China's Space Capabilities:

CAST Academy of Space Information Systems

Summary

China's Academy of Space Information Systems (ASIS) is one of 19 entities subordinated to the China Academy of Space Technology (CAST) with missions in satellite or manned spacecraft research, design, development, or manufacturing. ASIS is located in Xi'an and is sometimes called the CAST Xi'an Branch Academy.

Chinese open-source media provide few Okay details on ASIS space systems. However, an examination of ASIS research reporting in academic journals identified 47 reports published since 2018. These provide some insight into the research that supports ASIS design and manufacturing functions. Clusters of these report topics suggest the following priorities in recent ASIS space systems development:

Academy of Space Information Systems (ASIS) Headquarters

Source: ronwefan.com

Hardware Design:

- Satellite antenna design, including analysis through modeling and simulation
- Development of systems for a Chang'e-4 lunar mission relay satellite
- Design of other satellite hardware such as data storage for x-ray telescope satellites
- Simulation of space vacuum and low temperatures for testing space-borne hardware

Data Processing:

- Deep learning and AI algorithms to enhance clarity of optical images
- Advanced radar signal processing for multiple-input multiple-output (MIMO) radars
- Guidance software for hypersonic vehicle reentry into the atmosphere

Taken together, the data indicate that ASIS is probably not the sole developer of any whole system or space vehicle project. This does not necessarily make ASIS a minor player. It may indicate a CAST matrix approach to satellite design and manufacturing, that any one CAST project takes contributions and subsystems from a variety of its subordinate institutions.

Background

China has an immense state-owned spacecraft (manned and satellite) research and production infrastructure consisting of scores of companies and factories distributed under the supervision of corporations and "academies." Many of these have evolved over time from government ministries into state-owned enterprises. Space production is dominated by two such giant enterprises: China Aerospace Science and Industry Corporation (CASIC) and China Aerospace Science and Technology Corporation (CASC). Responsibilities for space research, development, manufacturing, and launching are distributed across numerous academies under each of these entities.

CASC is mainly engaged in the research, design, manufacture, test, and launch of space products such as launch vehicles, satellites, manned spaceships, cargo spaceships, deep-space exploration craft, and a space station, as well as strategic and tactical missile systems. For the most part, CASC's spacecraft and satellite manufacturing entities are found in the CASC Fifth Academy, also known as the China Academy of Space Technology (中国空间技术研究院), or CAST.

Previous China Keyhole reporting[1] identified 30 CAST organizations that appear to be involved in satellite development and manufacturing. Of these, 11 appeared to perform ancillary functions such as space component quality assurance, facilities management, or non-space commercial production. The other 19 appear to have missions in satellite or manned spacecraft research, design, development, or manufacturing.

This report is intended to identify the role of one of these entities, the CAST Academy of Space Information Systems (ASIS), in space systems development. This report is based on open-source materials available through search of the Chinese-language portion of the Internet. It uses general descriptions found in public Chinese media and taken from CAST itself. However, the primary data source used to characterize the ASIS role under CAST is research reporting by ASIS available in Chinese archives for academic journal articles.

Names For This Institution

CAST identifies this subordinate entity by the name "空间电子信息技术研究院," which translates as "Academy of Space Electronics Information Technology." However, multiple journal articles by authors working in this entity used this same Chinese name but used the English name "Academy of Space Information Systems" for their unit in English article data or abstracts. Since the research personnel themselves have used the "Academy of Space Information Systems" term as their English name more frequently than any other translation, that is the name adopted for this report.

[1] See China Keyhole - The CAST Catalog: China's State Organization for Satellite Manufacturing, December 14, 2021.

This entity has several other names in both Chinese and English. ASIS is the current identity of what was originally the Southwest Institute of Electronics of the Chinese Academy of Sciences. It was known as the Xi'an Institute of Space Radio Technology (西安空间无线电技术研究所) when established in 1968 under CAST. It is sometimes referred to by the more generic title of "504 Institute" (504 所). It also uses the name "CAST Xi'an Branch Academy" (五院西安分院) in several sources. In addition, one Western source identified this entity as the "Academy for Space Communication," but it is unclear if the Chinese ever used this English name. For the remainder of the report, it will be called ASIS.

