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SHUTTLE SPACELAB SIMULATION USING A LEAR JET AIRCRAFT

MISSION NO. 3

NASA TM X-62,410

John O. Reller, Jr., Carr B. Neel
and Robert H. Mason

AIRBORNE SCIENCE OFFICE
NASA • AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA 94035

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16 Abstract

The third ASSESS mission using a Lear Jet aircraft was conducted by the Airborne Science Office (ASO) at Ames Research Center in November 1973, to continue the study of scientific experiment operations in a simulated Spacelab environment. The experiment in far infrared astronomy was developed by a university scientist to utilize the Ames 30-cm, open-port telescope mounted in the aircraft Prior to the mission, research planning and equipment preparation by the principal investigator (PI) and his research associates were observed and documented. A flight readiness review for the experiment was conducted by the ASO mission manager one month before flight, this new feature had a salutary influence.

Nine of the ten scheduled flights were completed during the simulation mission and all major science objectives were accomplished The PI's equipment was well qualified for flight and gave little trouble, telescope malfunctions occurred early in the mission and were corrected. Both real-time and post-observation data evaluation were used to assess research progress and to plan subsequent flight observations for maximum effectiveness

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SHUTTLE SPACELAB SIMULATION USING A LEAR JET AIRCRAFT – MISSION NO. 3

John O. Reller, Jr., Carr B. Neel, and Robert H. Mason

Ames Research Center

SUMMARY

The third ASSESS* simulation mission using a Lear Jet aircraft was conducted by the Airborne Science Office, Ames Research Center, during the week of November 12, 1973. This mission continued the study of the operation of scientific experiments in a simulated Spacelab environment. As on the previous missions, the constrained environment of Spacelab was simulated by locating mission operations at a remote, semi-isolated site, by confining the participants to this site for the duration of the mission, and by restricting outside communication to telephone contacts through the ASO mission manager

A particular feature of the mission was the careful observation of the experimenters' activities at the home laboratory as they readied their equipment for the mission. Premission activities also included a formal Flight Readiness Review (FRR) of the experimental equipment. The success of this review, as measured by the experimenters' adherence to the scheduled launch date and the lack of problems with their equipment during the mission, suggests strongly that an analogous procedure be used with Spacelab experiments.

Problems with the aircraft delayed the mission schedule for one week The schedule was then followed as planned, including one week for installation, checkout, shakedown of the experimental equipment, and refinement of operating procedures before the confined period of the mission This preparatory week, which is somewhat analogous to the use of a simulator preceding an actual Spacelab mission, also included four flights, one an engineering check flight.

Ten flights were scheduled for the Spacelab flight simulation period. Nine were flown, the second planned flight was cancelled because of a combination of telescope problems and a minor malfunction of experimenters' equipment The first two days of the mission were marred by persistent problems with the Ames 30-cm telescope. However, these problems were overcome, and the last three days and six flights were quite routine. The experimenters' own equipment gave very little trouble and no spare components were used during the entire period.

The major research objectives of the mission were accomplished. To augment these results, four postmission flights were requested for further refinement of measurements in selected areas. Analysis of data during the mission indicated the scientific results were very promising, and early publication was in order.

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*ASSESS Airborne Science/Shuttle Experiments System Simulation

INTRODUCTION

The management and operations procedures that characterize airborne research programs in the Airborne Science Office (ASO), Ames Research Center, are conducive to quality of scientific research, timely attainment of research objectives, and overall experiment economy. Beyond question, the primary element in the success of the ASO approach is the direct involvement of the research scientist in all aspects of the program, with his full responsibility for the development, integration, and operation of his own experiment.

To the extent that the functional goals of the Shuttle Spacelab program resemble those of the ASO, the basic management concerns are analogous, and the ASO experience suggests a potential model for effective and economic operations in space. As a means of achieving the greatest benefit from the ASO experience in Spacelab planning, the ASSESS study program has been evaluating ASO management concepts and practices: their form and control in ongoing airborne science missions, and their effectiveness under constraints that simulate Spacelab operations in selected airborne missions.

The ASSESS program is guided by a working group with representatives from NASA Headquarters and several research centers. Additional ASSESS missions with enhanced simulation constraints are under consideration for both the Lear Jet and the CV-990 aircraft. These missions will address Spacelab concepts now being developed, and in the case of the CV-990, considerable attention will be devoted to the interactions between individual experimenters working in a group situation in confined quarters aboard the aircraft.

The third ASSESS simulation mission was similar to the previous two in physical arrangement – that is, the primary support facilities consisted of the Lear Jet aircraft and the housing trailers. However, the content of the mission differed significantly in several ways. First, the experimenters were an experienced flight team, having flown two normal Lear Jet missions and one Shuttle simulation mission (ASSESS #2). They were selected purposely to avoid the delays associated with the development of a new experiment and to test new methods of monitoring progress during experiment preparation and testing. To this end, the principal investigator agreed to utilize his proven experiment and build only backup equipment as necessary to ensure reliable operation. With this understanding, a mutually acceptable and firm "launch" date was set. In support of this agreement, the ASO mission manager was to ensure that planned modifications to the Ames telescope would be completed, flight tested, and approved in time for training exercises during the premission week.

