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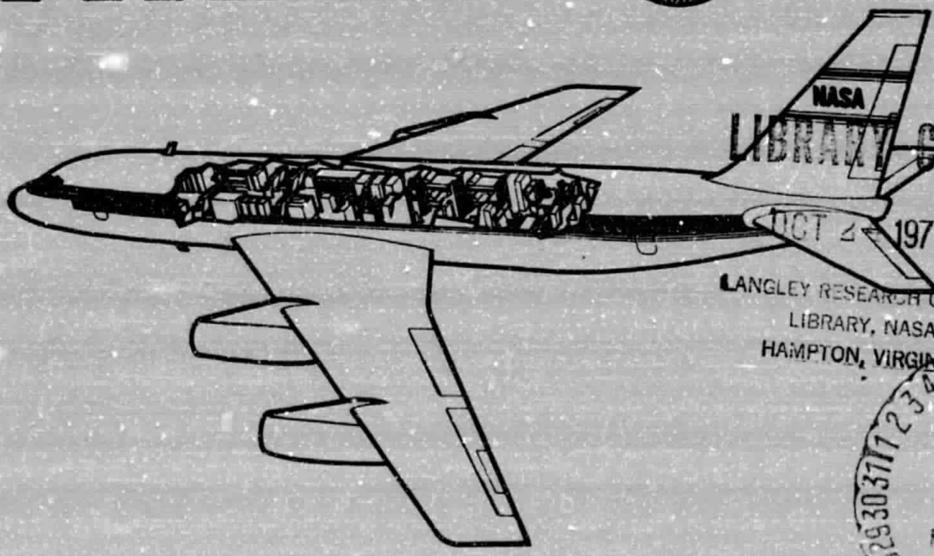
ASSESS II MISSION



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EXECUTIVE SUMMARY

NASA/ESA CV-990

SPACELAB SIMULATION

(ASSESS II)

A Joint Endeavor By

The National Aeronautics and Space Administration

and the European Space Agency

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1. INTRODUCTION

This Executive Summary represents an initial report and briefly covers the highlights of the ASSESS* II Project. The report is in three main sections. The first parts cover factually, without analysis, the background, project organization, and project implementation. These first parts are intended to serve as background for the last section which presents results and brief evaluations of major issues and activities of particular interest in Spacelab planning.

Information for this report was obtained from the records of a team of observers, a general mission debriefing, interviews with participants, and the mission documentation. NASA and ESA personnel joined in preparation of this report immediately following the close of the mission.

2. THE ASSESS PROJECT

The ASSESS II project was a detailed simulation of Spacelab operations using the NASA/Ames Research Center CV-990 aircraft laboratory (Fig. 1) to represent the Shuttle carrier and Spacelab pressurized module/pallet combination to carry a complex payload of experiments in a manner similar to that planned for the Spacelab era. The project was carried out for the benefit of Spacelab planning to identify and analyze cost-effective techniques for addressing management and operational acitivities. It was a cooperative project between NASA and ESA with payload and flight responsibilities assigned to those organizations which have been given those responsibilities for early Spacelabs.

The project covered a period of approximately eighteen months from initial approval to flight, and studied the full range of Spacelab-type activities including:

- Management interactions
- Experiment selection
- Hardware development
- Payload integration and checkout
- Mission Specialist (M/S) and Payload Specialist (P/S) selection and training
- Mission Control Center/Payload Operations Control Center interactions with ground and flight problems
- Real time interaction during flight between Principal Investigators (PIs) and the Mission Specialist/Payload Specialist flight crew
- Retrieval of scientific data and analysis

* ASSESS is an acronym for Airborne Science/Spacelab Experiments System Simulation. A list of other acronyms and abbreviations is given on page 44.

Figure 1. CV-990 Aircraft and Living Quarters

3. BACKGROUND AND ORGANIZATION

3.1 Mission Background

The ASSESS Program was initiated by the Airborne Science Office (ASO) at NASA/ARC to identify simplified low-cost techniques used by ASO in integrating and carrying experiments aboard airborne laboratories which might be applied effectively to Spacelab. Several ASSESS missions to simulate Spacelab operations were conducted prior to ASSESS II including one NASA/ESA joint mission aboard the CV-990 in 1975. [Ref. 1]

A decision was reached in late 1975 to conduct ASSESS II as a joint mission sponsored by NASA Office of Applications (OA) and Office of Space Flight (OSF) together with ESA. Operational costs were shared. Experiments from the U.S. were totally funded by NASA, while in Europe the basic experiments were funded nationally with ESA providing funds to interface the experiments into the ASSESS Mission. It was agreed to involve planned Spacelab management elements to test and evaluate interface activities. MSFC was assigned responsibility for the payload and appointed a Mission Manager, KSC was given responsibility for Launch Site Payload Processing, and JSC was assigned Flight Operations--all working closely with ARC where the aircraft was stationed and where the final integration and flight phase would be conducted. In Europe, their payload responsibility was assigned to ESA/SPICE.

The mission received final approval in March 1976, and "launch" occurred 14 months later on May 16, 1977.

3.2 Mission Objectives

a) Science related
- Evaluate experiment selection procedures
- Evaluate participation of PI in mission planning and implementation, and utilization of an Investigators' Working Group (IWG) chaired by a Mission Scientist
- Maximize science data

b) Management
- Study proposed NASA and ESA/SPICE Spacelab payload management concepts and interface relationships
- Evaluate Mission Manager, Mission Specialist, and Payload Specialist roles in mission planning and implementation

c) Analytical Engineering and Mission Planning
- Evaluate the methods and effectiveness of performing analytical system engineering, mission flight interface definition, and interface control

d) Payload Specialist Selection and Training
- Evaluate methodology of Payload Specialist selection and training
- Determine practicability of a PI as a Payload Specialist

e) Mission Specialist Selection and Training
- Evaluate the Mission Specialist responsibilities concerning:
    1) requirements for managing and operating the experiment support equipment
    2) in-flight coordination and integration of the payload operations

f) Ground Operations
- Identify ground operations and testing requirements for efficient experiment integration and checkout
- Evaluate Mission Specialist, Payload Specialist, and PI involvement in experiment ground operations
- Understand and gain an appreciation of integration activities pertinent to Spacelab payloads

g) Mission Planning and Flight Operations
- Assess methods and degree of real time experiment/mission planning for Spacelab missions
- Evaluate concept of proxy operation and maintenance of experiments by P/S during flight operations
- Evaluate POCC concept and operating procedures

h) Documentation
- Develop and evaluate minimum cost documentation approach consistent with Spacelab payload requirements

3.3 Project Guidelines

Major ASSESS II project guidelines were as follows:

- Maximum Spacelab reality within funding limits and the limitations inherent with aircraft operation
- Ten-day mission with payload crew confined to the aircraft and contiguous living quarters with one aircraft flight planned for each 24-hour period. The total of the aircraft flights and confined periods between flights to represent a single Spacelab mission
- Payload crew to consist of two European Payload Specialists to operate the ESA experiments, two U.S. Payload Specialists to operate the NASA experiments, and one Mission Specialist. No cross-training between NASA and ESA experiments except for the ESA medical experiment involving all Payload Specialists
- Communications with the ASSESS Spacelab crew to conform to actual Spacelab communications procedures as far as practicable. Communication to be established between the ground and the aircraft throughout flight periods
- Centralized experiment control panels to be provided in the aircraft
- The aircraft flight crew (pilot, copilot, navigator) not to be included in the simulation exercise
- A few unconstrained personnel (called ghosts) to participate in the flights to assure continuous operation of basic aircraft systems that were not designed for operation from the centralized control panels

3.4 Mission Management

3.4.1 Mission Steering Group (MSG)

An MSG was established at the beginning of the project with representatives from every major participating organization. The MSG was unique to ASSESS, and is not planned for Spacelab. The participating NASA Headquarters program offices were represented along with MSFC, JSC, KSC, ARC, and ESA Headquarters and ESA/SPICE. The MSG was cochaired by representatives from NASA/OA and ESA/SPICE. Four meetings were held.

Functions of the MSG were to provide overall guidance to the simulation in order to achieve maximum benefit for Spacelab planning. Accordingly, the MSG established the mission guidelines and provided an overall management forum for resolution of inter-center/agency responsibilities.

3.4.2 Management Structure and Responsibilities

Figure 2 shows the management structure, which with the exception of the MSG, corresponds closely to that planned for early Spacelab missions.

3.4.3 Mission Scientist and Investigator Working Group (IWG)

A Mission Scientist, along with a Deputy Mission Scientist, were appointed by MSFC. ESA also appointed a Mission Scientist from ESTEC.

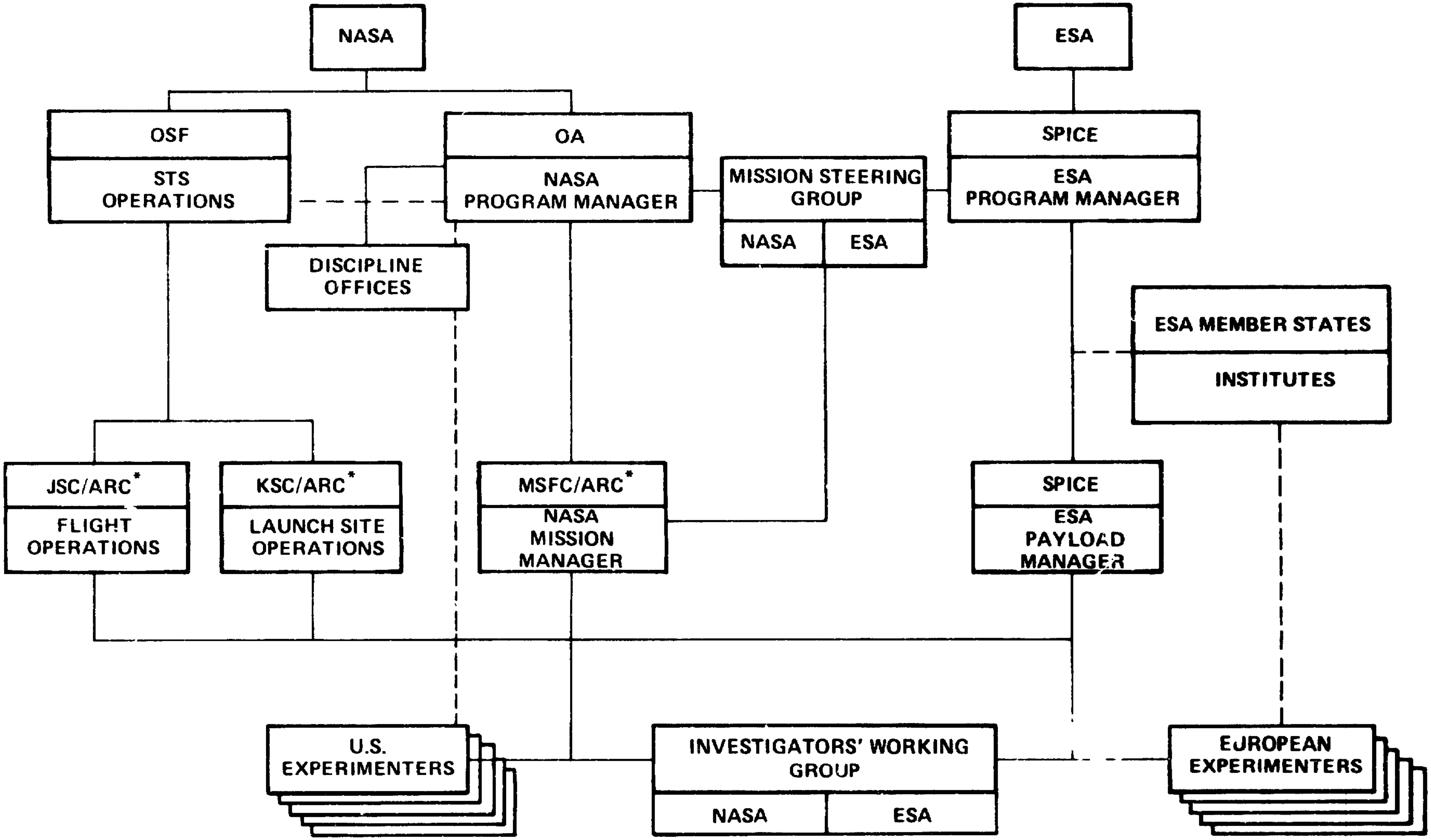
An Investigators' Working Group (IWG) was established early in the ASSESS II Project, and was made up of a PI from each experiment. The Mission Scientist from MSFC chaired the IWG with the ESA Mission Scientist as cochairman. Functions of the IWG were to provide a forum for PI discussion and to make recommendations concerning science plans and priorities for the mission. NASA and ESA IWG members provided recommendations to their respective managements for Payload Specialist selection. Two meetings were held.

