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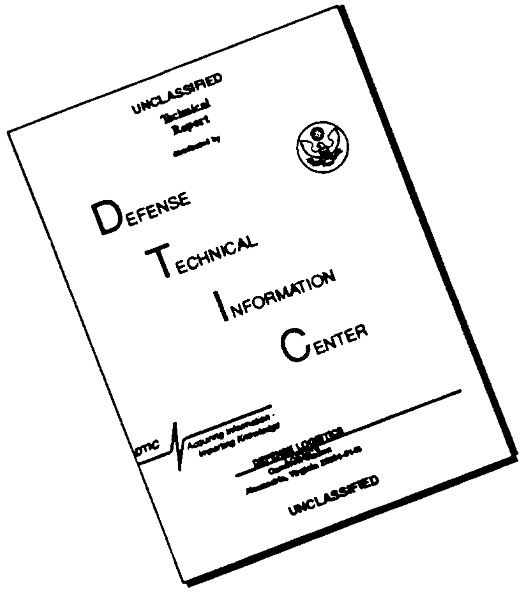

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SEMI-REAL SIMULATION FOR ANTI-AIRCRAFT MISSILE GUIDANCE AND CONTROL SYSTEMS

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ABSTRACT

This paper introduces the development of simulation technology in guidance and control systems of anti-aircraft missiles of China, and describes the major pieces of equipment in the anti-aircraft missile simulation laboratory, including the Main Frame Simulation Computer System (MFSCS), the sensor environmental simulation system and the simulation software, etc.

The history of the development of technology for anti-aircraft missile guidance and control system simulation in China is already 30 years old.

In the beginning, because the digital computers used had limited capabilities, especially limitations in speed calculations, the calculation time for a group of mathematical algorithms for a few dozen seconds of flight control processes of an anti-aircraft missile often required dozens of minutes or more to complete. Therefore, it was basically impossible to introduce introduce the guidance and control system equipment which require live time information exchange to simulation experimental equipment. At this time simulation was called mathematical simulation.

Naturally, at that time simulation computers were often used to carry out simulation experiments. The simulation computer used constantly changing simulation voltage to express physical quantities in the changing process. They used different simulation circuits to perform such mathematical calculations as integration, multiplication, and addition. Because the simulation computation components created only a very slight time delay (as far as missile flight process is concerned), solid objects of the guidance and control system such as the automatic pilot or the rudder could be introduced into the simulation experiment. This was what we commonly referred to as semi-real simulation experiments. Because we used simulation computers, and simulation circuitry was not very precise, stability was poor, and only a limited number of forms of numerical calculations could be expressed, this type of simulation was limited to a certain degree.

As computer technology and precision machinery, optics and electronics and radio technology quickly developed, the methods and physical methods for the laboratory expression of anti-aircraft missile guidance and control process became more complete, and engineers were able to construct more complex simulation experimental systems to meet the needs of a new generation of anti-aircraft missile research and development. The Ministry of Aeronautics and Space Beijing Simulation Center's RF homing simulation laboratory and infrared homing simulation laboratory are typical examples of China's anti-aircraft missile guidance and control simulation laboratories. Below I will briefly introduce the components of the anti-aircraft guidance and control simulation laboratory and their uses.

I. Mainframe Simulation Computer System (MFSCS)

The mainframe simulation computer system is a major component of the laboratory. Prior to the semi-real simulation experiment, it has mathematical simulation of the anti-aircraft missile flight process intercepting the target. Based on the requirements of the semi-real simulation experiment, with some of the parameters and conditions of the solid objects of the missile system, it makes calculations of the missile dynamics formulas and live time calculations of the dynamic formulas of the missile's target. At the same time it exchanges information with the solid objects, thus carrying out live time semi-real simulation.

In anti-aircraft missile guidance and control system semi-real simulation experiments the simulation of target characteristics (radio or optical characteristics) is a very important mission. This part of the work includes two tasks. One the real time, dynamic calculation of a group of time series data streams based on an mathematical model of the target characteristics. The other is, at the same time as performing the above task, to load this group of data streams onto the target simulator of the experimental system, thus achieving the goal of describing the simulation of the target environment. If the mathematical models of the target characteristics are relative movement parameters between the missile and the target as inquiry indicator data bank, then the main frame simulation computer system can handle this task. In the semi-real simulation of homing guidance or remote control command guidance systems, it is possible to use a special target computer to compute the various radar reflection cross sectional areas or antenna branch circuit angular error recognition characteristic curve. At this time, the movement parameters of the missile and target can be relayed in real time from the mainframe simulation computer to the target computer.

II. The sensor environmental simulation equipment

The second major component is the sensor environmental simulation equipment. In semi-real simulation experiments, not all components of a missile are used in the experiment. What are first attempted to be used are the missile system's sensing components and detection equipment. For example, homing guided missile heads, the missile rate gyro, the inertia measurement complex and the ground guidance radar receiver are can take part in the experiment in their actual forms, because these pieces of sensitive sensing equipment either directly form error command signals or participate in forming error command signals within the missile control system, so they control the missile flight and are important components of the guidance control system. Some equipment such as the missile rate gyro directly affects the dynamic characteristics of controlled flight. Also often used in semi-real simulation are the automatic pilot which is directly connected to these sensors or missile computer, ground guidance and control computer and rudder system, thus through the experiment testing is done of the guidance and control system's dynamic characteristics. Testing the matching up of the major component systems aboard the missile and the ground control system.

