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XI'AN SATELLITE CONTROL CENTER AND CHINA SATELLITE TELEMETRY, TRACKING AND CONTROL NETWORK

Zhang Yinlong

Xi'an Satellite Control Center

ABSTRACT: China Satellite TT& C Network consists of the Xi'an 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 commmand of XSCC, as well as the oceangoing instrumentation ships. XSCC is possessed of data-processing system of multi-function, command & monitoring equipment and communication equipment, etc.. In the field of conducting TT&C for recoverable satellites and geostationary satellites, the TT& C technology of China Satellite TT& C Network shows the advanced level.

Key Words: satellite ground surface protection, fixed-type ground station, mobile-type ground station, tracking and telemetry command station, China.

I. General Description of Satellite Tracking and Control Network in China

The China Telemetry, Tracking, and Control Network (TT&C) is composed of the Xi'an Satellite Control Center (XSCC), several TT&C stations, and ocean-going instrumentation ships. The XSCC

is the communication hub, the command control center, and the data processing center of the China Satellite TT&C Network. Since the XSCC is the management organization of the China Satellite TT&C Network, generally, the XSCC roughly stands for the China Satellite TT&C Network.

A. Composition of China Satellite TT&C Network

The network is compatible with the tracking and control of low-earth-orbit satellites and geosynchronous satellites. The network includes the seven following specialty systems:

(1) Tracking and telemetry system

By using radio tracking and telemetry equipment on satellites in acquiring the motion parameters of satellite distance (R), orientation angle (A), pitch angle (E), and distance variation rate (R-dot) in order to determine the orbital elements (also called the orbital root number) of the satellite.

(2) Telemetry system

The system utilizes radio telemetry equipment receiving and demodulating telemetry signals from satellites, to acquire satellite engineering parameters and telemetry parameters.

(3) Remote control system

By utilizing radio remote control equipment to issue remote control commands for the satellite, thus controlling the motion and operational status of the satellite.

(4) Data processing system

The system is composed of computer hardware and software.

There are three levels of computers: computers at the telemetry and control center, computers at the telemetry and control station, and microcomputers in the telemetry and control equipment. Computers at the center are a computer cluster composed of mainframe computers for complex real-time and post-data--processing tasks, which will be described below. The computers at the station include mini- or microcomputers, used mainly for data collection and exchange also with a certain capability for data processing. Microcomputers in the equipment consist of terminals for the equipment, used mainly for data recording and automatic monitoring.

(5) Communication system

The system is composed of a circuit terminal, a data transmission terminal, exchange equipment, and a data link, which is further subdivided into wired links, wireless links, and satellite communication links. The communication modes include voice, telemetry telegraphy, facsimile, data transmission, and transmission of television pictures.

(6) Time frequency system

The system is composed of timing equipment, signal generators, and frequency sources. The time frequency systems of the center and the various stations are compared and synchronized with the standard time signal broadcast from the Shaanxi Astronomical Observatory, thus ensuring time synchronism of the entire network.

(7) Command and monitoring system

The system is composed of voice adjustment equipment, monitoring display equipment, keyboard, and command device, to collect data and display the network status, as well as the operational status of the TT&C equipment and spacecraft, thus providing information for command and analysis personnel, in addition to transmitting command and control orders.

B. Main Stations of the China Satellite TT&C Network

According to different properties and tasks, there are three categories of stations in the network:

(1) Fixed-type low-earth-orbit TT&C stations

Three stations (Changchun, Nanning, and Kashai) are the fixed-type low-earth-orbit TT&C stations; the major TT&C equipment includes a VHF/UHF unified TT&C equipment, dual-frequency doppler velocimeters, telemetry and demodulation equipment, remote control equipment, and monopulse radars, among other items of equipment. The VHF/UHF unified TT&C equipment applies the information channel comprehensive technique with the telemetering of R, A, E, and R-dot, telemetry, and remote control functions. The error in variation of distance measurements is not greater than 0.1m/s; the error in distance measurement of monopulse radar is not greater than 10m; the error in angle measurements is not greater than 0.2min; and the error in variation of distance measurement is not greater than 0.2m/s.

The Nanning TT&C station will soon be equipped with an S-waveband unified TT&C equipment, uplink frequency between 2025

and 2120MHz, a downlink frequency between 2200 and 2300MHz, and with similar system and technical indicators comparable to similar products made abroad.

