

## Attempt of automated space network operations at ETS-VI experimental data relay system

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### ABSTRACT

National Space Development Agency of Japan (NASDA) is to perform experimental operations to acquire necessary technology for the future inter-satellite communications configured with data relay satellite. This paper intends to overview functions of the experimental ground system which NASDA has developed for the Engineering Test Satellite VI (ETS-VI) Data Relay and Tracking Experiment, and to introduce Space Network System Operations Procedure (SNSOP) method with an example of Ka-band Single Access (KSA) acquisition sequence. To reduce operational load, SNSOP is developed with the concept of automated control and monitor of both ground terminal and data relay satellite. To perform acquisition and tracking operations fluently, the information exchange with user spacecraft controllers is automated by SNSOP functions

### 1. INTRODUCTION

NASDA has launched several types of satellites since 1975. The tracking and data acquisition operations for these satellites have been conducted by using NASDA's ground stations network, four S-band ground tracking stations, 3 stations in Japan and one in Sweden, but with no space network. NASDA has yet no experience of performing the satellite mission operations with a space network.

ETS-VI Space Network system described in this paper has been developed by NASDA under the Space Operations and Data System (SODS) program, as an experimental system to obtain the necessary technology for the inter-satellite communications. As a follow-on program, NASDA will launch COMETS in 1997 and enhance NASDA's space network

technology of ETS-VI for the future operational system.

### 2. ETS-VI SN SYSTEM

ETS-VI Space Network (SN) system consists of space segment and ground segment. Figure-1 illustrates the ETS-VI SN system.

#### 2.1 Space Segment

ETS-VI will be launched by H-II launch vehicle in 1994. It will be located at 153.8 degrees East longitude. ETS-VI mounts two experiment equipments for the experiment: S-band Inter-satellite Communications Equipment (SIC) and Ka-band Single Access Equipment (KSA).

SIC can provide one forward service and two return services simultaneously to support user spacecraft on low earth orbit. The 19 elements phased array antenna attached to the body of spacecraft provides return link service for up to 2 users simultaneously. Only 16 of the 19 elements are used to provide forward link service to one user. The SIC operates on a fixed frequency (2106.4 MHz forward/2287.5 MHz return)

KSA provides high-data rate support by using new frequency band: 23 GHz forward/ 26 GHz return. The 23/26 GHz KSA will be the first inter-satellite communications equipment on orbit. For experiments, only 80 cm parabolic antenna provides one forward and one return link services at a time.

#### 2.2 Ground Segment

ETS-VI SN ground segment is located in Tsukuba Space Center. It consists of 6 major functions.