Description

The CAST website identifies this subordinate entity with the following description:

> "[ASIS] is located in Xi'an, Shaanxi Province. Its primary missions are research and development, production, and related electronics research for space vehicle payloads and electronic systems equipment, space vehicle telemetry, weapons equipment, and satellite-use electronic systems and equipment. This academy has produced critical products for manned spacecraft missions, lunar and deep-space exploration missions, and Beidou navigation satellite missions. For China, it is a leader in several fields: communications satellite technology development, satellite navigation technology, satellite data transmission and processing technology, space-based antenna research and development, satellite remote sensing technology, satellite link technology, and measurement and control technology for ground, maritime, and space-based equipment. It has made thousands of pieces of equipment for China's communications broadcast satellites, navigation satellites, remote sensing satellites, weather satellites, scientific research satellites, and Shenzhen spacecraft."

Very little in terms of reliable descriptions or references to ASIS were found that expand on this definition. Most descriptions found in job recruiting postings or other online media essentially repeated this paragraph. ASIS itself had a limited website (cast504.com) that is no longer online. Archived data from this website did list "castxian504@163.com" as an email address for the unit.

Location

CASC (CAST's higher-level headquarters) identified ASIS as headquartered in the Xi'an Space Industry Base Park with additional research and development centers in Beijing and Shanghai. Multiple sources including job postings by CAST also identify ASIS as being in the Xi'an Space Industry Base, with the street address No. 504 East Changan Road, Xi'an (西安市航天产业基地, 西安市东长安街 504 号). This address equates to a location on the south side of Xi'an (see map, right). Unclassified satellite imagery of this location shows a large and relatively new walled complex with multiple buildings that occupies a full city block, as shown below.

ASIS location in Xi'an

Source: 2345.com

ASIS complex in the Xi'an Space Industry Base

Source: Google Earth

CASC has stated that ASIS was established in this complex in 2015. A review of unclassified satellite imagery confirmed that construction began at this complex in 2010, and these structures were externally complete by December 2015. The approximate geographic coordinates for this facility are 34 09 20N 108 51 50E.

The most prominent building is a high-rise structure of about 16 stories, shown below left in enlargement and with a ground-level image of the same building on the right from the video mentioned earlier. Another view of this building appears on the first page of this report. In that image, the name at the top of the building appears more clearly and includes the number "504" at the end.

Probable ASIS Headquarters building

Source: Google Earth

Image from ASIS video

Source: ixigua.com

Leadership

The Director of ASIS was identified in Chinese news media in October 2021 as Li Jun (李军). The same report identified Li Li (李立) as Deputy Director and Shen Dahai (沈大海) as Party Secretary. Li Jun has served as Director since at least 2016. He had previously served in ASIS as the Party Secretary. He has apparently been at ASIS since at least 2008, since CASC reported that he and others went overseas that year for industry visits.

ASIS Director Li Jun

A 2017 report on formalizing a partnership between ASIS and the University of Electronic Science and Technology of China listed ASIS participants and their positions (see

below). Some of the leadership may have changed in the four years since this appeared, but Li Jun is still in place as the Director.

ASIS leadership positions (2017)

Li Jun (李军), Director
Wang Wei (王伟), Deputy Director (since replaced by Li LI)
Tan Xiaomin (谭小敏), Chief of Radar Institute
Wu Chunbang (吴春邦), Chief of Antenna Institute
Liu Yang (刘洋), Chief of Market Research and Development
Zhai Shenghua (翟盛华), Chief of Communications
Zhang Jianhua (张建华), Chief of Digital Transmission

Identifying ASIS Work in Online Media

ASIS does not advertise the nature of its work in any detail, but CASC itself, in a 2018 article posted at its website, identified some of the Chinese space programs that ASIS has been involved in. It claimed that ASIS "had successfully participated in the completion of 150 satellite launch missions" since 2008. Specific contributions listed include:

- Beidou satellite navigation system (navigation subsystem, antenna subsystem, inter-satellite link)
- Beidou-3 (assembly based on barcode recognition, multi-site testing, and remote testing)
- Hongyan global low-orbit satellite constellation communication system

A 2019 article in People's Daily also identified some accomplishments in space technology programs that ASIS has been part of. These included ASIS contributions to:

- Shenzhen manned spacecraft program (lighting and instrumentation)
- Beidou-2 navigation satellite program (rubidium atomic clock)
- Chang'e lunar lander program (moon landing radar, antenna, data transmission, measurement and control)
- Chang'e-4 mission Queqiao relay satellite (deep-space large-aperture umbrella antenna)

In addition, a 2020 promotional video shot at ASIS (called the 504 Institute in the video) presented images apparently from inside the labs and assembly halls at this facility. The rooms and objects shown were not identified in the film. Sample images from this video are shown below.

