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GROUND DATA SYSTEM FOR SPACE FLYER UNIT (SFU)

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ABSTRACT

The Space Flyer Unit (SFU) is an unmanned, multi-purpose, retrievable and reusable space platform. The first mission of SFU (SFU-1) will be launched by NASDA's H-II launch vehicle in early 1995, and retrieved by NASA's Space Shuttle after several months in orbit. Two Japanese ground stations, several ground stations of NASA, and a ground station in Chile are used for tracking of SFU-1. The control center of SFU-1 is the Sagamihara Operations Center (SOC) of ISAS located in Sagamihara, Japan. This paper describes the tracking and data acquisition network for SFU-1, the configuration and design policy of the SFU operations control system, and data processing schemes used for mission operations of SFU.

Key Words: Mission operations, spacecraft tracking system, space data system

1. INTRODUCTION

The Space Flyer Unit (SFU) is an unmanned, multi-purpose, retrievable and reusable space platform (Ref. 1). SFU is jointly developed by the following three institutes of the Japanese government : (1) the Institute of Space and Astronautical Science (ISAS) under the Ministry of Education, (2) the Institute for Unmanned Space Experiment Free Flyer (USEF) under the Ministry of International Trade and Industry, and (3) the National Space Development Agency of Japan (NASDA) under the Science and Technology Agency.

The SFU spacecraft consists of the core system and payloads (experiment equipments). The core system provides the payloads with standardized services such as electric power, command and data handling, etc. The core system of SFU is reusable if approriate refurbishment and maintenance are performed after the flight. Therefore, SFU can make several flights without major modifications to the core system, each time with a different set of payloads. Each payload is independently operated provided its operations do not cause resource conflicts with other payloads.

The first mission of SFU (SFU-1) will be launched by NASDA's H-II launch vehicle from Tanegashima Space Center in Japan in early 1995, and retrieved by NASA's Space Shuttle after several months in orbit. The operational altitude is about 500km, while the retrieval will take place at about 300km. SFU-1 has the following eleven payloads :

- Two-dimensional array deployment
- High voltage solar array experiment
- Infrared telescope
- Electric propulsion experiment
- Material experiment
- Space biology experiment
- Space plasma measurement
- Gradient heating furnace
- Mirror heating furnace
- Isothermal heating furnace
- Testing of the exposed facility of the Japanese module of the Space Station Freedom

The following sections describe the tracking and data acquisition network for SFU-1, the configuration and design policy of the SFU operations control system, and data processing schemes used for mission operations of SFU.

2. TRACKING AND DATA ACQUISITION NETWORK FOR SFU

The ground stations to be used for a particular flight of SFU are selected based on the operational requirements of that flight, and the location of the control center is also decided based on the responsibility assignment of that flight.

Fig. 1 shows the tracking and data acquisition network for the first flight of SFU (SFU-1). The primary ground station for SFU-1 is the Kagoshima Space Center (KSC) of ISAS located in the southern part of Japan. The Okinawa Tracking and Data Acquisition Station (OTDS) of NASDA, located in an island in the southern part of Japan, is used as a backup ground station to ISAS KSC during critical phases.

Since the operational altitude of SFU-1 is about 500km, contact with those Japanese stations can be established only during five or six orbits out of 16 orbits per day. Therefore, three Deep Space Network (DSN) stations of NASA (i.e. Goldstone, Canberra and Madrid) and three Ground Spacecraft Tracking and Data Network (GSTDN) stations of NASA (i.e. Bermuda, Wallops and Merritt Island) are used to extend the ground coverage during critical phases. The Santiago ground station of the University of Chile is also used during critical phases. Since the Santiago station covers almost the same orbits as the Japanese stations augmenting the coverage from the Japanese stations, the Santiago station serves as an ideal auxiliary station when critical operations are performed over the Japanese stations.

The control center of SFU-1 is the Sagamihara Operations Center (SOC) of ISAS, which is in the city of Sagamihara of Japan. All flight operations for SFU-1 are performed at SOC except for the proximity operarions phase during which SFU communicates directly with the Space Shuttle Orbiter.

Except for the proximity operations phase, all commands are generated at SOC and transmitted to SFU through a ground station in realtime. Realtime telemetry data received at a ground station is transferred to SOC in realtime, where it is monitored, analyzed and archived. Playback data from the onboard data recorder is temporarily stored at the receiving ground station and delivered to SOC in an offline mode after the tracking pass.