A major new element in the third ASSESS mission was the Flight Readiness Review (FRR), scheduled one month prior to "launch." At this time, the experimenters were asked to demonstrate that their experiment was ready for flight and to describe the precautions taken to assure reliable operation. The FRR was viewed as the cutoff date beyond which no significant equipment changes could be made or tests performed. A similar review was scheduled for the telescope systems that were being modified by the Ames group responsible for their operation. Other changes in mission format and content included those in ASSESS monitoring procedures, premission week activities, and flight scheduling.

To date, the study of ASO ongoing missions (designated as ASSESS, Phase A) has been documented in references 1 to 3; simulation mission studies (designated as ASSESS, Phase B) in references 4 and 5. The present report is the third in the Phase B series. It describes in detail the procedures set up for the conduct of the mission and its observation. The experiment and its operation are discussed, together with the experimenters' plans for fallback procedures in case of anticipated problems. The FRRs are discussed to the level of tests performed on individual components of equipment. Time lines are given both for the preparatory period at the experimenters' home base and in detail for the confined period.

Support activities and material, tool usage, normal maintenance procedures, and communications facilities are listed. This fund of basic information is evaluated with respect to mission accomplishments and compared with similar results from previous ASSESS simulations. Features having particular meaning and application to planning for research management and operations in the Shuttle Spacelab environment are identified and discussed.

Section 1

1. MISSION PLAN

1.1 Guidelines

The Airborne Science Office (ASO) established the following mission guidelines to satisfy existing program obligations and to comply with selected Shuttle constraints

1. The mission period would be five consecutive 24-hr days, preceded by a normal work week for installation and checkout and a two-day "hands-off" period.
2. Experimenters would make authentic scientific measurements
3. The operations goal would be two flights per night, to concentrate experiment-operation time during the mission
4. Experimenters and copilot/observer would be confined to airplane/trailer complex for the duration of the mission.
5. Experimenters would be permitted to modify their existing experiment to operate more effectively and more reliably.
6. Aircraft preparation, experiment integration and the flight program would be conducted in accordance with standard ASO operation. (For example, the experimenters would have prime responsibility for most aspects of experiment integration.)
7. The experimenters would be permitted to bring "on-board" any spare subassemblies or components they considered necessary to ensure mission success, test equipment and tools would be limited to those that could be justified. ASO would supply and document the use of any additional test equipment, tools, or parts that were required, and maintain supporting GFE in working order.
8. During the mission, no direct personal contact between the experimenters and people outside the ASSESS management and observation groups would be permitted, all outside communication would be by telephone.
9. The ASO mission manager and ASSESS observers would be housed in a separate section of the work trailer. The mission manager would be mission coordinator between the "Shuttle" crew and Ames support personnel

1.2 Organization

1.2.1 Management

The scientific research for the third simulation mission was managed, for the most part, in the same manner as the ASO's ongoing Lear Jet astronomy program. The mission manager coordinated installation and checkout of the experimental apparatus, and handled aircraft logistics and maintenance. For the simulation period, a mission-coordination center was set up in a separate room of the

"Shuttle" work trailer and manned 24 hr a day. All contacts with the "Shuttle" crew were handled by telephone through the ASO mission manager or his designate.

1.2.2 Experimenter/Flight Crew and Observers

The experimenter team was chosen from the ongoing ASO astronomy program using the Lear Jet airplane. The principal investigator and his assistant had participated in the previous ASSESS mission (ref. 2). The copilot was the same scientist/astronaut from the Johnson Space Center who had flown in the previous ASSESS mission. He again acted as ASSESS observer during the flights and on the ground to provide data on experimenter and equipment performance pertinent to the program.

An ASSESS observer was stationed in the mission-coordination center in the work trailer at all times. His function was to record all experimenter and copilot work activities in the trailer. Experience from the first simulation mission showed the need to supplement the observations of the copilot/observer because of differing work/sleep schedules of the "Shuttle" crew members (ref. 1).

The pilots were provided in normal rotating assignments by the Flight Operations Branch of Ames Research Center.

1.2.3 Support Personnel

Support for the mission was provided by a number of groups at Ames Research Center. Mechanical installation of the equipment racks and telescope hardware was done primarily by the Metals Fabrication and Aircraft Services Branches. The work was monitored by the Inspection Branch and the Airworthiness Engineering Group of the Flight Operations Branch. Supplies and equipment were provided by ASO laboratory personnel. During the mission period, support also was available from the ASO flight planners, the Flight Operations Branch, the Aircraft Services Branch, and the Inspection Branch.