Interior images from ASIS promotional video, 2020

Source: ixigua.com

ASIS Academic Research Reports

Like other Chinese academics, researchers at this entity publish academic journal articles describing the results of their research projects. Research papers do not necessarily cover the full scope of all work types at ASIS or all projects undertaken here. Still, clusters of research subjects revealed in their written work can suggest some of the systems being developed and the role of ASIS in that development.

To identify current work, a search of Chinese online research reporting from early 2018 to mid-2021 was conducted and identified a total of 47 journal articles written or co-authored by ASIS personnel. Academic data bases held these articles, with title, authors, abstract, publication journal, and publication date. Analysis of this information did reveal several patterns in their work—clusters of topics and what role ASIS has been playing in space systems development in recent years.

Sorting through these materials showed that 23 articles described work done in support of space systems **hardware design**. Another 13 articles focused on software, primarily on improved methods of **data processing** for information downloaded from space systems. Specific articles and a review of the research themes are described below.

Hardware Design

In research reporting, a significant cluster of the design work was focused on satellite-borne antennas. The ASIS roles in this work appear to be design of antenna hardware and testing of designs through modeling and simulation.

Satellite Antenna Design

There were nine ASIS reports found on satellite antenna design. Research reports in this category include the following seven articles:

- Design Of A Ka-Band Side-Fed Offset Cassegrain (SFOC) Multi-Beam Satellite Antenna (2018)
- Attitude Maneuver Strategy For Zero Doppler Beam Center Of Fast Response SAR Satellite (2018)
- Divergence Opportunity Analysis On Zenith-Passing Blind Zone Of Satellite Antenna (2018)
- Gravity Effect On Deployment Dynamics Of Astromesh (2018)
- Design And Verification For Umbrella-Type Deployable Antenna Of Chang'e-4 Lunar Relay Satellite (2018)
- The Key Technologies For Radial Rib Deployable Antenna Of Chang'e-4 Relay Satellite (2019)
- Manufacture Of Large Aperture And High Precision Composite Reflector (2019)
- International Project Management Mode Of Exported Satellite Antenna (2019)
- Analysis Of Flexible Body Constraint Characteristics Of Space-Borne Perimeter Truss Antenna (2020)

The abstracts from these articles show emphasis on design and testing, as in one report on the proposed design of an antenna for a high-throughput satellite and the results of testing the hardware in some unspecified way. Another described manufacturing techniques for space-borne carbon fiber honeycomb sandwich reflectors, with emphasis on their formation in high-precision molds and and curing techniques.

The majority, however, described the testing and analysis of antenna designs through modeling and simulation. This included overcoming blind zones in a maneuvering satellite antenna through modeling antenna operations, testing the deployment of an Astromesh antenna in space by modeling its operation in zero-g conditions, and simulation and analysis of the cable-net system used for a space-borne perimeter truss antenna. One other article described the derivation of attitude control parameters for a synthetic-aperture radar (SAR) satellite, with results of Matlab simulation that tested the proposal.

Two of the articles shown above support the Chang'e lunar exploration mission. The first Chang'e spacecraft was launched in 2007, and Chang'e-4, which has both a lander

and a rover, was launched in 2018. In these reports, design features for the radial-rib deployable antenna for this satellite are described such as on-orbit deployment, mesh formation and maintenance, and ultra-low temperature environmental adaptability.

Other Hardware Design

There were another three ASIS articles found about other aspects of the relay satellite for Chang'e-4, which appears to have been a major project for ASIS:

- Mission Analysis And System Design Of Chang'e-4 Lunar Relay Communication Satellite (2018)
- Research And Analysis For Relay Communication System Of Chang'e-4 Lunar Relay Satellite (2018)
- Technical Characteristics Of The "Queqiao" Relay Communication Satellite For Chang'e-4 Lunar Farside Exploration Mission (2019)

Again, the ASIS contribution appears to have been in equipment design. The report contents indicate that their work was primarily focused on design of a satellite to provide relay communication service between Earth ground stations and the Chang'e-4 lunar lander. Design considerations discussed included selection of mission orbit, arrival and maintenance of the orbit, and relay communications design trade-offs.

