum Leap (Part 2): The Strategic Implications of Quantum Technologies," *China Brief*, 21 December 2016. https://jamestown.org/program/quantum-leap-part-2-strategic-implications-quantum-technologies/



The Nanshan Observatory also has a 1.2m optical telescope (left) that has participated in quantum communications experiments.

In late December 2019, the research team successfully established links between the Micius and a mobile ground station.[298] While the technology is still under development, eventually, the network of ground stations could help support secure communications for the military.

State Radio Spectrum Management Center [中国无线电管理]

A little-discussed component of China's space ground segment and space tracking system is the State Radio Spectrum Management Center [中国无线电管理] has responsibility for radio monitoring and spectrum management (filling a role similar to one of the Federal Communications Commission (FCC) in the United States). It is directly under the Ministry of Industry and Information Technology (MIIT) of the People's Republic of China and directly supports space tracking missions.[299] Monitoring stations [监测站] are located in Beijing, Chengdu (Sichuan), Fujian, Harbin, Shanghai, Shenzhen, Shenzhen, Chengdu, Shaanxi, and Urumqi, and Yunnan, many of which future large-scale radio-direction finding stations and radio satellite communication stations.[300] Other affiliated stations have been identified in Tibet and Inner Mongolia. The national network plays a role in locating and eliminating sources of radio interference with satellite transmissions.[301]

The Beijing station is part of the network of global stations of the International Telecommunications Union (ITU). Established in 2003, the facility is used for space radio Monitoring. It has seven receivers capable of monitoring non-GSO satellites and GSO satellites with a visible arc of 50° East longitude to 180° East longitude.[302]

The Beijing station (left) has satellite monitoring capability and played a role in supporting the Shenzhou 6 & 7 missions, as well as multiple Chang'e missions.

The organization appears to closely coordinate with the SSF and other parts of the Chinese armed forces, for example, jointly holding an exercise All-PLA reserve spectrum management center [全军预备役电磁频谱管理中心].[303]

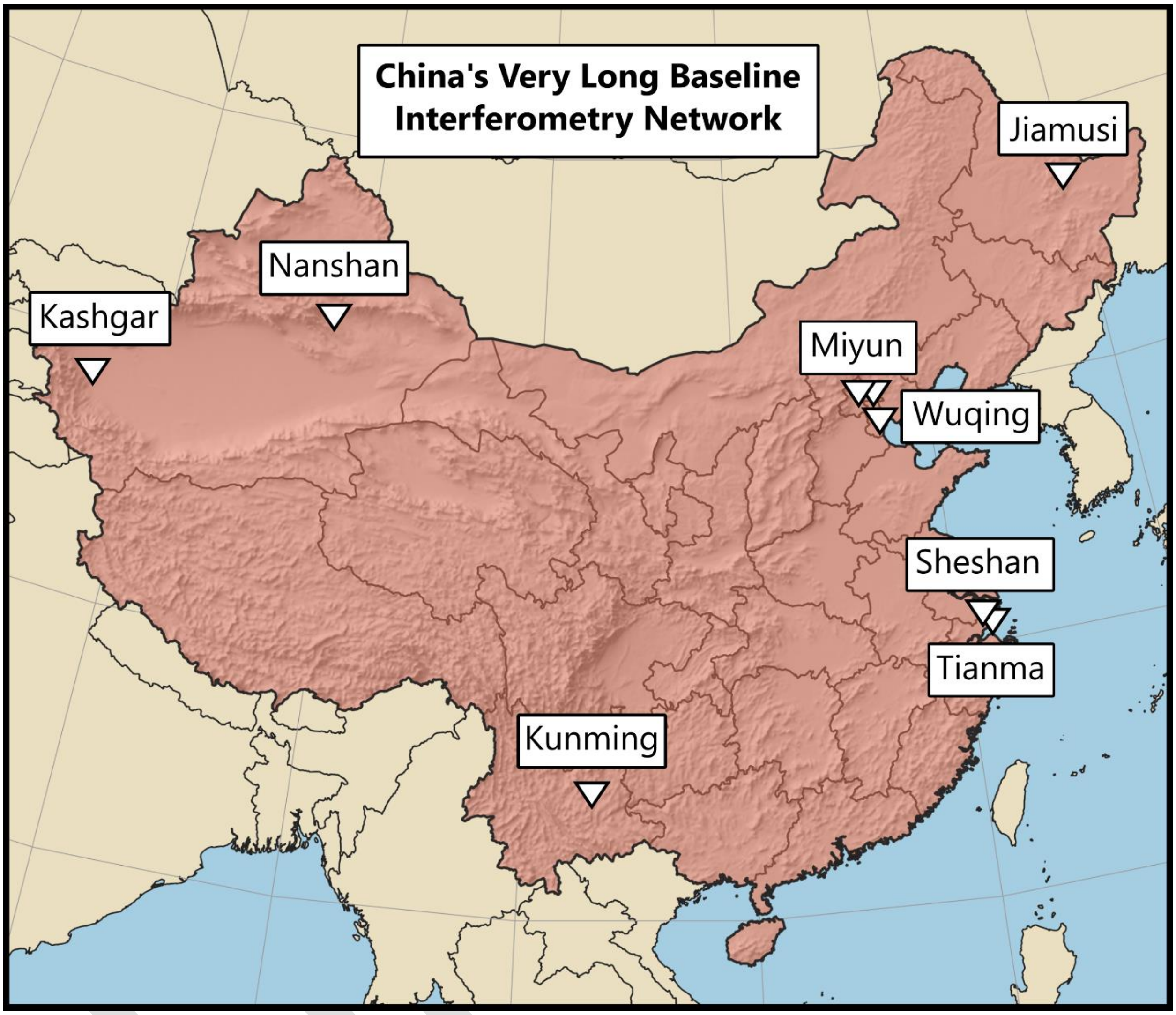
Shenzhen Station

Very Long Baseline Interferometry (VLBI) Network

A technique called very-long-baseline interferometry (VLBI)[304] can be used to improve the reception of very faint radio signals such as those from distant galaxies or spacecraft operating in deep space. VLBI combines data from physically distant receivers to enhance the quality of that data, providing sharp imaging of distant objects or improved data reception from spacecraft.

To support its science projects and space exploration programs, China has built an expansive VLBI network, including stations in Nanshan (Urumqi), Miyun (Beijing), Kunming, Seshan, and Tianma (Shanghai), Wuqing (Tianjin), and a data processing center in Shanghai.[305]

While these stations appear to coordinate closely with CLTC, the Xi'an Control Center, and other components of the PLA SSF Space Systems Department, they are, in most cases, directly subordinate to observatories under the China Academy of Sciences (CAS).



