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A System Study for Satellite Operation and Control in Next Generation

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1. Abstract

Ever since the first satellite, ETS-1, in 1975, 28 NASDA satellites in total have been launched.
With regards to satellite operations, NASDA has developed realtime TLM/CMD processing systems which could be commonly used for different types of satellite. Presently the third generation system is operational.
Meanwhile, the recent trend of satellite operations is becoming more complicated, for example, CCSDS-adapted Satellites are emerging and computer technology is developing quite rapidly.
Moreover, NASDA's role in satellite operations is changing from mainly Satellite Bus operations to experimental/whole satellite mission operations.
Considering these circumstances, NASDA has initiated a study for the next generation system which is suitable for operations of future satellites keeping in mind the following viewpoints.

- Demands from mission support
- Trend of satellite design
- Progress of computer environment

This is an interim report of the study.

2. NASDA's Present system

2.1 Tracking and Control System

The present Tracking and Control System is shown in Fig.-1. It consists of the followings:

- Network system(tracking stations, network control, etc)
- Satellite Operation and Control system(TLM and CMD operation)
- Support system(orbit determination,planning of operation,etc)
- Space Network system(network via Data Relay Satellite; experimental)

2.2 System Configuration of Satellite Operation and Control system

NASDA's Satellite Operation and Control system, based upon the "system applying to all satellites", consists of the following elements.

- Satellite system
  The realtime on-line subsystem and off-line subsystem which are composed of satellite functions and satellite unique functions.
- Database Manager
  Single system, common to all satellites, to manage database for parameters.

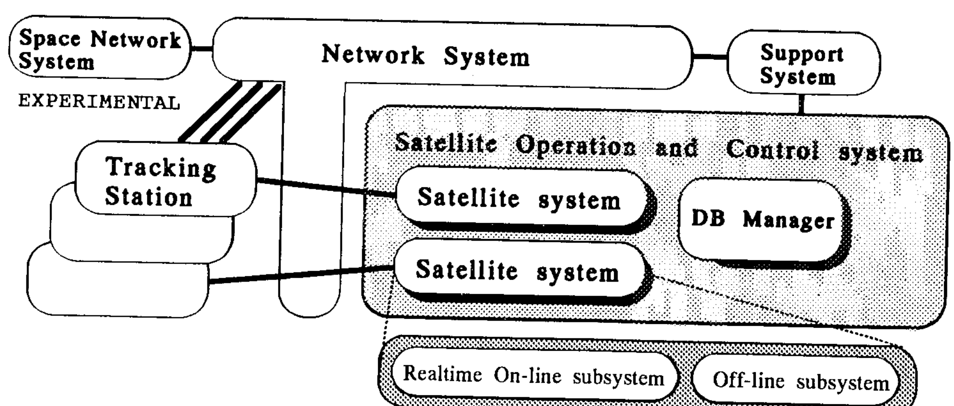

Fig.-1 NASDA Tracking and Control System

3. Objectives of the Study

In this section, necessity of the next generation system (named "SOC-X") is introduced, addressing the following viewpoints:

- Demands from mission support
- Trend of satellite design
- Progress of computer environment

3.1 Demands from mission support

- Supporting mission

The present system is made up and used for satellite operations without making clear distinction of housekeeping operation or activity of supporting missions.
Hence, NASDA needs a new concept for SOC-X, which is "Providing interface to support mission" on user's side.

- Variety of missions

The present systems, based upon the "concept applying to all satellites", have difficulty supporting various missions entirely, because of a shortage of mission support functions.

A variety of support functions as well as further study on how to implement the functions on the common system are required.

3.2 Trend of Satellite design

- Accommodation to CCSDS

NASDA satellites are adapting the CCSDS recommendation. Therefore, SOC-X is requested to support the corresponding CCSDS communication environments. SOC-X will deal with both conventional and CCSDS satellites.

- Satellite autonomy and autonomous operation

High performance and autonomy of onboard equipments will change the tasks of satellite operations on ground as follows.