(2) Fixed-type low-earth-orbit/geosynchronous satellite TT&C stations

Three stations (Weinan, Minxi, and Xiamen) are fixed-type low-earth-orbit/geosynchronous satellite TT&C stations. The major items of TT&C equipment at the Weinan and Minxi stations include dual-frequency doppler velocimeters, telemetry and demodulation equipment, remote control equipment, C-waveband unified TT&C equipment, and C-waveband guidance instruments, among others. The C-waveband unified TT&C equipment has the functions, including the measurement of R, E, A, and R-dot, telemetering (in code compiling and simulation), remote control (with command and synchronization), and functions. Used for the equipment, the antenna radius is 10m; the carrier wave modulation is PM/FM for the uplink, and PM for downlink. Distance measurement applies a hybrid system of pseudocode and sideband audio. The random error of distance measurement is not greater than 10m; the random error of angle measurement is not greater than 0.15min; and the error in variation in distance measurement is not greater than 0.03m/s for the uplink phase modulation.

Within the year, the Weinan and the Xiamen stations will be equipped with the international standard C-waveband unified TT&C equipment with uplink frequency between 5925 and 6425MHz, and downlink frequency between 3700 and 4200MHz. The antenna diameter is 15m and the digital type sideband system is used for

distance measurement. The technical indicators are basically the same as the C-waveband unified TT&C equipment.

(3) Mobile type TT&C stations

The first mobile station, the second mobile station, and the recovery telemetry station are the three mobile TT&C stations. The first and second mobile stations can be deployed at appropriate sites, as required, to fill the gaps of the satellite TT&C network and for telemetry by the carrier rocket navigation region. The main TT&C items of equipment at this kind of mobile station include the mobile type VHF/UHF unified TT&C equipment, and the mobile-type monopulse radar; such radar of the first mobile station is high-mobility digital-type tracking and telemetry radar, with performance corresponding to the AN/MPQ-39 radar in the United States. The recovery and telemetry station is responsible for telemetry after satellite reentry module reenters the atmospheric layers as well as research and recovery and for searching for the reentry module. The station is equipped with recovery and telemetry radar, helicopter-borne radio orientation equipment, among other items of equipment.

While executing satellite telemetry and control tasks, ocean-going instrumentation ships are also included in the satellite TT&C network, as a vital integral part.

II. XSCC

A. The main functions of the XSCC are as follows:

(1) Real-time prescribing of telemetry and control scheme

for automatic adjustment of multiple (six) satellites

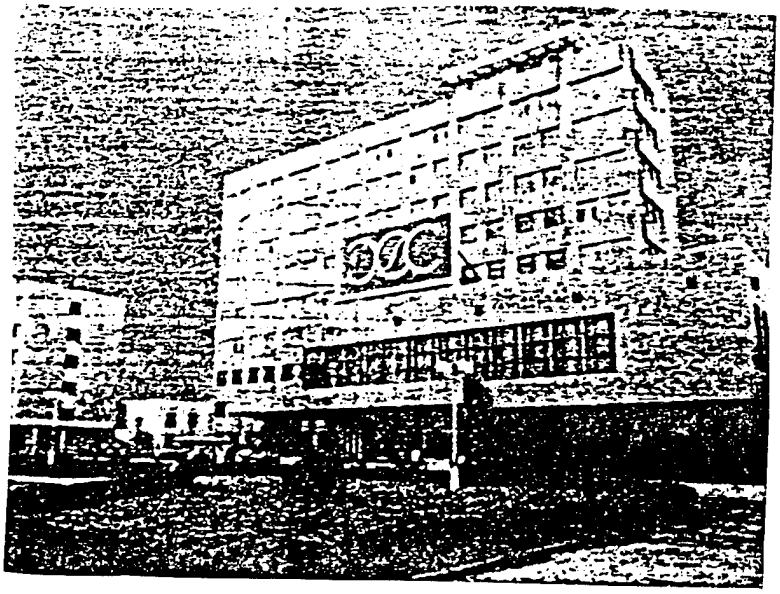

Fig. 1. Exterior view of Xi'an Satellite Control Center

The tracking telemetry data collection, and remote sensing data of the satellites and carrier rockets acquired by the data collection, telemetry, and control stations, as well as instrumentation ships, in addition to real-time and post-processing;

Determination of satellite orbital elements and attitude parameters for computation of subsatellite tracking, and announcement of observation forecasts;

Monitoring of satellite operation and activities to issue control commands for monitoring and control of operational status of the telemetry and control network; and

Accomplishing the recovery of reentry-type satellites, as well as long-term telemetry control and management of long-

service-life satellites.