1.3 Schedule

In planning for the simulation mission, a 12-week period for laboratory preparation and testing of the experiment was chosen jointly by ASO personnel and the experimenters. Within this time frame was a two-week period previously scheduled for the experimenters to participate in a normal series of flights on the Lear Jet.

On-site activities related to the ASSESS mission were planned to extend over a two-week period. The first five days were devoted to experiment integration and check flights, the next two were a "hands-off" period, and the final five were the mission itself. One month prior to the start of the mission, the experiment and the telescope, which was supplied by Ames Research Center were subjected to FFRs at the experimenters' laboratory and Ames, respectively.

1.4 Operations Plan

1.4.1 Facilities

The simulation complex consisted of the Lear Jet aircraft and two trailers (fig. 1-1). The complex was located in a relatively isolated parking lot well removed from other flight operations activities. The site and adjacent roadways were blocked off from casual traffic. From the site, the aircraft could either be towed to the hangar area for maintenance or taxied to the runway for flight. Weather permitting, flights were to originate and terminate at the taxi position on the roadway, as shown in figure 1-2, with most aircraft operations performed at the simulation site. The area was illuminated with floodlights to permit aircraft servicing at night.

The mission aircraft was a Lear Jet Model 24 (figs. 1-1 and 1-3). At maximum gross weight, the climb to a cruise altitude of 13.7 km takes about 30 min. Maximum cruise time at this altitude is about 1-1/2 hr at a true airspeed of 430 knots. For flights in which the Ames telescope is used, cabin altitude can vary up to 7.6 km, requiring that oxygen masks be donned prior to takeoff. The experiment equipment weight is limited to about 270 kg. The main cabin of the aircraft has a volume of only about 4.25 m^3 (150 ft^3), and space is at a premium; it is difficult for two experimenters using oxygen equipment to work in this confined space for the duration of a 2-hr flight (fig. 1-4).

As for previous ASSESS missions, the aircraft intercom system was modified to give the copilot/observer the added options of a "hot-mike" loop with the experimenters and a private tape recorder system, as well as to allow recording of all communications within and from outside the aircraft on a common recorder.

Accommodations for the copilot/observer and experimenters consisted of living quarters and a work area (fig. 1-2). The former was a standard air-conditioned vacation trailer with four separate beds and the usual facilities. Windows were covered for daytime sleeping. The work area used by the copilot/observer and the experimenters was a 3- by 7-meter space in a standard office trailer. A partition separated the work area from a second room, which was used by the mission manager and ASSESS observer.

1.4.2 Logistics

The logistics plan for the mission dealt primarily with "Shuttle" utilities and aircraft operations. All supplies for experiment maintenance were onboard at the start, as specified in the mission guidelines. "Shuttle" utilities are electrical power and cryogenics. Electrical power at 60 Hz and 120 V, and 28 Vdc was available in the aircraft and in the work area. The work area also contained 120 V, 400 Hz power. Use of power and energy for experiment maintenance was measured in the mission coordination area. A protective structure was provided to permit filling of the experimenters' Dewar in the rain.

At the start of the mission, the living quarters were stocked with linens and paper supplies, cleaning supplies, eating and cooking utensils, and supplemental food supplies. The plan was to deliver one hot meal a day and store frozen food onboard for the other two meals. Meals would be ordered by telephone through the mission coordination center. The schedule for eating was not planned in advance, but was left to the simulation crew.

