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ABSTRACT

This paper will cover the primary activities involved in conducting Spacelab flight operations. Spacelab flight operations are characterized by a unique partnership between the operators of the Space Transportation System (STS) and the Mission Management organization. This partnership involves both the activities of the flight control personnel and the flight crew and must exist as an integrated team in order to be able to successfully complete a Spacelab flight.

This paper will discuss an overview of how this partnership functions from the initial planning phase though the actual flight conduct. The responsibilities and functions of the flight crew members will be discussed as well as the make up of the flight control team. A typical flight scenario describing the basic operation of the Spacelab will be covered. A description of the Mission Control Center (MCC) and Payload Operations Control Center (POCC) capabilities will be given.

INTRODUCTION

The first Spacelab flight will be a new experience when compared to previous U.S. manned space flights. Not only will this flight involve a U.S.-developed Orbiter and a European-developed Spacelab, but it will also involve a truly unique partnership between the STS flight operations team and the Mission Managers team to carry out a very complex mission. The two major partners must work together over the span of years to be able to finally conduct a safe and productive mission. This partnership begins early in the planning phase on the basis of determining operational feasibility and gradually grows in level of effort through the final planning and flight phases.

The STS flight operations team is comprised of the flight controllers in the MCC at the Johnson Space Center (JSC) and the basic flight crew made up of a Commander, Pilot, and Mission Specialists. There are also many other people at JSC associated with the planning and preparation of a successful flight operation. These people are involved in the development of the flight profile, the implementation of the mission control facilities, and the training and simulations associated with preparation of the flight operations team for the mission. The STS flight operations team is also responsible for the conduct of the verification flight test (VFT) activities associated with the first two Spacelab flights.

The Mission Managers payload operations team is responsible for the part of the mission having to do with the operation of the experiments, and the planning and direction of this activity will be focused in the JSC Payload Operations Control Center (POCC). The POCC is a flight operations facility especially designed to be used for controlling payload operations and is located in building 30 at JSC on the same floor as the STS flight control areas. The close proximity of the POCC to the STS Flight Control Room will allow for the rapid and easy interaction between the two partners in the operation necessary to conduct such a mission.

Onboard the Orbiter and Spacelab exists another unique partnership, the flight crew made up of STS career astronauts and payload specialists working together in a team effort to keep the Orbiter and Spacelab working smoothly to support the experiment operations. The Spacelab 1 mission flight crew will operate the spacecraft on two 12-hour shifts which will provide round-the-clock operations for the total flight. The MCC and POCC will be operated on a 24-hour-per-day basis to provide the necessary timeline planning and vehicle systems surveillance.

PREFLIGHT PLANNING

The flight operations activities in support of a Spacelab mission normally begin with the receipt of the payload mission requirements, approximately 2 to 3 years prior to the scheduled launch date. During this early timeframe as shown in Figure 1, one or more compatibility assessments may be performed for the purpose of identifying and evaluating potential impacts associated with supporting the proposed payload mission.

The detailed flight operations preflight planning activities are initiated at some point in time after the Cargo Integration Review, which is conducted approximately 18 months prior to launch to assure that the payload is physically and operationally compatible with the STS. The time to conduct the detailed preflight planning activities will be a function of the mission complexity as well as the number of times a given type of flight has already been flown. These planning activities can generally be categorized into four interdependent functions: (1) flight design, (2) crew activity planning, (3) flight operations support planning, and (4) training planning and development. Each of these fucntions, as discussed below, are accomplished through the joint efforts of both the JSC flight operations team and the payload or user team.

The end result of the flight design activity is a detailed trajectory and flight profile that includes such information as maneuver sequences, attitude and pointing, orbital parameters, consumable analyses, and communications coverage. The detailed trajectory and flight profile will be prepared by JSC approximately a year before launch for complex and new types of flights based on user requirements such as approximate launch date, mission duration, altitude and inclination. It then becomes the basis for much of the other planning activities.

Crew activity planning is the analysis and development of required activities to be performed by the crew. Crew activity timelines (refered to as the Crew Activity Plan or CAP) plus any necessary procedures and reference data to accomplish the flight are developed by both the JSC STS operator and user and stowed onboard in the STS and payload flight data files (FDF). Typical FDF components are listed in Figure 2.