Additional reports described the design process for a variety of other hardware used in satellite operations. Samples of these articles include:

- Design And Verification Of Data Storage System For Hard X-Ray Modulation Telescope Satellite (2018)
- A Novel Design Of Miniaturized Space-borne Micro-strip Circuits Using Π-Type Interdigital Circuit (2018)
- Design Of Pre-Distortion Linearizer For Ka-Band Final Amplifier Of Receiver (2018)
- Simulation And Design Of A Ku-Band Analog Phase Shifter (2018)

Space Environment Effects

ASIS has also been involved in the simulation of space vacuum and temperatures for testing of a variety of space-borne hardware. Reports in this area include:

- Failure Analysis Of GaN Power Amplifier Due To Single Event Dielectric Rupture Of MOS Capacitor (2019)
- Design And Performance Test Of A Low Passive Intermodulation Absorber (2020)
- Methods For Improving Measurement Accuracy Of Space-borne Multiplexers In Thermal Vacuum Tests (2021)

The research indicates ASIS conducts physical tests in a simulated space environment. Two of these reports describe the use of a space environment simulation chamber, in

one case to study the impact of thermal vacuum on hardware performance and in the other to study temperature changes on spacecraft system-level signal interference. The third gave results from heavy ion radiation experiments carried out to study the radiation tolerance of other hardware. That report described the results of the test, identifying which components of the amplifier were vulnerable to the radiation.

Data Processing

The second major research cluster was on processing methods for data from satellite systems. Of the 13 projects found in this category, there were 8 reports on improved processing of optical imagery data and another 3 reports that described radar signal processing.

Optical Image Processing

Within the optical imagery set, most articles found described the use of deep learning or the AI construct "convolutional neural networks" to enhance optical images. For the most part, the abstracts of these articles do not address satellite imaging systems per se, but the term "remote sensing" appears in some cases. The reports found that addressed AI functions in image processing are the following:

- A Multi-Focus Image Fusion Algorithm Based on Deep Learning (2018)
- Remote Sensing Image Fusion Based On Deep Learning Non-Subsampled Shearlet (2018)
- Image Defogging Algorithms Based On Multi-Scale Convolution Neural Networks (2019)
- Image Denoising Algorithm Based On Information Preservation Networks (2019)
- Infrared Image Fusion Algorithm Based On Convolutional Neural Networks (2019)
- Image Denoising Algorithm Based On Wavelet Transform And Convolutional Neural Networks (2020)

Accurately deciphering the abstracts for these articles would require a significant background in artificial intelligence processes. The researchers are obviously writing for other researchers in their field rather than the general public. Nevertheless, useful trends can be identified from the abstracts in order to characterize the work in general terms.

First, several of these studies involve image fusion and developing algorithms for AI assistance in the fusion process. The authors defined remote-sensing image fusion as "a method of selectively combining image information with different observation characteristics obtained by different sensors." In one study, an infrared and visible light image fusion algorithm based on a convolutional neural network is proposed. In a multi-focus fusion study, focused image blocks and defocused image blocks in an image are classified by a scoring mechanism derived from a deep learning network. The authors

claim that "the boundary zone of image focus and defocus is then subdivided and repaired."

Other reports also emphasize the use of convolutional neural networks to improve image clarity. In one article, an "end-to-end convolutional neural network" is used to learn the mapping relationship between foggy images and clear images, resulting in measurable defogging. In another, a convolution neural network "with information preservation blocks with relatively low computational complexity" is used to remove image noise while protecting the edge information and texture details of the image. In a third report, an effective image denoising algorithm that combined "the advantages of a stationary wavelet transform with a convolutional neural network" was tested.

The nature of the work done at ASIS in all these cases appeared to be the same: an algorithm was proposed and tested, and "the experimental results show" the image improvements. Some results were quantified, such as by citing the general image quality index and the spectral angle mapping in the results, or reporting changes in the image's peak signal-to-noise ratio. Other results are characterized more generally, such as citing "good performance on the evaluation indexes of mutual information, edge information retention, entropy, and average gradient."

Two other studies addressed optical image processing without specifically mentioning AI processes. These were:

- Remote Sensing Image Fusion Based On Structured Sparse Representation And Detail Injection (2018)
- Analysis Of Spatial Rice Cluster Characteristics Based On Ground-Based Scatterometer (2019)

The 2018 report discussed "high- and low-frequency structured dictionaries" while the 2019 study also described "double-sparse representation to obtain the high- and low-frequency structured dictionaries." These are terms used in signal processing but do not necessarily indicate the use of AI processes.