3.4.4 Mission Specialist (M/S)

The Mission Specialist, from the scientist astronaut group at JSC, was recommended to the Mission Manager and approved by the Program Manager. A second Scientist Astronaut from JSC was appointed to serve as backup.

The Mission Specialist was responsible administratively to JSC, but functionally reported directly to the ASSESS II Mission Manager at MSFC. The role of the Mission Specialist for ASSESS II was established as follows:

- To act as the in-flight alter ego of the Mission Manager and to be generally responsible for coordination and conduct of combined payload operations during flight
- To be the single interface between the Payload Specialists and STS flight crew (pilot/copilot)
- To be responsible for all aircraft experiment-support systems such as power distribution, central data system, etc.



* ARC SUPPORTED MSFC, KSC, AND JSC IN THEIR RESPECTIVE FUNCTIONS.

Figure 2. ASSESS II Management Structure

- Upon approval of the NASA Program Manager, to be trained to act as a Payload Specialist and operate experiments during the flight mission
- To work with the POCC, MCC, Payload Specialists, and Flight Commander (Pilot) to solve in-flight problems caused by equipment failures and/or flight conditions leading to changes of science priorities

3.4.5 Payload Specialists (P/S)

NASA selected two P/Ss from JPL. Thirty-three P/S nominations were submitted, 31 of them from JPL. To reduce training and travel costs, NASA assigned the Assistant Mission Manager from MSFC as the single backup P/S, who thus served a dual role and divided his time between mission management activities and P/S training. ESA selected four P/Ss: one from the University of Southampton, one from the ESA Space Science Department, and two from DFVLR. A dozen candidates applied. The ESA plan was to appoint two as prime P/Ss and two as backup. In reality, ESA decided, with NASA Program Manager concurrence, to change one of the P/Ss during the mission flight period so that three of the ESA P/Ss participated as payload flight crew members.

The Payload Specialists reported administratively to JPL and ESA respectively. Prior to arrival at Ames, they reported managerially to the MSFC Mission Manager and to the ESA Payload Manager respectively. After arrival at Ames, they were integrated into the mission management team. In addition to their flight role, they actively participated in the ground operation and test phase.

3.5 Flight Payload

Experiments selected for the ASSESS II payload are given in the table on the next page.

Some elements of the payload were considered to be experiment support devices analogous to Spacelab experiment support systems to be operated by the STS organization. These included aircraft provided systems such as the experiment power distribution system, the ADDAS data handling system, a water vapor overburden radiometer, and two gyrostabilized mirrors.

Most equipment was mounted in or on standard CV-990 equipment racks. Experiment control functions, except for the IR telescope, were centralized in five Spacelab-like racks which were grouped in the forward area of the aircraft for operation by the Payload Specialists. Figure 3 shows the payload in the aircraft including these control racks.

EXPERIMENTS FOR ASSESS II MISSION

ORGANIZATION	INSTRUMENTATION	MEASUREMENT
ESA Experiments		
Observatoire de Paris, Meudon France; Max Planck Institut, Garching, Germany; University of Groningen, Netherlands	30-cm open port telescope with TV tracking. IR Photometer and Fabry-Perot Tilting Filter Spectrometer	IR line spectroscopy and IR galactic cold cloud temperatures
University of Southampton, England	Image intensified integrating TV camera-near IR	OH Airglow wave structure
DFVLR-Oberpfaffenhofen, Institut f. Physik der Atmosphare, Germany	LIDAR (Light Emitting Detection and Ranging) -1 μm	Concentration of scattering aerosols in atmosphere
DFVLR-Bad Godesberg, Institut f. Flugmedizin, Germany, and NASA/Ames	Physiological sensors	P/S medical reaction to time and stress changes
Observatorio de Capodimonte/ Instituta de Physica, Firenze, Italy	Michelson Interferometer -sub mm	Chromospheric temperature
ESA/ESTEC	EMI measuring equipment	EMI characteristics of aircraft systems and payload
NASA Experiments		
NASA/JPL	Two synthetic aperture radars - X band and L band	Radar terrain maps for earth resources feasibility study
NASA/JPL	Microwave limb sounder -167 GHz	Spectral lines of trace gases in atmosphere
NASA/JPL	Laser Absorption Spectrometer -10.6 μm	Atmospheric ozone concentration
NASA/LaRC	Infrared heterodyne radiometer -10.6 μm	Atmospheric ozone concentration
NASA/GSFC	Swept and fixed band radio receivers VHF & UHF	Monitoring of selected communication band usage

Figure 3. Payload with Spacelab-type Racks in CV-990 Aircraft

4. MISSION IMPLEMENTATION

4.1 General

Figure 4, on page 11, shows the overall project schedule. Experiment preparation, integration planning, Payload and Mission Specialist selection and training at PI facilities, flight planning, and other associated activities took place over the first 10 months leading to integration of the European experiments at ESA/SPICE in Germany beginning in January 1977. System Level Payload Integration at ARC started in March, and required about a month. Launch Site Payload Processing on the aircraft also required a month, and ended in mid-May. The simulated Spacelab flight began on May 16, 1977, 14 months after final project approval.

4.2 Experiment Selection and Funding

European experiments were selected by ESA in April 1976, following an Announcement of Opportunity. Funding of these experiments was handled on a national basis with ESA adding necessary funds to support the activities peculiar to the ASSESS II Spacelab simulation.

NASA/OA decided initially to select experiments from their ongoing experiment program, and a baseline group comprised of five experiments was approved in May 1976. Because of shortness of time, OA emphasized the selection of experiment prototypes destined for the Spacelab era that had previously flown on the CV-990 aircraft. It was also recognized that one or two experiments might have to be dropped from the baseline because of development or funding problems. Iterations within NASA/OA delayed full solidification of the NASA payload for several months. Funding was finally distributed in December 1977, except for one experiment (from GSFC) which, because of special approval requirements, was not authorized and funded until February 4, 1977, the last day Program Management agreed to accept the experiment with any chance of success.

4.3 Investigator Requirements Document (IRD)

The IRD form was prepared by the MSFC Mission Management staff with a plan to cover, in a single document, all experiment interfaces for the project from hardware and data interactions through POCC and flight requirements. One IRD form was sent from MSFC to each experimenter, followed by visits of system engineers from ESA and NASA to each experimenter in June and November, 1976. During these visits, the PIs were assisted in filling in the requested information by the visiting engineers. At the close of these visits, the IRDs had been filled in to the extent possible at that time. No further effort was made to complete the IRDs after November 1976. Open items still remaining following the second round of visits were individually handled directly between the PIs and cognizant project management personnel.

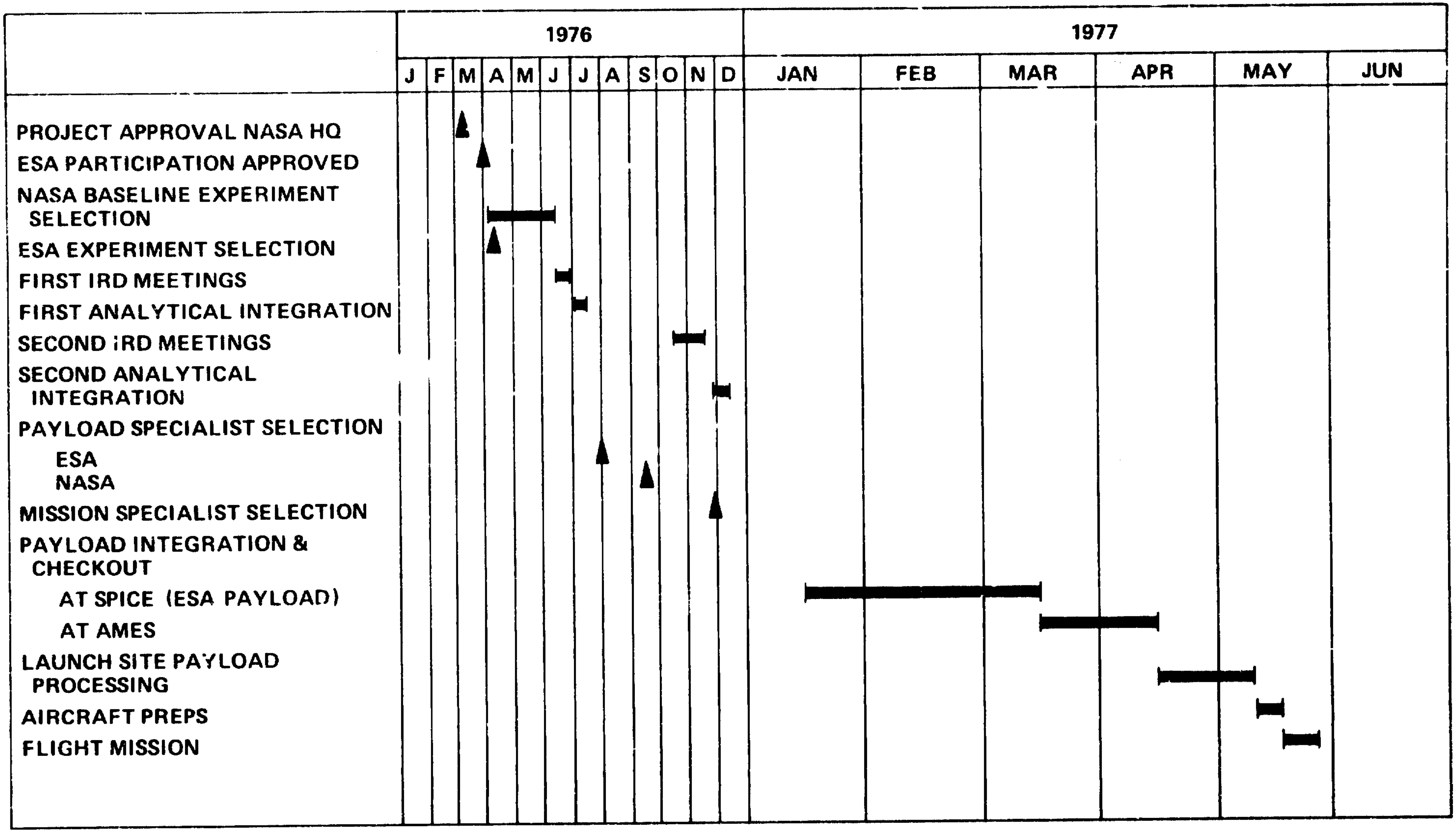


Figure 4. ASSESS II Schedule

4.4 Analytical Integration

Two formal analytical integration efforts were conducted at MSFC in July and December, 1976, utilizing information from the IRDs. The first session was organized into three basic groups to address Ground Operations, Flight Operations, and Payload Configuration. Many details were not available at that time, which permitted only gross planning in several areas. The initial look at flight operations did establish that it was possible to meet nearly all experiment objectives.