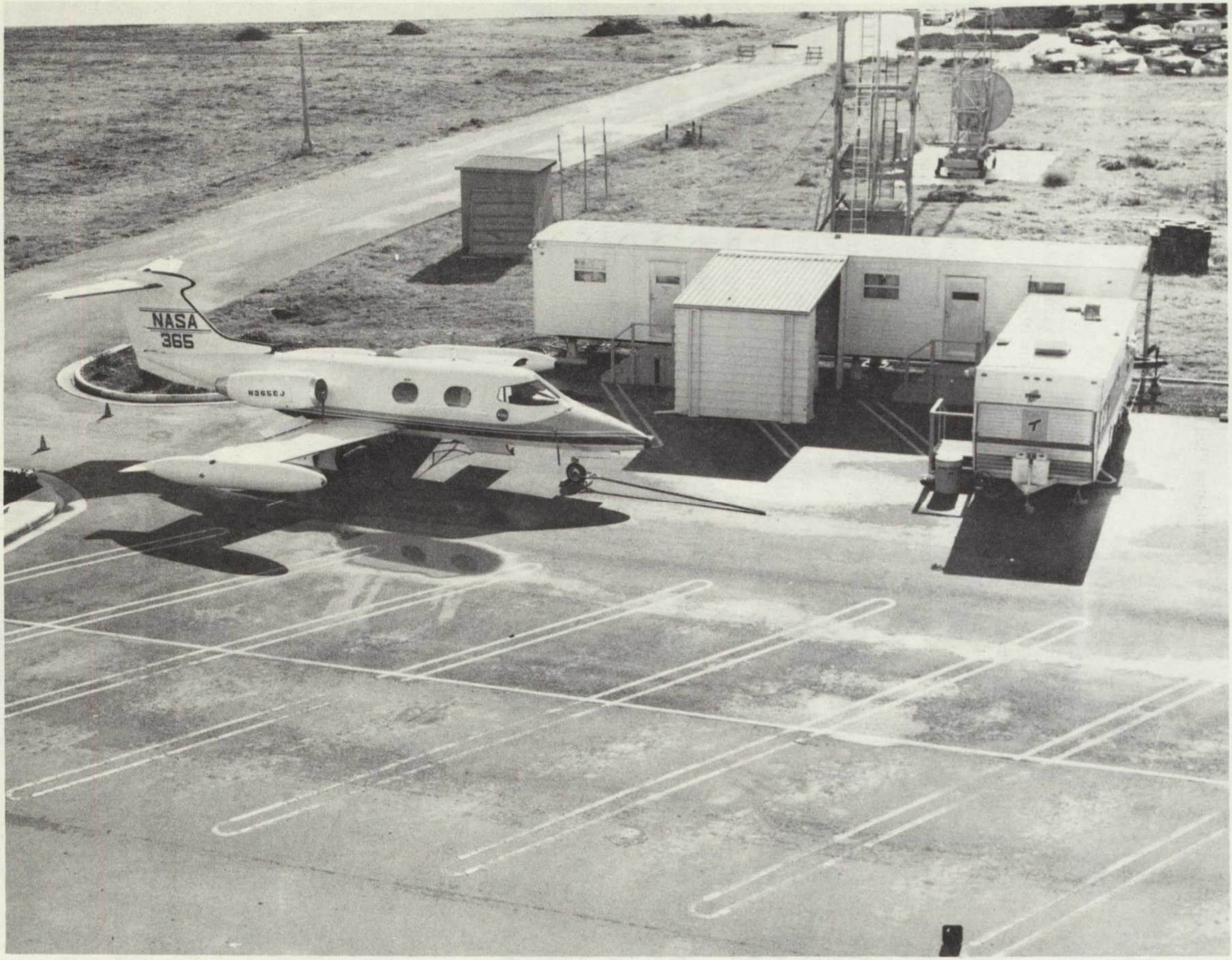

Figure 1-1. – View of simulation site.