China’s first large-scale radio telescope that laid the foundations for a VLBI network is the 25-m Sheshan Observatory [佘山] in Shanghai, completed in 1986.[306]

The Xinjiang Observatory Nanshan [南山], located south of Urumqi, has a 25-m radio telescope that was completed in 1993. In 2016, a second 25-m dish was added to the facility, which also features a number of large optical telescopes. It is an important component of China’s Very Long Baseline Interferometry (VLBI) network, along with stations in Beijing, Kunming, and Shanghai.[307]


Yunnan Astronomic Observatory

To support the Chang'e 1 mission, the Lunar Exploration Program Ground Application System was established, and in 2006 radio telescopes were built in Miyun (Beijing), Kunming (Yunnan). The telescopes operate in the S/X band and participate in precision tracking of the Chang'e spacecraft's orbit and downlink scientific data it collects.[308] The Miyun station features a 50-m radio dish, and the Yunnan Astronomical Observatory's radio telescope in Kunming has a 40-m dish.[309]

In 2012, Shanghai Observatory added a second large radio telescope, a 65-meter receiver in Tianma [天马.[310] In 2016, China completed the Five-hundred-meter Aperture Spherical Telescope (FAST), a valley-spanning radio telescope in Pingtang County [平塘县], Guizhou, used to study pulsars and other cosmic phenomena.[311]

In late April 2020, a 70m station was completed in Tianjin's Wuqing District [天津武清区]. The newest addition to China's Deep Space Network is part of the National Astronomical Observatory and will support China's Mars and Lunar exploration missions.[312] Plans are already underway to expand this network, including the 110meter steerable Qitai Radio Telescope in Xinjiang scheduled for completion in 2023.[313]

These stations communicate with those under the Xi'an Satellite Control Center, including Swakopmund, Namibia, and components of international VLBI networks such as European Space Agency receivers in New Norcia (Australia) and Cebreros (Spain). East Asia Very Long Baseline Interferometry network, which includes radio telescopes in Japan and South Korea.[314]

3. China's Global Space Infrastructure

While the preceding sections have almost exclusively discussed space ground infrastructure within China's borders, since the early 1990s China has built or leased many stations abroad. Though most are subordinate to the organizations outlined above, their histories and role in China's economic strategies and diplomatic efforts means that they can be viewed together.

3.1 Overview

China has built or leased stations all over the globe to support its space program, and increasingly supports commercial operations.[xviii] As outlined in the preceding sections, this growth was initially driven by the manned and lunar space programs. However, as Chinese industries became involved in satellite design and launch capabilities in the 1990s, exports of space platforms and services have risen in prominence, symbolized by the launch of the China-Brazil Earth Resources Satellite (CBERS) in 1999.

China's ground segment also plays a role in its two major externally-focused strategies: the Going Out Strategy and Belt and Road Initiative. In October 2000, China announced the "Going Out" Strategy [走出去战略] to promote Chinese companies abroad and improve their global competitiveness. Backed by heavy subsidies, Chinese companies have provided launch services for over 20 countries and international organizations.[315]

Space infrastructure has also been linked to the Belt and Road Initiative, introduced in 2013. In October 2016, SASTIND and the NDRC issued *Guiding Opinions* setting out for priorities for the development of the Belt and Road Space Information Corridor ["一带一路" 空间信息走廊].[316]

The Corridor's primary goals are to improve space infrastructure coverage of the areas of the Belt and Road (the strategically important significant areas in China's periphery), increase the competitiveness of China's space industries through sales of services and access to technology. Against this background of state-promoted commercial activity, scientific in space has increased.

[xviii] Building a global network of ground stations for space missions is itself not unusual. The U.S. set up stations in Nigeria and Singapore to support launch of the Explorer 1 satellite in 1958. A global network of stations also supported the Apollo missions. The U.S. Army built a global network of satellite tracking and reference sites used to support the SECOR (Sequential Collation of Ranges) satellite series, a mapping and navigation initiative in the 1960s predating GPS, that had roughly 25 sites outside the continental United States 1971 See: NASA Directory of Observation Station Locations [Volume 2], 2nd Edition., NASA, November 1971. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720012596.pdf

Commercial Stations Abroad

In addition to stations operated by the Chinese military and the Chinese Academy of Sciences, commercial operators are increasingly becoming involved in ground segment operations. As demand for satellite-based services increases, the demand for more numberous stations abroad will rise.[xix] Several Chinese companies, including Shenzhen Haiweitong, CASC, and SinoSat, provide commercial satellite services. These systems often require a global network of ground stations in North America, Europe, and Sri Lanka, as well as stations within China in Kashgar in Xinjiang, Beijing, and Hong Kong (see inset).[317] Sino Satellite Communications (SinoSat) supports its satellite broadband communication network with stations in Beijing, Hong Kong, Kashgar, Sri Lanka, Europe (and two in North America.[318] Others offer broadband satellite communications and internet connections to maritime users such as MarineSat [海卫通] and MarineTel [海星通]. These services use Very Small Aperture Terminals (VSAT) aboard the ships to communicate with a constellation of communications satellites in geosynchronous orbit.

The MarineTel platform is used by over 6,000 ships and oil platforms, including 4,000 fishing vessels.[319]

Other examples of commercial applications that will drive deployment of additional stations satellite collection of Automatic Identification System (AIS) tracking signals. AIS are emitted by civilian ships and are used for cargo tracking, and collision avoidance. A private Chinese company, He'de Aerospace [和德宇航] has launched five satellites since 2017 as the basis of a larger constellation to collect AIS data.[320]

As commercial opportunities expand—accelerated by Chinese government promotion of the National Civil Space Infrastructure Plan, Space-Earth Integrated Information Network Mega Project and Belt and Road Space Information Corridor—more of these stations will likely come online and become important components in China's ground segments.

International Cooperation

China is a participant in a number of international space exploration and infrastructure sharing initiatives. Currently, CNSA has signed 117 cooperative agreements with 37 countries and four international organizations, and participated in activities with 16 space-related international

[xix] For comparison, U.S. commercial satellite imagery company Planet, which operates over 150 satellites uses a global network of 45 ground stations to downlink data. See "INNOVATION, ITERATION, AND AUTOMATION," Planet, Accessed July 2020. https://www.planet.com/company/approach/

organizations.[321] It has also deepened cooperation in the development of sensors and other aspects of satellite R&D with countries including Switzerland, Italy, and Poland.[322]

NASA and the Chinese Academy of Sciences signed an agreement to cooperate in limited project-specific activities in plate tectonics and geodynamics research (satellite laser ranging and GNSS) in 1992 that remains in effect to this day.[323] China has also participated in U.S. data-sharing and downlinking initiatives such as the Landsat Ground Station Operations Working Group.[324] Other international organizations include the International Laser Ranging Service (ILRS).[325]

China is a founding member of the Square Kilometer Array (SKA) Observatory Convention, along with China, Australia, Italy, the Netherlands, Portugal, South Africa, and the United States.[326] The project will build a massive array of small radio dishes in Australia and combine data with other radio observatories in participating countries to conduct a number of scientific experiments including tests of general relativity, and provide observational data for the search for dark matter.

The Beijing Institute of Tracking and Telecommunications Technology (BITT) profiled earlier in this report created a Space Research and Development Center [航天研究发展中心] in 2000, which became the platform for engaging in international technological cooperation with over 20 nations including the United States and Russia.[327] It also plays a role in the construction of facilities overseas and was responsible for the construction of foreign TT&C stations in Chile and Kiribati.[328]

While the primary goal of China's stations abroad appears to have been commercial opportunities, it has also paid diplomatic dividends. Cooperation in satellite development with France and Brazil has helped further relations with those countries. China and Brazil have jointly developed the China-Brazil Earth Resources Satellite (CBERS). CBERS is similar to NASA's Landsat or the European SPOT programs, which publish earth observation data for agricultural, land-use planning, and environmental monitoring programs. Data CBERS is being offered to many countries in Africa. Other domestically developed satellites such as the Fengyun weather satellite offer similar value and have been linked to China's Belt and Road Initiative. For example, China built a Fengyun receiving station in cooperation with the Mozambique National Institute of Meteorology Maputo Mozambique as part of extending the Belt and Road Initiative.[329]

In 2007 China announced that it was going to share data from CBERS-02B satellite with African nations. Ground station operations began in South Africa in 2009.[330] The CBERS program was expanded globally in 2010 with the singing of the "CBERS Data Global Data Distribution Agreement" in Brazil.[331] CRESDA has created a platform for data-sharing from the CBERS-04 earth observing satellite with ASEAN countries.[332]

Space Infrastructure and the Question of Dual-use

China has made real achievements in space, but while there are regular calls within the United States and our allies and partners to deepen cooperation with China, strategic competition and fears that information or technology could be adapted for military use loom in the background. Since China began to build or lease TT&C stations abroad they have been subject to intense scrutiny regarding their connections with China's military—and with good reason.

