GEOSTATIONARY SATELLITES LAUNCHED BY NASDA

I. NASDA TRACKING AND CONTROL SYSTEM

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ABSTRACT

Tracking and Control Network of National Space Development Agency of Japan consists of Tracking and Control Center (TACC) and three Tracking and Data Acquisition Stations (TDS).
The tracking and control software system in TACC is divided into five subsystems as follows; telemetry and command processing, orbit determination, attitude determination, maneuver planning and command generation, and mission analysis.
This software system operates in two different modes, namely on-line and off-line mode corresponding to launch phase and stationary phase respectively.

Keywords: Tracking and Control Network, Software System

1. INTRODUCTION

National Space Development Agency of Japan (NASDA) was established on October 1, 1969, as the nucleus of the nation's space development effort. Since then, this organization has been responsible for development and operation of Japanese launch vehicles and artificial satellites.

2. SATELLITE MISSIONS OF NASDA

NASDA has launched and taken care of several application satellites at medium altitude as well as those on geostationary orbits. Besides NASDA has conducted orbit determination of scientific satellites launched by the Institute of Space and Aeronautical Sciences of University of Tokyo (ISAS).

2.1 Contributions of NASDA

The NASDA's major launch vehicle, called the N-I rocket was developed by 1975. This is a three stage rocket with height of 32.6 m and diameter of 2.5 m (first stage), and the payload is about 130 kg on the geostationary orbit. The N-I rocket have launched the following medium altitude satellites.

.KIKU (Engineering Test Satellite-I: ETS-I)
This was the first satellite launched by NASDA aiming at testing the capability of N-I rocket as the launch vehicle. The satellite, weighing 83 kg, was successfully put into the orbit of about 1000 km in altitude in September 1975.

.UME (Ionospheric Sounding Satellite: ISS)
This spinning satellite, weighing 139 kg, and with altitude 1000 km, was launched in February 1976. However, the satellite lost contact one month after the launching due to the malfunction in the onboard power system.

.UME-2 (Ionospheric Sounding Satellite-b: ISS-b)
This satellite of weight 142 kg, as the back-up of UME, was launched in February 1978.

By the medium altitude satellite missions, NASDA was able to verify the capability of the housekeeping and orbit determination.
The geostationary satellites launched by the N-I rocket were as follows.

.KIKU-2 (Engineering Test satellite-II: ETS-II)
This was the third satellite launched by the N-I rocket in February 1977. At the 7th apogee on the transfer orbit, the AKM was fired and it was successfully placed into the drift orbit.
Then, through a sequence of station acquisition maneuvers, the spinning satellite was moved into the geostationary point at 130° east longitude.

.AYAME (Experimental Communications Satellite: ECS)

.AYAME-2 (Experimental Communications Satellite-b: ECS-b)
These spinning satellites were launched successively in February 1979 and in February 1980. They were put into the transfer orbit, however the radio signal from these satellites ceased shortly after the AKM ignition. Thus the mission objectives of these satellites were not achieved.

Through the tracking and control operation of these geostationary satellite missions, we have confirmed the compatibility between the satellites and the tracking and control system.

The other geostationary satellites launched by Delta 2914 rockets are as follows.

.HIMAWARI (Geostationary Meteorological Satellite: GMS)
This satellite was placed at 140° east longitude in July 1977, in co-operation with the Global Atmospheric Research Program (GARP) of the World Weather Watch (WWW) project.

.SAKURA (Medium-Capacity Communications Satellite for Experimental Purposes: CS)
This satellite of 350 kg in weight was placed at 135° east longitude in December 1977.

.YURI (Medium-Scale Broadcasting Satellite for Experimental Purposes: BSE)
This triaxially stabilized satellite of 350 kg in weight was placed at 110° East in April 1978.

For these geostationary satellites, NASDA conducted the tracking and control operation from the transfer orbit injection to the station acquisition. After stationing, these satellites were delivered to the users such as Japan Meteorological Agency (GMS), Radio Research Laboratory (CS, BS), Nippon Telegraph and Telephone Public Corporation (CS), and Japan Broadcasting Corporation (BS). NASDA has conducted the housekeeping operations and the station keeping maneuvers including orbit and attitude determination, maneuver planning, command generation, and maneuver evaluation.