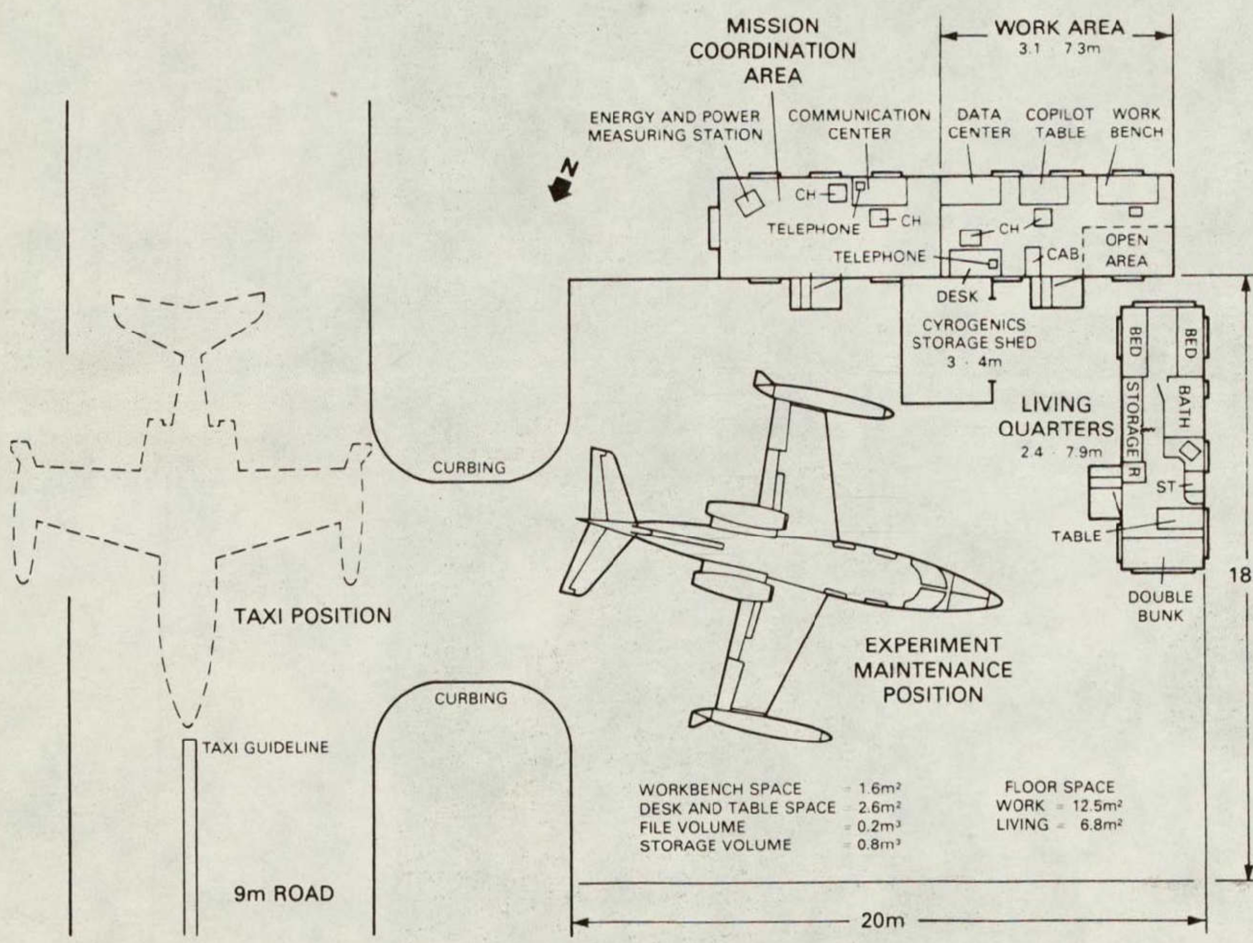

Figure 1-2. – Arrangement of the simulation complex.

Figure 1-3. – Entry door and telescope port in Lear Jet aircraft.

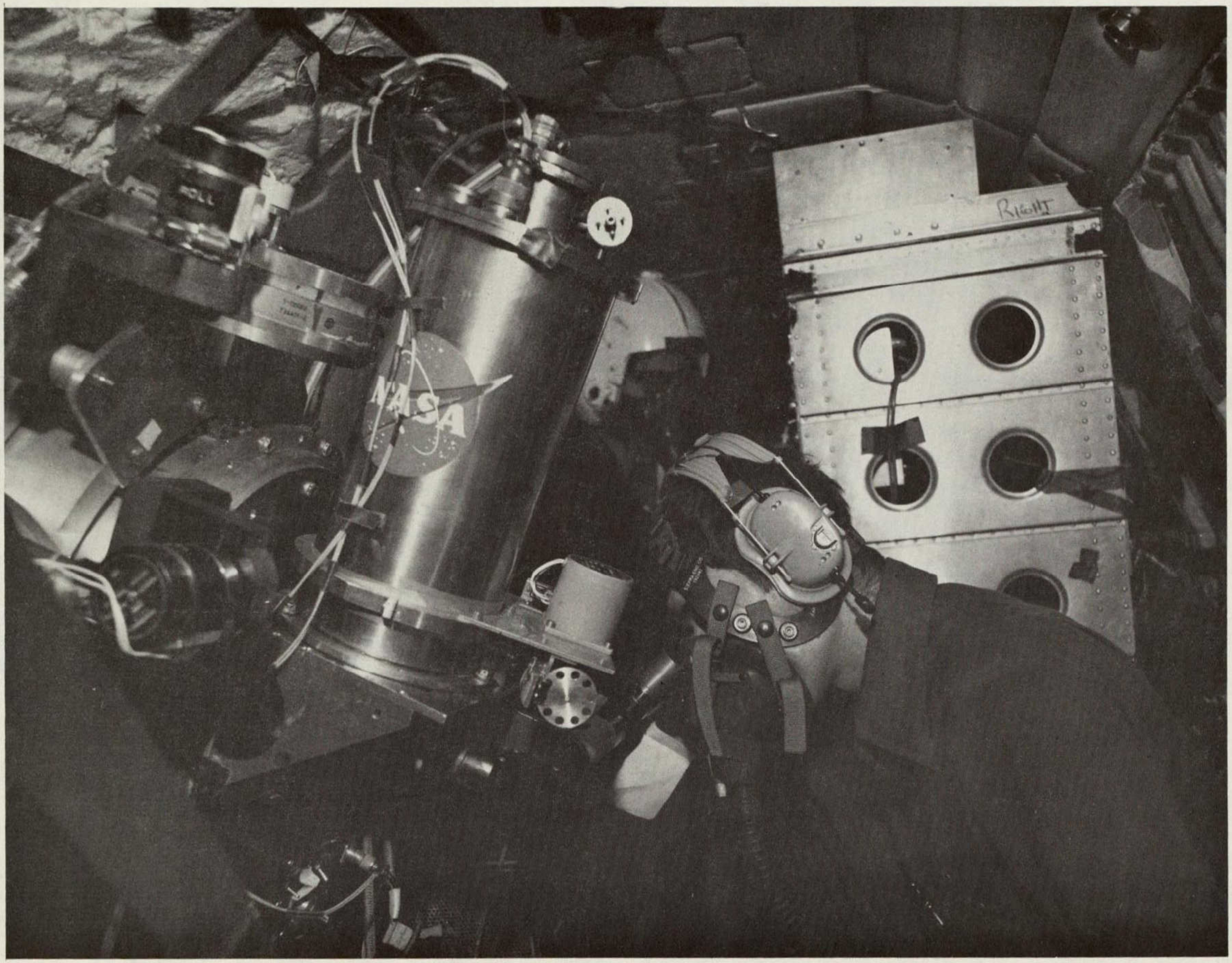

Figure 1-4. – Experimenters at work stations in Lear Jet cabin.