In order to sensors of the missile systems be able to "measure" as close as possible the same information in semi-real simulation experiments as the signal measured during the process of the actual missile flying to intercept a target, it is necessary to construct within the laboratory environmental simulation equipment which is very compatible to the sensors.

The physical equipment which is used to simulate optic and electronic environment of the target and its dynamic characteristics is called the target simulator. It is often a very complex system. The Beijing Simulation Center's infrared target simulator is an example of such a simulator. It can receive missile and target dynamic parameters received from the main frame simulation computer and simulate the target as an infrared source moving upon a certain area. At the same time, it can simulate the energy on certain infrared spectrum as well as certain interference and background. A well designed target simulator should have as small an error as possible between the target characteristic it simulates and the mathematical model of the target characteristics, and after this mathematical model is revised, it should still form an optical (infrared) and radio environment which conforms very closely to the revised mathematical model.

In remote control command guidance anti-aircraft missile semi-real simulation, because of the difficulties in achieving this feat of engineering, the laboratory does not use RF electromagnetic field radiation methods, but the simulated radar signal is feed back into circuitry which serves as the radar, thus forming guidance radar target and missile signals.

As for whether target characteristic mathematical models are able to actually reflect the simulation of target characteristics, it must be determined by performing special theoretical research and actually measure, and then revising the model. This is an important topic of simulation. It is also a task which must be performed prior to conducting anti-aircraft missile guidance and control system semi-real simulation.

The physical equipment which is used to simulate the missile motion characteristics environment is the missile simulator. There are two types of these. One is the simulated missile angular motion environment, often a three axis flight platform. The rotating platform can, based on the requirements of the angular motion sensor (gyroscope, homing missile head, etc) on the missile, reproduce the angular velocity vector of the middle flight process or angular position on a designated coordinate system. Another type is one which simulates the missile linear motion environment. It can be achieved with a linear acceleration simulation platform.

It can simulate a mechanical environment, causing the missile linear accelerator to sense linear acceleration during the flight process, thus providing precise information to the autopilot stability circuit or the missile velocity and positioning system.

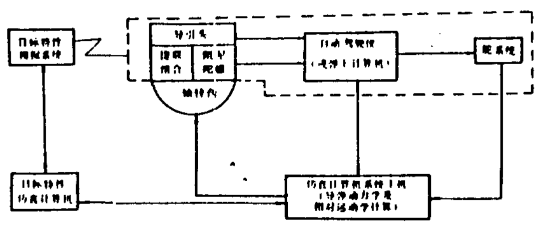
The sensor environment simulation equipment described above is all based on the "sensing function" of the sensors and not on the function of human sense organs. This is the standard for whether or not certain environment simulation equipment is a realistic "simulation".

III. Simulation software

The third major component is simulation software. The software compiling the mathematical model of the missile dynamics (including the guidance and control system mathematical model and the missile and target relative motion mathematical model) and the target characteristics environment mathematical model is primary simulation application software. In order to make this software run hand in hand with laboratory equipment, live time management software is also required.

In this manner, the simulation experiment design engineers can, as required by the anti-aircraft missile guidance and control system overall design agencies, divide this into stages, carrying out semi-real simulation experiments beginning with the simple and proceeding to the more complex. When they are writing up the experiment report after completing the experiment, they will, based on their understanding of the semi-real simulation experiment system, provide the results of the simulation experiment with a certain amount of confidence within a certain confidence range. This task is one of the major jobs of system simulation. However, it cannot be done in the laboratory. It must be combined with the calibration, recognition and determination of the aforementioned guidance dynamics mathematical model and target characteristic mathematical model. When reliable data gathered through flight experiments or field experiment are processed scientifically, so the mathematical model more accurately describes the actual systems and processes, then mans' knowledge of semi-real simulation of the actual system process will also become more accurate.

Block diagram of anti-aircraft missile guidance and control semi-real simulation experiment



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IV. Laboratory simulation of offensive and defensive operations

For anti-aircraft missiles, in addition to guidance and control systems, if the dynamic process of the launch control system and fuse and warhead matching control system in actual operations were also described in simulation experiments, then simulation would be a more complete simulation of the anti-aircraft missile's operational process.

In simulation laboratory research, it is also possible to introduce simulation of command, control and communications systems, thus allowing the simulation to be extended to the overall weapons system.

Even more significant, if while studying anti-aircraft missile system semi-real simulation, consideration is given to the semi-real simulation of surface-to-surface missiles, then the attacker and defender ECM, penetration and counter-penetration strategy, interference and counter-interference simulation could, to a certain degree, be carried out within the laboratory.

This type of offensive and defensive combat semi-real simulation is the natural extension of the semi-real simulation of the individual weapon anti-aircraft missile guidance and control systems. It is also the result of 30 years of simulation technology development.

A thorough going study of offensive and defensive combat semi-real simulation will certainly promote further developments in weapons system simulation technology, providing effective means and tools for China's defense modernization construction.