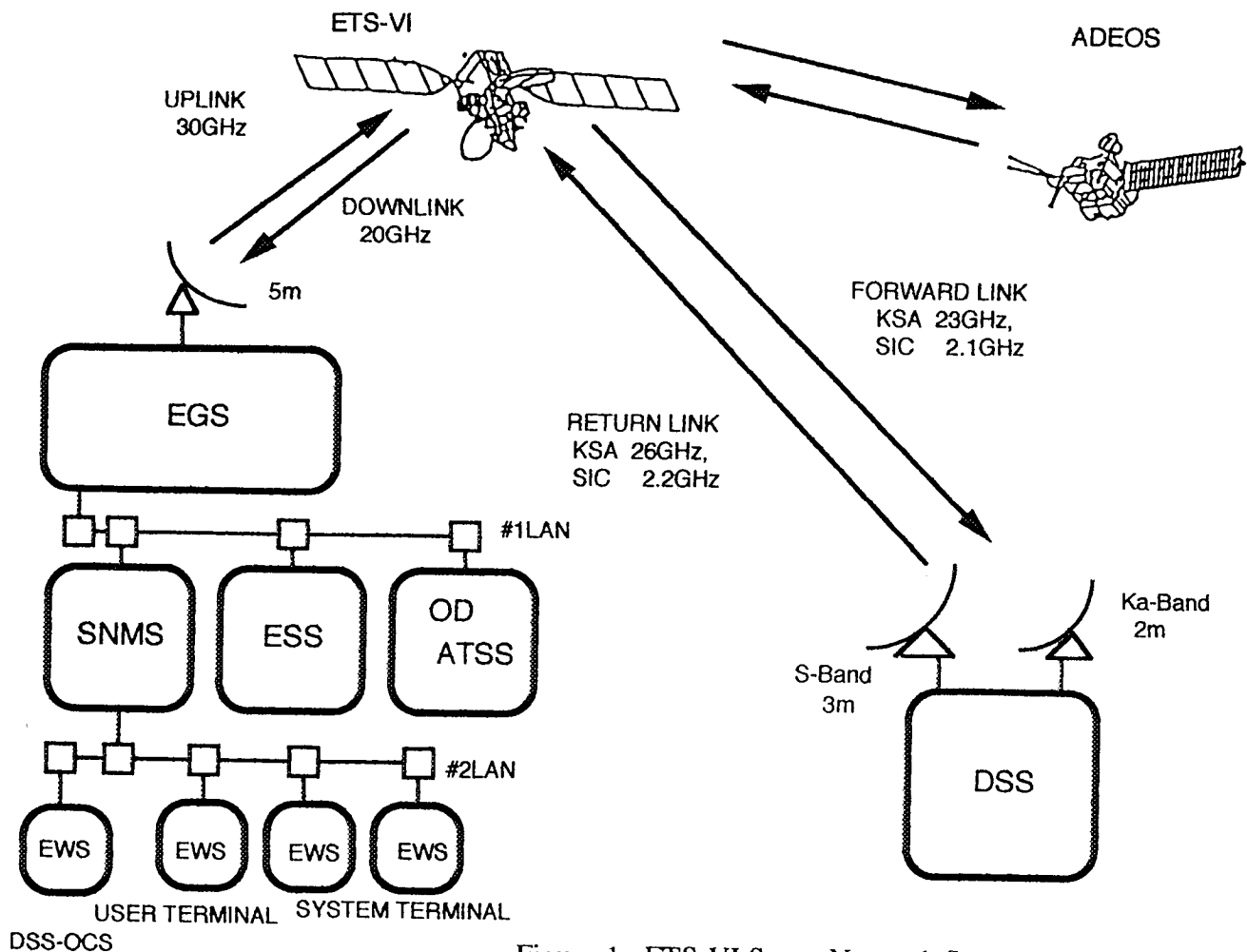


Figure-1 : ETS-VI Space Network System

**(1) Experimental Ground Station (EGS)**

The EGS provides the telemetry and command functions for ETS-VI and also provides the telecommunication functions necessary for transmitting and receiving user data through the ETS-VI. The EGS interfaces with the ETS-VI through Ka-band (30 GHz uplink/20 GHz downlink) Space-to-Ground Feeder Link. These uplinks and downlinks are done through a 5-meter antenna.

**(2) Dummy Satellite Station (DSS)**

The DSS provides the telecommunication equipments to emulate the user spacecraft. The DSS has functions of receiving SIC/KSA forward links and transmitting SIC/KSA return links to ETS-VI. The SIC forward/return services are sent/received through a 3-meter antenna, KSA services use a 2-meter antenna. The DSS is normally located in the Tsukuba Space Center, Japan, and is transportable for experimental purposes.

**(3) Space Network Management Subsystem**

The SNMS is a core of the ETS-VI SN ground segment. ETS-VI SN system control is provided by the SNMS, which consists of a configuration of computer setup to control and monitor the ETS-VI and the EGS. The SNMS also provides a interface with the User Operations Control Center (OCC), through a user terminal for the scheduling and real time operations.

**(4) Orbit Determination/Acquisition and Tracking Support Subsystem (OD/ATSS)**

The OD provides orbit computation for earth orbiting spacecraft and tracking performance assessments for the SN.

The ATSS provides all system calculations necessary for the initial acquisition and tracking operations. One computer (EWS) is shared between OD and ATSS.

(5) Experiment Support Subsystem (ESS)  
 The ESS provides the following functions.  
 -Accumulation of the experiment data  
 -Analysis of the experiment data  
 -Fault Isolation analysis (KSA system)

(6) DSS-OCS  
 The Dummy Satellite Station-Operations Control Subsystem(DSS-OCS) provides DSS control. Its primary functions is to monitor the DSS conditions and generate the commands to the DSS.

### 3.ACQUISITION SEQUENCE

During the initial acquisition, many complicated processes occur in combination with the user OCC, the ETS-VI, and the user spacecraft in order to establish the inter-satellite communication links between the two satellites. Understanding of these processes is required. Obtaining these operations techniques is one of the most important objectives of the experiments.