The second analytical integration at MSFC updated flight plans, arrangements for the POCC, and the aircraft configuration. Continuing changes in experiment configuration and coordination of data interfaces were handled by telephone and letter directly with ARC. Flight planning was iterated among MSFC, JSC, and ARC throughout the pre-flight period.

4.5 Investigator Working Group Activities

Two meetings of the Investigator Working Group (IWG) were convened immediately following each formal analytical integration activity in July and December, 1976. The IWG identified complementary science objectives and negotiated science scheduling and target allocations for flight planning. Analytical engineering results, mission plans, and schedules were presented to the IWG for discussion and iteration. The IWG also made recommendations regarding P/S selection.

4.6 Payload Specialist/Mission Specialist Selection and Training Activities

European P/S candidates were submitted by the participating PI organizations, DFVLR, and ESA. Screening tests were conducted on candidates for ESA by the DFVLR Institute of Aviation Medicine and the Lufthansa Medical Office for Flight Personnel. These tests were based on criteria for airline flight engineers. Using the results, ESA management, with recommendation from the European IWG members, selected four P/Ss to participate in ASSESS II--two to be later designated as prime, and two as backup.

In the U.S., the single P/S nominations from GSFC and LaRC were withdrawn, leaving 31 from JPL, where laboratory-wide advertisement had been conducted. JPL narrowed their nominations to two candidates who met the payload operator requriements issued by MSFC. The Assistant Mission Manager from MSFC was designated to serve as the sole backup P/S for U.S. experiments to save training and travel costs. These three were accepted by the IWG and mission management.

P/S training generally consisted of about one week of classroom-type training with each PI plus an additional two weeks of hands-on training with the experiment equipment at the PI laboratory. For secondary experiment assignments, they received only about one week of hands-on training at the PI laboratory. This hands-on training varied, since the schedule of single visits to the PI laboratories found the experimenter equipment in widely varying degrees of completion. The M/S did not visit the PI laboratories, but he did observe and train on aircraft experiment support systems on earlier CV-990 flights. Also, the U.S. P/Ss and the M/S participated in some of the analytical integration process at MSFC.

Further valuable training occurred during P/S and M/S participation in the payload integration process. The ESA P/Ss and the M/S (part-time) participated at SPICE in Europe in the ESA/SPICE integration and simulated mission operation of the European installed instruments. All P/Ss and the M/S participated (both interface and payload operation) in System Level Payload Integration and Launch Site Payload Processing at ARC. During this period, the NASA P/Ss received their training on the medical equipment.

4.7 Integration of ESA Payload in Europe

ESA brought all European experiments together at ESA/SPICE (Porz-Wahn, Germany) for centralized integration of their portion of the payload. Activities at this centralized site during the period from January 15 to March 15, 1977, included:

- Completion of experiment development and integration
- ESA acceptance testing
- EMI characterization and corrective action where necessary
- Flightworthiness verification
- Development and integration of experiment software
- Experiment integration on system level
- Interexperiment compatibility testing
- Mission Simulations
- Training of flight and ground support personnel

As part of the ESA integration activities, a CV-990 mockup was constructed (Fig. 5) with DFVLR support. Features of this mockup included flight crew living quarters and power and data handling support systems. In addition, a remote POCC was provided.

The integration activities were performed under ESA management by PI teams and the P/Ss, supported by DFVLR technicians. Further support was provided by an ARC safety engineer and a contract data processing engineer. ESA management involved in this integration were also very active in the later phases of the project at ARC. Experiment hardware was upgraded where necessary to meet flight standards, European payload level P/S training was completed, and operational timelines and procedures were exercised and consolidated. In addition, the interaction between the payload flight crew and the PIs on the "ground" was developed and practiced during simulated flights.

4.8 System Level Payload Integration (Level IV Integration)

System Level Payload Integration was the initial payload activity at ARC and accomplished total hardware and software integration with the "Spacelab" interface elements. This was the first time the entire payload came together. Both NASA and ESA provided compatibility and mission simulation testing and payload crew integrated training. The integration was performed using a combined NASA/ESA checkout team under the direction of the MSFC Ground Operations Manager with full participation of the PIs along with the P/Ss and the M/S. This approach was analogous to the MSFC plan for system level payload integration of the Spacelab I payload.

System Level Payload Integration was performed on the hangar floor (independent from the aircraft) using a Payload Checkout Unit (PCU) to simulate the onboard interfaces with experiments. Figure 6 shows a photograph of the integration layout. The experiments and associated cabling were arranged approximately like the planned flight configuration. The PCU fed simulated carrier housekeeping signals to the experiments and also interfaced data outputs planned for data handling on the aircraft. Principal activities included:

- Experiment preparation by the experimenter
- Physical/electrical integration with the PCU
- Experiment checkouts, calibrations, alignments, and software verification
- Experiment/PCU functional and compatibility tests
- A Simulated Mission Sequence Test
- Flightworthiness verification

Prior to experiment connection to the PCU for initiation of checkout, each PI listed his instrument status with identification of all known problems.

U. S. experiments were sequentially integrated upon delivery during a 10-day period. European experiments, which had been through an integration and operation sequence at ESA/SPICE, were delivered together and were integrated as a group within a short period (4 days). Combined NASA and ESA experiment integration and testing required an additionl 1½ weeks.

Experimenters and their staffs, along with the P/Ss and ARC technicians, performed hardware and cable installation of the experiments. Integration activities were conducted using MSFC system checkout procedures which incorporated individual PI generated experiment test sequences. MSFC imposed a uniform work control system for all integration activities of the payload checkout team which had the following features: identification of problems, authorization and scheduling of all test and problem solving activities, certification of all tests and problem corrections, and a complete log of open and closed items. After an experiment was integrated with the PCU, the PI worked on his experiment as required using the work control system. The PIs were requested to keep a log book to record activities and changes in their hardware.

The schedule was closely tracked using daily meetings to identify open items and to schedule all activities. Single shift operation was planned, but extensive calibrations (not previously requested by the PIs for system integration) combined with experiment and data interface problems, necessitated daily overtime and weekend operations.

At the end of this integration task, MSFC, supported by each experimenter and ESA management, certified the payload to KSC with identification of equipment status and all open items.