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CHINA'S APPLICATION SATELLITE ACHIEVEMENTS AND BENEFIT ANALYSIS

BY: Yang Jiali

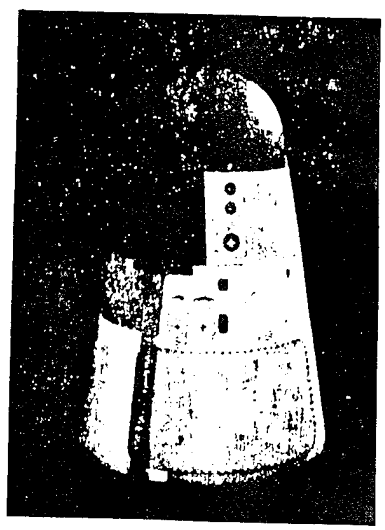
ABSTRACT

By the end of 1990, China had launched 30 China-made earth satellites. Of these, 19 were application satellites which include recoverable remote sensing satellites, telecommunications satellites and weather satellites. The related departments of the state use the data from China's recoverable remote sensing satellites to perform territorial surveys, geological surveys, mineral prospecting, mapping, forest and grassland investigations, environmental monitoring and protection, earthquake prediction, sea route construction, highway construction, railway and bridge construction, water resource development, city planning, and scientific research such as microgravity. The related departments use the data from China's meteorological satellites for weather forecasts, etc. The related departments have developed various projects, via China's communications satellites, including communications, broadcast, television relay, facsimile, TV education and finance. In this article preliminary analysis of the economic benefits of the 11 satellites successfully launched by China during the Seventh Five-Year Plan are also provided. Finally, this article describes new requirements from different departments for application satellites for the next ten years.

Following the successful launch of its first man-made satellite on May 24, 1970, China has developed application satellites as a major policy of China's space technology development. By the end of 1990 China had launched 32 satellites which included eight scientific and technology experimental satellites, 12 recoverable remote sensing satellites, six communications and broadcast satellites, two weather satellites, two balloon satellites for testing atmospheric density and two foreign satellites. These satellites have been of obvious benefit in economic construction, national defense construction and in scientific and technological fields.

I. Recoverable remote sensing satellites

Fig. 1 One of China's recoverable remote sensing satellites



In 1975 China first used its Changjiang-2 rocket to successfully launch a recoverable remote sensing satellite. The satellite was recovered on the earth's surface according to plan. By 1990, China had successfully launched a total of 12 of these satellites, and all had been recovered according to plan. Recoverable remote sensing satellites have brought back large amounts of high resolution, high clarity satellite photographs, and by using these photographs we have received large amounts of data concerning China's territory, and valuable information for geological resources, water conservancy development, petroleum prospecting, mapping, environmental monitoring, earthquake prediction, railroad construction, highway construction, bridge construction, sea lane construction, environmental protection, project sites, urban planning. Recoverable satellites have also conducted low gravity materials science and low gravity biological experiments for Chinese and foreign scientists in their scientific research, achieving satisfactory results. Here we will raise some examples to illustrate.

National territory satellite photographs. These can be used in scientific research and production and construction fields. In 1985 and 1986 China launched two territory survey satellites which provided more than 3000 satellite photographs of China's territory. Each photograph covered an area of about 2000 square kilometers. These photographs were used with excellent results in 15 trial areas (Beijing, Tianjin and Tangshan, and the Huanghe Delta region). Social and economic benefits were obvious, showing that the application of national satelite photographs are an important indicator of modernization in national resource survey and ecological environment monitoring. In geological survey for example, through petroleum geological interpretation of satellite photographs of the northern part of the Tarim Basin, new information on the oil forming structure was discovered. In Beijing seven predicted mineralized areas were located. In Neimenggu chromium mines and iron mines were located. In earthquake geology survey, direct drafting of earthquake geological maps was completed. Maps of the scale of 1:50,000 and 1:100,000 were drawn up of the Huanghe Delta. Combining satelite photographs with existing ocean maps and measured depth data, China's first photomap of the Nansha Islands was compiled, with a positional error of less than one kilometer. In harbor and river channel construction, the mud flow patterns of the Huanghe, Luanhe and

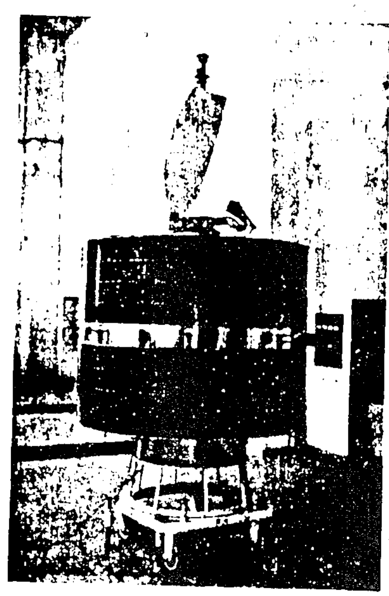
Haihe and their interactions were determined. In the Heilongjiang water resources and flood prevention survey conducted jointly by China and the Soviet Union, the inundation loss surveys for 13 projected water resource pivotal dams were completed as ell as the Kuti Project geological survey and flood prevention special survey. Using national satellite photographs, 500 special series maps were drawn up showing the water resources, land utilization, forestry resources, land degeneration areas, shifts in natural environments, earth crust stability, for selection of railway lines, solid ore production resources, tourist sites, in the Beijing, Tianjin and Tangshan area of 550,000 square kilometers, and maps of the coastal situation. In land planning, the areas of total land, tillable land, water areas, land used for housing, forests, salt areas, sandy land and erosion areas of 47 county level units in Beijing, Tianjin and Tangshan were determined. It was determined that 355,000 mou of land were lost to cultivation in Beijing between 1951 and 1988, that the average amount of farmland per resident in the Beijing, Tianjin and Tangshan areas was 1.35 mou per person, about 10 percent of the average farmland per person nationwide. The cost of the survey was only seven to 30 percent that of conventional surveys.