The acquisition and tracking operations for space network is much complex in comparison to the usual direct communications with the ground station network. The last tendency of mass data and high rate transmission, for example, requires data relay satellite to have antenna bigger and frequency higher, and eventually make the operations more complicated. In fact, although the KSA antenna of ETS-VI is only 80-cm in diameter, the KSA has a very narrow radiation beam because the frequency band is so high, 23/26 GHz band. Eventually the KSA is required to point its antenna precisely toward the user spacecraft during acquisition.

For the ETS-VI SN experiments, NASDA plans to use the Advanced Earth Observation Satellite (ADEOS), as a user spacecraft, which will be launched in 1996 from Tanegashima Space Center, NASDA. Table-1 shows the KSA typical acquisition sequence between the two satellites.

The acquisition sequence shown in table-1 is nominal procedure. However in case ETS-VI fails,for example, to acquire the return beacon signal from ADEOS at step E4, ETS-VI will start the antenna movement for signal search.

Table-1: Typical Acquisition Sequence

| ETS-VI  | ADEOS   |
|---|---|
| Step-E1<br>Update orbit elements stored at onboard computer | Step-A1<br>Update orbit elements                                  |
| Step-E2<br>Antenna point toward ADEOS                       | Step-A2<br>Antenna point toward ETS-VI                            |
| Step-E3<br>Transmit Forward beacon signal                   | Step-A3<br>Acq. ForwardBeacon<br>Start Antenna auto tracking mode |
| Step-E4<br>Acq. RTN signal<br>Start ANT auto track          | Step-A4<br>Transmit Return signal                                 |
| Completion of initial acquisition                           |   |
| Start Forward and Return Services                           |   |

### 4. AUTOMATED SN OPERATIONS

#### 4.1 Automated SN operations

Establishing an automated SN operations system is one of the key-elements that NASDA intends to develop by the era of our operational Data Relay Satellite System. NASDA thus made an attempt to develop a new automatic operations method, SNSOP (Space Network System Operations Procedure), as a experimental method at the ETS-VI Experimental SN ground system. This method concentrated on the following points:

- To control both ETS-VI and EGS automatically in accordance with the pre-determined acquisition sequence.

- To monitor the network conditions effectively.
- To move into recovery procedures automatically as much as possible if any of the checks fail
- To create/modify the operations sequences easily.
- To exchange the operational information with the user OCC timely.

#### 4.2 Hardware

All control and monitor of the EGS and ETS-VI is performed by SNSOP installed in the SNMS, although manual intervention is still possible. The SNMS consists of the host computer and two EWSs (one for SIC, the other for KSA). The SNSOP process can be divided into two processes; (1) a client process in the EWS, (2) a server process in the host computer. Figure-2 shows their functional assignments.

#### 4.3 SNSOP

The SNSOP is a flow chart list which consists of the combination of process boxes and flow lines. The process box can define a statement, an arithmetic expression, a logical expression, a control command for SNSOP and so forth. The flow line is a line, which can define one-way direction, for connecting between two process boxes. The SNSOP can be composed of a main-SOP, a sub-SOP and a mini-SOP structurally. The SNMS provides a MMI for creating and modifying the SNSOP easily. Process boxes used in the ETS-VI SN system are shown in figure-3 and as follows:

- Start Box : States the start of main-SOP
- End Box : States the end of main-SOP
- Entry Box : States the start of sub/mini-SOP
- Return Box : States the end of sub/mini-SOP
- Process Box: Defines the free text (ex.arithmetic expression,etc.)
- Exec1 Box : Defines the execute command for ETS-VI
- Exec2 Box : Defines the execute command for EGS
- Exec3 Box : Defines the execute command

- for other ground elements
- Check Box : Defines the TLM# to compare with data base value.
- Branch Box : Defines the branch condition.
- Loop Box : Defines the loop process based on a branch condition.
- Store Box : Defines the stored CMDs for ETS-VI
- StoreExe Box: Defines the execution of stored commands
- Sub-SOP Box: Defines the sub/mini-SOP#
- SN/OpsMSG Box: Defines SN or OpsMsgID