To some extent, this is to be expected; most countries' space programs emerged from military initiatives. The nature of space technology itself further complicates the issue, as much of space infrastructure is inherently dual-use.[xx] PNT satellites can guide tractors *or* tanks. Imagery from earth observation satellites can offer valuable insights to municipal governments *or* strategic planners. Military access to communications satellites, including civilian satellites, has been an important feature of war for at least 30 years.[xxi] Militaries regularly make use of commercial imagery, and other remote sensing data and many countries that might compete in other ways cooperate to share data for land use or weather monitoring purposes. The National Reconnaissance Office (NRO), which operates U.S. reconnaissance satellites has recently expanded its relationship with commercial imagery providers.[333] These relationships also benefit the commercial sector, and Chinese authors regard U.S. civilian success in space in part as a result of close cooperation between NASA and the U.S. Air Force.[334]

The overlap between TT&C stations, early warning systems, signals collection stations, missile instrumentation ships and space tracking ships has been rather blurry. Ground stations, which have particularly provoked questions about sovereignty and military purposes, have particularly complicated history serving in both roles, since they can be used to assist in missile or space launches—or intercept those communications.[xxii] This becomes more complicated when it involves establishing facilities on foreign soil, but is also a regular feature of space operations. The U.S. required TT&C support for its first satellite launch, the Explorer 1 satellite in 1958, and set up stations in Nigeria and Singapore. In the 1960s, the U.S. Army built a global network of satellite tracking sites used to support the SECOR (Sequential Collation of Ranges) satellite series, a mapping and navigation initiative predating GPS, used roughly 25 sites outside the continental United States 1971.[335] The Apollo lunar program and subsequent U.S. space exploration missions have also required a global network of stations. Operations of NASA's earth observation satellite constellation involves a global network of stations to operate, including a core network is composed of facilities within the United States, in Svalbard, Norway, Alice Springs Australia, and Neustrelitz Germany. It has also joined by stations in Brazil, Canada, China, Germany, India, Indonesia, Italy, South Africa, South Korea and Sweden.[336]

How then to understand China's development of similar infrastructure? A key point to make is that in China's case this relationship is even closer due to historical factors and its political system, which is structured with the military directly subordinate to a ruling Leninist political party, rather than to a national government. As outlined in this study, almost every component of China's space programs are administered by or works in close connection with its military. While organizations like CNSA present a civilian face for China's space programs, cursory analysis of

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[xx] Historically, the contemporary distinction between civilian, military, and "dual-use" in regards to space is largely derived from the American experience in space and the Eisenhower administration's attempts to prevent inter-service competition. See: Roger Handberg "Dual-Use as Unintended Policy Driver: The American Bubble," in Societal Impact of Spaceflight, Steven J. Dick and Roger D. Launius, eds. NASA, Washington D.C. 2007.https://history.nasa.gov/sp4801-chapter18.pdf, 356-357

[xxi] Chinese observers reference the point that during the first Gulf War in 1991, U.S. use of military and commercial space infrastructure included over 70 satellites, 118 mobile ground stations and 12 commercial satellite terminals. See: Jiang Lianju [姜连举], ed. *Lectures on Space Operations* [空间作战学教程], Beijing: Academy of Military Sciences Press, 2013, 191

[xxii] For example, the NSA built a collection station in Asmara, Eritrea—then a province of Ethiopia—to gather telemetry signals intelligence (TELINT) or Foreign Instrumentation Signals Intelligence (FISINT) on the Soviet command station for Soviet deep space objects and Soviet space probes. See: "Telemetry Intelligence (TELINT) During the Cold War," National Security Agency Center for Cryptologic History, 2016. https://www.nsa.gov/Portals/70/documents/about/cryptologic-heritage/historical-figures-publications/publications/misc/telint-9-19-2016.pdf, 24.

their leadership and structure indicate they are civilian in name only. China Launch and Tracking Control (CLTC), the organization responsible for China's TT&C network and support ships, is believed to now be a component of the PLA Strategic Support Force Space Systems Department. The Yuanwang ships under the China Satellite Maritime Tracking and Control Department and their deliberately-obfuscated connections to the PLA are another point of concern.

More broadly, the civilian organizations under the China Academy of Sciences have close ties to the PLA. There appears to be significant cooperation between SSF units involved in space tracking, including the Deep Space Network, and the National Astronomical Observatory of China [国家天文台], which share data and cooperate on technical issues. One article describing cooperation between Jiamusi Deep Space Station and described their cooperation as "joint military-civil cooperation that achieved 'win-win' results [军地联合科研取得了双赢的效果]."[337] Fears that technologies developed in the commercial sector, often with foreign inputs, are justified as Chinese companies are themselves explicit that that technology will be spun-on for military use. The creation of a "Satellite Application Comprehensive Center" in 2018 under CASC's 5th Academy's [航天科技集团五院][xxiii] Satellite Application General Department [卫星应用总体部], for example, is intended to encourage private investment in and use of satellite resources, and direct the results of these toward the military.[338]

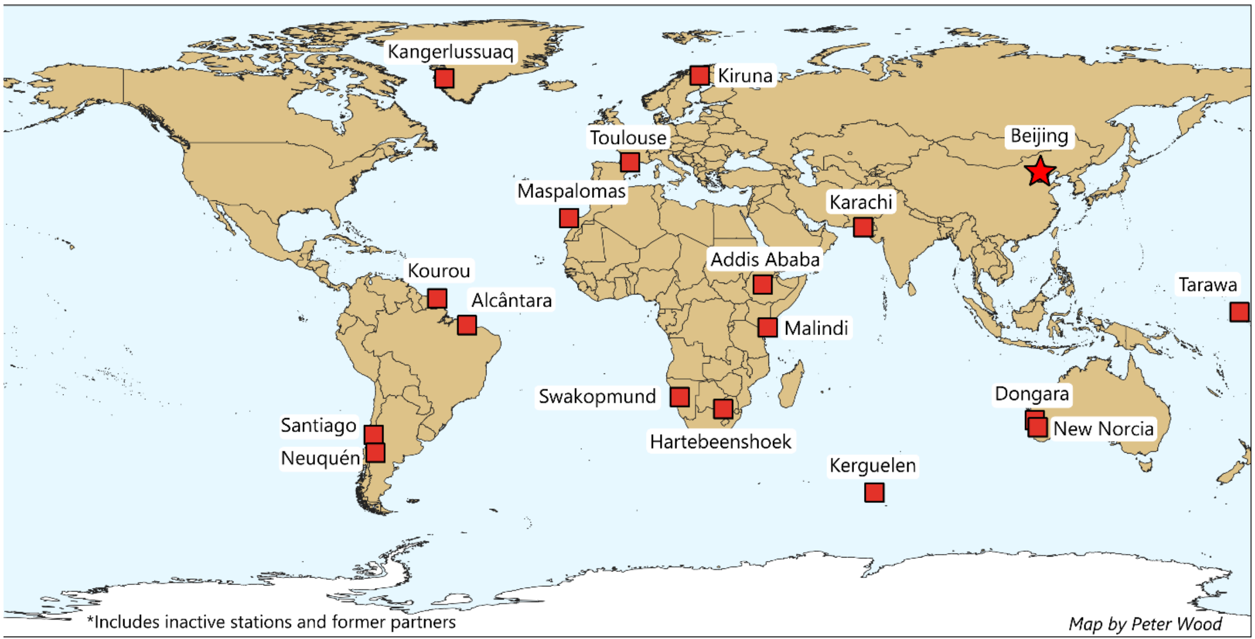
In summary, overlap between civilian and military sectors is a regular feature of space operations, including the ground segment. Evaluating China's development of a network of stations outside its borders should be viewed through that lens, but with the understanding that China has chosen to obfuscate these ties.