2.2 Future Missions of NASDA

In February 1981, KIKU-3 (Engineering Test Satellite -IV: ETS-IV) was launched by the N-II rocket from the Tanegashima launching site. It was successfully placed on the transfer orbit, confirming that the N-II rocket has the capability of placing the payload of 350 kg on the geostationary orbit. Table 1 shows the future satellites to be launched by the N-II rockets.

3. NASDA TRACKING AND CONTROL NETWORK

NASDA built a launching site on Tanegashima, which is a southern island of Japan. For the tracking and control network, NASDA has the following center and stations.

.TACC : Tracking and Control Center
TACC is placed in the Tsukuba Space Center, located at 50 km north of Tokyo. The main portion of the data processing system is installed in TACC.

.TDS : Tracking and Data Acquisition Station
NASDA has three main TDSs, namely, Katsuura,

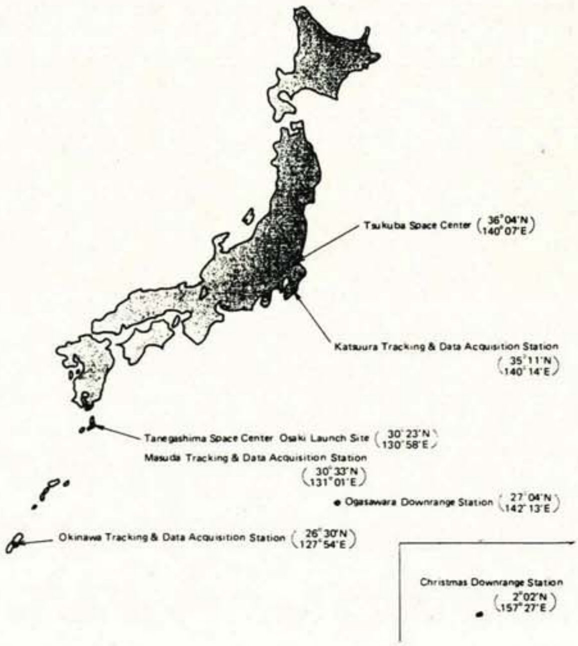

Fig. 1 Tracking and Control Network of NASDA

Satellite	Mission	Weight and Dimension	Launch Date
Goostationary Meteorological Satellite-2 (GMS-2) (140°E longitude)	Almost same performance as 'HIMAWARI'	Weight: 340 Kg Shape : Cylinder Dia. : 210 cm Ht. : 440 cm	August to September, 1981
Communication Satellite-2 (CS-2a) (135°E longitude)	Almost same performance as 'SAKURA'	Weight: 350 Kg Shape : Cylinder Dia. : 220 cm Ht. : 350 cm	January to February, 1983
Communication Satellite-2 (CS-2b) (135°E longitude)	On-orbit spare of CS-2a	Same as above	August to September, 1983
Maritime Observation Satellite (MOS-1) (sun synchronous)	Observation of marine phenomena	Weight: 750 Kg Shape : Box-type with a solar paddle	FY 1985
Broadcasting Satellite (BS-2a) (110°E longitude)	Almost same performance as YURI	Weight: 350 Kg Shape : Box-type with two solar paddles	FY 1983
Broadcasting Satellite (BS-2b) (110°E longitude)	On-orbit spare of BS-2a	Same as above	FY 1985
Aeronautical Maritime Engineering Satellite (AMES) (160 ∿ 180°E longitude)	Engineering test for mobil satellite system	Weight: 350 Kg Shape : Cylinder Dia. : 220 cm	FY 1985 (TBD)

Table 1. Future Satellite Missions of NASDA

Masuda, and Okinawa. They are equipped with the antennas for tracking and telemetry-command communication. All acquired data are transmitted to TACC. Tracking and control operations on the routine basis are provided through this network.

• Downrange Stations
Downrange stations at Chichijima Island in Ogasawara and Chiristmas Island are installed for the purpose of confirming the trajectory and ensuring the flight safety of launch vehicles which are beyond visible coverage of Tanegashima Space Center. In particular, Christmas down range station performs tracking operations at such critical events as the satellites separation from the launch vehicles and the putting geostationary satellites into the transfer orbits.

Fig. 1 shows the geographical distribution of TACC, TDS, and Downrange stations.
Due to the limited coverage of tracking network in Japan, continuous communication links with satellite are difficult to maintain. In such cases when the tracking support of other agencies is necessary, NASA tracking stations provide tracking and control support to supplement NASDA's activity.