The STS Summary Crew Activity Plan will be developed in a time frame compatible with the need date of the Payload Operator. This document incorporates the Reference Flight Profile and schedules crew activities for the STS flight phases (launch, rendezvous, entry, etc.), crew work/rest cycles, and crew personal and system maintenance periods. The STS Summary CAP will be sent to the user with the Reference Flight Profile to serve as a baseline for the payload crew activity planning and scheduling that must be performed.

The user will then develop the payload procedures and produce a Payload Summary Crew Activity Plan that is consistent with STS constraints and schedules and with the scientific activities necessary to accomplish the payload flight requirements. Some modifications to the STS activities may be needed to enhance or optimize the payload activities; the intent is to accommodate the payload flight requirements as completely as possible within the planning resources limits, while maintaining STS vehicle and crew safety limits.

The STS crew activity planners will combine the payload activities with the STS activities to create a single Integrated Summary Crew Activity Plan. Those STS activities required to support the payload activities will also be scheduled.

Flight Operations Support Planning is that set of tasks which must be accomplished to ensure that STS systems and ground flight control operations can adequately support the proposed flight. It also includes that planning performed to ensure a smooth execution of the flight itself. Inputs from the user and the results of the analyses performed during flight design and crew activity planning are the primary inputs to the flight operations support planning activity. These inputs are used in the development (or revision) of the following flight controller documentation:

- STS Integrated Flight Rules
- Console Handbooks
- Command Plan
- STS Comm and Data Plan
- STS Systems Handbooks
- MCC/Network Support Plan
- Systems Operating Procedures
- MCC/POCC Interface Procedures
- Flight Control Operations Handbook
- Flight Software Documentation

Also accomplished during this planning period are detailed STS systems and consumables analyses for the flight, using the Reference Flight Profile and the Crew Activity Plan as the basis for the analysis. As a result, consumables budgets and redlines for the flight are produced.

The training preparation task for a specific flight begins with the determination of training requirements. If new facilities are needed, they must be identified far enough in advance to allow funding and design work. Once the training requirements have been identified, standardized training plans will be modified to fit the flight requirements, the training facilities will be scheduled, the simulation scripts written, and the actual training performed to support both flight crew and flight controller tasks. All STS-related training, both for onboard and flight control personnel, is the responsibility of JSC. All payload-related training is the responsibility of the user. Close coordination is, therefore, required to achieve a compatible and balanced training plan.

FLIGHT OPERATIONS PROFILE

Flight operations is comprised of six distinct phases; prelaunch, powered flight, activation, operations and maintenance, deactivation, and entry. The prelaunch phase is a KSC function; however, several hours before launch, vehicle data will be transmitted to JSC for display to the Flight Control team. Spacelab flights that consist of a manned module will normally be launched partially activated and thus be transmitting data that must be monitored by the flight crew and Flight Control team. Pallet-only Spacelab missions will

normally be launched in an unpowered or passive mode, and will not require system monitoring.

Prelaunch operations begin with flight crew ingress approximately 1-1/2 hours prior to launch. After crew entry into the Orbiter, the mission specialist will have selected Spacelab data displayed on a CRT (Figure 3) for monitoring the health of systems that had been activated. There is also a panel, known as R-7 (Figure 4), that provides control of the activated systems. During the powered flight period and until Spacelab activation starts on orbit, the mission specialist, with Mission Control Center assistance, will make the determination of Spacelab system health and the need to switch to a secondary system.

Orbital insertion will be achieved approximately 45 minutes after launch when the Orbiter Maneuvering System (OMS)-2 burn is complete. Then the Orbiter systems will be reconfigured to provide additional power and cooling for Spacelab. At approximately 1:25 hours after launch the payload bay doors will be opened. Spacelab activation can begin approximately 1:40 hours after launch.

Spacelab systems are activated in a logical manner to support flight crew entry into the Spacelab module about 2 hours after launch. The mission and payload specialist(s) can then enter Spacelab for inspection, and unstowing of experiment equipment for setup and operations. Mission-dependent equipment, such as the high rate multiplexer, high data rate recorder, scientific airlock, viewing window heaters, experiment power and cooling distribution subsystems are then activated as required.

The on-orbit operations and maintenance (housekeeping) will have assistance from Mission Control for the first several Spacelab flights. During later mature operations, the flights will become more autonomous and require less support from Mission Control. On-orbit duties, other than system monitoring and necessary reconfiguration, will include filter cleaning. LIOH canister changeout and condensate water dumping. Consumables management is an ongoing duty. If the average electrical power usage is above the premission planning levels, the mission may have to be shortened. Nitrogen usage for scientific airlock repressurization is also restricted to planned usage.