[xxiii] Also known as the China Academy of Space Technology [中国空间技术研究院], China's main developer of spacecraft

3.2 Chinese TT&C Stations and International Partners

The following map and descriptions of ground stations, arranged alphabetically by country, are identified as having been leased by cooperating with or directly constructed and operated by China's space programs. While some of these stations are commercial operators that provide services to a wide range of other countries, they are included due to their identification by Chinese officials as part of "China's network."

Chinese Space Tracking Stations and International Partners



Country	Location	Mission	Coordinates
Argentina	Neuquén	Deep Space Tracking	-38.192607, -70.148405
Australia	Dongara	Shenzhou spaceflight missions	-29.046755, 115.351077
	New Norcia	Deep Space Tracking, Lunar Missions	-31.0482, 116.191
Brazil	Alcântara Launch Center	China-Brazil Earth Resources Satellite (CBERS)	-2.334606, -44.419621
Chile	Santiago Station	Shenzhou spaceflight missions	-33.150239, -70.667962
Ethiopia	Entoto Observatory	ETRSS-1	9.108695, 38.807249
France	Kourou, French Guiana	Deep Space Tracking, Lunar Missions	5.222222, -52.773611
	Issus Aussaguel, Toulouse, France	Shenzhou spaceflight missions	43.428655, 1.497401
	Kerguelen Station	BNU-1 Polar Satellite	-49.351939, 70.256424
Greenland	Kangerlussuaq	Beidou	67.018341, -50.708817 *
Kiribati	Tarawa - *Inactive*	Shenzhou spaceflight missions	1.356354, 172.932916 *
Kenya	Malindi	Shenzhou spaceflight missions	-2.996044, 40.194204
Namibia	Swakopmund	Shenzhou spaceflight missions	-22.574645, 14.548539
Pakistan	Karachi, Dehmandro	Shenzhou spaceflight missions	25.193106, 67.099325
Spain	Maspalomas Station	Deep Space Tracking, Lunar Missions	27.7633, -15.6342
South Africa	Hartebeenshoek Station	China-Brazil Earth Resources Satellite (CBERS)	-25.890095, 27.685227
Sweden	Kiruna	Shenzhou spaceflight, downlinking	67.881219, 21.061046
*: Imprecise location			

Dongara, Australia
[当加拉站]

The fifth station to join China's network of overseas TT&C ground stations is located in Dongara in Western Australia. Owned by the Swedish Space Corporation (SSC), it was first leased to support the 2011 unmanned Shenzhou 8–Tian Gong docking mission.[339]

The decision to allow Chinese use of the facility was criticized. Des Ball, an Australian academic, and security expert, claimed the station was dangerous as the Shenzhou 8 was being used to collect electronic intelligence.[340]

Santiago, Chile
Santiago Station
[圣地亚哥站]

China has also used antennas in Santiago, Chile, to support Chang'e, Shenzhou, and satellite missions.
China Satellite Launch and Tracking Control General (CLTC) began cooperating with the University of Chile's Space Research Center in 1994, and leasing satellite tracking and control equipment.[341] In 2008 CLTC built the China Santiago Ground Station [圣地亚哥中国卫星地面测控站] and supported the Shenzhou 7 mission that year. The facility is currently operated by SSC Chile.[342]

CLTC signed an agreement for access to a 10-m C-band antenna at Santiago in May 2010. The station appears to be under the Xi'an central control center and to provide data to Xi'an and Beijing centers.

Addis Ababa, Ethiopia

Highlighting the ways China is using space for diplomatic inroads is its relationship with Ethiopia.

In 2018 the Ethiopian Ministry of Science and Technology signed a cooperative agreement with CNSA. The Chinese delegation indicated that they are "ready to provide training and support and to launch satellites in addition to the comprehensive cooperative agreement on space activities."[343]

China launched Ethiopia's first-ever satellite in December 2019. While donated by China, Ethiopian scientists participated in its design, and 20 Ethiopian engineers have been trained in China to operate the ground station.[344] The 65-kilogram microsat features a multi-spectral wide-angle camera to collect agricultural data.[345]

The purpose of the satellite is to support agricultural transformation, forest resource monitoring, weather forecast, and infrastructure projects. Ethiopia currently relies on data and services from foreign satellites, which costs millions of dollars each year. The new satellite is intended to be the first step toward Ethiopia developing its own capabilities.[346]

The ground station for the satellite is based at the Entoto Observatory and Research Center located in the mountains north of Addis Ababa. Construction of the observatory began in 2008, and it currently has two 1-meter telescopes and a satellite receiver.[347]

The Ethiopian Space Science and Technology Institute (ESSTI) [埃塞太空科学技术研究所] cooperates with, among others China Aerospace Science and Technology, China Aerospace Vehicle Technology Corporation, and China Great Wall Industrial Corporation.[348]

French Stations

In 1984, the Xi'an Satellite Measurement and Control Center and the French government signed an agreement to cooperate on space tracking.[349] Since then Chinese organizations and the French space agency Centre National d'Etudes Spatiales (CNES) have cooperated in several different areas of space exploration, notably using European Space Agency and French-run stations in Toulouse, Kerguelen Islands and at the Guiana Space Centre in French Guiana to support satellite tracking and deep-space communication missions.

Another area of cooperation is the China France Oceanography Satellite (CFOSAT). Initiated in 2016, CFOSAT is a joint mission devoted to the observation of ocean surface wind and waves undertaken by the Chinese and French Space Agencies.[350] Both countries contribute to the ground segment. The Chinese contribution to the ground segment is composed of a "Satellite Control Center" located in Xi'an (China), three TT&C ground stations in Beijing, Sanya, and Mudanjiang,[351] and a Mission Center for data processing, distribution and archiving. The French CFOSAT Ground Segment is composed of two X-band Stations, located in Kiruna (Sweden) and Inuvik (Canada), and two mission centers: one operated by CNES in Toulouse (France) for near-real-time processing distribution of data, and data archiving, and a second one for differed-time data processing, distribution and archiving operated by Ifremer in Brest (France). Some ground stations within China, such as the China Academy of Sciences-operated station in Kashgar downlink data from the French SPOT (Satellite Pour l'Observation de la Terre) earth observation satellites.[352]

Issus Aussaguel Toulouse, France

Issus Aussaguel is home to a large TT&C station operated by CNES that has participated in various Chinese space missions. On October 2, 2011, Xinhua News reporter learned from the Beijing Institute of Tracking and Telecommunications Technology (BITTT)[xxiv] that the nation's land, sea, and space-based trinity manned spaceflight TT&C communication network [陆海天基三位一体载人航天测控通信网] undertook its first mission supporting the docking of the Tiangong-1 and Shenzhou-8.[353] In response to the mission requirements, a new station in Dangara, Australia, was added to the network, forming an international network with Alcantara station in Brazil and Aussaguel station[xxv] and Kerguelen station.