- Simplification of Command data generation scheme
- Monitoring equipments through onboard autonomous supervision function in parallel with the conventional monitoring of all telemetry information

In addition, operating procedures will change over to the new way from ground-based actions to onboard autonomous control.
NASDA is in now a transition phase, and it is necessary to cooperate with satellite design.

3.3 Progress of computer environment

Computer environment is rapidly advancing more than the time the present system was designed.

- Progress in computer technology includes:
  - Enabling more complicated process
  - Minimizing the cost of computer
  - Displaying high value added information to the operator
  - Improving man-machine interface

- Progress in network environment
  - Network technology of LAN
  - Use of common resources and distributed function via LAN
  - High speed WAN, which is suitable for LAN
  - Standardization of LAN environment

4. Consideration of SOC-X

4.1 Concept for satellite operation

Cooperative operation with the mission users becomes more important in the future satellite operations. Moreover, satellite operation not only housekeeps the satellite, but also provides functions to utilize satellite payloads to the mission users. Apparently, it is required to be more "mission " and "end-user" oriented.

4.1.1 Definition of SOC-X

SOC-X directly interfaces with satellite according to the concept of "mission" and "end-user oriented". It could be defined as a "Provider of data between satellite and mission users". SOC-X provides mission support functions as described below and in Fig.-2.

- Providing operation environment to users for housekeeping of payload and mission execution
- Controlling the satellite safety

4.1.2 Providing mission environment

The mission operating environment provided by SOC-X is for the housekeeping of satellite resources, including mission equipments, and for the real-time mission data interface between the satellite and users.

- Housekeeping the satellite resources

There are many items of resource to be managed on satellite. These resources are controlled by SOC-X while mission users would operate their equipment under this controlled environment.
In this configuration, mission users are allowed to control only each mission part individually.

- Data interface with satellite

Data interface function provided by SOC-X is the real-time data transfer of TLM and CMD including transparent data interface, engineering data conversion of TLM, and generation of CMD.
However, it is undesirable for SOC-X to have direct interface with the user, in terms of system security and satellite safety. Accordingly, it becomes important to provide a system which satisfies the users' requirements and protects the Satellite Operation and Control system.
NASDA is considering a method for user interfaces taking into account the above aspects, which also include non-realtime data interface.

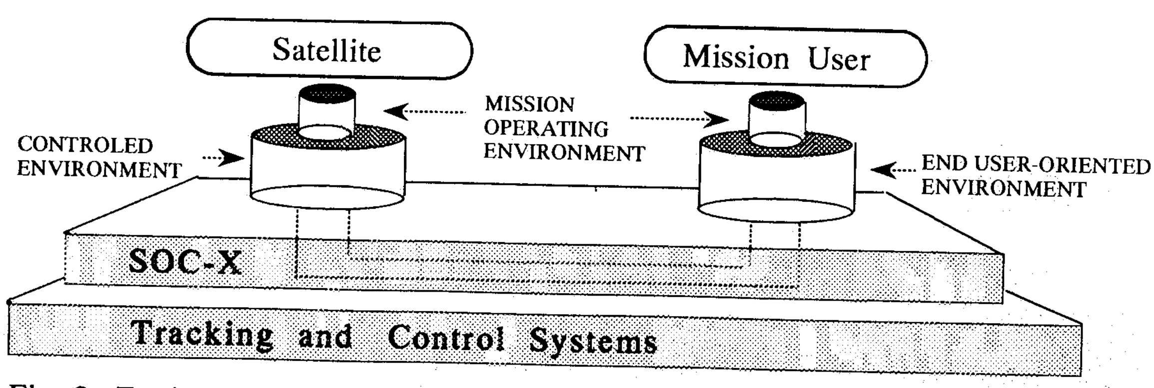

Fig.-2 Environment provided by SOC-X

4.1.3 Satellite Safety Operation

SOC–X must provide protection to satellite resources.

- Supervising satellite status

The present operation takes necessary recovery action after detecting of anomaly by monitoring TLM. However, "prediction of anomaly by inference" might be the goal. This requires the satellite operation planning information in order to know how the resources will be used.