Orbit determination is performed at SOC and the Jet Propulsion Laboratory (JPL) of NASA during critical phases. During the mission operations phase, orbit determination is performed at the Tracking and Control Center (TACC) of NASDA based on the RARR data from ISAS KSC. During the rendezvous operations before the retrieval, C-band radar stations of the U.S. Government are used for orbit determination of SFU, and the Johnson

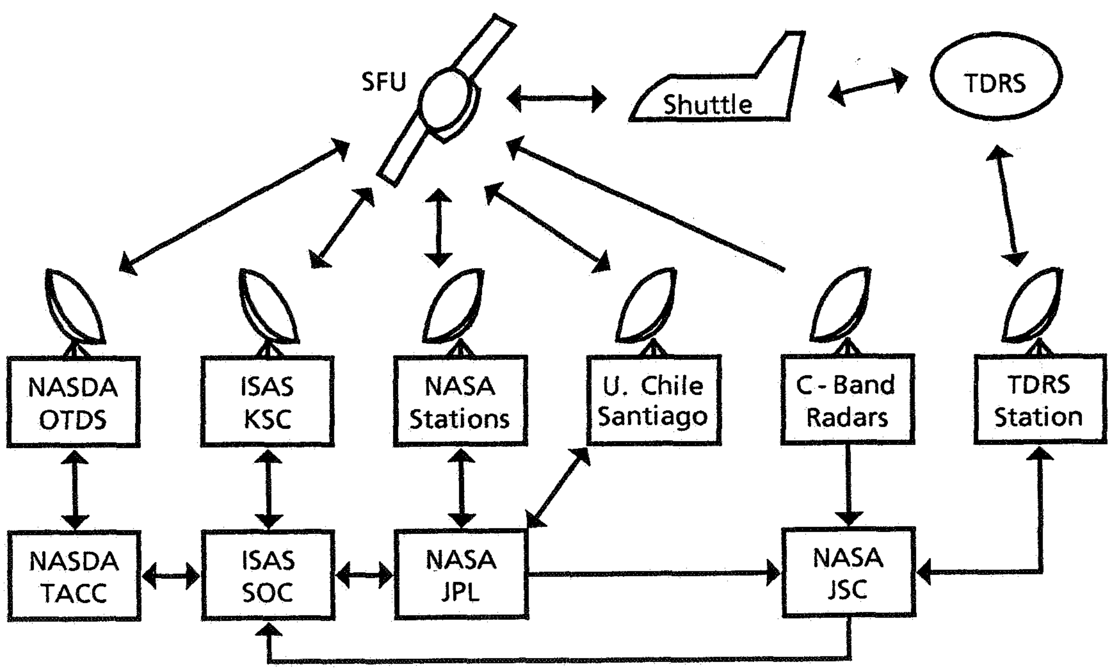

Fig. 1 Tracking and Data Acquisition Network for SFU-1

Space center (JSC) of NASA provides SOC with the state vectors of SFU.

During the proximity operations phase, telemetry data is monitored at the Space Shuttle Orbiter, the Mission Control Center (MCC) of JSC and SOC. Commands will probably be issued at the Space Shuttle Orbiter and MCC of JSC during this phase.

3. SFU OPERATIONS CONTROL SYSTEM

3.1 Design Philosophy

The SFU operations control system is dedicated to SFU, not shared with other projects, because the mission operations requirements for SFU are very different from those of other Japanese space missions. The following is the design philosophy of the SFU operations control system:

1) Virtually any ground station can be incorporated into the system with only a small modification to the gateway software. The control center can be placed at any of the three institutes participating in the SFU project.

2) A distributed system architecture and a modularized software structure are adopted so that the system can be modified easily for future flights of SFU and new technology can be introduced without modifying the entire system.

3) Industry standard software and communications protocols are used whenever possible in order to facilitate interconnection of computers of different manufacturers.

3.2 System Configuration

Fig. 2 shows the basic configuration of the operations control system for SFU-1. There are some other offline computers which are not shown in Fig. 2. All the computers at SOC use the UNIX operating system, and most of the software developed for this system is implemented in the C programming language.