[xxiv] This institute is now affiliated with the Space System Department of the PLASSF.

[xxv] This is usually referred to in Chinese sources as Aussaguel Station [奥赛盖尔站] or by the nearest large city Toulouse [土鲁斯]

Port-aux-Français, Kerguelen Islands, France
[凯尔盖朗站]

Located in the south-central Indian Ocean, the TT&C station at Port-aux-Français, in the Kerguelen Islands (also known as the Desolation Islands), is operated by CNES.

Chinese sources indicate the station has supported the October 2011 docking between Shenzhou-8 and the Tiangong-1 station, among other missions.[354] Its location makes it ideal for providing coverage in an area that would otherwise require dispatch of one of the Yuanwang ships.

Malindi Station, Kenya
[马林迪站]

Malindi station, operated by the European Space Agency, is equipped with an S-band transmitter/receiver and L- and X-band receivers.[355]

Malindi participated in tracking of the Shenzhou 5 mission, China's first crewed spaceflight, providing TT&C coverage between the Swakopmund (Namibia) and Karachi (Pakistan) stations. [356]

The station provided important data assisting with the braking maneuver and re-entry of the Shenzhou 6 mission.[357]

Tarawa, Kiribati

[吉利巴斯 or 基里巴斯], Tarawa Station [塔拉瓦站]

As China made preparations for its crewed spaceflight program, it began identifying potential locations for ground stations. Located in the central Pacific, Tarawa offered more reliable coverage while being significantly cheaper than using the Yuanwang TT&C ships. Tarawa previously hosted a ground station for the U.S. Army Map Service's SECOR Geodetic Satellite Observation Station (part of a predecessor to GPS) in the 60s and 70s.[358]

Negotiations between China and Kiribati to build a station in Tarawa began in June 1996, and in September of that year, China signed a 15-year lease for a 1-hectare plot of land to build a space tracking station.

While the agreement stipulated that "The Chinese government promises that the measurement and control station will be used exclusively for peaceful purposes and will not be used for military purposes at any time," there were concerns about the station's proximity to U.S. missile testing ranges in the Marshall Islands.[359]

The station was completed in 1996 and was rented for 1.2 million RMB per year (roughly $1 million at the time).[360] The establishment of the station was a significant cost-savings measure, as, without it, China would have been required to dispatch space tracking ships, which cost three times as much.[361]

Kiribati maintained diplomatic relations with the PRC until November 2003, when it switched recognition to Taiwan. The tracking station was shut down, but the facilities were apparently mothballed, not removed.[362] Kiribati switched recognition back to the PRC in September 2019, raising the possibility that the station could be restored.

Swakopmund, Namibia
[斯瓦科普蒙德]

China and Namibia signed an agreement to set up the TT&C station for China's crewed space program in October 2000, with the particular goal of assisting with control of the re-entry and landing phases. The station was completed in July 2001 and is subordinate to the Xi'an Satellite Control Center.[363] In 2003, during the Shenzhou 5 mission, the station coordinated with the Yuanwang 3 TT&C ship operating off the coast of Namibia. Since 2008 Namibia has sent students to China to learn high-tech skills related to the station, with the goal of expanding the use of remote sensing data and other space applications in the country.

According to the Namibian Ministry of Education officials, the station will encourage the use of space applications for land and town planning, disaster and flood management, agricultural surveys, and other tasks.[364] In 2012 China and Namibia signed an agreement to employ Namibians at the station to facilitate skills transfer.[365]

Dehmandro, Karachi, Pakistan
[卡拉奇站 or “South Asia Station” 南亚站]

China has a long-standing history of cooperation with Pakistan’s missile and space industries. In 1990, China launched Pakistan’s first domestically produced satellite, the Badr-I. This program also extended to ground operations.

The Karachi station, China’s second overseas TT&C station, was unveiled on October 1, 1999. It is housed inside the headquarters of Space & Upper Atmosphere Research Commission (SUPARCO), Pakistan’s space agency.[366]

China signed a joint research agreement with Pakistan for in 2006 space technology that was extended in May 2007.

In November 2009, China Great Wall Industry Corporation, a subsidiary of CASC, was contracted to support the construction of two ground stations for Pakistan’s 1R communication satellite (PAKSAT-1R).[367] The ground TT&C system included the Karachi main station and a secondary standby station in Lahore [拉合尔备站].

China has continued its cooperation with Pakistan in space, launching a second geostationary satellite in August 2011.

Hartebeenshoek, South Africa
Hartebeenshoek Ground Station

To help downlink data from natural resources satellites, China has established an agreement with the South African National Space Agency (SANSA) to use the Hartebeenshoek ground station.

The station was originally built by NASA in 1961, as the Deep Space Instrumentation Facility (DSIF) to support tests of early space probes such as Ranger and Surveyor and later missions, including Apollo.[368] The site was closed in 1974 due to political instability and the Apartheid regime.

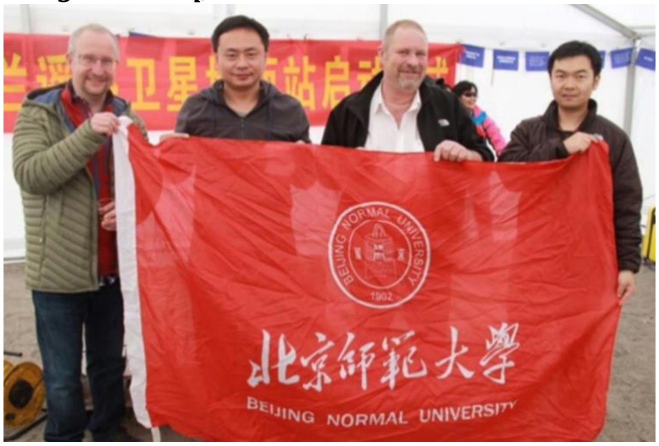
The China Centre for Resources Satellite Data and Application (CRESDA) and the South African National Space Agency (SANSA) signed an agreement in 2008, giving SANSA the right to freely receive, process, archive, and distribute CBERS satellite data.[369]

Kiruna, Sweden
Artic Satellite Receiving Station
[北极卫星接收站]

This station in northern Sweden is part of the Aerospace Information Research Institute/China Remote Sensing Satellite Ground Station (RSGS). The station was completed in December 2016. The station is able to receive data from earth-observing satellites and supports China's Gaofen project [高分重大专项], the umbrella for its Gaofen (lit. High Resolution) imaging satellites. China's National Satellite Meteorological Center also receives data from the Kiruna station.

Kiruna also acts as one of two polar ground stations for the Chinese-French Oceanography Satellite (CFOSAT). The station consists of one 12-meter S/X/Ka Frequency antennae.[370] Its ability to receive data at higher bandwidths (such as Ka-band 4×1.5Gbps) means that it can more rapidly download and transmit data from satellites, which Chinese media note as significant.[371]

Kangerlussuaq, Greenland



In May 2017 Beijing Normal University (BNU) [北京师范大学] and Greenland Tele-Post and the Greenland Institute of Natural Resources held a launch ceremony for the Greenland Satellite Ground Station [格陵兰卫星地面站] in Kangerlussuaq [康克鲁斯瓦格], Greenland.[372, 373]

These satellites will help support not only the Beidou satellite navigation system but also China's larger ambitions for the Arctic.[374] One of the participants, Cheng Xiao [程晓] (second from the left in the photo above), is the Dean of BNU's Institute of Global Change and Earth System.[375]

According to an article in *S&T Daily*, part of the impetus for the project was China's reliance on U.S. Satellite data when China's nuclear-powered icebreaker Xuelong [雪龙] was trapped in Arctic ice in January 2014.[376] To reduce this reliance and further Chinese scientific studies, China plans a constellation of 24 small satellites to provide continuous coverage. This will be later supplemented by high orbit Synthetic aperture radar satellites, with the overall project slated for completion by 2030. Chinese scientists, for example, note that the U.S. Europe and Canada have achieved large-scale continuous observation of the arctic and that existing polar-orbiting satellites (such as the Fengyun satellites) cannot provide the same type of observations.