Preparation for deactivation will start about 12-16 hours before entry with Spacelab deactivation completed by 4 hours prior to entry. All equipment must be stowed and secured, tunnel and airlock hatches closed, and subsystems reconfigured to support the partially powered Spacelab during entry.

The same CRT display used from prelaunch to activation is called up to support system monitoring from deactivation to rollout after landing at KSC.

FLIGHT CREW OPERATIONS

The flight crew for any Spacelab flight will be tailored to meet the specific needs of the mission. All missions will utilize a Commander (CDR), a Pilot (PLT), and one or more Mission Specialists (MS). One or more Payload Specialists will be utilized as required to perform highly unique or specialized tasks required by specific experiments. The flight crew, while made up of individuals selected for their skills in a particular area will function together as the inflight team to operate the Orbiter, the Spacelab, and the experiments in a coordinated manner to satisfy the payload objectives.

During prelaunch operations, the crew's attention will be dedicated to launch preparations of the Orbiter and the Spacelab. Normally, little will be done in support of experiment operations until after Spacelab activation. The CDR and PLT will be devoted to the readiness of the Orbiter for launch, and the task of operating the Orbiter. While the CDR and pilot are completely involved in the tasks associated with flying the Orbiter, the MS is responsible for monitoring the health of the Spacelab and whatever payload activity necessary, as well as some Orbiter systems monitoring. The Payload Specialist(s) will basically be able to sit back and enjoy the launch phase. The CDR, PLT, and MS will have voice communications with the Mission Control Center and the PS will be able to monitor the voice loops and talk to the other crew members on the intercom.

Many of the Spacelab flights will have experiment operations conducted around the clock and the work will be scheduled over two shifts. Some of the dedicated life science missions may be conducted on a single shift basis though. For flights like Spacelab Missions 1 and 2, one shift of crew members will be busy activating the Spacelab and beginning experiment operations while the second shift will be settling down for 8 hours of sleep so they will be rested for their first shift of experiment operations. Normal team assignments will include the CDR, one MS, and one PS on one team; and the PLT, one MS, and one PS on the second team.

The activities required by the crew to conduct experiment operations will vary considerably from mission to mission. Pallet-only missions will be conducted from the Orbiter aft flight deck, while missions utilizing the manned module will involve operations split between the aft flight deck and the interior of the module. It is during the time of Orbital experiment operations that the team aspect of the total crew operation is evident towards achieving the payload mission objectives.

Consider an experiment requiring maneuvering of the Orbiter in a precise relationship to the field lines of the Earth's magnetic field. This type of experiment would use the CDR or PLT to maneuver the Orbiter, the MS to configure the Spacelab and Orbiter systems to support the experiment operation, and the PS to monitor and operate the experiment equipment. The MS and PS are probably involved at the same

time in monitoring the status of other experiments that are operating simultaneously.

Frequently the crew will be split between the aft flight deck area and the module or the Orbiter mid-deck in order to operate the Orbiter and Spacelab at the same time experiments are being conducted. There will be two active voice links to the ground, one with the MCC for operation of the Orbiter and the other one with the POCC for operation of the experiments. The MS will act as the inflight focal point for the inflight activities integrating the inflight requirements of both the STS and payload into a single workable plan.

MISSION CONTROL CENTER AND PAYLOAD OPERATIONS CONTROL CENTER

During the on-orbit phase, flight operations support will be provided jointly by the Mission Control Center (MCC) and JSC Payload Operations Control Center (POCC). In contrast to the STS flight operator, who is responsible for real-time support of STS elements (including the Spacelab systems) the POCC team under the direction of a POCC Director will be responsible for real-time payload systems and science support.

The flight operations concept that has evolved as a baseline for the STS operations organization within the MCC consists of three basic elements: a Planning Operations Management Team (POMT), multipurpose support groups and a small Flight Control Team. Reference Figure 5.

The POMT serves primarily to perform a preflight function, with management responsibility for the detailed development, planning, scheduling, and status of all STS flights.

The multipurpose support teams provide direct support for preflight planning and training activities and, during the flight, provide systems and trajectory statusing support to the Flight Control Room on a routine and periodic basis.