Photographic surveying: Through photographic surveying of photographs obtained from satellites it is possible to draft 1:25,000, 1:50,000 and 1:100,000 scale maps which are highly accurate. Each satellite photograph covers an area 140 times that of an aerial photograph, and the area covered on each orbit is approximately equal to two maps of China. This can allow interpretation of major topographical features and provide indicators for mineral prospecting, provide clues for the location of future mineral prospects, can be used to study the scope of water and snow ground cover, sand shifting, evolution of river deltas and the evolution of lakes. It can be used for surface area surveys, iceberg and coastal area surveys, island surveys and shallow water ocean bottom topographical surveys.

Space low gravity study: A total of more than 200 low gravity on-board experiments have been conducted on recoverable satellites. In an experiment on August of 1987, a remelting crystal furnace was used to conduct a gallium arsenide crystal growth experiment which also concerned antimony-chromium-mercury, indium antimonide and other metallic composite materials. In this experiment, the gallium arsenide crystals grown did not contain any contaminant lines, were structurally complete, and had a uniform component ratio. This experiment was of very great academic and economic value.

II. Communications broadcast satellites

Fig. 2 Chinese application communications and broadcast satellite



China began research and development of stationary orbit communications satellites in the seventies. In 1984 it successfully launched its first experimental communications satellite, using the Changjiang-3 rocket. Following this launch, China quickly developed application model communications satellites. As of the present time, China has launched four application model communications satellites, allowing China's communications, television and broadcast enterprises to by-pass traditional development stages. Such services as telephone, digital facsimile, image transmission and broadcast television relay are already in use. Television reception and communications are no longer a problem in remote areas.

Broadcast television: China's communications satellites relay 30 channels from the Central People's Broadcast Station to the outside. They broadcast programs of the Central Television Station and from the Xizang television station. Using time division multiplexing, they relay programs from the Yunnan, Guizhou and Xinjiang television stations. As of the present time, more than 20,000 three to six meter satellite ground receiving stations have been construction throughout the country, improving the transmission quality of broadcast television programs and expanding the area with television reception capabilities.

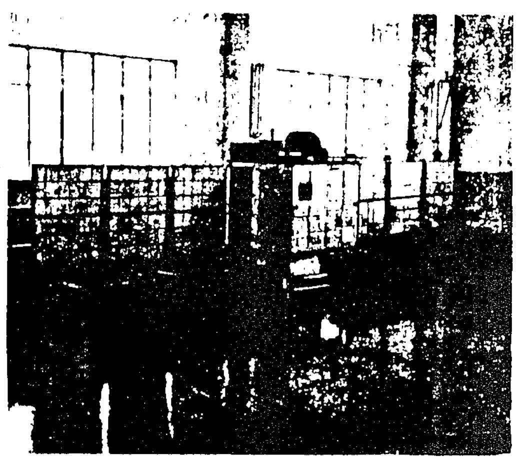
Television education: Using communications satellites to relay educational television programs. The nationwide educational system has constructed more than 3,000 educational television stations and relay stations and receiving stations and more than 30,000 viewing sites. According to a sampling survey conducted by the Educational Television Station, there were 10 million formal students and self-study viewers of educational television.

Long distance radiotelephone: As of 1989 there were already more than 1,500 satellite circuits, which represented six percent of all circuits. In addition, the Ministries of Petroleum, Coal and Water Resources had also opened up 200 new circuits. At the present time, China is in the midst of building medium sized satellite communications ground stations in all its major cities. It is estimated that by the end of the year there will be 7,000 to 8,000 circuits.

Finance: Satellites provide China's Peoples Bank with data transmission. Centered around the main station in Beijing, there are 350 smaller stations forming a network structure between the main bank and the lower level banks. It has lead to modernized management in financial clearing and transfers, financial management, television contact, business training, television conferences, greatly reducing travel expenses.

III: Weather satellites

Fig. 3 China's second polar orbit weather satellite, the Fengyun-2



China's first weather experimental satellite was the Fengyun-1 which was launched in 1988 using the Changjiang-4 rocket. This satellite obtained high quality cloud photographs and captured images of such weather systems as frontal cloud systems, secondary turbulence cloud systems, tropical air circulation, storm clouds, equatorial convergence zones, tropical cloud masses and typhoons as well as topographical characteristics and snow accumulation. In 1990 China successfully launched its second polar orbit weather satellite with markedly improved capabilities. The quality of cloud pictures taken by this satellite was comparable to those taken by United States weather satellites of the same period.