Radar Signal Processing

Three other ASIS reports were on radar detection and imaging. They did not mention use by space-borne assets but instead focused on the technical aspects of radar signal processing. The reports are:

- DOD and DOA Estimation Of Targets Using Bistatic MIMO Radar Based On LP EVD (2018)
- Experimental Analysis Of Sea Clutter Using Airborne Circular Scanning SAR In Medium Grazing Angle (2019)
- Target Location By Bistatic MIMO Radar Based On J-Orthogonal Matrix (2019)

Two of the research reports discussed multiple-input multiple-output (MIMO) radar, a type of phased array radar where antenna elements are located close together to obtain better spatial resolution and obtain low-probability-of-intercept radar properties. The 2018 report described signal processing by eigenvalue decomposition (EVD) and replacement of the linear prediction (LP) algorithm to reduce computation complexity. The abstract claims that "simulation results verify the effectiveness of the method." A second report also addressed a new method to enhance the precision of a linear prediction algorithm for direction of departure (DOD) and direction of arrival (DOA) estimation in bistatic MIMO radars.

The third report addressed modeling sea clutter as an aid to processing synthetic aperture radar (SAR) images. The research involved analyzing the validity of available sea clutter models for range Doppler images from different scan angles for moderate sea state in the medium grazing angle. In language typical of these reports, its conclusions were somewhat murky: "By the analysis of the fitting performance between the histogram of real data and the amplitude probability density function (PDF) of empirical distribution models and the goodness-of-fit (GoF) test for real data from different scan angles, it is indicated the generalized K(GK) distribution with generalized Gamma texture distribution can fit the sea clutter well for different scan angles in the medium grazing angle."

Other reporting discussed processing of satellite data for meteorological purposes, including detection of wind energy and direction and the processing of signals from microwave temperature sounders on Fengyun weather satellites.

Hypersonic Vehicle Guidance

Two articles from 2020 on software processes diverged from the usual work on image processing and instead reported work on hypersonic vehicle guidance software. These articles were:

- Predictor-Corrector Reentry Guidance With Crossrange Dynamic Constraint (2020)
- Algorithm Of Reentry Guidance For Hypersonic Vehicle Based On Lateral Maneuverability Prediction (2020)

The ASIS role here appears to be developing guidance system software through reentry guidance simulation. The first of the two reports discussed "guidance strategy" in terms of defining a guidance corridor for a reentry glide vehicle and analyzes the disturbance of atmospheric density and aerodynamic parameters which cause uncertainty in the predictor model. The simulations used the "CAV-L, a kind of hypersonic vehicle," as the research object for the simulations. The second article extended the discussion by proposing an algorithm of reentry guidance "based on prediction of the vehicle's lateral maneuverability."

Conclusions

To summarize, CASC and official Chinese media have named a small handful of space programs that ASIS has been involved with, including:

- Shenzhen manned spacecraft program
- Beidou satellite navigation system
- Chang'e lunar lander program

In praising ASIS' contributions, these sources mostly pointed to satellite subsystems worked rather than whole programs. ASIS is credited with developing antenna systems, atomic clocks for satellite navigation, moon landing radar, inter-satellite links, and data transmission systems, as well as providing testing services.

The academic work found provided more granular detail. In some cases, this confirmed claims made in official media such as antenna work and the Chang'e communications relay satellite. If journal article clusters can be taken as a rough indicator of research work focus, this data suggests that ASIS has been largely contributing to space systems development in two ways:

Hardware Design

- Satellite antenna design, including testing and analysis through modeling and simulation
- Development of systems for Chang'e-4 lunar mission relay satellite
- Design of other satellite hardware such as data storage for an x-ray telescope satellite
- Simulation of space vacuum and low temperatures for testing space-borne hardware

Data Processing

- Deep learning and AI algorithms to enhance clarity of optical images
- Advanced radar signal processing for multiple-input multiple-output (MIMO) radar
- Guidance software for hypersonic vehicle reentry into the atmosphere

Taken together, the data summarized above indicate that ASIS is in fact deeply involved in space systems development. However, with the possible exception of the Chang'e lunar communications relay satellite, ASIS does not appear to be the sole developer of any whole system, or even the primary entity among many working on a space vehicle project. This does not necessarily make ASISa minor player in CAST's constellation of space development enterprises. This may be typical of a CAST matrix approach to satellite design and manufacturing, that any one CAST project takes contributions and subsystems from a variety of its subordinate institutions.