It was intended that all flights be based at the simulation complex. In fact, however, all but the first flight originated from the Ames hangar area. There were two reasons for the change in plan. First, the flight plan desired by the experimenters called for two flights separated in time by about an hour and a quarter. This period was too short to permit towing the aircraft to the hangar for servicing and returning it to the simulation complex for the second flight. In addition, weather conditions necessitated that the aircraft be moved from the site to the hangar for the first flight of the evening on all but the first day of the mission. Thus, aircraft operations planned for the simulation site were mostly done in the hangar area, thereby simplifying the activities of the ground-support crew. These operations included normal maintenance, preflight checks, and servicing of the oxygen supply tanks. Much of the preflight checkout of the experiment similarly was done in the hangar area, and the experimenters and their Dewar shuttled by car between the two locations.

1.4.3 Mission Operations

Mission-related operations were scheduled for the week prior to the starting date. Experiment installation was to begin on Monday, October 29, with the first checkout flight early Wednesday evening. On Thursday, a rehearsal on all preflight, flight and postflight experiment and aircraft operations was scheduled at the simulation site, with a checkout flight in the early evening. Final tune-up of the experiment and the aircraft on the ground was planned for Friday, with the weekend free for rest and relaxation. The mission operations plan called for the simulation mission to begin with a briefing session at 2 p.m. on the following Monday.

The experimenters started installation on schedule October 29 and were ready for a check flight by Wednesday as planned. However, at just this time the aircraft had to be returned to the manufacturer for emergency repair of avionic systems, and the schedule slipped a week. An engineering check flight was flown on the following Wednesday morning, November 7, and three data flights were flown on successive evenings that week during the preparation period. After a two-day rest period the experimenters and the copilot/observer moved to the simulation complex on Monday, November 12, and based there until the debriefing meeting scheduled at the end of the mission.

The ASO mission manager for the Lear Jet astronomy program served in his normal capacity as focal point and coordinator for any problems that occurred, in addition to the day-to-day arrangements for overall operations. Daily flight planning was handled in the normal manner by the ASO flight planner, using information on desired targets and sequence of observations furnished by the principal investigator (PI) at the start of the mission, as well as daily update information. Completed flight plans were posted in the work area at the simulation complex.

The daily time schedule of mission operations was completely at the discretion of the simulation crew, who keyed their activities to the flight schedule. Experiment maintenance time, eating and sleeping time, etc., were entirely open at the start of the mission.

1.4.4 Support Operations

Insofar as possible, the support operations plan followed the procedures normally used in the ongoing Lear Jet astronomy program. Overall coordination was provided by the ASO mission manager. He initiated the requests for aircraft services and flight crew support. For this simulation mission, the special support activities related to the remote site, the life-support functions, and the round-the-clock schedule were planned in cooperation with the ASSESS program manager and representatives of the various support groups.

Support activities of the Ames Flight Operations Branch consisted of their normal functions, adjusted to the mission time schedule. The Aircraft Operations Office was normally in radio contact with the aircraft while in flight and within radio range. Aircraft commanders and backup pilots were assigned by the Flight Operations Branch, at the written request of the ASO mission manager. Normally, a different individual served as command pilot each night. He participated actively in the operations planning, accepting responsibility for special taxiing arrangements relative to other local flight operations and for a detailed aircraft activities schedule and aircraft safety to be used before, during, and after flight. He also monitored the physical condition of the experimenters and their fitness for flight, and verified that the aircraft life-support O_2 system was maintained in "top shape."

Support for aircraft navigation and flight planning was provided by the ASO, using normal channels. The decision for flight originated with the experimenter who submitted his request to the ASO mission manager. When approved, it was passed to the ASO flight planner for implementation. Copies of the completed flight plan were returned to the experimenters and the command pilot.

ASSESS personnel made the necessary arrangements for food supply during the mission, and for other logistics related to ASSESS observations.

1.4.5 Safety

In all ASO missions, flight safety is of prime importance, and normal precautions for the protection of personnel and equipment are well established. Safety requirements applicable to experiment design are given in the Lear Jet Experimenters' Handbook.