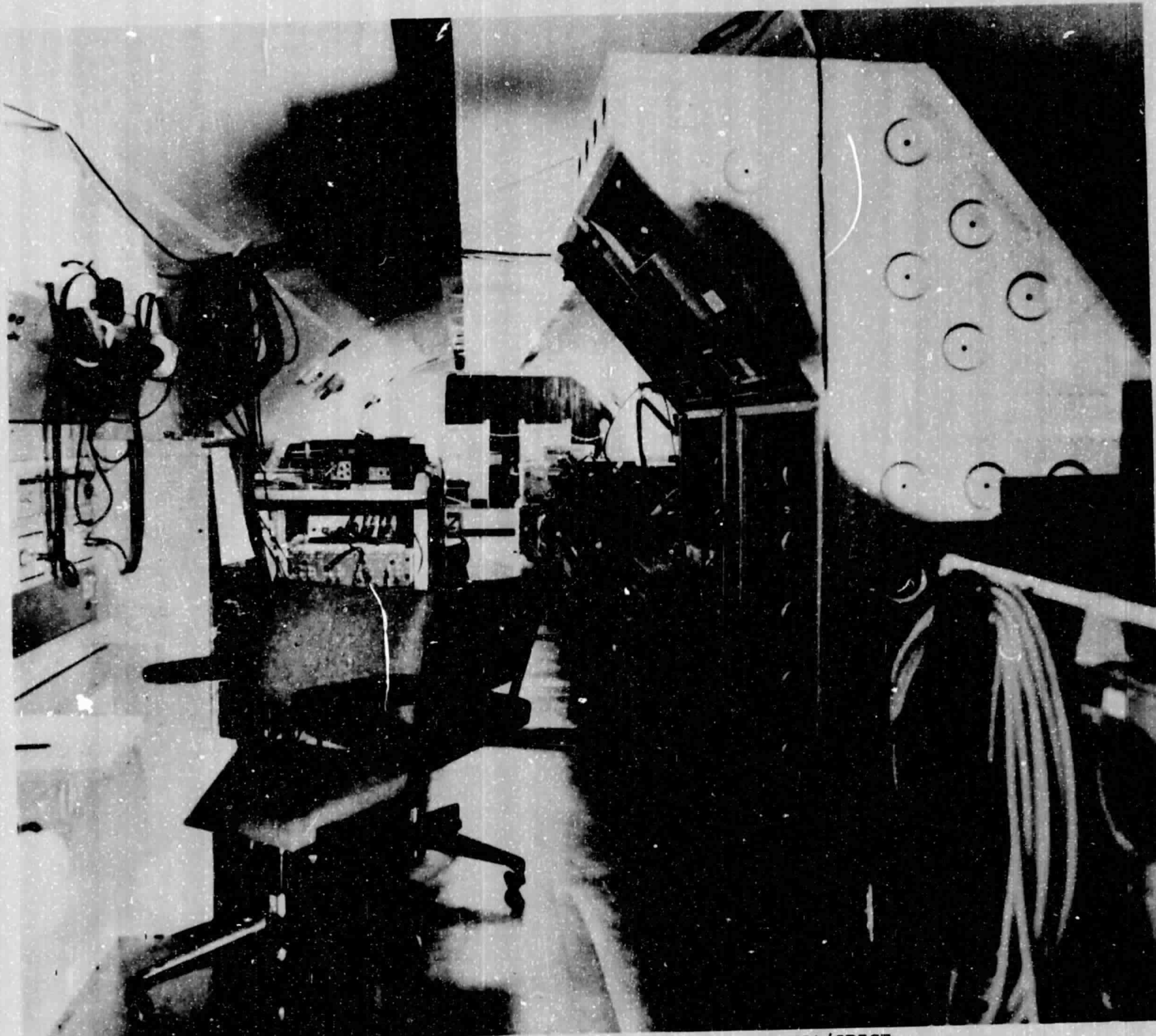


Figure 5. ESA Payload in CV-990 Mockup at ESA/SPICE

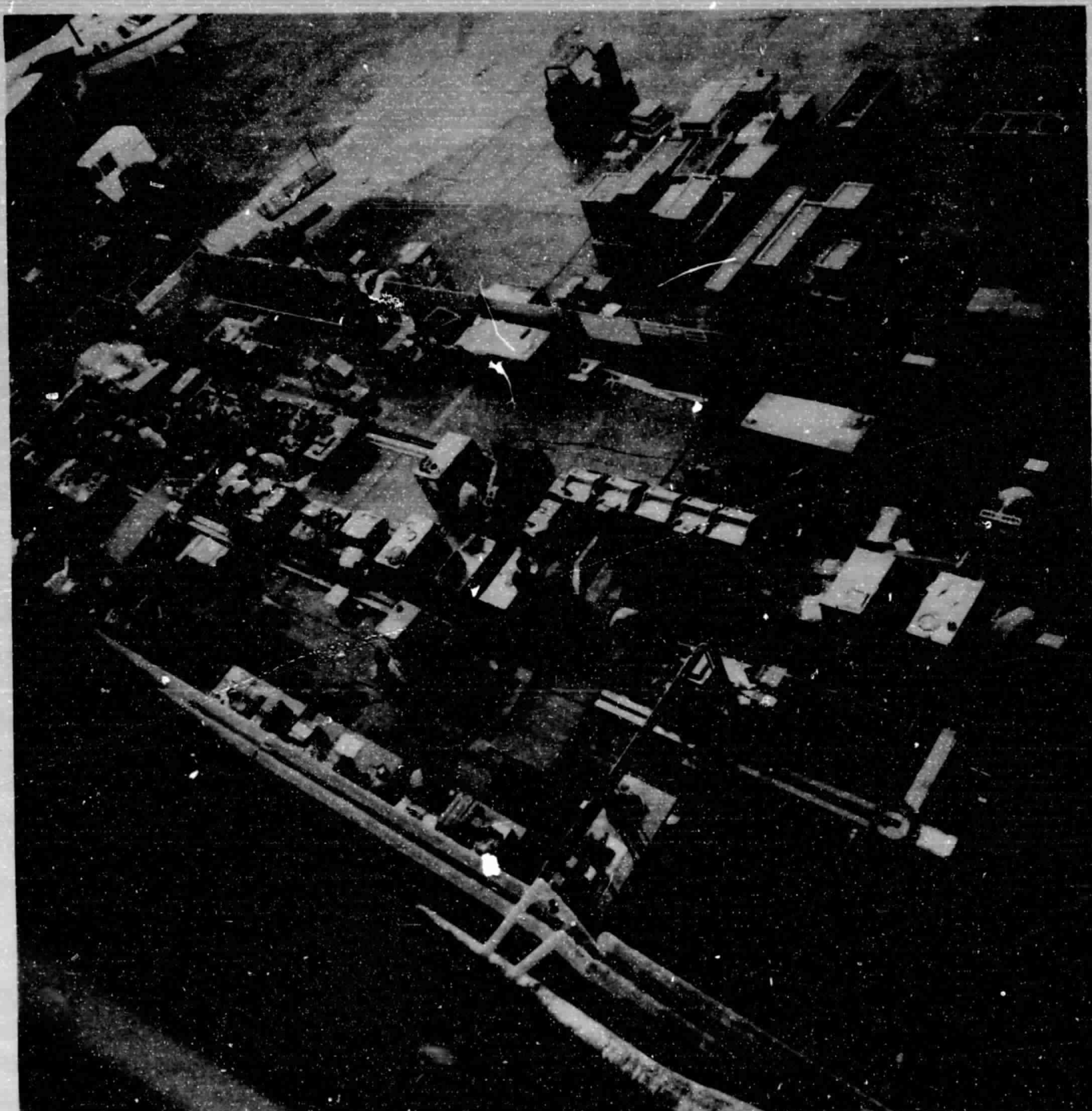


Figure 6

Payload Integration and Checkout Area at Ames

4.9 Launch Site Payload Processing (Level III/II/I Integration)

Launch Site Payload Processing was managed by KSC and involved installation and checkout of the payload in the aircraft, preparatory for flight. Activities included: experiment installation, experiment/aircraft interface verification, experiment testing and calibration, compatibility test, mission sequence test, an all-up Integrated Mission Simulation, and final preparation for launch. The entire process was completed during a four-week period by a team composed of KSC, ARC, MSFC, the M/S, P/Ss, and experimenter personnel.

Experiment installation was completed during the first two weeks and involved a number of changes due to incomplete analytical integration information and several changes in PI requirements. These changes were for increased testing and calibration on board the aircraft which were beyond the requirements initially identified in the IRDs, and they were approved to maximize the science return. A single-shift schedule, similar to the Level IV integration plan, was planned for launch site processing, but daily and weekend overtime work was required to maintain the schedule and meet the flight date.

Significant features of the activity on board the aircraft were the considerable amount of experimental testing found to be necessary to insure achievement of payload objectives and the large number of hardware and software problems encountered during experiment operations.

All onboard activities were conducted under a uniform work control system in which all tasks were planned, scheduled, and documented. The P/Ss represented the PI and were responsible for experiment integration, testing, troubleshooting and repair, with the PI being called in when necessary. The responsibility for any work internal to an experiment remained with the experimenter. A formal stowage list was prepared, including a flight data file, tools, test equipment, materials, and spare parts. All items were placed aboard the aircraft similar to preparation for space flight.

An Integrated Mission Simulation was carried out on May 5 and 6 as a final checkout and training exercise. This was a full-up dress rehearsal covering a continuous 31-hour period and involved the payload crew (in confinement), the PIs, the MCC/POCC staffs, and management personnel.

At the completion of launch site processing, a Flight Readiness Review was held at which KSC certified to the Mission Manager that all payload requirements had been completed ready for launch.

4.10 Mission Control Center and Payload Operations Control Center (MCC and POCC)

An MCC was established at Ames and was operated by JSC, with support from ARC, to manage aircraft flight operations. An MCC Flight Operations Director from JSC was in charge of flight planning activity and real-time communications with the aircraft flight crew relative to implementation of the flight plans or any changes dictated by flight constraints of payload requirements. The MCC and its operation were a very abbreviated representation of that planned at JSC for the more complex arrangement for interaction with Shuttle.

The POCC at Ames was organized and operated by MSFC in a manner similar to their plans for Spacelab I. They staffed the POCC with a Payload Operations Director, a Payload Activity Planner, and an Operations Coordinator, along with the Mission Scientist and a representative from each experiment. Voice communications were provided to maintain contact throughout the flight mission among all elements of the POCC, with the payload crew, and the MCC. The only additional communication links were a video downlink and a text uplink similar to the system planned for early Spacelab flights and operated by the MCC. In the POCC, the Mission Scientist coordinated the PI science requirements and science communications with POCC management and the payload flight crew. Additional separate facilities were provided close to the POCC operations area for PI conferences and data analysis.

POCC operations consisted of:

- Updated payload planning on a daily basis
- Briefing of the payload flight crew for each day's activities
- Communications with the payload crew to address problem areas and coordinate decisions with the payload crew
- Daily operations debriefing
- Quick-look scientific data analysis by the PIs

4.11 Conduct of the Flight Mission

Nine aircraft flights (data-take periods), totaling 53 flight hours in nine successive days, were carried out to represent a single Spacelab mission. The M/S and four P/Ss were fully confined to the aircraft and living quarters throughout the entire period. Preestablished timelines for P/S preparation and operation of experiments were used as baselines for pre-data-take periods and data-taking operations of the payload. Daily briefings and debriefings were conducted before and after data-take periods from the MCC for flight operations and from the POCC for payload operations. As the flight proceeded, payload problems and flight conditions necessitated real time changes from the preplanned experiment objectives tracks and changes of plans for given experiment observation periods. Communication was possible with the paylaod crew during data-take as well as the ground based periods. Communication was generally poor over the HF radio system during aircraft flights. The M/S coordinated communications to and from the payload crew. Communication blackout periods were scheduled into the overall timeline to represent Spacelab communications blackout periods.

Generally most experiments produced good data, but many real-time problems occurred and were addressed by onboard and ground based personnel, which resulted in varying degrees of correction and several alterations of flight plans. Approximate flight data-take time and the major problems for each experiment were as follows:

IR Astronomy - 45 hours	- Misalignment of optics caused large offset signal - P/S minimized at expense of sensitivity, but did not eliminate. - Pump failure - P/S timeshared pump from another experiment and later repaired it. - Computer program problems (occasional). P/S switched to manual mode.
Airglow - 35 hours	- One camera out of alignment electronically. P/S attempted adjustment at length without success. - Tape recorder jammed - P/S oiled part and restarted.
IHR - 46 hours	- Reference channel weak throughout mission. Not fixed - degraded data. - Optics left in wrong position for one data-take period. Finally reset (10% data time lost).
LAS - 46 hours	- Low sensitivity throughout mission. P/S realigned and effected some improvement.
LIDAR - 46 hours	- Blown fuse prevented signal detection. Data lost for one data-take period. P/S replaced fuse. (10% data time lost). Data link to ADDAS occasionally malfunctioned. Corrective procedure employed by P/S.
Medical - 53 hours (data also taken throughout non-flight periods)	- One of the tape recorders failed - P/S replaced it with onboard spare - little data loss.

SAR - 41 hours	- Inoperative optical recorders (2) (basic grounding problem) - lost all data first four data-take periods. Experiment declared failure for the mission. PI then fixed the recorders (outside mission constraints) for last five data-take periods (45% data time lost).
AEES - 53 hours	- Persistent EMI throughout mission on one receiver - P/S could not identify fix. PI fixed after constrained mission. Noise generator failed occasionally - reduced calibration accuracy. (P/S restored operation). Secondary chart recorder failed - reconnected to spare channels of MLS recorder.
MLS - 46 hours	- Automatic mode chosen by PI for P/S operation caused low signal output. PI recognized problem - P/S not asked to change mode as he was not trained in manual mode. PI improved after constrained mission.
Capodimonte - 46 hours	- Amplifier failed - P/S replaced with spare. Operated with degraded data for one data-take period.
EMI - 53 hours	- Loose electrical connector. Fixed by non-flight personnel after first data-take period. No data lost.

4.12 Use of Central Data System

Eight of the ten instruments were designed to interface with the central data handling system (ADDAS).

The experiment/ADDAS interface data handling sophistication varied from simple use of ADDAS only to obtain housekeeping data (which was recorded by ADDAS for the entire mission), to onboard interaction with ADDAS for experiment calibration, and, in some cases, limited data reduction using the ADDAS system. Some experiments had their own microprocessors. Three experiments had flown before on the CV-990, so that their data system interfacing problems were reduced.

