Space Station Freedom Ground Data System: Design and Operations

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ABSTRACT

Over the previous year the Space Station Freedom (SSF) Program (SSFP) ground data distribution system has become independent of a number of data systems that were to have been provided by other National Aeronautics and Space Administration (NASA) programs. Consequently, the SSFP has outlined the basic architecture of a new data system dedicated to supporting SSF requirements. This has been accomplished through a complete redesign of the ground network and a reallocation of selected functions.

There are a number of aspects of the new ground data distribution system that are unique among NASA programs. These considerations make SSF ground data distribution one of the most extensive and complex data management challenges encountered in the arena of Space Operations. A description of this system comprises the main focus of the paper.

Key words: Space Station Freedom, data system, operations

1. INTRODUCTION

The SSFP is an international endeavor with space and ground-based elements contributed by the United States through NASA, the European community through the European Space Agency (ESA), Japan through the National Aerospace Development Agency (NASDA) and Canada through the Canadian Space Agency (CSA).

The Space Station Manned Base (SSMB) will be a multipurpose orbiting facility providing the means for a permanent human presence in space and the pursuit of scientific endeavors in areas such as microgravity and materials sciences, astrophysics, human physiology, and earth sciences. Experiments may be conducted either inside the pressurized modules or exposed to space at truss attach points.

Beginning in 1999, Freedom will provide the capability for permanent human habitation during the Permanently Manned Capability (PMC) phase. Prior to this stage, a Manned Tended Capability (MTC) is planned. In this intermediate phase of construction, temporary habitation and experimentation will occur during visits by the space shuttle crew. MTC will begin with the delivery of the first pressurized module in 1997. Prior to that time, the truss "infrastructure" necessary to support the pressurized modules with power, communications, and other utilities will be delivered and assembled in space.

The ground data distribution system planned by the SSFP will be developed over the same time period and will continue to evolve during the 30-year orbital life of the SSMB. Initial capabilities, in place about the time of the first delivery mission in 1996, must ensure the safe operation of the systems on orbit. The initial scientific use of the SSF in 1997 will require a far more extensive and capable ground network to support the investigations of the international scientific communities participating in the program.

It is important to note that the ground data processing and data distribution functions are the most recent major additions to the SSFP. Prior to 1991, two programs were under way within NASA to provide these services centrally to all NASA space programs, including unmanned satellites. In that year, these programs, NASA Communications II (Nascom II) for data transport and the Customer Data Operations System (CDOS) for data processing, were eliminated from NASA due to budget considerations, and the responsibilities for data services required by the Earth Observing System and SSFP were transferred to those programs. The SSFP has maintained much of the data-driven architecture envisioned by the CDOS and Nascom II programs, but has tailored the implementation to suit the specific needs of the program through a complete redesign of the ground network and a reallocation of selected functions.

2. UNIQUE REQUIREMENTS

As currently projected, the primary data volume driver for SSF data operations will be the science data downlink. Operation of the SSF as a science laboratory will begin in earnest upon the arrival of the first complement of payloads in 1997. A variety of payloads are already scheduled for the MTC period, but primary emphasis will be on microgravity and life-sciences payloads. These areas of research place distinct requirements on the SSFP ground-based data systems. Life-sciences payloads will rely heavily on video, and its correspondingly high data rate, for information collection. Microgravity science is sensor-data-intensive and depends on real-time interaction between the payload and ground-based operators for payload operations. The dual nature of these requirements — large data rates and real-time operations — provides a challenging environment for SSFP ground operations.

Further demands result from the international nature of the Program. International and joint payloads require the distribution of downlinked data to the International Partners (IPs), often with the same real-time requirements of U.S. payloads. Uplink data (both core and payload) destined for IP modules will be given the same priority as U.S. uplink data, but must first pass through source authentication processes.

An additional, and perhaps most challenging aspect of SSFP communications is the requirement to allow continuously expanding data rates over the 30-year life of the program. Unlike previous long duration missions, such as Voyager, the expansion of the SSMB and evolution of its contingent of payloads will allow data requirements to increase over the life of the program. Developments such as the deployment of the next generation of tracking and data relay satellites at the end of the century will make rapidly expanded data rates feasible — and likely.