Of the three basic elements in the new operations concept, the Flight Control Team is the only "flight dedicated" element. This team is on duty 24 hours per day for the duration of each STS flight. This small group, headed by a Flight Director, provides direct, real-time support to the crew through flight monitoring and assistance during launch and entry, and by following the flight activities during the orbital phase. The intent of the "flight-following" approach is to provide minimum routine support services and to stay abreast of the flight situation in the event of a need for major maneuvers, or timeline changes, or in response to a contingency. This team will also direct response from the multipurpose support groups to contingency situations. Since each Flight Control Team is dedicated to a single flight, several teams can be active at any one time in the MCC, supporting simultaneous flights and vehicle test or simulation activities.

Coordination between the MCC and POCC is conducted primarily by the Flight Director and the Payload Officer located in the Flight Control Room. The Flight Director will provide the management interface for all real-time decisions which involve joint STS and payload interests. The Payload Officer is the primary working interface for coordinating payload operations with the STS flight operations.

The JSC POCC will provide the facilities and accomodations necessary to monitor and control the payload operations. Normally the responsibility for managing and staffing the JSC POCC lies with the user or Mission Manager; thus, the organization structure is flexible and may vary somewhat from flight to flight. However, the user is expected to designate a Payload Director within the POCC who has overall responsibility for all payload operations decisions.

Generally, the same data that are available to the STS controllers within the Mission Control Center are also available to the user in the POCC. The POCC also provides similar capability to the MCC for command uplink and voice communications both with the onboard crew and with flight controllers in the MCC. Figure 6 provides a summary of the standard capabilities in the JSC POCC for data monitoring, command and control, accommodations, and services.

TYPICAL PREFLIGHT PLANNING FLOW FOR SPACELAB FLIGHTS

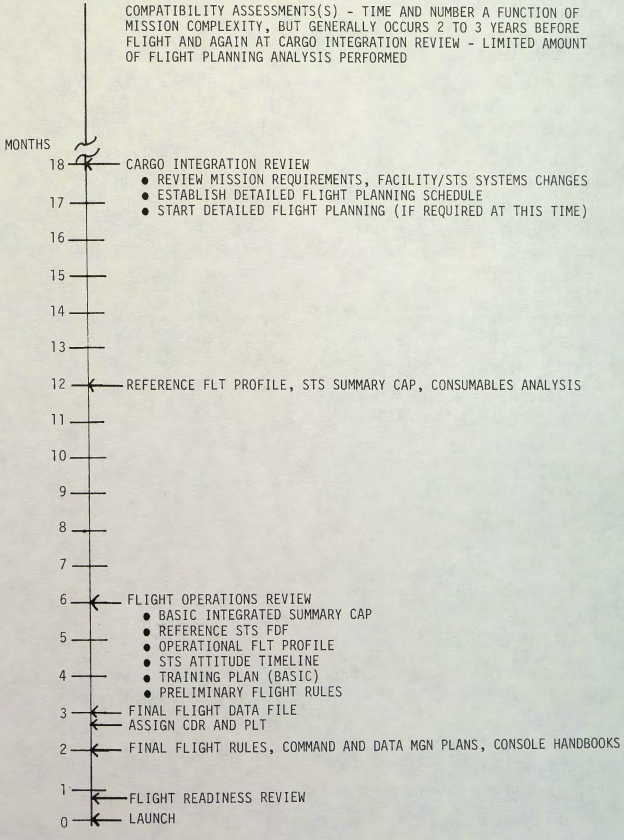

Figure 1.

TYPICAL FDF COMPONENTS
OFT/OPS

STS FDF

ALL FLIGHTS

LAUNCH C/L
ENTRY C/L
RESCUE C/L
UPDATES BOOK
STS CREW ACTIVITY PLAN
ORBITER SYS C/L
DPS DICTIONARY
ORBITER HK C/L
ORBITER SCHEMATICS
ORBITER MALFUNCTION PROC
PHOTO/TV OPS BOOK
STOWAGE BOOK
ORBITAL MAPS
OPERATIONAL STAR CHART
APPROACH CHARTS
CUE CARDS
  LAUNCH
  ENTRY
  ORB SYS OPS
  ORB/PL INTERFACE
  EVA PREP/POST
ZERO-G RESTRAINTS
NOTE BOOKS
WORLD MAP BOOK

FLIGHT VARIABLE

SPACELAB SYS C/L
SPACELAB SOFTWARE C/L
SPACELAB ACTIVATION C/L
SPACELAB DEACTIVATION C/L
SPACELAB SCHEMATICS
SPACELAB MALFUNCTION PROC'S
CUE CARDS
  SL MODULE SUBSYSTEM OPS
  SL PALLET SUBSYSTEM OPS
EVA C/L
RENDEZVOUS BOOK
DEPLOY/RETRIEVE C/L

PAYLOAD FDF

PAYLOAD EXP C/L
LOG BOOKS
PAYLOAD SCHEMATICS
PAYLOAD MALFUNCTION PROC'S
PAYLOAD CREW ACTIVITY PLAN
EARTH OBS BOOK
PAYLOAD EXP SUMMARIES
PAYLOAD EXP REFERENCE DATA
CUE CARDS
  EXP OPS
EXPERIMENT STAR CHART

Figure 2.