4. TRACKING AND CONTROL SOFTWARE

NASDA tracking and control software system is divided into five subsystems as follows.

1) telemetry and command processing (T/C)
2) orbit determination (OD)
3) attitude determination (AD)
4) maneuver planning and command generation (MN)
5) mission analysis (MA)

Detailed descriptions of mission analysis subsystem appear in Ref. 1.

4.1 Software System

4.1.1 T/C Subsystem. T/C subsystem consists of two modules as follows.

. on-line telemetry and command processing
. housekeeping data processing

The on-line telemetry and command processing module collects telemetry data from TDS and arranges them into the framed format. Thereafter the framed telemetry data and command history are transferred to the housekeeping module.
This module makes lists of the required items of telemetry data and shows them in the curved format on the x-y plotter or the graphic display unit. Thus T/C subsystem offers real time monitoring of the satellite status and appropriate housekeeping commands to TDSs.

4.1.2 OD Subsystem. OD subsystem consists of three modules as follows.

. tracking data preprocessing
. orbit determination
. orbital event prediction

Tracking data preprocessing module handles the data types such as range, range-rate, angle (azimuth and elevation), and doppler shift individually or simultaneously. Collected data from TDSs are merged together and arranged in the time sequence.
The weighted Baysean estimation theory is applied to the preprocessed data in the single batch processing mode. For the iterative procedure, the Keplerian elements are mainly used, although trajectory generation is performed by the special perturbation method using the Cartesian elements.
From the estimated orbital elements, the required span of trajectory is generated for the purpose of orbital event prediction such as AOS (Acquisition of Signal), LOS (Loss of Signal) and eclipse etc. These events are informed to TDSs and other subsystems.

4.1.3 AD Subsystem. AD subsystem for spin stabilized satellites is divided into three modules as follows.

. telemetry data preprocessing
. attitude determination
. sensor event prediction

Telemetry data preprocessing module picks up sensor data such as sun angle, earth chord width, and dihedral angle from the framed telemetry data. For the preprocessed data, Baysean weighted least mean square method is applied to the attitude determination module. Not only attitude elements but also certain biases are simultaneously estimated, and high precision is achieved by means of executing the appropriate estimation of biases.

4.1.4 MN Subsystem. This subsystem contains four main modules as follows.

. Apogee Kick Motor Firing (AMF) planning
. station acquisition planning
. station keeping planning
. command generation and evaluation

AMF planning module gives the optimized AMF time and attitude, if necessary, considering post-burn sequences. AMF simulation capability is also available taking AMF time and attitude errors into consideration (see Ref. 2.).
Optimum station acquisition sequence is obtained by man-machine interactive usage of the station acquisition planning module.
After stationing, the station keeping planning module gives north-south, east-west, and attitude keeping maneuver schedule (for east-west station keeping, see Ref. 3.).
The attitude and orbit maneuver commands are generated by the iterative command simulation adopting the appropriate model of the satellite reaction control subsystem. If necessary, maneuver evaluation is performed comparing predicted attitude or orbital elements with the realized ones.

4.2 Distribution of System

Tracking and control system has two operating modes corresponding to the resident computers as the following.

. M system on FACOM M180II AD duplex computers
. F75 system on FACOM 230-75 duplex computers

M system is scheduled to operate during the launch phase in real time oriented mode. The major portion of interface is implemented on the direct access devices. This enables quick co-operation of subsystems through the busy maneuver sequence around AKM ignition.
F75 system takes care of the satellites during the stationary phase in off-line mode, because each subsystem operates independently in the routine operations. Each residence of subsystem is depicted in Fig. 2.
For both systems, operationable facility is achieved by man-machine interactive usage of the graphic display unit. Some parameters can be corrected by