IV. Benefit analysis

Experience has demonstrated that space technology promotes economic growth, increases economic benefits and changes in the economic structure. The economic benefits of application satellites are normally not direct and do not exist independently, but are concealed in the economic results and social activities of those entities they serve and play an indirect role through the entities they benefit. Also, there are a number of services for which there is no noticeable short term benefit, but the benefits of which only become apparent over a long period of time. The following factors should be considered when analyzing the benefits of China's application satellites: (1), Overall benefits of application satellites should be considered, including social benefits, economic benefits, technological benefits, especially social benefits. (2), The benefits of application satellites are dynamic, and increase with additional investment, increased research and with different stages of application. These are usually divided into initial benefits, stable benefits, decreasing benefits and retired benefits. Of these, stable application stage benefits, that is, stable benefits, are proportionally the greatest. (3), China's satellite growth can be divided into two stages in application satellites. these are the exploratory experimentation stage and the experimentation application stage. To facilitate discussion, we will only present an initial analysis of the "Seventh Five-Year Plan" as an example.

1. During the "Seventh Five-Year Plan" China developed and successfully launched 11 satellites which included one Dongfanghong-2 application communications satellite and three Dongfanghong-2A application communications satellites for domestic communications, five recoverable satellites and two weather satellites.

(1). The three Dongfanghong-2A communications satellites had a total of 12 relays all of which have been placed into use. At the present time it costs 1.5 million Dollars per year to lease one INTELSAT relay. These 12 relays represent 90 million Dollars over five years, or the equivalent of 468 million Renminbi. According to estimates of some foreign consulting companies, the ratio of income between INTELSAT and its long distance telephone companies is 1:16. Because our satellites are used for domestic communications and distances are not so great, this income ratio may be considered to be 1:5. In this case, this benefit would be 2.34 billion Renminbi.

(2). Other application satelite systems, such as remote sensing satellites, earth survey satellites and weather satellites. According to foreign statistics, the increased value ratio is generally set at 20:1 to 10:1. Using our estimates which are lower than these, benefits would be about 1.96 billion Renminbi.

In summation, direct economic benefits from satellites launched during China's "Seventh Five-Year Plan" are estimated at

4.3 Billion Yuan. Social benefits were even higher. For example, more than 10 million people participated in television education. If training expenses were calculated at 500 Yuan per person per hour, the value would be five billion Yuan per year.

2. Space technology is a highly comprehensive technology, and many achievements have been transferred to the civilian economy, bringing with them improvements in technology and improvements in labor conditions, improving product quality, increasing labor productivity. As of the present time, more than 1800 achievements have been reused in the civilian economy.

(1). Using the heat pipe technology used for temperature control in satellites, heat pipe heat exchangers, heat pipe hot bodies, constant temperature devices, small heat pipes used in plastic film and electronic elements and heat pipe solar energy collectors have been developed. If a hot pipe heat exchanger is mounted in the baking room of a sizing machine, it would reduce energy consumption by the sizing machine 15 percent a year, about the equivalent of increasing the sizing speed by 30 percent.

(2). Using the high resolution imaging technology and video tube technology of remote sensing satellites, medical X-ray televisions have been successfully developed which can be widely used in surgery and clinical diagnosis in orthopedics. We now have the capacity of producing 1000 of these machines annually, with a value of production of over 30 million Yuan.

(3). On the basis of the satellite control microcomputer, the STD-5000 industrial control microcomputer has been successfully developed. This is widely used in more than 1000 systems in the pharmaceutical production, railroad signal processing, the candy industry, turbo temperature control and lathe digital control, occupying 40 percent of the domestic market. Annual production capacity has already reached 1000 machines per year with a value of 15 million Yuan.

(4). On the basis of satellite communications technology, large numbers of different types of television receiving stations have been developed and produced.

(5). Using recoverable technology, 7.1 million timers of different sorts have been produced.

(6). Using satellite long distance high speed data relay technology, a data collection, transmission, storage and processing automated management system has been developed for Shenyang's Zhongwo Reservoir. This can be widely applied in reservoir management.

IV. The future of China's application satellites

As application satellites are placed into operation, China's Post and Telecommunications, broadcast, television, agriculture and forestry, national resources and culture education agencies will attempt to use domestic satellites and thus application satellites may accelerate the process of modernization of these departments and improve work efficiency and increase self confidence. In future years money and finances, national security, construction, energy, coal, oceanic, railroads, water transport, foreign relations, posts and telecommunications, broadcasting and space science research departments will all express their enthusiasm and support for the development of China's satellites, and will even place additional and greater demands upon them.

According to possible demands placed on China's application satellites by the dozen and more ministries, commissions and bureaus as well as by foreign entities, according to preliminary statistics, in the next ten years China will have to develop large capacity communications broadcast satellites, moveable communications satellites, banking communications satellites, polar orbit weather satellites, stationary orbit weather satellites, oceanic satellites, resources satellites, fire and disaster satellites, earth survey satellites, navigation and positioning satellites, biological satellites, low gravity scientific experimentation satellites and space science exploration satellites.