3. GROUND DATA DISTRIBUTION ARCHITECTURE

The figure on the following page presents the SSFP ground data distribution architecture, which consists of the elements listed below. A distinction is made between payload data and core data (i.e., SSMB system data).

SSMB The Space Station Manned Base is the free-flying space station element.

TDRSS The Tracking and Data Relay Satellite (TDRS) System (TDRSS) is a constellation of geosynchronous NASA communications satellites designed to support low earth orbit science missions.

WSC The White Sands Complex, located near Las Cruces, New Mexico, is the site of the TDRSS ground terminal. WSC provides the sole capability for TDRS uplink and downlink connectivity.

SSCC The Space Station Control Center, located at the Johnson Space Center (JSC) in Houston, Texas, will be the focal point for SSMB operations. The SSCC will perform the following functions:

- Command and control of the SSMB
- Management and integration of core operations and core operations planning
- Interface with Engineering Support Centers (ESCs) for maintenance and sustaining engineering support

- Interface with the POIC to receive payload commands for uplink to the SSMB
- S- and Ku-band data capture
- Core data processing, archiving, and distribution
- Video processing and distribution.

POIC The Payload Operations and Integration Center, located at Marshall Space Flight Center (MSFC) in Huntsville, Alabama, will be the focal point for payload operations. The POIC will perform the following functions:

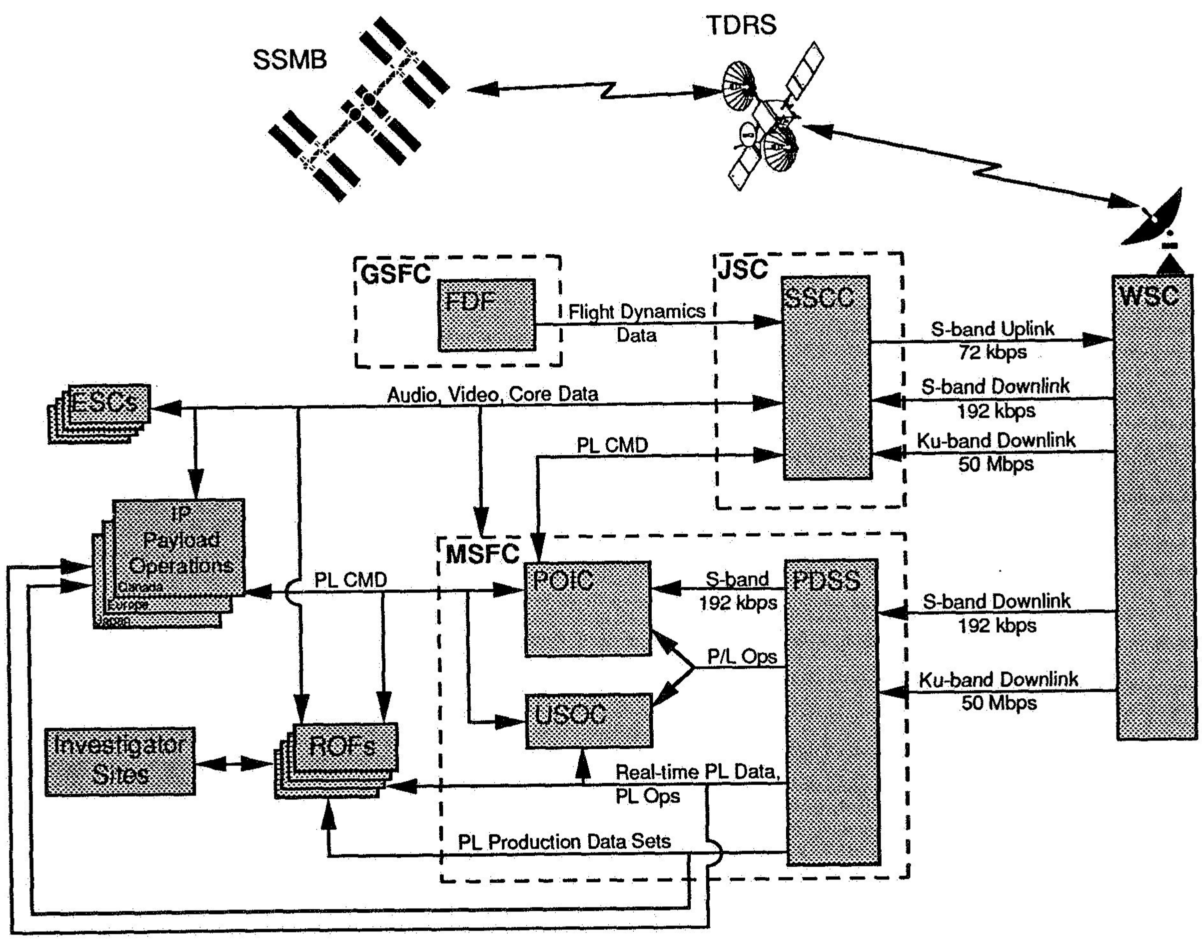
- Management and integration of payload operations and payload operations planning
- Interface to the users for audio, payload commanding, and payload file transfer
- Integration and transmission of payload command streams to the SSCC.