There are two major local area networks (LAN's) at SOC, which are shown as two thick lines in Fig, 2. These are standard Ethernets, and TCP/IP is used as the communications protocol. The left LAN (SFU LAN) is basically for online spacecraft operations, while the right LAN (SFU Experiment LAN) is used for distributing data to experiment data processing computers.

The SFU Gateway is a communications processor used to communicate with ground stations and other space centers such as JPL and JSC. The SFU Gateway receives telemetry data, orbit data (state vectors and RARR data) and administrative data (sequence of events, etc.) from a ground station or another space center, and transfers the received data to an appropriate computer at SOC with the SFU standard protocol and format. The SFU Gateway receives command data, orbit data and administrative data from a computer at SOC, and transfers the received data to an appropriate ground station or center. The SFU Gateway also stores the received data temporarily in case the data is lost during transmission. The SFU gateway consists of a primary computer and a backup computer.

The SFU Monitor and Control Computer (SMCC) is used to issue commands and to monitor and archive housekeeping telemetry data. SMCC consists of a primary host computer, a backup host computer and several workstations for man/machine interface. These workstations are connected to one of the host computers via a LAN local to SMCC.

The Timeline Generator (TLG) validates planned operations sequences and generates command sequences. TLG consists of a primary workstation and a backup workstation.

The Experiment Monitor Computer (EMC) is used to monitor and archive experiment and housekeeping telemetry data. It distributes telemetry data with some ancillary data to the Experiment Data Processing computers where offline analysis of experiment data is performed. EMC consists of a host computer and several workstations for man/machine interface. These workstations are connected to the host computer via a LAN local to EMC.

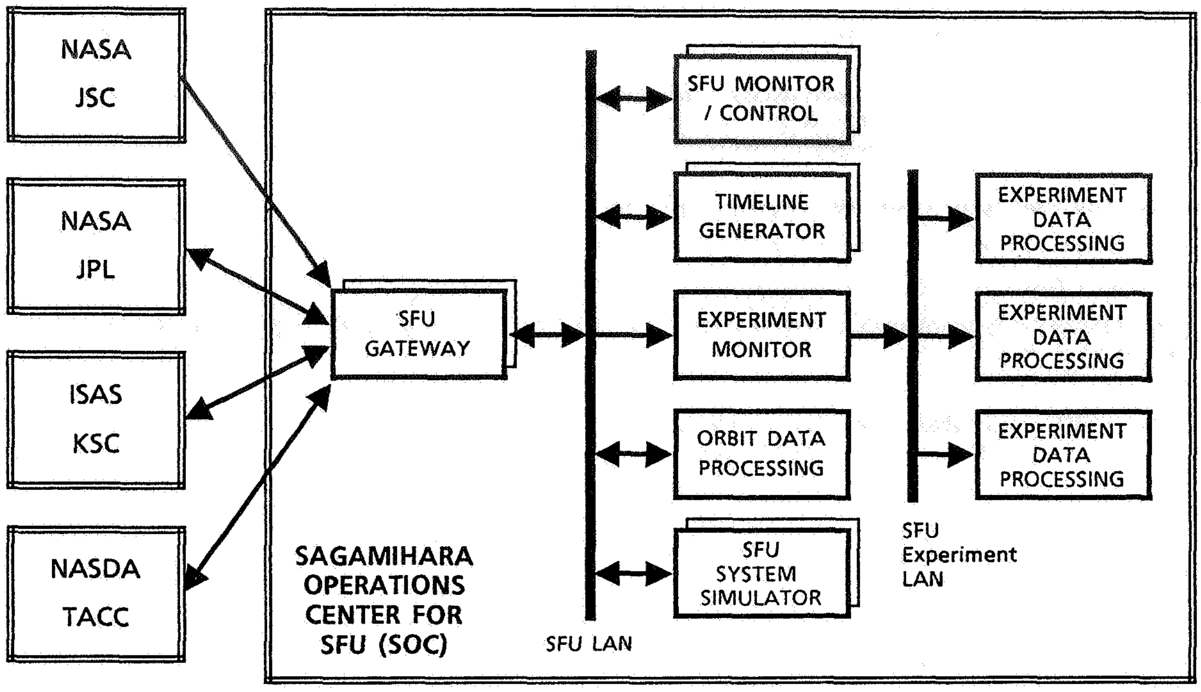

Fig. 2 SFU-1 Operations Control System

The Orbit Data Processing Computer (ODPC) performs orbit propagation and coordinate system conversion. ODPC consists of one workstation.