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THE XIAN SATELLITE CONTROL CENTER AND CHINA'S SATELLITE TT&C NETWORK

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ABSTRACT

The China Satellite TT&C Network consists of the Xian Satellite Control Center (XSCC), a number of fixed TT&C Stations including Changchun, Minxi, Xiamen, Weinan, Nanning and Kashi Stations, three mobile TT&C stations which are under the direct command of XSCC as well as the ocean-going instrumentation ships. XSCC possesses a data processing system which has multi-function command and monitoring equipment and communications equipment, etc. The TT&C technology of the China Satellite TT&C Network exhibits advanced levels in the field of conducting TT&C for recoverable satellites and geostationary satellites.

I. Introduction to the China Satellite TT&C Network

The China Satellite TT&C Network is composed of the Xian Satellite Control Center (XSCC), a number of TT&C stations and ocean-going instrumentation ships. The XSCC is the communications hub, the command and control center, and the data processing center of the China Satellite TT&C Network, Because the XSCC is the managerial agency for the China Satellite TT&C Network, it is the term normally used when referring to the China Satellite TT&C Network.

1. The make-up of the China Satellite TT&C Network

The China Satellite TT&C Network is a satellite TT&C system which can be compatible to near earth satellite TT&C as well as geostationary satellite TT&C. It includes the following seven special systems.

(1). The tracking and telemetry system

This system uses radio tracking and telemetry equipment to for tracking and instrumentation of the satellite and to obtain satellite parameters such as range (R), azimuth (A), elevation angle (E) and range rate of change (R). It is used to determine satellite orbital factors (also called orbital basic factors).

(2). The telemetry system

Using radio telemetry equipment this system receives and interprets satellite telemetry signals, thus obtaining satellite engineering parameters and control and survey parameters.

(3). The remote control system

This system uses radio remote control equipment to transmit remote control commands to the satellite, thus controlling the movement and operations of the satellite.

(4). The data processing system

This system is composed of computer hardware and computer software. There three levels of computers - the TT&C center computers, TT&C station computers and microcomputers of the TT&C equipment. The TT&C center computers are a group of large mainframe computers. These computers are responsible for the complex live time and follow-up data processing tasks (these operations will be described later). The TT&C station computers are small or microcomputers and are primarily used to collect and exchange data. They also have a certain data processing capability. The TT&C equipment microcomputers are TT&C equipment terminals, primarily used for data recording and retrieval and for automatic TT&C functions.

(5). The communications system

This system is composed of circuit terminals, data transmission terminals, switchboard equipment and communications links. The communications links include landline links, radio links and satellite communications links. The commutations modes include voice, telex, facsimile, data transmission and television image transmission.

(6). The time frequency system

This system is composed of timing equipment, signal generators and oscilloscopes. The XSCC and the TT&C stations time frequency systems are calibrated to the standard time signal broadcast by the Shaanxi Observatory to ensure the times of the entire T&C network are synchronized.

(7). The control and monitoring system

This system is composed of voice dispatching equipment, monitoring display equipment, keyboards and command modules. By collecting and displaying the operational status of the TT&C network, TT&C equipment and space vehicles, it provides command personnel and analysts with information and relays command orders and control instructions.

2. The primary TT&C stations of the China Satellite TT&C Network

The China Satellite TT&C Network TT&C stations are divided into the following three categories by their nature and by their missions:

(1). The fixed near earth orbit satellite TT&C stations at Changchun, Nanning, Kashi are fixed location near earth satellite TT&C stations. Their primary TT&C equipment includes VHF/UHF uniform TT&C equipment, dual frequency doppler tachymeters, telemetry interpretation equipment, remote control equipment, and single pulse radars. The VHF/UHF TT&C equipment uses channel synthesis technology. It has R, A, E R, telemetry and remote control functions. The error of range rate of change is no greater than 0.1 meter per second. The single pulse radar ranging error is no greater than 10 meters. The angular error is no greater than 0.2 mil. The range rate of change is no more than 0.2 meters per second.

The Nanning TT&C station is about to be equipped with S band uniform TT&C equipment. The upper frequencies are 2025-2120 megaHertz and the lower band frequencies are 2200-2300 megaHertz. This equipment is of the same technological levels as similar foreign equipment.

(2). Fixed near earth satellite/geosynchronous satellite TT&C stations

The Jinan, Minxi and Xiamen stations are fixed near earth satellite/geosynchronous satellite TT&C stations. The Jinan and Minxi stations primarily TT&C equipment includes dual frequency doppler tachymeters, telemetry interpretation equipment, remote control equipment, C band uniform TT&C equipment and C band guidance instruments. The C band uniform TT&C equipment has R, A, E, R and telemetry (coding telemetry and analogue telemetry) capabilities. The antenna for this equipment has a radius of ten meters and carrier wave modulation form is PM/FM on top and PM on the bottom. The ranging is done using a combination of pseudo-code side-tone ranging. The ranging random error is no greater than 10 meters. The angular random error is no greater than 0.15 mil, and the range rate of change error is no greater than 0.03 meters per second (upper band PM).

The Jinan and Xiamen stations will be equipped with international standard C band uniform TT&C equipment within the year. This equipment has an upper frequency of 5925-6425 and a lower frequency of 3700-4200 megahertz. The Antennas are 15 meters across, and ranging is done using a digital side-tone system. Its technical indexes are basically the same as the C band uniform T&C equipment.