FDF The Flight Dynamics Facility, located at Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, will provide orbit and attitude data to support TDRSS acquisition and SSMB position determination.

PDSS The Payload Data Services System, located at MSFC, will be responsible for payload data distribution. The PDSS will perform the following functions:

- S- and Ku-band data capture
- Production data processing and archiving
- Real-time and processed data distribution
- Line outage recording and data rate buffering.

ESC Geographically dispersed Engineering Support Centers will provide maintenance and sustaining engineering support in various areas of SSMB systems expertise.



USOC NASA will provide the U.S. Operations Center at MSFC to house the U.S. payload operations capability. In addition, U.S. users may establish Remote Operational Facilities (ROFs) at geographically dispersed sites.

IP Interfaces Each International Partner (IP) will access the SSF ground data system at a dedicated interface point located within the continental United States. IPs are responsible for data transport between the interface points to their various operational centers, which are described in Section 6.

4. CORE OPERATIONS

Core operations are discussed in terms of the uplink and downlink data paths.

4.1 Core Data Uplink Path

SSCC operators will initiate core commands. Core commands and data files will then be generated at the SSCC, merged with the POIC uplink data stream, multiplexed with multiple voice channels, and transmitted to the WSC for uplink to the SSMB via S-band at 72 kilobits per second (kbps).

4.2 Core Data Downlink Path

The 192 kbps S-band downlink will be formatted in accordance with the Consultative Committee for Space Data Systems (CCSDS) recommendations for Advanced Orbiting Systems (AOS). The data stream will consist of CCSDS packets containing multiple voice channels, payload safety telemetry, and core telemetry.

Core telemetry will be downlinked via TDRSS and forwarded to the SSCC. The SSCC will process and archive these data for use by SSCC operators and ESC engineers. Payload users will also have access to archived ancillary parameters, but will probably prefer to build their own customized ancillary data sets on board and have them downlinked and routed to the PDSS.

Core video data and core data originating from the on-board recorders will also be archived at the SSCC. Recorder data will be archived with all other core data, but the manner in which these data packets will be time ordered with other data for later retrieval is undetermined. The optimal method of video archiving is also still under study.

IP core data will be routed to the locations described in Section 6.

4.3 Core Operations Security

Consistent with the requirements to protect the health and safety of manned missions, the SSFP uplink command data stream will be encrypted at the SSCC and decrypted on board.

5. PAYLOAD OPERATIONS

Payload operations are discussed in terms of the uplink and downlink data paths.

5.1 Payload Uplink Data Path

Payload users will generate commands and data files for uplink to their respective payloads. These data may be transmitted in real time or non-real time to the POIC. At the POIC, the various payload command loads will be combined into an integrated payload command load and transmitted to the SSCC for uplink.