China's current satellites, including the ZY-03, Gaofen-3, or Fengyun weather satellites, do not provide sufficient observations or at a sufficiently detailed level to complete the necessary scientific projects.[377] In December 2019, China launched BNU-1 satellite [冰路卫星], lit. "Ice Road Satellite" built by Beijing Normal University to conduct polar research.

BNU hopes to build follow on stations in Antarctica as more polar monitoring satellites are deployed.[378]

Scientists at BNU are spearheading a so-called "Tri-polar Environment and Atmosphere Scientific plan" [三极环境与气候变化国际大科学计划] often shortened to "Tripolar plan" [三极计划] which involves studying both poles as well the Qinghai-Tibetan plateau [青藏高原] which are major indicators of climate change. Satellites deployed as part of the plan are meant to augment the data collection capabilities of existing Gaofen and Fengyun earth-observing satellites.

Additional Polar Sites

In addition to the sites in Sweden and Greenland, China has established research stations near both poles that may be upgraded to communicate with satellites in polar orbits. [xxvi]

Arctic

Canada - Inuvik Satellite Station

Data from a joint Chinese-French Oceanography Satellite (CFOSAT) is downlinked to the Inuvik Satellite Station in northern Canada and Kiruna in Sweden.[379] Chinese scientists have also expressed interest in establishing a polar research station in Canada.[380]

Finland:

In April 2018, the Institute of Remote Sensing and Digital Earth of the Chinese Academy of Sciences [中国科学院遥感地球所] and Finland signed a "Sino-Finnish Arctic Space Joint Research Cooperation Agreement" to support cooperation in four main areas: data exchange and information services in alpine and polar regions [高山和极地寒区], satellite data downlink capabilities, scientific research and ground experiments, and personnel visits.[381]

The agreement also included plans to build an "Arctic Space Observation and Information Service Joint Research Center" in collaboration with the Arctic Space Centre of the Finnish Meteorological Institute (FMI-ARC) in Sodankylä [索丹曲莱] in northern Finland. The joint research center, officially inaugurated in October 2018, is positioned as the data and international network center for the alpine regions envisioned in the "Ice Silk Road" and "Digital Silk Road" plans under the Belt and Road Initiative.[382] Russian state-controlled news agency Sputnik cited this development as a new breakthrough in China's quest to conquer the arctic following its establishment of the ground station in Kiruna.[383]

In September 2019, China's Aerospace Information Research Institute of the Chinese Academy of Sciences (AIRCAS) [中国科学院空天信息研究院], a new organization created out of the merger and reorganization of RADI and two other CAS research institutes, announced that the joint research center had been completed.[384] According to AIRCAS, this development marks an important progression of this cooperative relationship: the near-real-time download of data through FMI-ARC will provide strong data support for scientific research and information services in the alpine region.

[xxvi] Satellite communications are not without their downside: the distances radio waves must travel (for example, from an area within China to a satellite in geostationary orbit 36,000km above the equator), in addition to processing time introduces significant delay of between 240-260 milliseconds. Line of sight is also an issue, and communications are even more difficult above 75°N or below 75°S. See: "The main disadvantages of satellite communications" [卫星通信的主要缺点], Jiayantech [石家庄嘉彦科技有限公司], 14 November 2017.http://m.jiayantec.com/index.php/news/337.html

Norway - Svalbard Satellite Station

Image Source: Maxar Technologies, Google Earth 2020

China opened its first scientific research station in the arctic in Ny-Ålesund (Yellow River Station) in 2004.[385] The Svalbard Satellite Station, which is over 100 km away from the Yellow River Station, is a major station for global satellite networks. Chinese actors were alleged to have launched a cyber-attack on two U.S. satellites in October 2007 and July 2008 through the station, but these reports have not been verified.[386]

Antarctica

Chinese Scientific Stations in Antarctica	
Great Wall Station	长城站
Kunlun Station	昆仑站
Taishan Station	泰山站
Zhongshan Station	中山站

China has built several scientific research stations in Antarctica. On various expeditions, Chinese scientific research teams have set up radar reflectors for calibrating satellites and established a reference station [准站] for the Beidou GNSS.[387] There are apparently plans to turn it into a fully-functional TT&C station.[388] A fifth station is being built in the Ross Sea area under the working name "Victoria Land Newly Built Station" [维多利亚地新建站].[389] Basic surveying and mapping work for this station was completed in January 2014.[390]

In her examination of China's expanding interests and activities in Antarctica, Anne-Marie Brady noted that China's draft Comprehensive Environment Evaluation (CEE) for the new base published in January 2014 highlighted climate change research, space science, and remote sensing as key projects, meaning that it will likely play a role in space tracking or related tasks.[391]

Conclusion

The size and sophistication of China's space ground segment within China and abroad, has increased significantly. China seems on track to meet many of the milestones for the National Civil Space Infrastructure Plan, and is now capable of providing global control, downlink, and tracking operations of objects from low-earth orbit to deep space. This network of stations and the relationships that enable them continue to bear fruit in terms of deepening relationships and opening markets for Chinese space services. China will continue to place high value on space not only for its strategic significance, but for the billions of RMB for China thousands of jobs space-related industries are expected to create. The ground segment will play a vital role in this endeavor.

Changes in technology are also going to change the shape of China's space infrastructure. There is an ongoing shift away from large expensive stations as networks of small, but cheap optical and radar satellite tracking stations and radio ground stations become more popular. These stations will not reduce the need for large installations necessary for deep space missions, but it will mean that China can easily build redundant and highly accurate systems to connect space-based internet-of-things, downlink data or track satellites and space debris.

Ultimately, as part of the Space-Earth Integrated Information Network Mega Project, Chinese scientists and engineers plan to build a constellation of space-based sensors, linked by data-relay satellites that can provide the necessary services without involving leasing or building stations abroad. While this project deserves to be monitored because it will have important impacts on China's economic and strategic capabilities, it must be noted that it lags behind military programs run by the DOD and dwarfed by commercial projects underway in the United States.

The U.S. and its allies and partners have benefited from scientific cooperation with China, but going forward this must be done with a realistic understanding of China's intentions and real nature of the organizations to be partnered with. Navigating the need to cooperate in space as a global commons, including sharing tracking data, is complicated by its role as a strategic domain.

While China has in many ways benefitted from the opacity surrounding its space program and supporting organizations, this study makes it clear that with even cursory research the curtain can be pulled back. The United States, along with our partners and allies who choose to engage with China on space issues, should, at minimum, understand the nature of the organizations they are working with and the consequences for international norms of a China strengthened by access to international space technology.