The SFU System Simulator (SSS) receives commands from SMCC, simulates some of the subsystems and experiments of SFU, and sends telemetry to SMCC and EMC. SSS consists of two host compouters (primary and backup) and two workstations (primary and backup).

The experimenters can bring any computers as Experiment Data Procesing Computers (EDPC's) if they can be connected to the SFU Experiment LAN. For the first flight, several minicomputers and several workstations will be used as EDPC's. There is no connection to other computer networks such as Internet because of security requirements.

4. COMMAND DATA PROCESSING

4.1 Mission Planning and Command Generation

Mission planning is carried out by integrating into the mission timeline the Functional Objectives (FO's) requested by the experimenters and flight planning team. An FO is a unit for generating the mission timeline. Each FO has a sequence of commands to be executed, the amount of resources required to perform the FO, and FO execution rules related to that FO (e.g. FO's which must be executed prior to that FO). There is a standard format to describe FO's and each FO is generated as an FO file by some offline computer. The command sequence in the FO file is written in a high level language called the SFU Command Language (SCL). Some FO files (e.g., FO's for orbit correction maneuvers) are automatically generated by an offline computer.

The requested FO's are arranged by an operator, and a time ordered FO sequence is fed to the Timeline Generator (TLG). TLG checks whether or not the FO sequence violates resource allocation rules or FO execution rules. If the sequence violates any of the rules, an operater modifies the FO sequence through interctive operations with TLG. When this process is completed and the final FO sequence is obtained, TLG generates an Event File which contains the integrated sequence of commands generated from the original FO files. TLG also calculates event times such as AOS and LOS times, and includes the event information in the

Event File. The entire Event File is written in SCL.

4.2 Command Execution and Verification

The Event File generated by TLG is sent to SMCC (Fig. 3). The Event File is then interpreted and executed in the following way. Commands to be executed during a station contact are converted to binary command data and transmitted to the spacecraft with some interactive operations by the operator. Commands to be loaded in the onboard command memory and executed later are converted to memory load commands and transmitted to the spacecraft by the directions of the operator. Commands in the Event File are automatically transmitted unless other operations are specified in the Event File. The operator can abort the execution of the Event File and manually issue commands any time.

If the spacecraft must be in a certain status when a command is going to be executed, then SMCC verifies the status of the spacecraft using the received telemetry data before sending the command. After sending a command, the result of the command execution is verified with the telemetry data. When a critical command has been sent, the command transmission process is suspended until the execution result is verified. For a non-critical command, the execution result is not verified right after the transmission. At the time specified in the Event File, the execution results of non-critical commands which have not been verified are verified simultaneously. If a verification fails, SMCC generates an anomaly report, alarm the operator, and abort the execution of the Event File.

5. TELEMETRY DATA PROCESSING

5.1 Telemetry Checking

Received telemetry data is fed to SMCC and EMC simultaneously (Fig. 4). SMCC processes only housekeeping data, while EMC can process both housekeeping and experiment data. Against received telemetry data, two kinds of checking are performed as follows:

1) Limit checking - Checking that the value of a received telemetry data is between a pair of fixed limit values.