(3). Mobile type TT&C stations

The first mobile station, the second mobile station and the recovery instrumentation station make up the three mobile TT&C stations. The first and second mobile stations can be deployed in appropriates area depending on the requirements in order to fill in the gaps of the TT&C network and the carrier rocket's instrumentation. The primary TT&C equipment of these mobile stations includes VHF/UHF uniform TT&C equipment and mobile type monopulse radar. The first mobile station monopulse radar is a highly mobile digital type tracking instrumentation radar. Its capabilities are comparable with the United States AN/MPQ-39 radar. The recovery instrumentation station is responsible for tracking and searching for the satellite reentry capsule after it reenters the atmosphere and for recovery. This station is equipped with recovery radar and helicopter radio direction finding equipment.

The ocean-going instrumentation ships are also entered into the TT&C network when conducting a satellite instrumentation mission. They serve as major components of the satellite TT&C network.

II. The Xian Satellite Control Center

1. The functions of the Xian Satellite Control Center, hereafter referred to as the Control Center

Live time determination of the TT&C plan (also referred to as TT&C policy), conducting TT&C automatic scheduling of multiple satellites (six satellites).

Collecting satellite and carrier rocket tracking and metering data and telemetry collected by the TT&C stations and the instrumentation ships and conducting live time processing and follow-up processing of this data.

Determining satellite orbit factors and attitude parameters, implementing the satellite's next point orbit plan and issuing forecasts.

Monitoring the movement and operational status of the satellites, generating control instructions and exercising monitor and control of the operational status of the TT&C network.

Exercise management over the recovery of recoverable satellites and long term TT&C of long-term satellites.

2. Composition of the Control Center

The Control Center is primarily a data processing system. It also has command, supervision and control equipment and communications equipment, time frequency equipment and service equipment and facilities. Figure 1 and Figure 2 show the Building and the command room. This article will merely introduce the data processing system and other primary components.

Fig. 1 The Xian Satellite Control Center

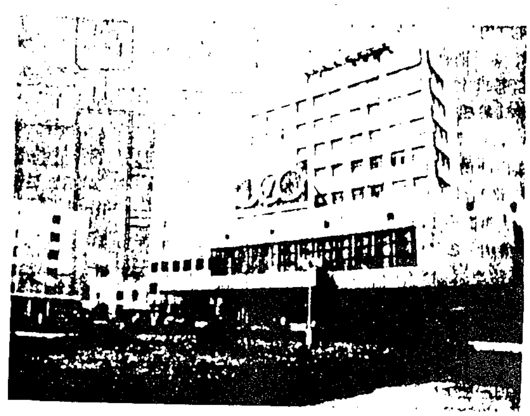


Fig. 2 The Xian Satellite Control Center command room

(1). The data processing system

The data processing system mainly includes computer hardware and T&C application software.

The computer hardware includes three NCI 2780 computers, two VAX 8700 computers, and several VAX-II computers and lots of peripheral equipment. The three NCI 2780 computers and the two VAX 8700 computers are connected through Ethernet. Physically, the five computers form a VAX group through a star coupler using CI. Logically, outside the group, the two NCI 2780 computers operate in a duplex mode, serving as front end computers. Communications between the computers uses the two methods of large network and CI. The two serve to back up each other, thus improving reliability and processing capabilities. The two front end computers form a remote computer network with the TT&C station computers through a communications control processor (CCP) and communications links.

The TT&C application software is either near earth satellite TT&C software or geostationary satellite TT&C software depending on the object satellite. There are four types of software depending on the nature of the software. (1), live time software which includes information exchange, orbit planning and forecasting, attitudinal planning, controlled quantity computation and monitoring and display software. (2), follow up processing software includes tracking and instrumentation data follow-up processing and telemetry data follow-up processing software. (3), multiple satellite TT&C software includes multiple satellite plan generation, multiple satellite automatic scheduling, man-machine interface and system allocation and management software. (4), Simulation software includes TT&C network operational status simulation and satellite dynamics simulation software.

(2). Command monitoring and control equipment

The Control Center's command monitoring and control equipment includes voice dispatching junctions, programmable command modules and special monitoring display equipment. The special monitoring display equipment includes primary processors, display processors, visual frequency distributors, display terminals (display screens and large screen projectors), keyboards and hard copying equipment. It can display graphics, images, text, and graphs. This monitoring and display equipment has the capability of enlarging, reducing, overlaying, slow motion and man and machine communication.

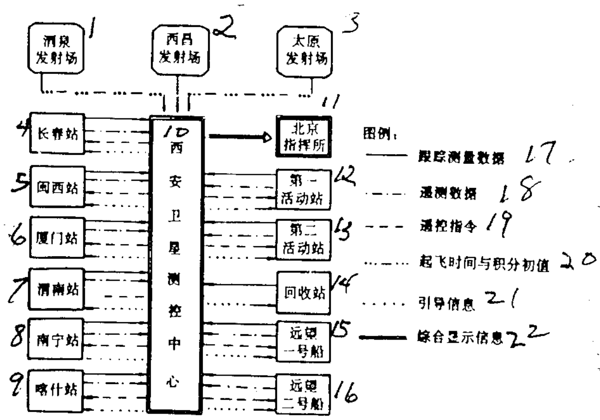
(3). Communications equipment

The Control Center has landline communications equipment, radio single sideband communications equipment and satellite communications ground stations. The satellite communications ground stations include a 13 meter and a 12 meter station, which can use domestic communications satellites and international communications satellites for communications. This facilitates linking up with international TT&C networks.