Several individuals, as well as specific Ames organizations, interfaced with the Lear Jet experiment to ensure a safe operation. The ASO mission manager was involved as coordinator of the overall program, the experimenters as direct participants in every flight, and the pilots as the responsible flight officers. The involved organizations were the Airworthiness Engineering Group of the Flight Operations Branch, the Inspection Branch, and the Airworthiness and Flight Safety Review Board (AFSRB); their duties and functions relative to the design and integration of airborne experiments are described in reference 2.

Prior to the ASSESS mission, the AFSRB was given a detailed review of the safety aspects of all new designs, operational plans, and contingency considerations. The presentation was made by the ASO mission manager with the backing of representatives from the Ames organizations supporting the mission. For this particular mission, the telescope installation had been approved earlier by the AFSRB, so that the review concentrated on the unique features of the experimenters' sensing equipment, the mode of flight operation, the considerations for personnel constraints, and the aircraft operations from the simulation site.

The Lear Jet experimenters had previously attended the required one-day high-altitude training course at a nearby military installation, and a local training session on Lear Jet life-support systems and emergency procedures. Both men satisfied the requirements for a current FAA Class II flight physical certificate, and were examined by an Ames-approved physician immediately prior to the start of the mission. An Ames flight surgeon was assigned to monitor the experimenters' physical condition during the mission.

1.4.6 Contingency Procedures

Procedures for handling contengency situations were established for ASSESS Mission #3. Weather contingencies were of foremost concern, since the aircraft was to be parked outside at the simulation site for normal operation. Fatigue or illness of the crew was considered, since either could jeopardize mission performance. Provisions were made for landing at alternate airfields, which would have interrupted the simulation aspects of the mission, and for major aircraft or experiment maintenance problems.

The following contingency procedures were adopted for the constrained period of operation:

1. In the event of a major maintenance problem (or rain), the aircraft was to be *stationed in* and *depart from* the hangar. The "Shuttle" crew was to be taxied from the simulation site to the hangar by car for each flight.
2. If a problem with the experiment required some part or item of test equipment that was not available "on board," the item was to be supplied if considered necessary for mission success.
3. The Aircraft Commander could elect to:
   a. Recover to the Ames hangar in case of bad weather or a safety problem.
   b. Cancel the upcoming flight in case of overfatigue of pilots or experimenters.
4. If either pilot became ill, he would be replaced by the assigned backup pilot. If one or both of the experimenters became ill, the upcoming flight would be canceled and rescheduled.
5. Any decision to cancel the mission would be made by the ASO mission manager in conjunction with appropriate personnel.
6. Alternate landing fields would be used in emergencies. If an emergency landing occurred at a nearby airport, the ASSESS duty officer would retrieve the "Shuttle" crew, and other Ames pilots would recover the aircraft; if at a remote airport, a decision would then be made as to the effect on the simulation mission and plans for subsequent operation.

1.4.7 Documentation

Normal ASO documentation procedures were used for the ASSESS mission. An aircraft work order called for installation of the telescope and experiment equipment was issued by the ASO mission manager. This order served three functions: it requested the Airworthiness Engineering Group to review and approve the safety and airworthiness of the experiment; it authorized fabrication of the attachment hardware; and it requested the Inspection Branch to inspect and approve the final installation.

Just prior to the flight period, the ASO mission manager initiated a Flight Request Record for the entire flight series. This authorizing document was circulated to those groups concerned with flight operations. All other coordination and decision-making activities were accomplished by the

ASO mission manager and the experimenters in informal discussions with representatives of the cognizant support groups.

The unique operations associated with a Shuttle simulation mission required some documentation in addition to that normally used. A mission operations plan for the detailed activities of the simulation mission was formulated by the ASO mission manager and the ASSESS program manager. This plan was submitted to the Airworthiness Engineering Group of the Flight Operations Branch for early concurrence and was approved at a full meeting of the Airworthiness and Flight Safety Review Board.

1.5 Experiment Installation

The basic research equipment for the mission consisted of the Ames 30-cm IR Cassegrain telescope and the experimenters' liquid-helium-cooled, dual-detector, grating spectrometer. The telescope system, including gyro-stabilization electronics, was the responsibility of the Ames Space Science Division and was modularized to facilitate rapid trouble-shooting and replacement of printed-circuit boards with a minimum of technical background knowledge. Replacement parts and the modular boards were readily available.

The telescope was mounted in the port-side passenger window of the main cabin and the gyro-stabilization electronics on a pallet located just aft of the door (fig. 1-5). Signal-processing electronics for the spectrometer were mounted in a standard Lear Jet rack located forward in the cabin on the starboard side. Power for this system was furnished by a dual 60-Hz, 115-V solid-state inverter mounted in the baggage compartment (fig. 1-6).

Installation of the equipment was accomplished by standard ASO procedures. To minimize on-site fitting of components, the experimenters were shipped a Lear Jet electronics rack for pre-installation of the majority of their electronics equipment in their own laboratory. On arrival at Ames, they participated in the installation of the experiment on the Lear Jet by the aircraft ground crew and other cognizant personnel.