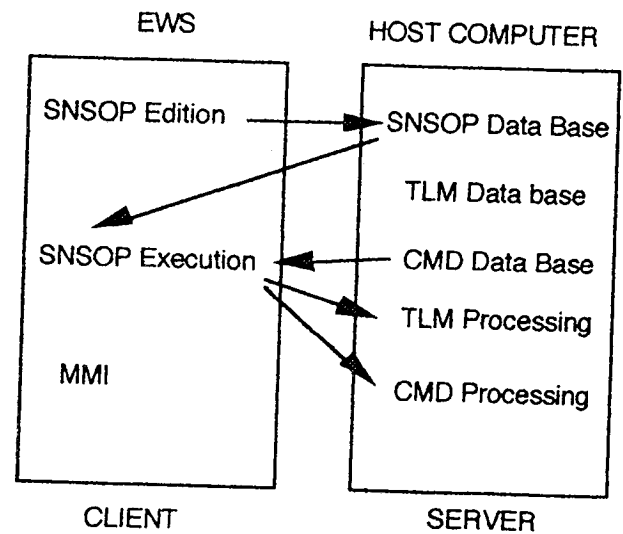


Figure-2 : SNMS functional assignment

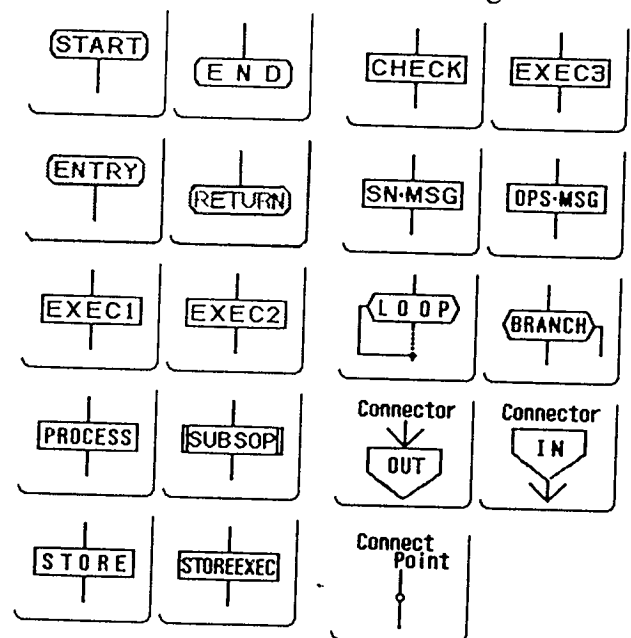


Figure-3 : Process Box

#### 4.4 Operation Description Data (ODD)

The ODD is a unique language developed by NASDA to be used in SNSOP. The system operator can easily describe a free text ,e.g., an arithmetic expression, a logical expression, branch condition, etc., in a process box by using the ODD. It can basically be divided into following groups:

##### (1) Arithmetic Assignment

- Constant
- Variable
- Array
- Arithmetic operator (+, -, x, /)
- Functions
- Assignment

##### (2) Logical Assignment

The assignment method is the same as arithmetic assignment.

- Logical operator  
and, or, not, xor

##### (3) Judgement condition

>, <, >=, <=, =, !=

##### (4) SNSOP control commands

The control commands used at ETS-VI SN system are as follows;

- Test : Compare the received TLM with canned value in data-base.
- Wait : Wait before moving to the next step for an appointed period of time.
- Wake : Break the current job and restart at the appointed time.
- Input : Input the value to the appointed variable name.
- Display : Display the value in the appointed variable name.
- Print : Print the value in the appointed variable name.
- Interrupt: Prohibit the interruption, or release it.
- GetTLM: Set the appointed TLM value to the appointed variable name.
- StoreCancel: Cancel the stored commands
- Save : Store the value in the appointed variable name to the appointed file
- Load : Get the value into the appointed variable name.
- Beep : Sound buzzer for the appointed time
- Exec1 : Execute the commands for ETS-VI
- Exec2 : Execute the commands for EGS
- Exec3 : Execute the commands for other ground elements
- Store : Store the ETS-VI commands

- StoreExec: Execute the stored commands
- OpsMsgGet: Get the operation message

#### 4.5 Execution of SNSOP

The SNSOP is executed one after another automatically in accordance with the flow chart list, and the manual operation is also possible. The automatic execution will be stopped temporarily when the system operator selects "Pause Mode" or sets a break point on the expected process box of flow chart list, or when the system operator is asked for his judgement by SNSOP. Following are the three modes during manual operation:

- Step Exec. mode : Execute one step only.
- Step Skip mode : Skip one step only.
- Box Skip mode : Skip one process box.

The transition from manual to automatic mode is performed by choosing "Restart Mode", and "Abort mode" is for the SNSOP forced end.