Two of the ESA experiments encountered significant problems in interfacing and operating with the ADDAS system. One problem was due to a complex timing inconsistency which, in fact, was not completely solved until the third data-take period. The other problem was due to an experiment hardware interface design incompatibility that required inordinate effort through experiment testing, Level IV integration, and launch site processing, but was fully solved just before flight. Both experiments correctly functioned after problem resolution, and no significant degradation in science return was experienced.

Both experiment software development and integration were, in general, performed by specialized ADDAS data system engineers working very closely with PIs for definition of requirements and experiment interfaces.

Data tapes from ADDAS plus some selected records directly from experiments were carried off the aircraft daily to simulate the Spacelab payload data downlink. Limited processing facilities were provided in conjunction with the PCCC, along with some PI furnished data processing equipment, to permit the PI to evaluate the condition of the experiment and request any changes in flight plan or experiment operation resulting from quick-look results.

4.13 Documentation

A special objective of the ASSESS II mission was to simplify procedures and minimize the amount of paper work necessary to accomplish the mission, consistent with plans for Spacelab. These criteria led to significant discussion in the Mission Steering Group and a Baseline Documentation and Information Flow for ASSESS II issued by the MSG about 10 months before flight. That plan is shown in Figure 7.

The actual documents issued by the various participants and used in the mission are given below. Top level inter-agency agreements between NASA and ESA Headquarters documents are not included since they were ASSESS unique and not applicable to Spacelab. Also, the ESA documentation used for the ESA payload integration and checkout in Europe is not included. The documentation is divided into three classes as follows:

CLASS A Reference documents - not mission unique

CLASS B Mission management documents - interfacing documents which would be reissued for each mission

CLASS C Mission implementation documents - internal working documents within a given organization

MSFC Documents

CLASS A)

- POCC Requirements
- POCC Operations Handbook
- POCC Operations Implementation Procedures
- Ground Operations Reference Document

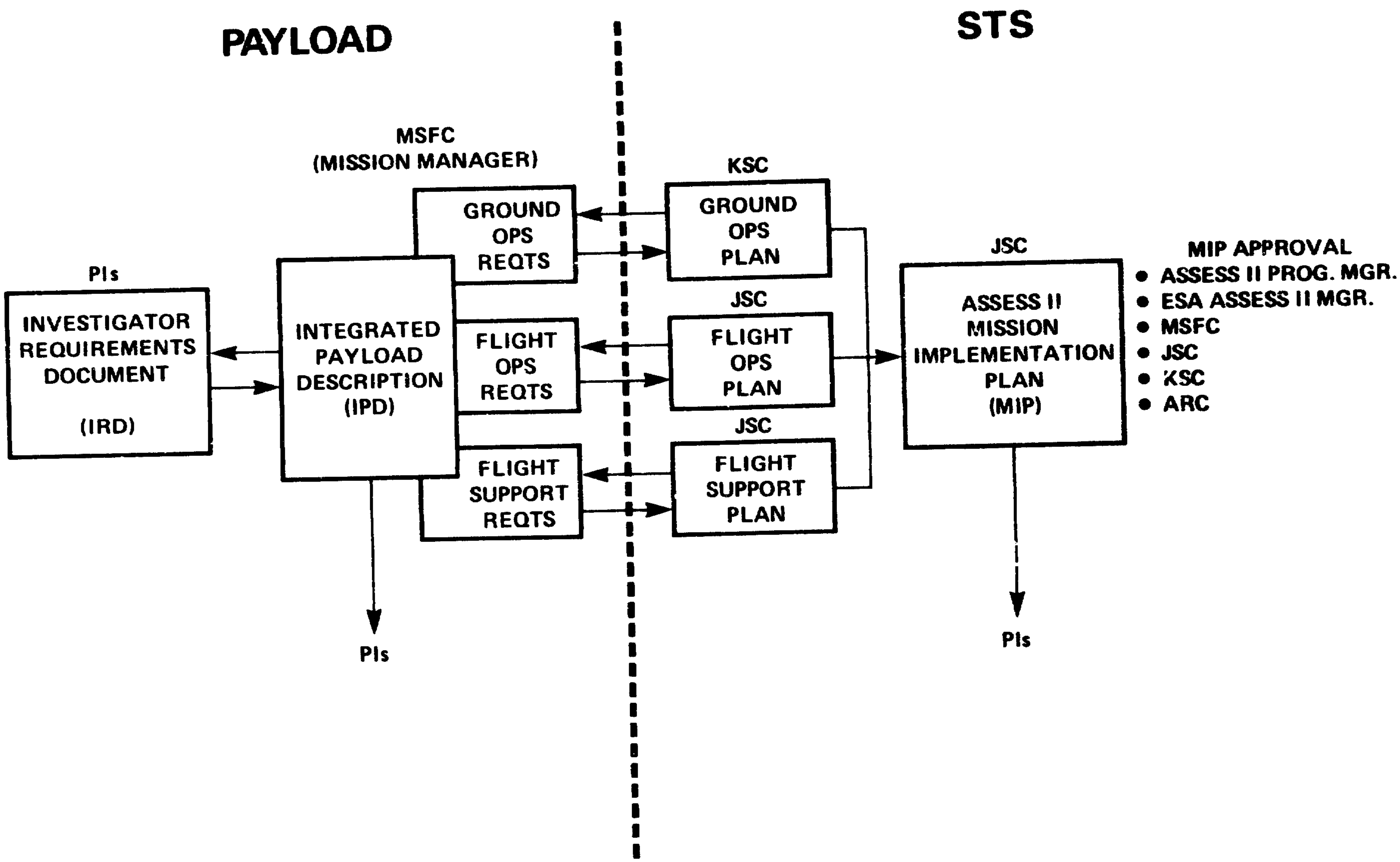


Figure 7. Baseline Documentation and Information Flow for ASSESS II

CLASS B)

- Investigator Requirements Documents (one per experiment)
- Payload Level IV and Launch Site Ground Operations Requirements Document
- Payload Flight Definition Requirements Document
- Payload Operator Requirements and Preliminary Training Plan
- Payload Specialists Training Implementation Document
- Level IV Integration Implementation Document
- Payload Mission Rules
- Payload Configuration Drawing
- Experiment Installation Sketches (Mechanical)
- Experiment Installation Cable Interconnect

CLASS C)

- Data Requirements Document
- Payload Flight Data File
- Detailed Payload Crew Activity Plans
- Payload Stowage List

<u>Level IV Detailed Documents</u>

- Investigator Log (one per experiment)
- Diagrams and Procedures
- Payload Procedures
- Problem Reports
- Test Preparation Sheets
- Discrepancy Report Tags

<u>POCC Documentation for each Flight</u>

- Director's Log
- Payload Planner's Log
- Communicator's Log
- Final Flight Plans
- Science Plan Chart
- POCC Operations Timeline
- Payload Crew Timelines
- Data Slice Requests (one per experiment as required)
- Data Terminal Time Assignment
- Record of Data Offloaded from Aircraft
- As Flown Data Logs (postflight)
- Science Summary Report (postflight)

<u>KSC Documents</u>

CLASS A)

- Launch Site Integration Implementation Plan (Part A)

CLASS B)

- Launch Site Integration Implementation Plan (Part B)
- Operation and Maintenance Instruction

CLASS C)

- Problem Report
- Discrepancy Report Tag
- Engineering Change Notice
- Launch Site Requirements Change Notice
- Test Preparation Sheet

JSC Documents

CLASS A)

- STS Rules
- MCC Console Handbook

CLASS B)

- Mission Implementation Plan
- Integrated Summary Crew Activity Plan
- CV-990 Daily Flight Plans
- Flight Support Work Schedules
- Integrated Mission Simulation Plan
- Data Retrieval Log

CLASS C)

- MCC Console Log

5. EVALUATION AND CONCLUSIONS FOR SPACELAB

5.1 Introduction

The ASSESS II mission was very successful as a simulation of Spacelab interfaces and activities. Management interfaces were exercised among experimenters and the ESA and NASA organizations to be involved in Spacelab. The gamut of activities to bring experimenters through development, integration into a payload, and through flight operation and data retrieval with active PI participation and an operating POCC and MCC was thoroughly experienced. An M/S and P/Ss were selected and trained, and performed satisfactorily in flight. The entire exercise was regarded by all participants as excellent and valuable training for future Spacelab operations. Some anticipated Spacelab activities were exercised extensively; others less so due mainly to funding limitations, particularly in the U.S., and aircraft system constraints. Also, it is important to point out that all parties were working to extremely tight schedules that forced some preliminary work to be done in parallel and some data to be late. No one had the option of adding additional manpower or funding to overcome the data and schedule problems.

It is not the purpose of this report to address scientific results, but a very general evaluation of the quality and quantity of scientific data is given for completeness. The data obtained from the experiments was of satisfactory quality in the majority of cases, and the ratio of data achieved to data expected was also good. The fact that the payload was interdisciplinary dictated that flight periods had to be prioritized because flight conditions were not conducive to data retrieval from all experiments at the same time. A first look at the results is summarized below:

LIDAR (Germany) - Good quality data in majority of the data periods.
IRA (France, Germany, The Netherlands) - New maps of several prime sources with good data on main targets.
LAS (U.S.) - Ozone detections were made only near end of mission.
IHR (U.S.) - Data not yet evaluated, but appears satisfactory.
AIRGLOW (England) - Good looking sky pictures for most data periods.
MLS (U.S.) - Data in all data periods, but sensitivity very low.
AEES (U.S.) - Data during all data periods, but partly masked by frequent electromagnetic interference in some receiver frequencies.
SAR (U.S.) - Ground mapping with L-band system during later data periods after PI was allowed to violate simulation rules and correct a critical physical integration error.
CAPO (Italy) - Solar and atmospheric data satisfactorily taken during most of data periods.
MEDICAL - (Germany) - Excellent data throughout mission.
EMI (ESA) - An engineering experiment that identified good approaches to eliminate or reduce EMI and also proved extremely valuable as troubleshooting apparatus.

The following conclusions for Spacelab were synthesized from the project and are followed in each case by a brief analysis.

5.2 Payload Selection and Funding

5.2.1 Payload Selection

(a) **Compatibility of payload scientific discipline requirements simplifies payload planning and mission implementation.**

For ASSESS II, a variety of scientific objectives required a wide variety of targets and times of observation, involving both day and night observation periods. With this mix of experiments, there was no possibility of operating all experiments efficiently at all times. Flight planning was seriously complicated by the mix of objectives, and experiment operations were necessarily compromised. Although for Spacelab it may be necessary in many cases to carry interdisciplinary payloads, similar scientific objectives will permit more simplified flight planning, increase efficiency of experiment operations, reduce scope of crew training, and should be expected to yield more usable data for an overall mission.

(b) Payload complement can be formed by selecting from ongoing experiment development programs or existing instrumentation.