Fig. 2. Command hall of Xi'an Satellite Control Center

B. Composition of Telemetry and Control Center

The data processing system is the main function of the center, provided with equipment items of command and control, communication, time frequency, and protection. Figs. 1 and 2 indicate, respectively, the exterior of the center and its command hall. The article presents only the major components of the data processing system.

(1) Data processing system

This system includes mainly computer hardware and software for telemetry and control.

Computer hardware includes three sets of NCI-2780 computers, two sets of VAX-8700 computers, several sets of VAX-II computers, in addition to large numbers of peripherals. Via an Ethernet, three sets of NCI-2780, and two sets of VAX 8700 computers form a local area network. Physically, five sets of computers compose a VAX cluster via a star-shaped coupler. Logically, two sets of

NCI computers operate in duplex outside the cluster, functioning as a pre-processor. Communications among computers have two approaches, with Ethernet and CI links. These two approaches are reserved to each other, thus upgrading system reliability and processing capability. Two sets of pre-processors form a long-range computer network with computers at the telemetry and control station, via a communication control processor (CCP) and communication links.

Based on telemetry and control objects, the applied software packages are classified into low-earth-orbit and geosynchronous satellite software. Based on software properties, there are the four following types: a. real-time software, including software for information exchange, orbital computations and forecasting, computation for attitude and control actions, as well as monitoring display. b. Post-processing software, including software for tracking and telemetry data and remote measurement data. c. Multisatellite telemetry and control software, including software for formation of multisatellite schemes, multisatellite automatic adjustment, man-machine interfacing, as well as system layout and management. d. Simulation software, including software for simulating the operational status of the telemetry and control network, and simulation for satellite dynamics.

(2) Command and monitoring equipment

The command and monitoring items of equipment at the center include voice adjustment machine, compilation command machine,

special monitoring equipment, which includes a main processor, a display processor, a video frequency distributor, a display terminal (screen and large-screen projector), keyboard and hard-copy equipment, capable of displaying pictures, images, letters, and curves. The monitoring and display equipment has functions of enlargement and shrinking of pictures, in addition to iterative addition, roving, and man-machine dialogue.

In addition to a large number of monitors for command and analysis personnel at the command hall, there are five large-screen projectors with screen dimensions 3x2.2m. These are glass lenticular screens.

(3) Communication equipment

The center has wired communication equipment, wireless single-side-band communication equipment, and a satellite communication earth station, which are in the type of 30 and 12-m stations, capable of communicating with communication satellites of China and other nations, for creating advantageous conditions for networking with other foreign networks.

C. Information Exchange Between the Telemetry and Control Center and Other Units

Fig. 3 shows the information exchange between the center, on the one hand, and the launch sites and the stations (ships), on the other hand. The communication norm adopts a high-level data link (HDLC).

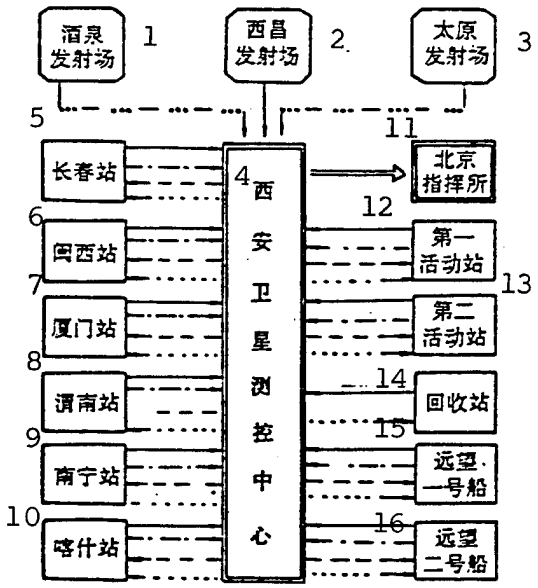

Fig. 3. Information exchange between Xi'an Satellite Control Center, on the one hand, and launch sites, telemetry and control stations (ships), on the other.