#### 4.6 Control Requests from user-OCC

The changes to the operating conditions or configurations of the ETS-VI SN ground segment can be initiated by the "Operations-Control" message from user-OCC to the SNMS. These messages are categorized into two groups: Class A and Class B.

The class A Ops-control message is executed automatically after completing the valid check at SNMS. The class B is performed with the SN operator's decision.

The operating SNSOP will be interrupted after the completion of validity check when the Ops-control message is received at SNMS, and another SNSOP for an Ops-control message will be called and started automatically.

#### 4.7 Monitor requests from user-OCC

The real-time monitoring of SN ground system at user-OCC is achieved via "SN message" and "SN message ID". The SN message is a telemetry data of ETS-VI SN system, and is sent to user-OCC every 2 seconds during support period. The SN message ID is used when the SN system wants to notify the key event of the current executing sequence, e.g.,

Completion of EGS setup, Bringing forward beacon signal up, etc., to the user-OCC. The message ID is sent to user-OCC by SNSOP.

The user-OCC can get information of which step the SN system is executing at a certain time via the SN message and SN message ID.

## 5. SNSOP DATA BASE

A total number of 61 main-SNSOPs are stored in the data base of SNMS. Many sub and mini-SOPs are linked with the main-SOP. The main-SOP can be classified as follows:

### (1) System Operations SOP

There are 11 SOPs for system operations, e.g., EGS initial setup, Pilot links on/off, TT&C links on/off, etc.

### (2) KSA Service SOP

4 SOPs are prepared for the KSA service operations based on the combination of types of initial acquisition sequence mode (Sequence#1, Sequence#2A, Sequence#2B) and KSA antenna pointing modes (CPU mode, Direct mode).

### (3) SIC Service SOP

4 SOPs are prepared for the SIC forward/return service operations based on the SIC antenna pointing modes (Orbit elements mode, Program mode, Real time mode, Direct mode).

### (4) Recovery SOP

The recovery SOP is called when any of the checks in the main-SOP fails. 11 SOPs are stored in the data base.

### (5) Ops-Control SOP

30 SOPs are stored in the data base. The Ops-control SOP is used when it is requested from the user-OCC.

Figure-4 shows the KSA service operations display for CPU/sequence#2A mode. The left window shows the main-SOP and the right is the sub-SOP of the second process box from the top of main-SOP.

## 6. SN Real-Time OPERATIONS

The real-time operations period is the time frame in which the user-OCC and the SN system perform necessary activities to support the command, telemetry, and tracking operations of a user spacecraft. These operations can be categorized as those occurring prior to the scheduled support start time, those occurring during the real support period, and those occurring post-support.

The following are the typical operations of each phase with an example of the KSA service operation (CPU mode).

### 6.1 Pre-support Phase

#### (1) User-OCC

a. Sending the KSA service requests to the SNMS by at least 30 minutes prior to scheduled start of service, through the user terminal.

#### (2) ATSS

a. Receiving the state vectors of both ETS-VI and user spacecraft if updated.

b. Processing of them by 30 minutes prior to

the scheduled start of service.

c. Calculating the parameters necessary for the acquisition and tracking operations, and sending them to the SNMS when required from the SNMS.

#### (3) SNMS

a. Choosing the next support service by at least 30 minutes prior to the scheduled start time.

b. Sending the calculation request of acquisition parameters to the ATSS and receiving it from the ATSS within a certain time.

c. Setting the parameters calculated at step b into the system variables of KSA service SOP.

d. Configuring the ETS-VI by SNSOP.

#### (4) EGS

a. Configuring the EGS by SNSOP.

### 6.2 Support Phase

#### (1) SNMS

a. Controlling KSA antenna operations by

- SNSOP.
- b. Initiating/terminating the services by SNSOP.
- c. Generating and transmitting the SN message and SN message ID to the user terminal located at the user-OCC.
- d. Operating service.
- e. Monitoring the SN performance.
- f. Verifying and processing the Ops-control from the user-OCC through user terminal if received.
- g. Initiating the recovery operations based on the recovery SOP if any of the checks fails.

(2) EGS

- a. Acquisition of service channel.
- b. Operating service.
- c. Reconfiguring/reacquisition service.
- d. Receiving and logging the tracking data if required.

(3) User-OCC

- a. Monitoring the SN performance via SN message and message ID.
- b. Sending the Ops-control if needed.