3. Information exchange between the control station and other entities

The command center information exchange between the launch site and the TT&C stations (vessels) is shown in Figure 3. The communications uses high data link codes (HDLC).

Fig. 3 Information exchange between the XSCC and launch sites and TT&C stations (ships)



1. Jiuquan launch site. 2. Xichang launch site. 3. Taiyuan launch site. 4. Changchun station. 5. Minxi station. 6. Xiamen station. 7. Jinan station. 8. Nanning station. 9. Kashi station. 10. Xian Satellite Command Center. 11. Beijing command station. 12. First mobile station. 13. Second mobile station. 14. Recovery station. 15. Yuanyang-1. 16. Yuanyang-2. 17. Tracking and metering data. 18. Telemetry data. 19. Remote control instructions. 20. Launch time and integrated initial data. 21. Guidance information. 22. Comprehensive display information.

III. Essentials of satellite TT&C

From the launch of China first satellite, the Dongfanghong-1 on May 24, 1970 until the end of 1990, the China Satellite TT&C Network has satisfactorily performed the TT&C mission for 30 satellites. Here, we will use the examples of the TT&C of recoverable satellites and geostationary satellites to illustrate the essentials of the TT&C performed by the Xian Satellite Control Center and its subordinate stations.

1. TT&C of recoverable remote sensing satellites

Orbit entry stage: The Control Center sends guidance information to the TT&C stations.

The TT&C stations track, meter and receive and interpret telemetry data and send this to the Control Station.

The Control Station performs live time evaluation of the satellite orbit entry status, determining initial orbit basic data.

Depending on the requirements, the Command Center will instruct the TT&C stations concerning TT&C to be carried out on the satellite.

Operational stage: Each time the satellite rises and falls in the sky in its orbit, the Control Center organizes the TT&C stations concerned to perform tracking and metering and to receive and interpret telemetry data. The Control Center performs real time processing of this data.

Recovery stage: On the orbit prior to satellite recovery, the Control center will instruct the TT&C stations to exercise control over the satellite to cause it to begin recovery sequence.

Satellite recovery control is jointly exercised by the TT&C network and the control system on board the satellite. When the satellite enters the recovery loop, the Command Center instructs the fist mobile station and the second mobile station to respectively send attitude instructions and instructions for the two capsules (satellite instrument capsule and reentry capsule) to separate. After the two capsules haver separated, the instrument pod continues in orbit, and the reentry capsule returns to the atmosphere under the control of the TT&C network.

After the reentry capsule has reentered the atmosphere, a parachute system is deployed, and the reentry capsule falls to earth under the parachute. The recovery TT&C stationed in central Sichuan uses helicopter radio direction finding equipment and ground radar to track the reentry capsule and provides real time estimates of the coordinates of the impact point of the reentry capsule. After the reentry capsule has landed, the recovery TT&C station coordinates with the units which developed to capsule in its recovery.

China has been successful in recovering all 12 of the recoverable satellites which it has launched. This illustrates that the China Satellite TT&C system has high precision and reliability in recovery TT&C, calculations and control.

2. Synchronous orbit communications satellite TT&C

Powered stage: The Control Center collects tracking, metering and telemetry data from the TT&C stations and ships, and performs real time monitoring of the flight of the carrier rocket.

Repositioning orbit: After the satellite has entered its orbit, the Control Center quickly calculates the key factors of the satellite orbit and its attitudinal parameters.

While the satellite is in motion, the Command Center uses the tracking and metering data and Telemetry (analogue telemetry and coded telemetry) data collected from the various TT&C stations and ships and makes repeated computations of the satellites orbital factors, attitudinal parameters and orbiting time. When control is required, the Control Center computes the amount of control and sends this in real time to the TT&C stations. The TT&C stations use remote control and synchronous control equipment to exercise control over the satellite. The control includes orbital control, attitudinal control, and orbiting time control. The purpose of the control is to cause the satellite to gradually be able to have its engines started up by remote locations.

The Control Center issues the instructions for TT&C stations to fire up the satellite's engines, and when this is done the satellite is accelerated, and leaves its elliptical orbit and enters quasi-synchronous orbit.

Quasi-synchronous orbit: Orbit control is exercised over the satellite, causing the satellite to establish an appropriate shift velocity, drifting toward its assigned position. When it arrives at that position, , "fixed point acquisition" control is exercised, causing the satellite to synchronize with the fixed point.

Synchronous orbit: Using remote control instructions, instruct the satellite to deploy its communications relays. The TT&C system is hooked up with the satellite communications system to exercise "in-orbit testing" of the satellite.

During the lifetime of the satellite, long term TT&C management is carried out over the satellite. This includes keeping the satellite at its fixed point, maintain its attitude, controlling the operational status and management over the satellite power sources.

The China Satellite TT&C Network has fully achieved high precision, high reliability, high degree of automation and high level of TT&C information utilization in its TT&C of synchronous communications satellites.