LEGEND: _____ - tracing and telemetry data;
._._. - remote sensing data
- - - - remote control command
...--... - takeoff time and initial value of integration
..... - guidance information
_____ - comprehensive display information

KEY: 1 - Jiuchuan Launch Site 2 - Xichang Launch Site 3 - Taiyuan Launch Site 4 - Xi'an Satellite Control Center 5 - Changchun Station 6 - Minxi Station 7 - Xiamen Station 8 - Weinan Station 9 - Nanning Station 10 - Kashi Station 11 - Beijing Command Post 12 - First mobile station 13 - Second mobile station 14 - Recovery station 15 - Yuanwang Number 1 Vessel 16 - Yuanwang Number 2 Vessel

III. Main Points of Satellite Telemetry and Control

From the launch of China's first artificial satellite, The East Is Red Number 1, from April 24, 1970, to the end of 1990, the China Satellite TT&C Network smoothly accomplished its task

with 30 satellites. By citing an example of a reentry-type remote-sensing satellite and a geosynchronous satellite, the major tasks of the XSCC and the subordinate stations are presented.

A. Telemetry and Control of Reentry Type Remote-Sensing Satellites

Orbital insertion segment: the center sends guidance information to the stations.

The station performs tracking, telemetry of satellites, in addition to receiving and demodulating the remote-sensing data, to be sent to the center on a real-time basis.

The center makes real-time decisions on orbital-insertion status of satellites for the determination of the initial orbital elements of the satellites.

As required, the center orders stations to apply control to satellites.

Operating segment: each time a satellite ascends into orbit, descends from orbit, and passes overhead, it is tracked and telemetered by the center and its stations for real-time processing of receiving and demodulation of remote-sensing data at the center.

With its related stations, the center applies control to the satellites, including data insertion into the satellite-borne computers. Each time a satellite leaves the territory, the center conducts orbital modifying computations, orbital forecast computations, and computations on the recovery drop point. The

above-mentioned computations are high in accuracy by using advanced and proven methods.

Recovery segment: in the orbit just prior to satellite recovery, the center with its related stations applies control to the satellite, to start its recovery program.

The satellite recovery control is jointly accomplished by the network and the satellite-borne control system. Upon entering the recovery orbit by the satellite, the center together with the first and second mobile stations, issues to the satellite the attitude and adjustment commands and the separation command for two modules (satellite instrumentation module and reentry module). After separation of the two modules, the instrumentation module continuously operates in orbit, while the reentry module returns to the atmospheric layer with control by the telemetry and control system.

After the reentry module enters the atmosphere, a parachute is automatically actuated, to descend. Located in Sichuan, the recovery telemetry station sends a helicopter-borne radio orientation equipment and a ground surface telemetry radar to track the reentry module with real-time forecasting of the drop point coordinates. After the module has landed, the recovery station along with the research units recover the module.

Recoveries were successful in 12 recovery-type remote sensing satellites launched by China. This indicates high accuracy and reliability of China's satellite telemetry and control system in recovery telemetry, computation, and control.

B. Telemetry and Control of Geosynchronous Communication Satellites

Powered segment: The center along with stations (ships) tracks and telemeters the data to monitor, on a real-time basis, the carrier and the flight situation.

Transfer orbit: after a satellite enters into orbit, in good time the center computes the center orbital elements and attitude parameters.

When the satellite is in operation, the center utilizes the tracking and telemetry data and the remote-sensing (simulated and programmed remote sensing) data acquired by stations (ships) to conduct repeated computations on orbital elements, attitude parameters, and spin rates of the satellite. When control is required, the center computes the control action to send to the stations on a real-time basis. The stations utilize its remote-control and synchronization control equipment to control the satellite, including orbital, attitude, and spin rate control. The purpose of control is to enable the satellite to fire its engine at apogee.

At apogee, in the ignition orbit, the center along with its stations sends engine ignition commands at apogee. After the burn, the satellite acquires additional velocity to be separated from the large orbital transfer orbit and enters into a quasi-synchronous orbit.

Quasi-synchronous orbit: orbital control is applied to the satellite to establish an appropriate drift velocity toward a fixed point. Then the fixed point acquisition control is applied

to execute synchronous point-fixation of the satellite.

Synchronous orbit: by using remote control command to switch on the satellite communication transponder, together with the satellite communication system, the telemetry and control system applies an in-orbit test of the satellite.

Within the satellite service life, long-term telemetry, control, and management of the satellite are performed, including maintaining the fixed-point for the satellite, attitude maintenance, control of operational status, and power supply management in the period when the satellite is out of visible range.

In measurement and control of geosynchronous communication satellite, the China Satellite TT&C Network adequately exhibits its high precision, high reliability, high automation, and high utilization rate of the telemetry information.

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