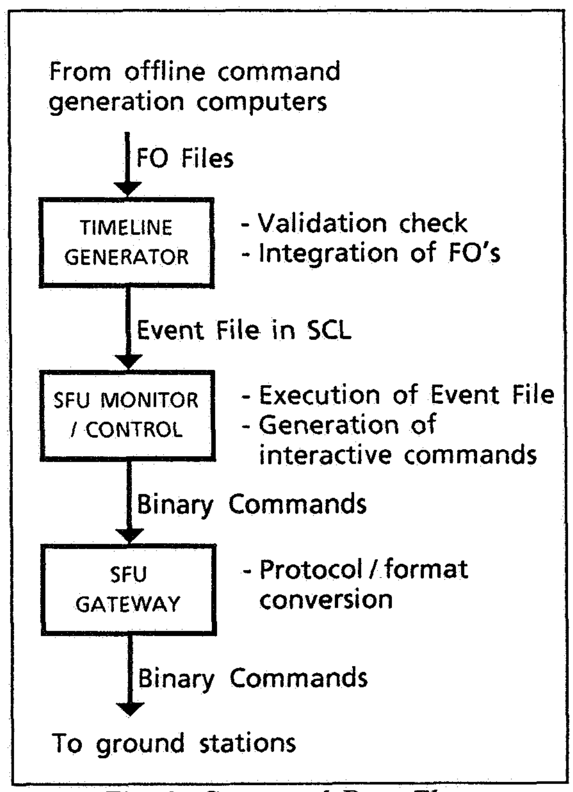

Fig. 3 Command Data Flow

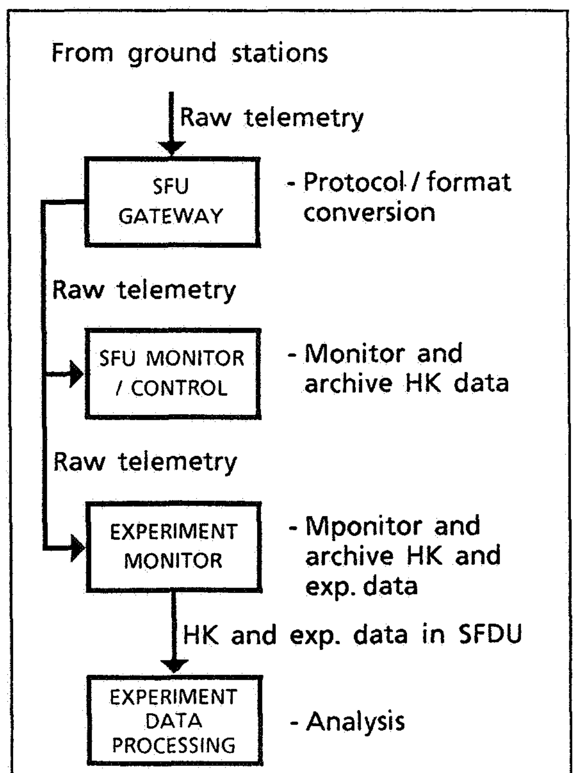

Fig. 4 Telemetry Data Flow

This checking is performed to detect a hardware error. Limit checking is performed against all realtime telemetry at the time of reception. The limit values can be changed by changing limit data files.

2) Mode checking - Checking that the value or status of a set of received housekeeping telemetry data satisfies the conditions described in a specified mode check file. This checking is performed to check that the spacecraft is actually in the desired mode. SMCC automatically executes mode checking if it is described in the Event File. The operator can manually initiate mode checking any time. Mode checking can also be performed in a batch mode against the telemetry data of a specified time archived in SMCC. Batch mode checking is useful for verifying the mode transitions of the spacecraft during an out-of-contact period.

If a check fails, an anomaly report is generated and the operator is alarmed to take an action.

5.2 Telemetry Display

Realtime telemetry data is monitored in realtime on the workstations of SMCC and EMC. Archived data is also displayed with the directions of the operator on these workstations. The display format is defined with a window definition language called the Display Format Descriptor (DFD). SMCC and EMC reads the display format request defined with DFD from a file, and generates the display.

Several windows can be drawn on one workstation, and a window consists of a alphanumeric table or a graphical plot. Some of the windows can be placed on the screen as icons, which can be opened with a direction of the operator. The display format request contains the following information for each window: the data items to be displayed in the window, the format of the table or plot, the colors to be used for normal data and out-of-limit data, etc. The result of some arithmetic operations can also be displayed by defining the operations with DFD. If a data fails the limit check, the color of the data on the display changes. If the data is being displayed in one of the icons, the color of the icon changes.

5.3 Telemetry Distribution

SMCC can provide a text file called the SFU Parameter File which contains the value of all housekeeping telemetry items derived from one major frame of telemetry. This file is used by TLG and SSS as the initial condition of timeline generation or simulation. EMC provides EDPC with the set of telemetry data requested by an experimenter in the SFDU format.

6. CONCLUSIONS

This paper described the tracking and data acquisition network and the operations control system of SFU-1. The operations control system is now in the stage of integration testing which will be finished in the fall of 1993.

7. ACKNOWLEDGEMENTS

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