Appendix 1: Timeline of China's Space Program

1956	Jiuquan Satellite Launch Center (JSLC), Base 20 Founded
1957/8/21	*First Soviet ICBM successfully tested*
1957/10/4	*First artificial satellite, Sputnik*
1958/11/28	*First U.S. ICBM*
1964/11/23	Seventh Ministry of Machine Building established to oversee space development
1965	China Satellite Maritime Tracking & Control Department, Base 23 Founded; Program to build China's first satellite (Project 651) initiated; Work begins on Long March 1 based on the first two stages of the DF-4 missile
1965/6/28	*Intelsat I World's first commercial Communication satellite begins operation*
1967/6/23	Xi'an Satellite Control Center (XSCC), Base 26 Founded
1967	China established the Satellite Ground Survey Department, Taiyuan Satellite Launch Center (TSLC), Base 25
1970/1/30	First successful launch of a Long March 1 (CZ-1) rocket
1970/4/24	Dongfanghong 1 launched aboard a Long March 1
1970/6	China begins Communications satellite project
1971/4	714 Project, China's first manned space program established. Later canceled.
1972	Beijing Satellite Communication Station established
1975/9	Satellite Measurement Center Established
1975/11/26	China becomes the third country to successfully launch and recover a satellite
1979/12	CAS Institute of Remote Sensing Applications founded
1979/12/29	Xichang Satellite Launch Center founded
1981	National Remote Sensing Center established
1981/9/20	China successfully launched a group of three satellites with a single rocket
1982/5	7th Machine Building Industry replaced by Space Industry Department [航天工业部]
1982/10	Successful test of the JL-1, China's first SLBM
1984/4/8	Dongfanghong 2 experimental geostationary communication satellite launched
1983	Seventh Ministry of Machine Building replaced with the Ministry of Aerospace Industry
1986	China Launch and Tracking Control (CLTC) established; 25-m Sheshan Observatory radio telescope completed
1986/2/1	First practical Chinese communications satellite put in orbit
1986/12	Sino-US Scientific and Technological Cooperation Agreement signed, supporting establishment of first Chinese RSGS ground station
1988	China-Brazil Earth Resources Satellite (CBERS) program established
1988/9/7	Fengyun-1experimental meteorological satellite successfully launched aboard Long March 4 rocket
1990/4/7	U.S.-made Asia-1 communications satellite launched, marking China's entry into the global space launch market.
1992/9/21	Work Begins on China's Manned Spaceflight Program
1993	CNSA formed from former Ministry of Aerospace Industry
	Nanshan 25-meter radio telescope outside Urumqi
1994	Beidou project established
1994	CLTC begins cooperating with the University of Chile's Space Research Center
1995	Satellite Control Center moved to Xi'an
1996	Tarawa TT&C station in Kiribati completed
1996/3	Beijing Spaceflight Control Center established
1997/6/10	Fengyun 2 launched
1998	General Armaments Department established
1999/10	China-Brazil Earth Resources Satellite Launched
1999/11/20	Shenzhou-1, China's first manned spaceflight experimental spacecraft launched from Jiuquan
2000/10/11	China and Nairobi signed an agreement on the establishment of an aerospace measurement and control station
2001/1/9	Shenzhou 2 unmanned mission
2001/4/25	National Astronomy Observatory of China founded through merger of independent China Academy of Sciences observatories and related organizations
2002/3/25	Shenzhou 3 unmanned mission
2002/11/29	Shenzhou 4 unmanned mission
2003/5	Bedou-1 System completed
2003/10/15	Shenzhou 5, China's first manned spaceflight
2004/5	PLA Air Force issues first strategy: "building a strong air force based on integrating air and space capabilities, and coordinating offensive and defensive operations"
2005/10/12	Shenzhou 6, Manned spaceflight
2006	Deep space network facilities in in Miyun, Beijing and Kunming, Yunnan completed
2007/1/11	ASAT test destroys FY-1C, creating over 2,000 pieces of debris

2007/10/24	Chang'e 1 lunar probe successfully launched
2008/4/24	First Tianlian data relay satellite launched
2008/9/25	Shenzhou 7 - Manned Spaceflight, first spacewalk.
2010/1/11	ASAT Test
2010/10/1	Chang'e 2 lunar orbiter launched
2010	China High-Resolution Earth Observation System (CHEOS) project approved, CNSA Earth Observation Data Center established
2011/9/29	Tiangong-1 space station launch
2011/10/31	Shenzhou 8, unmanned spaceflight – successfully docked with Tiangong-1 on 3 and 14 November 2011
2011/11	Contact with Yinghuo-1 /Fobos-Grunt Mars probes lost
2012	Beidou-2 System Completed; Tianma 65-meter radio telescope in Shanghai completed; Deep Space Network stations in Kashgar and Jiamusi completed
2012/4	Chang'e 2 begins interception of asteroid 4179 Toutati
2012/6/16	Shenzhou 9 – manned spaceflight - first crewed docking with Tiangong 1 space station
2012/12/27	Beidou Satellite Navigation System begins regional services for the Asia-Pacific region
2013	Test of ASAT capable of threatening satellites geosynchronous orbit
2013/1	Mid-course missile intercept test
2013/4/26	Successful launch of the first Gaofen-1 high-resolution earth observation satellite
2013/6/11	Shenzhou 10, second crewed docking with Tiangong 1
2013/12/2	Chang'e 3 launched - lands on Moon on 14 December
2014/7	Chinese ASAT test
2014/10	Wenchang Spacecraft Launch Site completed
2015	*National Civil Space Infrastructure Medium-Long-Term Plan* approved
2015/6/8	SASTIND and CAS established the Space Debris Monitoring and Application Center
2015/12	Chinese ASAT Test
2016/1	Strategic Support Force Founded, Space Systems Department created
2016/9/15	Tiangong-2 launched
2016/10/17	Shenzhou 11 – crewed docking with Tiangong-2
2018/5/20	Queqiao relay satellite launched
2018/12/8	Chang'e 4 launched
2019/1/3	Chang'e 4 lands on Von Karman Crater on far side of the moon
2020/4	70-m deep space antennae in Tianjin completed
2020/6/23	Beidou-3 System Completed
2020/7	Tianwen-1 Mars Exploration mission launched
2020/8	Xingyun-2 inter-satellite laser datalink successfully established between two satellites