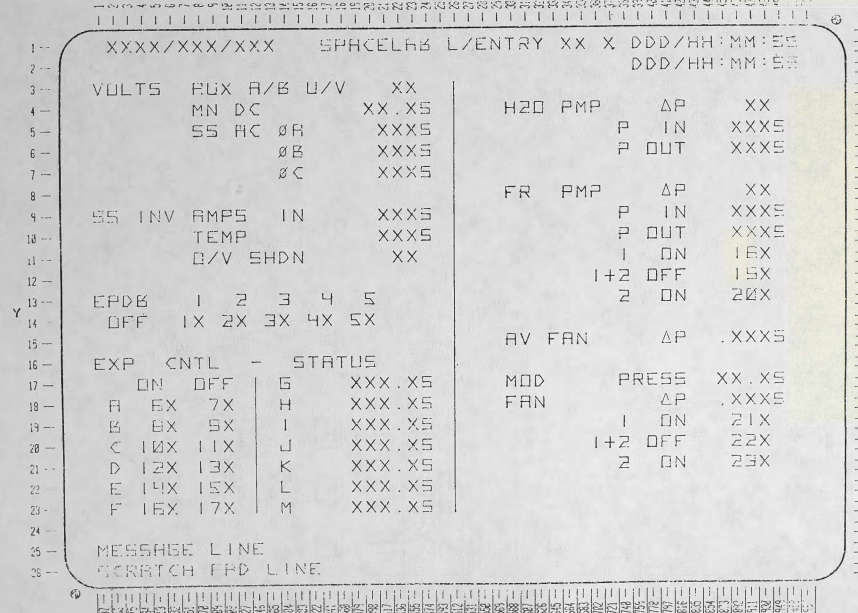

Figure 3. Spacelab Data Displayed on CRT

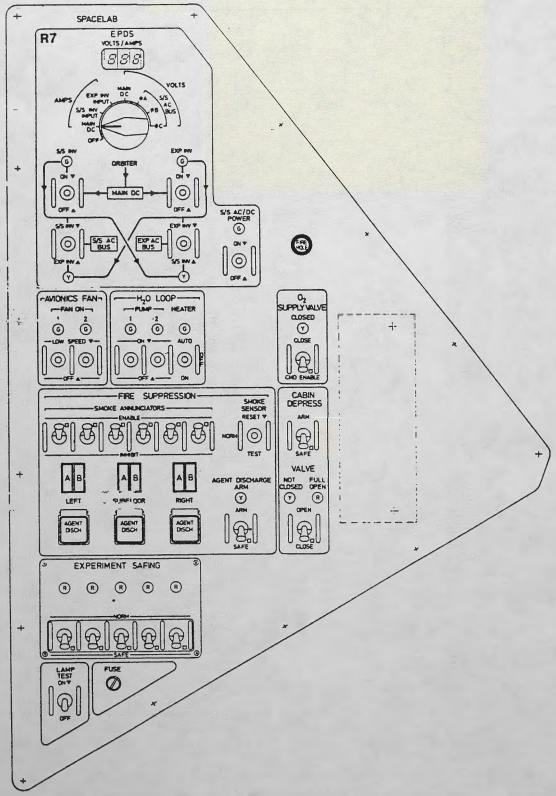

Figure 4. Spacelab R-7 Panel Control

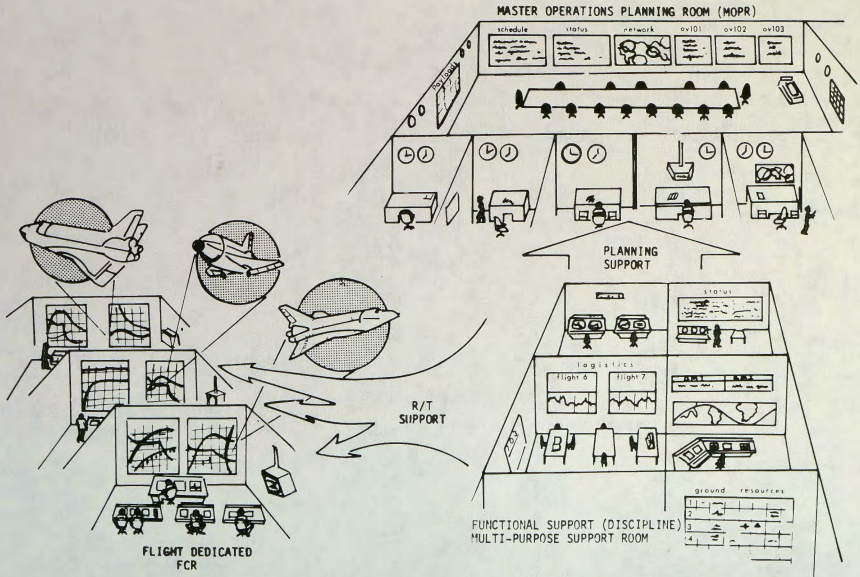

Figure 5. STS Flight Operations Concept

JSC POCC STANDARD CAPABILITIES

FACILITY	• CONSOLES, STOWAGE CABINETS, CHAIRS, TABLES, RECORDERS, TELEPHONES, HEADSETS FOR VOICE MONITORING, CONFERENCE AREAS, PROVISION FOR INSTALLATION OF USER-PROVIDED EQUIPMENT.
VOICE COMMUNICATIONS	• VOICE LOOPS (BOTH INTERNAL AND EXTERNAL TO JSC) FOR COORDINATING STS/PAYLOAD FLIGHT PLANNING ACTIVITIES. • TWO-WAY VOICE COMMUNICATIONS WITH CREW DURING FLIGHT. • VOICE TRANSCRIPTS AND/OR VOICE TAPES OF CREW CONVERSATIONS. • RECORDING AND PLAYBACK
COMMAND DATA (UPLINK)	• COMMANDS CAN BE INITIATED FROM AN ASSIGNED CONSOLE POSITION IN THE POCC • COMMAND HISTORIES CAN BE RETRIEVED FROM REAL-TIME PROCESSORS AND DISPLAYED ON THE CONSOLE. COMMAND HISTORIES MAY ALSO BE OBTAINED FROM OFF-LINE PROCESSORS (PRINTOUTS OR TAPES).