- Command control of satellite

Here, the validity of command and timing of its transmission are verified. This process also takes into account the conditions of satellite resources. However, to what extent and method of these checking should be used by SOC–X needs further study.

4.2 Satellite design trend

4.2.1 Approach to Mission–oriented and Commonality

The important aspect of this study is to overcome the contradiction between diversification of mission and commonality of satellite operation. Needless to say, these studies must be made with a close cooperation with satellite design and development.

4.2.2 Adaptation to CCSDS

CCSDS causes no big impact on Satellite Operation and Control system, however, it brings about some new concept of communication protocol between the satellite and ground.

In NASDA cases, the responsibilities of the following two subsystems in terms of CCSDS environment are unclear;

- Network system is responsible for the control of all equipments on ground and all systems of tracking station.
- Satellite Operation and Control system is responsible for the control of the satellite system.

Since it is still new for NASDA to develop the CCSDS equipments for onboard and ground, an issue on how to design s system most suitable for CCSDS environment was brought up.

A conclusion has not been reached, but the scope of new Satellite Operation and Control system must conform to the concept of the CCSDS standards.

4.2.3 Automatic and autonomous

Onboard subsystems will be more automatic and autonomous for high level mission operation, which result in reduction of operational load. These will cause a change in operation leadership on the ground so it is important to assign responsibilities to both onboard and ground systems respectively.

The operational load will be reduced by automatic and autonomous satellite operations, but the task of SOC–X increases because of the followings;

- Analysis on the cause of anomaly and countermeasure actions executed by autonomous onboard programs
- Verification of pre–arranged actions in automatic and autonomous onboard programs, prior to its execution
- Control of automatic and autonomous programs and supervision of the operating status
- Backup for onboard CPU failure

4.3 Utilization of new technology

4.3.1 LAN-based system

A use of new technologies, which were not available at the time of the present system design, is one of the key issues of this study. A LAN-based system is one of the concepts for SOC-X, which supports activities as follows.

- Common use of resources
- Distributed processing
- Reduction of duplicated functions

4.3.2 Reduction of operator's load

One of the subjects for reducing operational load is the telemetry monitoring. Currently the operator needs plenty of information to judge satellite conditions, thus it is quite important to develop a method where the system can predict anomaly. Artificial Intelligence(A/I) technology may help reduce this task.

4.3.3 Upgrading the operational environment

It is most desirable to provide more practical and condensed information to the operators. One of them is to utilize the latest computer technologies. It would provide a suitable operation environment to support NASDA's mission by:

- Visual information
- Multi Role terminal
- Unified man-machine interface

5. Summary of the study result

This section is an interim report about the concept of SOC-X.

5.1 Concept of SOC-X

NASDA's Tracking and Control system, now functioning only as the operator of a satellite, would also become a provider of satellite mission support environment.
In this concept, SOC-X would provide the following environment to mission users:

- Mission-oriented operational environment
- User-oriented interface environment
- Satellite configuration management

5.2 Element of SOC-X

5.2.1 Concept

The satellite operations consist of housekeeping and mission operations. Hence, the Satellite Operation and Control system is provided with Bus-control and Mission-control functions.

5.2.2 Bus-controller and Mission-controller.

Bus-controller(B-ctrl), which is a system applying to all satellites, is for the operation of whole satellite and bus equipment. B-ctrl is a front-end system to manage the whole satellite.

Meanwhile,Mission-controller (M-ctrl) is a customer-made system for each mission operation. M-ctrl has TLM and CMD functions for specific missions, and a back-end system which performs the housekeeping for mission equipment and control of mission equipments.

5.2.3 Interface between B-ctrl and M-ctrl

Telemetry data

In case of copious telemetry from a conventional satellite, B-ctrl delivers necessary telemetry to M-ctrl. With regards to the CCSDS cases, its telemetry is distributed to B-ctrl and M-ctrl individually from the CCSDS telemetry handling systems, but exchange of information between them would be done as follows:

- B-ctrl provides information needed to proceed the mission.
- M-ctrl provides information needed to manage the whole satellite system.