OA avoided the use of an Announcement of Opportunity for generating its payload complement for ASSESS II because of the limited time available and lack of funding to support proposals. Instead, in June 1976, OA identified payload candidates among various disciplines that were planned for future Spacelab missions and for which early prototype tests were being conducted with the CV-990. The five OA experiments flown on ASSESS II were selected by this method. In view of planned Spacelab/Shuttle launch rates in the mid 1980s, this selection method could be used with "discipline" Announcements of Opportunity used to secure proposals without regard to a specific mission (e.g., Spacelab I, etc.). Although ESA used an Announcement of Opportunity, all the experiments they selected were in some stage of development, which also supports the conclusion.

5.2.2 Payload Funding

The following conclusions arise particularly from experience with the NASA experiments on ASSESS II.

(a) Timely authorization and funding of the payload is mandatory to avoid serious impact on mission definition and resultant compromise of scientific return. Analysis of payload funding schedules is of equal importance to payload analytical integration.

Delay in distribution of funds, and authorization for one U.S. experiment, delayed configuration, interface definition, data processing software, and construction of experiment support hardware. These difficulties were reflected throughout the whole chain of participating organizations. The resultant extremely tight schedule for the one experiment necessitated premium time costs, caused equipment failures, and lost scientific data.

(b) Funding deficiencies and multiple funding channels must be avoided to prevent compromising payload elements.

The selection of five experiments comprising the baseline OA payload was made by the NASA HQ OA "discipline" program offices having management cognizance. Funding for hardware was available for all but one experiment, but was not adequate for integration and data analysis. Reprogramming from other funding sources caused delays in getting funds distributed. There was no central control authority established in NASA Headquarters (and, therefore, none at the mission management level) to work these problems. Multiple authorities over funding resulted in on-again-off-again decisions. One experiment was dropped for lack of funding, only to reappear later when reprogramming actions were taken.

(c) **Funding allocations should cover all required integration and mission operations support in addition to hardware development and data anlysis.**

Insufficient effort was made to budget for integration and support activities by experimenters. The analytical integration effort, in particular, was insufficiently supported, with resultant detriment to mission planning, integration, and checkout. Several experimenters were limited by travel fund restrictions to a lower level of personal support than was necessary to do a minimum proper job.

5.3 Management Relations

(a) **The Mission Steering Group (MSG) proved an effective forum for solving interface problems and exchanging views and philosophies on the conduct of the mission. ESA suggests that a similar multiorganizational group be used to oversee all joint Spacelab missions.**

The Mission Steering Group was established for ASSESS II specifically to guide the mission and establish ground rules for the simulation in order to maximize results for Spacelab. As the mission progressed, the MSG, with key representatives from all of the participating organizations, became a forum for addressing basic mission problems. ESA, particularly, believes such a body would serve a useful purpose in the same manner for Spacelab missions in which they are involved; NASA feels that such a body conflicts with its direct management responsibility, particularly the Mission Manager role, and does not agree that this approach is appropriate or required for Spacelab.

(b) **Mission Manager concept appears sound, but adequate staffing is essential and further development of the concept is necessary to insure efficient coverage of all program aspects.**

Implementation of the ASSESS II project under an MSFC Mission Manager worked well and could be implemented at any organization given responsibility for a payload. However, the Mission Manager must have adequate resources to fully organize the payload, identify and track all payload interfaces, conduct meaningful analytical integration, identify payload requirements to STS, and plan and staff the POCC during flight operations.

The engineering support provided was not adequate to properly handle the Investigator Requirements Documents and the analytical integration of physical, electrical, and data experiment interfaces. The result substantially altered an initial objective to implement the procedures proposed for Spacelab, and caused these areas of effort to be handled on an informal basis between the experimenters and ARC. However, there is reason to believe that additional analytical integration effort plus more effort to maintain current understandings of the experiment interfaces as the mission progresses toward flight would eliminate these difficulties.

The ESA/SPICE Mission Manager served as the single interface to the MSFC Mission Manager for the European experiments and also managed integration and operation of the ESA portion of the payload in Europe. KSC representatives in particular observed that the single interface of the ESA/SPICE Manager for the European experiments worked very smoothly and efficiently.

(c) **Management must clearly inform all participants early in the mission as to roles and responsibilities.**

It is essential that an early, deliberate effort be made by program and mission management to inform all prime participants as to various roles and responsibilities and the management paths required to obtain optimal results, particularly for such complex management arrangements as existed for ASSESS II and are planned for some Spacelab missions. The STS role, and its relationship to other implementing centers, was not clearly defined by NASA Headquarters at the outset of ASSESS II. Interviews with many participants late in the ASSESS project revealed that they had only sketchy ideas as to the responsibilities of various organizations and of their relationships with them.

ASSESS II was an initial trial for the Mission Manager concept for Spacelab and, in spite of early attempts to inform participants as to various roles and responsibilities, some modes of operation developed as the mission progressed. Some Payload Specialists and the Mission Specialist became involved well after the beginning. The Mission Manager at MSFC was changed in January 1977 to put all Office of Applications missions into one office. Continuity of effort and early complete identification of all participants' responsibilities are required for full understanding and most effective operation.

(d) Participation by the PIs throughout the mission planning and implementation phases can enhance overall mission understanding (by both management and user) and thereby improve science return. PIs must recognize their leadership position concerning their experiments.

In ASSESS II, each PI and/or his staff participated directly in IRD activity, IWG meetings, System Level Payload Integration, and the real time flight operations through the POCC. In addition, access to his equipment was relatively easy during Launch Site Payload Processing if he had such a need. The PIs were pleased with their degree of involvement. The only concerns expressed by them were a lack of feedback from the IRD submittals so they would know what commitments had been made, and a desire for an opportunity for greater science exchange during IWG actions.

The degree of responsibility by the PI for integrated tests, P/S training and operational procedures, and support of all mission operations with a sufficient and effective PI support team must be realized and fully supported by the PI.

5.4 Pre-Flight Planning and Payload Integration

5.4.1 Investigators' Working Group (IWG)

(a) The IWG can be a satisfactory forum for scientific inputs and a valuable channel for management/PI information flow.

On ASSESS II, the IWG concept was not fully exercised. The IWG met twice during ASSESS II, but the meetings, especially the second, were not well attended due mainly to lack of travel funds for PIs. This problem made transatlantic travel out of the question, and even meetings of the European half-IWG, or the U.S. half-IWG difficult. Within this severe constraint, the IWG had the following beneficial results: Evolution of a cooperative experiment between two PIs; inputs to Payload Specialist selection; transfer of information about the aircraft and the data handling system; and contributions to mission planning. With more extensive use of the IWG, all of these functions can be better exercised for Spacelab. In addition, early IWG meetings with management can be used to inform the PIs of mission plans, and iterate the integration requirements. The IWG, under charimanship of the Mission Scientist, can be an effective body for nominating payload specialits.

(b) The Mission Scientist (and any IWG cochairman or vice-chairman) needs to have clearly defined responsibilities, full support by the PIs, and be provided with a management overview.

The Mission Scientist served a key role in planning and execution of science activity and provided focus of science requirements and science tradeoffs to the Mission Manager. His effectiveness in performing this role was variable depending upon the degree to which all other participants recognized the requirement for his analysis of all science considerations. He worked with planners for flight operations to present the science case to mission management. This mode of operation was very effective. During flight operations, the NASA and ESA Mission Scientists were very successful in coordinating and managing PI activities. The Mission Scientist must be strong in his own right to promote and defend payload needs in the face of project implementation processes.

5.4.2 Investigator Requirements Document (IRD)

(a) A single requirements document interfacing with each PI is desirable and feasible. Face-to-face discussions with the participation of disciplinary experts are necessary to clarify interfaces. These discussions must start early in the mission, and must continue to be iterated to insure proper information transfer.

A single document for each experimenter to identify all requirements was used with limited success on ASSESS II. However, the concept appears very sound. The question and answer format was good, but the overall organization of the questions needs very careful study and arrangement to eliminate redundancy and achieve maximum clarity with brevity. Initial attempts to have the PIs fill out the document unilaterally were not satisfactory. Face-to-face meetings with the experimenters were necessary to clarify the need for interface information and obtain total understanding. When experimenters understood the requirements, in every case they very aggressively worked to produce needed information. The IRD, in most cases, served very well to focus PI attention on interface areas much earlier than would otherwise be the case.

Only a very small interfacing group (perhaps 3 or 4) is needed to deal with each experimenter, but it is absolutely mandatory that experts who fully know the Spacelab systems (electrical, mechanical, data system, etc.) work with the experimenters. The IRD must be a living document since much of the information will develop with time and the resultant document forms the basic source of experimenter input for integration and flight operations.

In ASSESS II, the IRD effort started well, even though the format needed much improvement, but the initial effort about a year before flight left many unanswered questions. After a second effort by MSFC and the PIs to complete all elements of the IRD, schedule pressure and unavailability of manpower necessitated gathering the balance of the required interface information on an informal basis. However, even with the limited application of the IRD on ASSESS II, there is general agreement that the basic concept is sound.

(b) The IRDs must be kept current so that they properly reflect changes in experiments as they are developed, but there must be a cut-off date beyond which all aspects of the experiments are fixed.

During ASSESS II, most experiments delivered to ARC for system payload integration had at least some configuration change from that worked out with the PI during the IRD baselining activity. Some PIs had added components, others had removed components, and some had changed component positions. This necessitated juggling hardware arrangements and recalculation of weights and overturning moments to insure safety. For the aircraft program extra effort permitted satisfactory recovery, but for Spacelab not only will the payload configuration have to be tracked closely, but the much larger number of components for many Spacelab experiments, coupled with the severe schedule and cost restrictions to handle many configuration changes, dictates a need to freeze the experiment configurations at an appropriate time.

5.4.3 Analytical Integration

(a) The analytical integration of a Spacelab payload must be accomplished in a timely, complete fashion so that all participants can receive complete payload definition and requirements early enough to plan the payload processing activities.

In ASSESS II, since the formal analytical integration effort was not fully completed, extensive real time effort was required by ARC to work with the PI and solidify final physical, electrical, and data interfaces. Hardware installation sketches were used by KSC in lieu of formal documentation. As a culmination of the compressed mission schedule, manpower, and late PI test requirements input, the final Launch Site Integration Requirements were delivered to KSC one week before start of Launch Site Payload Processing. As in several other activities, this allowed little time for review, and several changes were required to bring the payload to flight readiness.

5.4.4 Integration of ESA Payload in Europe

(a) For Spacelab payloads involving ESA experiments, testing, integration, and operation of those experiments under ESA management at a centralized European site is extremely beneficial.

The ESA sponsored integration, test, and operational activity at ESA/SPICE was extremely beneficial. In most cases, the experimenters needed deep support to get their equipment assembled and working properly. Individual assistance was supplied and many problems were identified and solved during the ESA/SPICE integration and operational activity. With support of a NASA safety representative, all safety issues were addressed, thus avoiding major difficulty later. Valuable training was accomplished. The ESA integration activity insured that the ESA complement arrived in the U.S. as a tested set of experiments, thus reducing their integration time with the balance of the payload.