6.3 Post-support Phase

(1) SNMS

- a. Dumping the operations history
- b. Conducting post-support debriefing with the user-OCC.

(2) OD/ATSS

- a. Receiving and logging the tracking data from the EGS in accordance with the direction from the SNMS.

7. CONCLUSION

NASDA is now in its final process of the ETS-VI launch scheduled on August '94. The experiment will begin from November '94 after completing the initial mission checkouts on orbit. We would like to verify the availability of the SNSOP method through the ETS-VI data relay experiment period and reflect it to our future data relay satellite system.

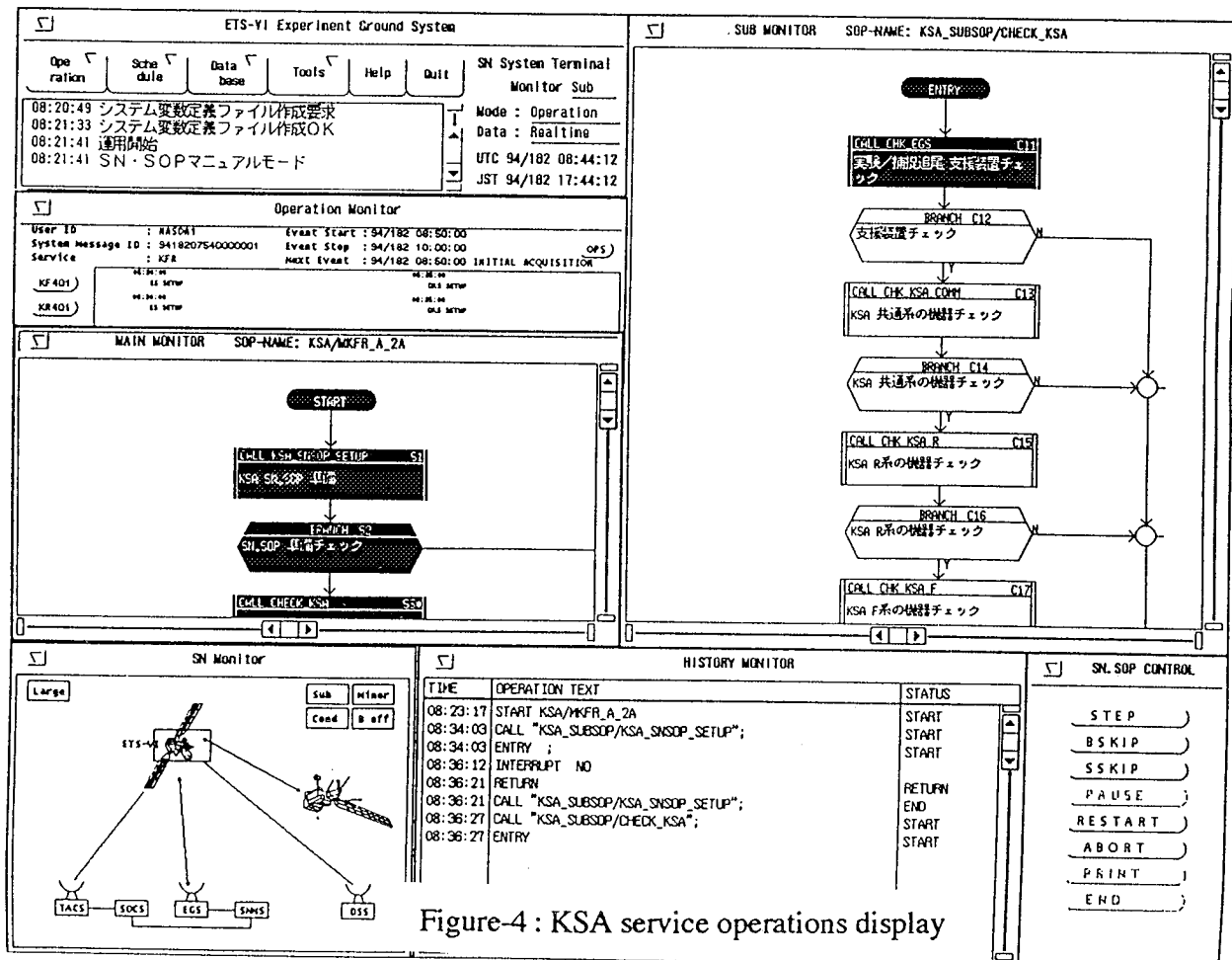


Figure-4 : KSA service operations display