Command data

Mission commands from users are generated and checked by each M-ctrl for payload safety. At this point, satellite safety is managed between B-ctrl and M-ctrl by exchanging information.
In case of conventional satellite, commands generated by each M-ctrl would be transmitted through B-ctrl. In other cases, for example, the distributed commanding of CCSDS, B-ctrl and each M-ctrl generate and transmit their individual commands under planned conditions.

5.3 Mission Support

5.3.1 Service environment

SOC-X provides the management function of satellite configuration. This configuration is independent of other missions and bus operation, and it assures the mission users with operation safety.
Furthermore, operations including the housekeeping of onboard mission equipment by B-ctrl is also possible.

5.3.2 End-user oriented service

Further services are considered:

- Data transfer
  Realtime communication with satellite(e.g.:TLM,CMD)
- Value added Data transfer
  - Delivery of TLM, which is converted to engineering data
  - Generation of CMD, which is converted from a descriptive information to actual command data
- Rental terminal

5.3.3 Interface Configuration

For the interface configuration provided to the users, are there three types as follows and also shown in Fig.-3:

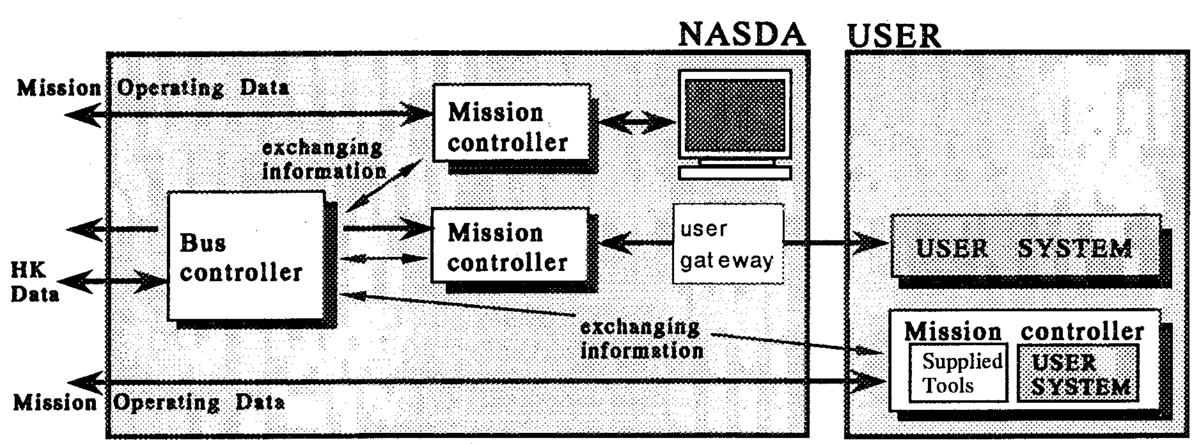

Fig.-3 Interface configuration (CCSDS type satellite, for example)

*** Utilization of NASDA supplied tool**

This tool supplied by NASDA, is provided with functions necessary to perform the mission operations for the users.

*** Access to Data GW system**

This Data GW system supplied by NASDA, functions as a data gate-way for the satellite and user's system, and links these two to perform mission operation.
The system provides the basic functions to relay the processed telemetry data to user's system and convert a descriptive information from the user to actual command data.

*** Development of User Own System**

A mission user develops each system by utilizing the functional tools supplied by NASDA.
As the user integrates these tools in his system, he is able to perform a mission control on his own.

6. Future subject

6.1 Future Study

This paper introduced an interim study result.
So far, several issues have been identified. We, for example, have some study items with the network system, and a certain extent of responsibility for SOC-X in terms of "Basic concept of NASDA satellite operation in future".
Indeed, the key element in developing system is to keep in mind conformity of satellite design and ground systems.
We hope to write a final report after having the major problems examined.

6.2 Development schedule

The current schedule is not yet approved. So far, the following schedule is being considered.

Fy	
1994	Conceptual Study
1995	System Study
1996	Preliminary Design
1997	Detail Design
1998	Development
1999	Integration Test

Systems Engineering

2. Reusable Systems

* *Presented in Poster Session*