Appendix 2: Chinese Ground Station Coordinates

Stations Within China		
Organization	**Location**	**Coordinates**
China Satellite Launch and Tracking Control General Department (CLTC)		
	Beijing Headquarters	39.962253, 116.385927
China Satellite Maritime Tracking and Control Department		
	Jiangyin, Wuxi	31.942827, 120.288723
Unidentified Probable Early Warning and Missile Instrumentation Radars		
Large Phased Array Radar (LPAR) Korla area, Xinjiang AR		41.641194, 86.236749
LPAR, Huanan County [桦南县], Heilongjiang Province		46.528092, 130.755276
LPAR, Yiyuan County [沂源县], Shandong Province		36.024856, 118.092048
LPAR Longgangzhen [龙岗镇], Zhejiang		30.286567, 119.128608
Beijing Aerospace Control Center		
HQ		40.071983, 116.256847
Xi'an Satellite Control Center		
Changchun Station [长春站]		43.725332, 125.540836 *
Qingdao station [青岛测控站], Qingdao, Shandong Province		36.194830, 120.302880
Menghai Station [勐海测控站] Menghai County, Yunnan Province		21.946553, 100.452665
Nanning Station [南宁测控站]		22.888060, 108.304440
	Yao'an Substation	25.489181, 101.169445 *
Lingshui [陵水测控站], Lingshui, Hainan Province		18.439798, 109.874072
Weinan Tracking Station		34.467904, 109.544941
Zhanyi Station, Zhanyi County [沾益县], Yunnan		25.638159, 103.715123
U/I Station Qujing, Yunnan [曲靖市]		25.499946, 103.788064
1st Mobile Station, Weinan, Shaanxi		34.503420, 109.416442 *
	U/I Substation	34.482661, 109.487657
2nd Mobile Station, Hetian, Xinjiang		37.164167, 79.871307 *
3rd Mobile Station main base		42.039565, 111.534044
Deep Space Network (Under XSCC)		
Jiamusi, Heilongjiang		46.493403, 130.770409
Kashgar, Xinjiang		38.423420, 76.712207
Neuquén, Argentina		-38.191439, -70.149627
Jiuquan Satellite Launch Center (JSLC)		
Jiuquan Satellite Launch Center [酒泉卫星发射中心]		40.983507, 100.206390
Secondary landing site [副着陆场]		40.536242, 101.022394 *
	Dashuli Radar Tracking Station [大树里雷达测量站]	40.722291, 99.992276
	U/I optical tracking station [光学测量站点]	41.326159, 100.365313*
	U/I telemetry station	41.103952, 100.279730*
	U/I Large Phased Array Radar (LPAR) Korla area, Xinjiang AR	41.641194, 86.236749
	U/I LPAR, Huanan County [桦南县], Heilongjiang Province	46.528092, 130.755276
	U/I LPAR, Yiyuan County [沂源县], Shandong Province	36.024856, 118.092048
	U/I large phased array radar (LPAR) Longgangzhen, Zhejiang [龙岗镇]	30.286567, 119.128608
Taiyuan Satellite Launch Center (TSLC) (Base 25)		
Taiyuan Satellite Launch Center		38.848333, 111.610278
LPAR under Unit 63726, Kongtong District, Pingliang, Gansu [崆峒区,平凉市]		35.483025, 106.571871
	Kelan County, Xinzhou, Shanxi [山西忻州岢岚县]	38.846732, 111.615985
Main radar tracking station, Yangqu, Shanxi Province [阳曲站]		38.016892, 112.636536 *
Mobile radar station, 6th dui , Yinchuan, Ningxia AR [宁夏银川]		38.494519, 106.277348 *

	U/I TT&C Station	38.808858, 111.611199
TSLC	Xingxian Station [兴县站]	38.507539, 110.920224 *
Xichang Satellite Launch Center (Base 27)		
Xichang Satellite Launch Center [西昌卫星发射中心] Liangshan Yi Autonomous Prefecture, Sichuan Province [四川省凉山彝族自治州]		28.245963, 102.028178
Launch Site		28.245963, 102.028178.
Yibin Satellite Observation and Measurement Station [宜宾测量站], Yibin, Sichuan		28.743607, 104.611790
Yibin Barracks		28.764813, 104.641389 *
Baita Mountain, Yibin possible auxiliary station		28.775649, 104.634663 *
U/I Satellite observation Station, Xuzhou, Yibin [宜宾市叙州区]		28.769159, 104.605508
XSLC Niutoushan tracking station [西昌卫星发射中心牛头山观测站/牛头山测控点]		28.196568, 102.069191
U/I Tracking Station		27.911767, 102.209881
Guiyang Observation Station in Huaxi County, Guizhou [贵州省贵阳市花溪县]		26.409398, 106.670273
Wenchang Spacecraft Launch Site (Under Xichang SLC)		
Wenchang Spacecraft Launch Site		19.652510, 110.938741
	Tongguling tracking station [铜鼓岭测控点]	19.639694, 111.029314
	Paracel Islands tracking station [西沙测控站], Duncan Island [三沙市西沙群岛琛航岛]	16.451586, 111.713916
Unidentified/ Probable Space Tracking or Missile Instrumentation Sites		
	LPAR Hui'an, Fujian Province [福建省泉州市惠安县]	25.126471, 118.751507
Aerospace Information Research Institute (AIR)		
Kashgar Station		39.504344, 75.930372
Miyun Station		40.451465, 116.858186
CAS National Astronomical Observatory of China [国家天文台]		
Beijing Observatory Station, Miyun, Beijing		40.557929, 116.976632
Changchun Satellite Observatory [长春人造卫星观测站]		43.790677, 125.443823
	U/I Substation	43.793982, 125.458251
Sheshan Observatory Station [佘山站], Shanghai (under Shanghai Observatory)		31.099321, 121.199758
Xinjiang Observatory Nanshan [南山]		43.471881, 87.177425
Yunnan Astronomical Observatory [昆明]		25.027370, 102.795947
National Satellite Meteorological Center [国家卫星气象中心]		
National Satellite Meteorological Center HQ, Beijing		39.947675, 116.320940
Beijing Weather Satellite Ground Station [北京气象卫星地面站]		40.050972, 116.276899
Guangzhou Weather Satellite Ground Station [广州气象卫星地面站]		23.164589, 113.338715
U/I Guangzhou Satellite Ground Station		23.243476, 113.411842
National Satellite Ocean Application Service [国家卫星海洋应用中心]		
Lingshui Station, Hainan		18.490251, 109.931629
State Radio Spectrum Management Center [中国无线电管理]		
Beijing Station		39.660041, 116.254973
Shaanxi Station		34.528998, 109.098328
Shanghai Station		30.864138, 121.582030
Shenzhen Station		22.579901, 114.499123
Urumuqi Station		43.850092, 87.554027
Yunnan Station		24.617104, 102.949126
Communications Stations		
Beijing Satellite Communications Earth Station [北京卫星通信地球站]		40.050966, 116.274398
International Stations		
Argentina	Neuquén	-38.192607, -70.148405

Australia	Dongara	-29.046755, 115.351077
	New Norcia	-31.0482, 116.191
Brazil	Alcântara Launch Center	-2.334606, -44.419621
Canada	Inuvik	68.319464, -133.552426
Chile	Santiago Station	-33.150239, -70.667962
Ethiopia	Addis Ababa, Entoto Observatory	9.108695, 38.807249
France	Kourou, French Guiana	5.222222, -52.773611
	Issus Aussaguel, Toulouse, France	43.428655, 1.497401
	Kerguelen Station	-49.351939, 70.256424
Greenland	Kangerlussuaq	67.018341, -50.708817 *
Kiribati	Tarawa - *No longer active*	1.356354, 172.932916 *
Kenya	Malindi	-2.996044, 40.194204
Namibia	Swakopmund	-22.574645, 14.548539
Norway	Artic Yellow River Station [黄河站], Ny-Ålesund, Svalbard	78.9232, 11.9345
	Svalbard Satellite Station	78.230302, 15.395534
Pakistan	Karachi, Dehmandro	25.193106, 67.099325
Spain	Maspalomas Station	27.7633, -15.6342
South Africa	Hartebeenshoek satellite ground receiving station	-25.890095, 27.685227
Sweden	Kiruna	67.881219, 21.061046
Chinese Scientific Stations in Antarctica		
Great Wall Station [长城站]		-62.216838, -58.961855
Kunlun Station [昆仑站]		-80.41734, 77.116449
Taishan Station [泰山站]		-73.85, 76.966667
Zhongshan Station [中山站]		-69.373587, 76.37165
*: Imprecise Location U/I: Unidentified or unconfirmed affiliation		

Endnotes

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6 The original Chinese is "天地一体化信息网络。推进天基信息网、未来互联网、移动通信网的全面融合，形成覆盖全球的天地一体化信息网络."

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