TELEMETRY DATA	• REAL-TIME MONITORING OF THE STS SYSTEMS DATA (SAME CAPABILITY AS MCC CONTROLLERS). • REAL-TIME PROCESSING AND DISPLAY OF PAYLOAD COMMAND AND CONTROL DATA. • REAL-TIME PROCESSING AND DISPLAY OF SCIENCE DATA CONTAINED IN INDEPENDENT SCIENCE DOWNLINKS. • NEAR REAL-TIME PROCESSING AND DISPLAY OF SCIENCE DATA CONTAINED IN INDEPENDENT SCIENCE DOWNLINKS.
DATA PROCESSING	• STANDARD UNIT CONVERSION, LIMIT SENSING, AND SIMPLE ARITHMETIC COMPUTATIONS. • ANALYSIS PROGRAM SUPPORT (THE AMOUNT OF SUPPORT WILL BE NEGOTIATED ON A CASE-BY-CASE BASIS).
TRAJECTORY	• ALL ONGOING TRAJECTORY AND ORBITER ATTITUDE INFORMATION WILL BE MADE AVAILABLE TO USERS AS REQUIRED. • ORBIT PHASE PROCESSING OF TRAJECTORY WILL BE PERFORMED AS REQUIRED TO SUPPORT PAYLOAD OPERATIONS.
OUTPUT DEVICES	• DIGITAL TELEVISION EQUIPMENT DISPLAYS • STRIP CHART RECORDERS • CLOSED CIRCUIT TV EQUIPMENT
VIDEO DOWNLINK	• CAN MONITOR IN REAL-TIME ALL STS-COMPATIBLE VIDEO DOWNLINK • VIDEO TAPES AVAILABLE POSTFLIGHT
REMOTE LOCATION INTERFACES	• TWO-WAY FACSIMILE • ACCESS PORTS AVAILABLE FOR TRANSMISSION OF VEHICLE RATE DIGITAL EXPERIMENT DATA AND FM ANALOG DATA. • REAL-TIME DATA DISPLAY

Figure 6.