IP payload commands and data files will be received by the POIC from the locations described in Section 6.

5.2 Payload Downlink Data Path

The Ku-band downlink will be formatted in accordance with the CCSDS AOS recommendations. The data stream will consist of 13 Virtual Channels (VCs) at a composite data rate of 50 megabits per second (Mbps). Of these VCs, 7 will carry high-rate payload data, 1 will carry low-rate payload data, 4 will carry SSF video, and 1 will contain fill data sufficient to ensure a constant downlink data rate.

The data stream will be downlinked via TDRSS to the WSC and subsequently broadcast via domestic communications satellite to both the SSCC and the PDSS.

The PDSS will capture and store the 50 Mbps broadcast from WSC for a limited time to protect against possible line outage or system failure. The PDSS will demultiplex the captured data in accordance with the CCSDS AOS formats.

The PDSS will separate the VCs and route the seven high-rate streams according to Virtual Channel Identifier (VCID). However, as the low-rate VC consists of data from multiple payloads, it must also be demultiplexed at the CCSDS packet level.

The PDSS will distribute selected VC and packet data streams to users in real time. These data will also be archived off-line for a period of two years. Archival will occur at the VC level. No further organization or labeling of the data will occur; consequently data requestors must know the channel and time at which the data were originally time-stamped.

The PDSS will also perform Level-Zero Processing (LZP) on selected VC data streams. LZP includes the removal of communications process artifacts such as headers and fill data, removal of data redundancies, time-ordering of data packets, and generation of data quality reports. LZP data will be archived on-line at the PDSS for a period of four days. Users may request and receive this data within 24 hours. The request must include the time of data production as well as the destination identification.

The PDSS will also provide "rate buffering" of selected data to match user ingest capabilities.

In addition, the PDSS will capture and demultiplex the 192 Kbps S-band data stream and forward it to the POIC in real-time to support payload operations.

Payload video from the SSF video system (not to be confused with payload digital image data, which is downlinked within the payload data stream) will be routed to JSC for distribution as a National Television Standards Committee (NTSC) analog signal.

Payload data, audio, and video will be routed to the IP locations described in Section 6.

5.3 Payload Operations Security

Payload downlink data will be protected to various degrees as they traverse the data system. Users who require additional protection (e.g., for sensitive corporate data or data whose release would be inconsistent with national policies on technology transfer) may employ their own protection mechanisms, such as encryption.

6. INTERNATIONAL PARTNERS

The IPs will develop and staff operational centers to support their payloads and modules. These centers will be compatible with the POIC. Data will be routed to and from the centers via gateways located within the continental United States.

CSA The Canadian Space Agency will provide the Payload Operations Center (POC) in Canada to support its robot arm and payloads.

ESA The European Space Agency will provide the European Payload Operations Control Center (EPOCC) at Oberpfaffenhofen, Federal Republic of Germany, to support the Columbus Attached Pressurized Module and European payloads.

NASDA The Japanese National Space Development Agency will provide the Space Station Integration and Promotion Center (SSIPC) located at Tsukuba Space Center (TKSC) near Tokyo, Japan. SSIPC will support the Japanese Experiment Module (JEM) and Japanese payloads.

7. FUTURE CHALLENGES

As the SSFP evolves over its 30-year life span, the ground data system will face significant challenges. As more numerous and complex payloads are added to the SSMB, downlink data rates are projected to climb from 50 Mbps to as much as 300 Mbps. With the addition of a Ka-band communications capability, data rates could exceed 300 Mbps. Global Positioning System (GPS) receivers may be added to the SSMB to enhance tracking capabilities. In addition, the payload users are expected to become far more geographically dispersed. The network that supports the SSF must therefore be modular, easily expandable, and robust.

The SSFP will face these and other unforseen requirements as they evolve. But the planned ground data distribution system will provide a solid basis for this growth and will allow NASA and its International Partners to carry out manned, scientific spaceflight well into the next millenium.