5.4.5 System Level Payload Integration (Level IV)

(a) The value of off-line System Level Payload Integration activities (Level IV) is directly related to the fidelity of the test facility and the completeness of the tests performed.

For ASSESS II, the off-line System Level Payload Integration activity (Level IV) was performed on the hangar floor. It was a minimum cost arrangement. This first-time integration of the entire payload uncovered many problems--most were solved and some were passed on to launch site processing where those plus many additional problems were addressed.

The ability to address all problems in an off-line system simulator is strongly proportional to the investement in simulator equipment to achieve high fidelity. Without the exact cabling configuration (both data and power) and duplicates of the flight support system, the most troublesome EMI type of problems cannot be identified.

(b) Off-line System Level Payload Integration activities (Level IV) are very effective in crew training.

For ASSESS II, although the ESA P/Ss had participated and trained during the ESA integration activity, the off-line System Level Payload Integration and operation at ARC was the first time all P/Ss had an opportunity to operate experiments as a complete payload. The P/Ss were given basic responsibilities during this phase, side by side with the experimenters, who also participated directly in this phase of integration. This was excellent training for the P/Ss, and it is highly recommended that P/Ss be given this same opportunity and assignment for Spacelab.

5.4.6 Launch Site Payload Processing (Levels III, II, I)

(a) For launch site integration, timely detailed technical definition of payload carrier interfaces is essential.

The Launch Site Ground Operations Requirements Document was delivered to KSC one week before start of Launch Site Payload Processing. Several payload interfaces were not completely defined. As a result, KSC had essentially no lead time to prepare for their work. Although present Spacelab guidelines limit KSC responsibility to interface verification, some severe experiment problems occurred which had to be addressed. For the Capodimonte experiment, one undefined signal interface had to be revised. An incorrect power connection on the SAR caused complete failure of the experiment from a Spacelab point of view, and was fixed during flight operations by permitting the PI to break the simulation rules and go aboard the aircraft to solve the problem.

(b) Effective launch site payload processing can be performed using a single direct payload manager interface to the KSC payload processing management. A payload test team approach, using the M/S, P/Ss, and PIs when necessary, under the jurisdiction of KSC to directly support and participate in the KSC launch site processing operations was very successful and is recommended for Spacelab.

For ASSESS II, the KSC launch site Manager, the MSFC Ground Operations Manager, who had handled the Level IV Integration, and the ESA Payload Manager worked closely together as a team, utilizing the M/S and the P/Ss full time. The Mission Manager was the single basic interface with KSC for the payload.

Although KSC maintained strict control of the schedule and operation, they were very receptive to participation by the experimenters to handle experiment problems, rather than creating procedures for use by others. This team approach is recommended for Spacelab integration at KSC.

(c) To minimize experiment systems failure, time should be scheduled to conduct experiment functional tests on the integrated vehicle. Failure to perform these tests implies, at least on priority experiments, technical risk that may not be commensurate with mission investment.

There is no fully satisfactory substitute for test of the payload components in the actual flight configuration. While a high-fidelity off-line test device does allow very significant debugging of the system interfaces and the payload experiments, there will always be at least minor configuration variations from the flight system that can produce serious anomalies in payload operation. In ASSESS II, each experiment was checked out on the aircraft after final integration. A number of problems were found and solved. For Spacelab, the KSC integration is baselined only to insure interface and EMI compatibility. It is recommended that a full operational check of at least priority experiments be included to insure proper data producing capability.

(d) Past experience should be applied to insure that experiment tests are conducted that will indicate possible experiment hardware weaknesses or susceptibilities.

A great deal of experience exists at both NASA and ESA Centers for checkout of experiments to be flown in space. The participation of the implementation Centers in the design review and test planning phases of the experiments can assist the PI's rate of success through experience transfer. The ground rule now being considered for Spacelab puts prime responsibility upon the PI to insure satisfactory operation of his experiment while the STS responsibility is limited to safety and interface compatibility. For ASSESS II, at the discretion of the experimenters, experiments were not thoroughly tested in all cases before flight. One prime experiment failed; others had operational problems. A positive approach to marry the knowledge of experienced personnel with the experimenters' responsibility to perform critical experiment tests is recommended.

(e) An all-up Integrated Mission Simulation is valuable and is recommended, at least for the early Spacelab missions. Inclusion of instrument operation to verify operational interfaces during the simulation enhances the probability of experiment success.

A generally effective end-to-end Integrated Mission Simulation was conducted in ASSESS II with the payload flight crew carrying out experiment operation supported by full MCC/POCC participation. Many problems were identified, some with hardware, and some with operations. This level of simulation offers the greatest possible degree of training for the total operations team (MCC, POCC, and payload crew), and should be included during the final integration period for Spacelab, especially for early missions.

(f) Facilities and associated equipment along with some schedule time should be made available at the launch site to allow for some experiment testing, solve last minute experiment problems, and allow for calibration requirements.

Experience has shown that some experiment problems will show up at KSC when the payload is integrated with the actual flight system. Also, some experiment calibrations must be performed with the flight system hardware to obtain acceptable flight data. Both of these cases were evident in ASSESS II.

Most hardware problems can be quickly and effectively solved at the launch site, but some electrical and job shop capability close at hand is necessary along with simple procedures to use this capability. Airborne payload integration at Ames has been highly successful, particularly because of these strong capabilities. They were extensively used for ASSESS II and are recommended for KSC.

5.4.7 Safety

(a) Safety considerations for ASSESS II were applied with a low level of formality, but the experience did not contribute materially to understanding the required level of detail necessary for Spacelab.

Safety considerations for the basic aircraft system and the payloads at Ames were handled by the Airworthiness Assurance Office. General safety inspections were handled on a daily basis during integration and ground operations by the Inspection Branch with simple squawk sheets which incorporate provision for signoff on the same sheet upon corrective action. Final all-up mission safety approval is issued in writing by the Airworthiness and Flight Review Safety Board after formal meeting(s) with review of all safety related items and operational procedures. All flight personnel are required to participate in safety briefings. The Aircraft Commander is the final safety authority during flight. Many safety considerations for Spacelab were not required for ASSESS II; e.g., outgassing, flammability, stress corrosion, and detailed hazard analyses.

5.5 Payload Flight Crew

(a) The M/S role in ASSESS II and the management arrangement was very successful and is recommended for Spacelab.

After much controversy and delay, the arrangement for a Scientist Astronaut to serve as M/S for ASSESS II was worked out. There is no evidence that this arrangement would not work equally well for Spacelab. The M/S remained administratively under JSC, but was assigned functionally to the Mission Manager at MSFC. In addition to his ground based duties, he served on the flights as the alter ego of the Mission Manager. As the mission progressed, it became apparent to everyone that he operated very effectively as leader of the P/Ss, which came about naturally based on his background, training experience, and personality. The P/Ss were all well satisfied with this arrangement.

(b) The M/S functions for ASSESS II were unique to that position and served a vital need.

On ASSESS II, a prime function of the M/S was to bridge the gap between the experiments and the payload support systems (central data system, power supply and distribution system, and some special payload support devices such as gyrostabilized mirrors and a water vapor radiometer). Long term training is required to handle such systems, especially the data system, and, in fact, the six-month period for training for the ASSESS II M/S was wholly insufficient for him to totally handle the data system (a ghost operator was used). In addition to this basic function, it was natural for him to serve as the communications and operations coordinator during flight to maintain ground contact primarily because the aircraft had a single payload communication station at his console. The M/S handling of most communications unloaded the P/Ss, who were overburdened with direct experiment operation duties. Also, the M/S frequently served to support the P/Ss in operating functions. This team approach was very smooth and successful.

During integration and operation of the payload for Level IV and for Launch Site Payload Processing, the M/S was very valuable as an operations and training coordinator for the payload flight crew.

(c) The participation of M/S and P/S (time of selection, training schedule, etc.) should be included as an integral part of the mission planning so that their involvement begins at the optimum time commensurate with their assignments. In particular, P/S involvement should commence at a stage that would allow their inputs to the control and operations aspects of the experiment design.

ASSESS II P/Ss were selected eight months before flight. By the time they got to most of the PIs for training, much of the hardware design was solidified. As in ASSESS I, the P/Ss all made strong observations that their early input to design would have been very helpful toward making experiment operation more conducive to successful operation of the hardware and obtaining science data.

(d) Effective verbal communication skills should be an important criterion for P/S selection.

During ASSESS II, it was noticeable that some P/Ss were significantly less adept at giving and receiving information than others, with a tendency to communicate less effectively under stress. This affected the success of making repairs and collecting data. This aspect of competence must not be neglected when making P/S selection for Spacelab.

(e) Prior to final selection, P/S candidates should be subjected to some type of stress, including timeline activity.

Observations indicated that the ability of P/Ss to operate under stress of multiple activity varied considerably. In Europe, psychological tests were used that clearly eliminated some P/S candidates and raised concerns about others. These concerns were borne out on ASSESS II during the integration and flight periods.

(f) Any PI candidate for P/S must be fully cognizant of the workload time commitment and demonstrate his ability to support both roles.

On ASSESS II, one P/S was also a PI. Some interference was noted when he interrupted his ASSESS II activity to take care of urgent PI management responsibilities. Very careful consideration should be given to any PI who proposes to be a P/S on Spacelab to assure his genuine willingness to forego his basic PI duties, or have them handled by others, and that he thoroughly understands the time required away from his home base for meetings, training, and operational duties associated with the Spacelab payload.

(g) The use of backup P/S from the Mission Management team is feasible, but practicability depends upon the balance of duties required for a specific mission.

For ASSESS II, the U. S. Assistant Mission Manager was selected to be backup P/S for U.S. experiments. This plan for a single backup for both U.S. P/Ss was adopted particularly to save travel funds, and the individual was considered to be well acquainted with the U.S. experiments. His management duties were severely diluted, but he handled P/S training and generally represented the payload crew to management during the pre-flight phases in addition to undergoing his own limited training. The question arises as to whether capable candidates will be willing to accept only a backup assignment for Spacelab, with historically a very low probability of flight assignment, unless there is some accompanying responsible assignment (which dilutes both jobs), or some strong liklihood that a backup P/S assignment is a step toward prime assignment on another mission.

(h) Each crew candidate should be subjected to sufficiently realistic functional and environmental simulation of his roles early in the training period to permit self-evaluation of his desire to proceed.

Some substantial physical difficulties were experienced with the medical experiment by one P/S during the 72-hour collection of P/S preflight baseline medical data at ARC. The problem was sufficiently severe that, due to potential loss of medical data and/or degradation of his overall effectiveness, consideration was given to replacing him for the flight mission. However, in the actual mission, the medical data was collected and there was no detectable degredation of P/S performance due to the medical experiment.

(i) P/S training must be tailored to the individual P/S selected and the complexity and degree of P/S understanding of any given experiment. PIs must devote adequate time and effort to maximize the training effectiveness.