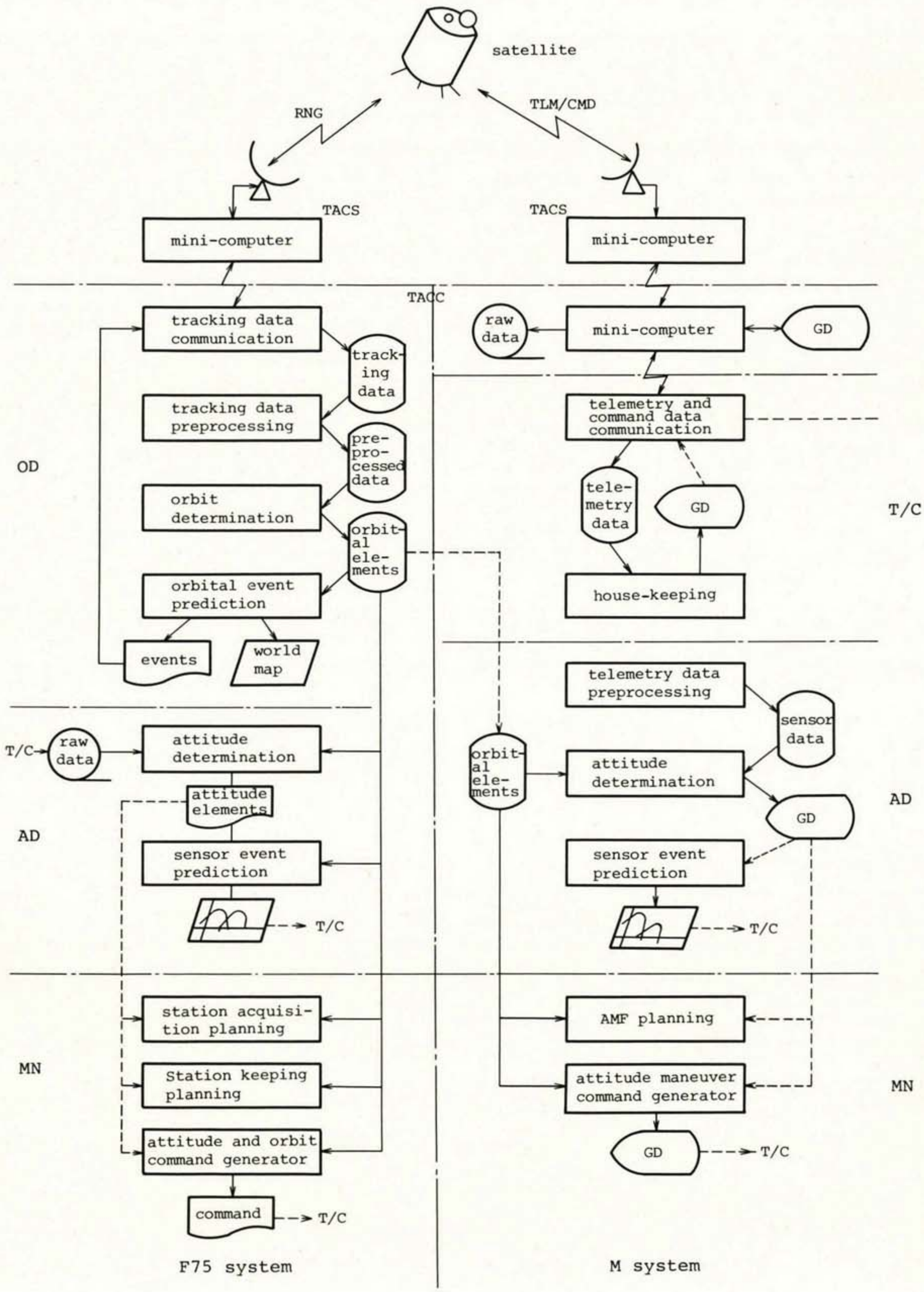

Fig. 2 Data Flow of Tracking and Control Software

console operation, and high precision of orbit or attitude determination is attained by manual rejection of bad data viewing a graphic display.
High reliability and accuracy are obtained by adopting the application software library which NASDA has developed by means of step-by-step improvements. This library contains not only the orbital dynamics package such as trajectory generation and sensor event predictions but also the database management subroutines for mathematical, physical, and satellite specific constants.

4.3 Organization of Operation

During the launch phase NASDA organizes Tracking and Control Team, in which Data Processing Division plays the central role to operate the tracking and control software system. Data Processing Division is conducted by the chief group consisting of subsystem chiefs. Each subsystem chief directs the corresponding group of operators in order to attain the scheduled mission sequence according to the decision criteria and operation flow. The spacecraft as well as the software manufacturers support Tracking and Control Team as the co-workers of NASDA.

5. CONCLUSION

NASDA tracking and control software system and NASDA tracking and control network supported by NASA STDN have accomplished their missions for all satellites launched by NASDA. For future satellite missions, new functions and capabilities are to be developed and attached to these systems.

6. ACKNOWLEDGEMENTS

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