On ASSESS II, P/Ss training was somewhat varied. Initial training was scheduled on a time basis per experiment without regard to P/S capability of initial understanding of experiments, but some adjustments were made as training progressed. Discussions with P/Ss after the mission indicated that training, in some cases, had been overdone for some experiments and inadequate for others. Mission management judgment should be blended with P/S desires to schedule training time consistent with the background and capability of each P/S for every experiment and its priority.

(j) NASA should consider means to provide independent travel fund support for P/Ss from Centers where this factor can prevent nomination.

The problem of selecting a P/S from a NASA Center raises the problem of devoting extensive travel funds to a single individual and organization with a center for benefit of others on Spacelab. The travel fund problem is so severe within NASA, under the present system, that any NASA organization is extremely reluctant to expend travel funds except for local benefit. For ASSESS II, the travel fund problem was very severe. Where payloads came from several organizations, special travel fund arrangements may be necessary to attract the best P/Ss.

(k) P/S participation in development of experiment operation procedures contributes significantly to their training and operational understanding, and supports their responsibility as the onboard PI representative.

For ESA experiments, the P/Ss were given the responsibility to develop operational flight procedures for their assigned experiments. This proved to be a very effective method to assure their complete understanding of experiment operation, and caused a very deep interaction with the PI to iterate various modes of operation. The further hands-on operational responsibility assigned to the P/S during Level IV and launch site integrations was an excellent combination to maximize P/S training for flight. NASA chose to have the PIs maintain responsibility for all procedure generation with review and iteration with the P/Ss. No difference in P/S operational success could be detected due to this different approach.

(l) Flight operations workload planning must allow for a P/S adaptation period, with attendant lower effectiveness for the first several days of the mission.

Even without the effects of zero-g, for ASSESS II the P/Ss readily stated that they required from one to three aircraft flights before they had reached a high degree of effectiveness in experiment operation. The P/S who had many details to consider but was concerned with only one operational goal developed operational effectiveness more rapidly than those faced with a multiplicity of operational goals (single vs multiple experiment operations). Even the M/S, with his considerable flight experience, felt that he was not handling his several duties with full efficiency until about the third flight. Increased experiment/system level training can minimize, but not eliminate, the initial lower effectiveness.

5.6 Flight/Ground Operations Interactions

(a) Adequate resources and time must be provided for training of POCC personnel, especially PI science teams.

The POCC for ASSESS II was fully manned as planned for Spacelab. Some POCC training occurred for ESA personnel during the ESA integration and operation activity in Europe, but very little operational training took place at Ames before the start of flight operations. Total plans for training at ARC could not be exercised due to minimum schedule time, total launch team workload, and the minimum on site PI support teams. Initial operations were inefficient, but improved with time. Whereas experienced management personnel may man key positions for Spacelab, which eliminates their training needs, most PIs will be untrained. PI participation in flight communications was very poor in many cases during ASSESS II, especially during the early flight period. Leadership of the PI group in the POCC by the Mission Scientist was very good, but some training for that arrangement is recommended.

(b) The TV text uplink is a beneficial mission operations tool. Facsimile capacity for transmission of troubleshooting information is desirable and should be incorporated into the Spacelab concept at an early date.

The TV text uplink and its Polaroid readout in the aircraft proved its utility by being used increasingly as the ASSESS II mission progressed. The ability to send simple messages to P/Ss and the M/S, with a record for reference, was found to be far less interruptive of work than extensive voice communication. Inability of the link to handle facsimile precluded sending wiring diagrams that were needed for troubleshooting.

(c) Periodic data samples from the Spacelab to the POCC during the mission are essential for PI experiment surveillance and to provide operations instructions back to the Spacecraft.

Data slices were passed to the POCC each day, and ground-based facilities were available through the POCC to determine the effectiveness of experiment operation. This system was highly successful, and is recommended for Spacelab. Some problems occurred with data interfaces to the experiments, but in every case a work-around was implemented so that nearly all data was retrieved.

(d) If backup P/Ss are to be used effectively in the POCC, they must be trained on all experiments. Also, on joint missions, Mission Scientists must be familiar with all experiments.

During ASSESS II, in-flight communication between the POCC and the M/S primarily concerned experiment operation and experiment troubleshooting. Communication is much more efficient if both sender and receiver are conversant to a reasonable level of detail with all aspects of the payload. For ASSESS II, the backup P/Ss served as the main POCC communicators and their payload training, along with close familarity with the flight crew, made this very effective.

The Mission Scientist must be conversant with the payload to a considerable level of detail so that he can make decisions on the best use of flight time. It is therefore imperative that he understand the science and operation of all experiments.

5.7 Experiment Hardware Considerations

(a) Automation of routine tasks is recommended in reducing P/S workload and operating errors; however manual bypass capability is also desirable.

Experiments that contained automation of routine tasks and did not require extensive adjustments or setup of controls by the P/S appeared to have a higher data-take success ratio than those with extensive manual setup and control. Two examples from ASSESS II illustrate this point. The infrared telescope experiment was highly automated with computer control. However, when the computer occasionally failed, adequate manual operation by the P/S was possible. One U.S. experiment was also highly automated with computer control, but not in such a way that the P/S could easily bypass it. The PI recognized early in the mission that the data was badly degraded, but gave no instructions to the P/S because there were no suitable manual control provisions.

(b) Use of off-the-shelf hardware should be considered where modifications or testing to meet the Spacelab constraints is cost effective.

As in ASSESS I, the majority of the components that made up the ASSESS II experiments were off-the-shelf items. Statistically they performed as well as specially constructed components. The primary reason for resorting to special construction was the need for a unique functional capability. Reliability, low power consumption, etc., were definitely secondary considerations.

(c) Payload integration and operations management personnel, as well as the payload flight crew, should have available a complete set of simplified schematics. These should clearly show all interface connections and controls for ready reference during integration and operation when problems occur.

During ASSESS II, except for Spacelab rack interfaces, PIs provided intra-experiment and control diagrams in varying degrees of detail. Other interface diagrams were hastily developed just prior to Launch Site Payload Processing by the Systems Level Payload Integration team in cooperation with members of the various PI teams. Over all, the level of detail in the diagrams was not sufficient to permit integration management personnel to efficiently pursue and solve problems. Even though it is recognized that intra-experiment hardware is a PI responsibility, unless some reasonable inner visibility is immediately available, internal components can cause severe interface problems without a capability to quickly trace the problem to the source.

5.8 Data Handling

(a) Face-to-face interactive discussions between responsible representatives of the experiment and the central data system with a resulting bilateral interface agreement, including verification procedures, are necessary to fully define and establish the data handling interface.

Interface resolution between experiments and the central data system is traditionally one of the most difficult areas. Usually experiment interface identification comes late in the process of experiment hardware preparation, which compounds the problem. A reasonable understanding by the experimenter of central data processor interface limitations may also affect the experiment design, and should come early enough to prevent the need for redesign. All of this dictates that experts from each side of the interface start face-to-face discussions early and continue that type of interaction until a firm interface is fully defined and agreed to by both parties. Attempts to define this interface without extensive discussion and understanding will almost guarantee problems except for the simplest type of data interface.

For ASSESS II, the key data system experts were unfortunately not brought into IRD discussions. This area turned out to be the most severe problem area with persistent difficulty in several cases. For Spacelab, proper early expenditures of travel funds and manpower in this area will almost certainly be cost effective and save later severe problems.

(b) Hardware and software interfaces should be standardized wherever possible between the experiment and the central data system to simplify integration and checkout and enhance operating reliability.

In the ADDAS system, all analog data is generally received through a single analog to digital converter that is sampled by standardized software. Thus, any analog signal that conforms to the limitations of the converter can be quickly and surely added to the data collection system. Limiting digital interfaces to a format and procedure for which the central computer is designed likewise reduces the need for special programming which is costly, prone to error, and generally makes inefficient use of all resources.

(c) Successful software debugging can be accomplished only if enough time is provided with all experiments being stimulated simultaneously in the planned flight configuration.

Although individual experiments to the central data system interfaces should be well verified by the time the total integration phase commences, interaction between experiment software modules can only be reliably tested in a full system environment, and sufficient time must be allowed to identify and solve total system problems which are almost guaranteed to show up. The ASSESS II schedule did not provide sufficient debugging time with all experiments operating, and consequently some severe data processing problems occurred during flight. Software debugging should be expected to continue well into payload integration, and with the real possibility that this type of problem is likely to show up during flight, it is recommended that the uplink be capable of handling data processing computer programs.

5.9 Documentation

(a) The fidelity of document generation and late issuance during ASSESS II resulted in lack of agreement among the participants on any immediate general conclusion for Spacelab on this subject. A separate analysis of documentation will be undertaken.

Identification and review of documentation on ASSESS II was difficult because very little documentation was generated until late in the project. The early IRDs were not completed. Lack of complete analytical integration did not produce the ingredients necessary for timely issuance of documents which required that data. Thus, although the ground and flight operations requirements documents were finally issued, they came too late for review or strong application, and the resulting ground and flight plans were consequently generated very late, mostly on the basis of informal inputs.

(b) For joint NASA/ESA missions, both sides should have an opportunity to review all basic mission documents. Some form of mission implementation agreement should be developed and jointly agreed to by both parties. This should identify those documents which commit each other's resources or significantly impact mission objectives and should be concurred in by both parties.

During the progress of the ASSESS II mission, ESA management felt they were being committed without recourse to certain lines of action by NASA issued documentation. No formal means was developed during the program for NASA/ESA discussion of such documents before their issue. ESA feels that they must be able to discuss jointly those areas where commitments of manpower are to be made before detailed policies are set by NASA issued documents.

Abbreviations and Acronyms

ADDAS	Airborne Digital Data Acquisition System
ARC	Ames Research Center
ASO	Airborne Science Office
DFVLR	Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt (the German Natioual Space Agency)
EMI	Electromagnetic Interference
ESA	European Space Agency
ESTEC	European Space Technology Center
GHz	Gigahertz
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HF	High Frequency
IR	Infrared
IRD	Investigator Requirements Document
IWG	Investigators' Working Group
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
MCC	Mission Control Center
MSFC	Marshall Space Flight Center
M/S	Mission Specialist
MSG	Mission Steering Group
μm	Micrometer
NASA	National Aeronautics and Space Administration
OA	Office of Applications
OH	Hydroxyl
OSF	Office of Space Flight
PCU	Payload Checkout Unit
PI	Principal Investigator
POCC	Payload Operations Control Center
P/S	Payload Specialist
SPICE	Spacelab Payload Integration and Coordination in Europe
STS	Space Transportation System
UHF	Ultra High Frequency
VHF	Very High Frequency

Experiment Designations

AEES	Airborne Electromagnetic Emission Survey
Airglow	University of Southampton
CAPO	short for Capodimonte
IHR	Infrared Heterodyne Radiometer
EMI	EMI experiment
IRA	Infrared Astronomy
LAS	Laser Absorption Spectrometer
Medical	Medical Experiment
SAR	Synthetic Aperture Radar
MLS	Microwave Limb Sounder

Reference 1: NASA/ESA CV-990 Spacelab Simulation - Executive Summary - July 1975. NASA TM X-62,457 and ESA-SL-75-1.