Prior to installation, the cabin layout and the electronics rack assembly were reviewed and approved by the Airworthiness Engineering Group and the Inspection Branch. The completed installation was again inspected and approved for flight by the same two groups. These inspections were for flight safety and airworthiness only. Performance and reliability of the experiment was the responsibility of the principal investigator.

Initial contacts between the experimenters and Ames personnel were handled through the ASO mission manager for Lear Jet operations. During installation of the equipment, however, the experimenters worked directly with the support groups. The mission manager was advised of progress and assisted in resolving any problems. Personnel from the Space Science Division assisted the experimenters in the installation, operation, and trouble-shooting of the telescope systems during the premission week.

1.6 ASSESS Observation Procedures

In accordance with the mission operations plan, observational data were collected at several locations during the preparation for, and operation of, ASSESS Mission #3. Initially, interest centered on the activities associated with the development, testing, and preparation of the

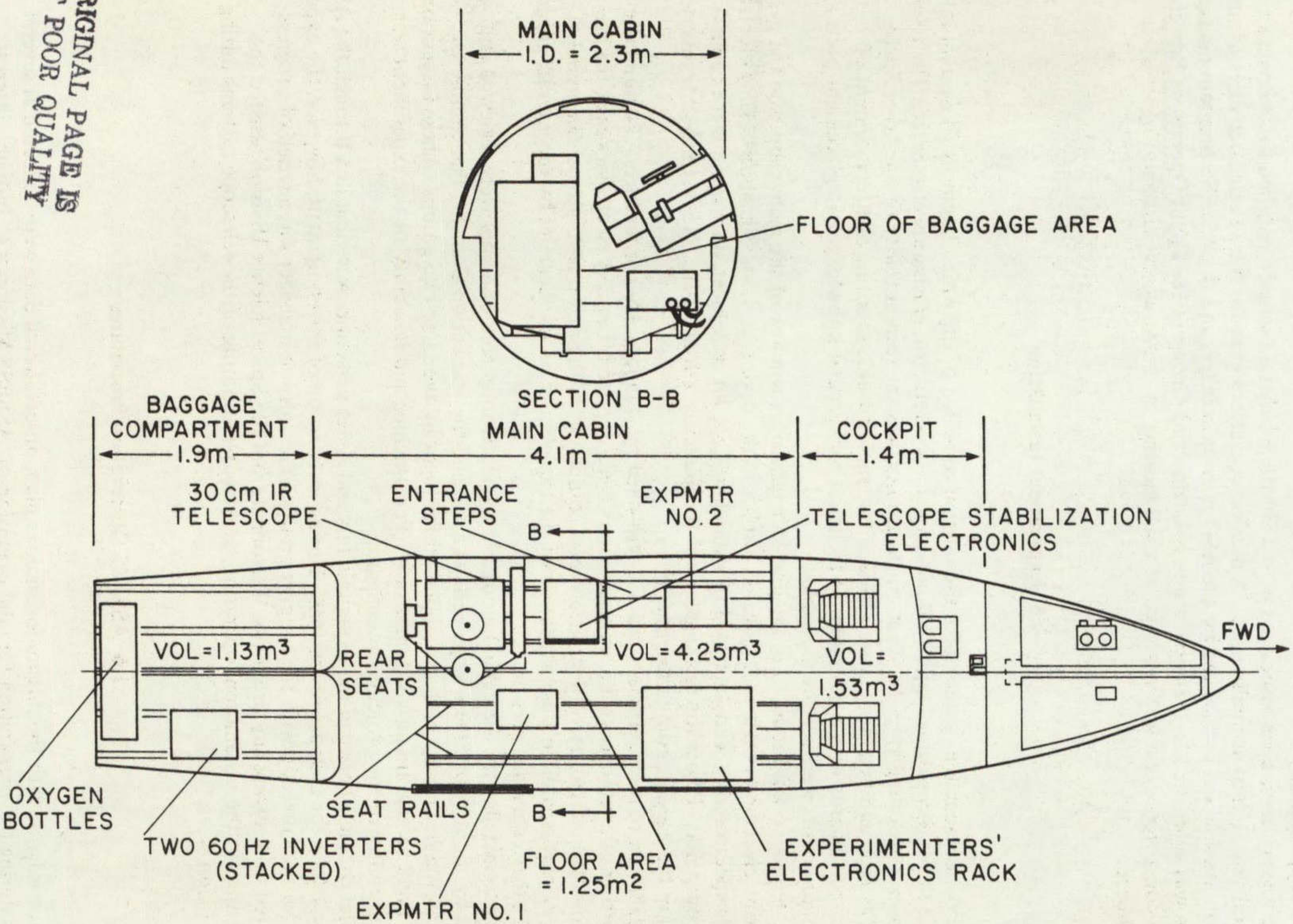

Figure 1-5. – Plan view of Lear Jet cabin.

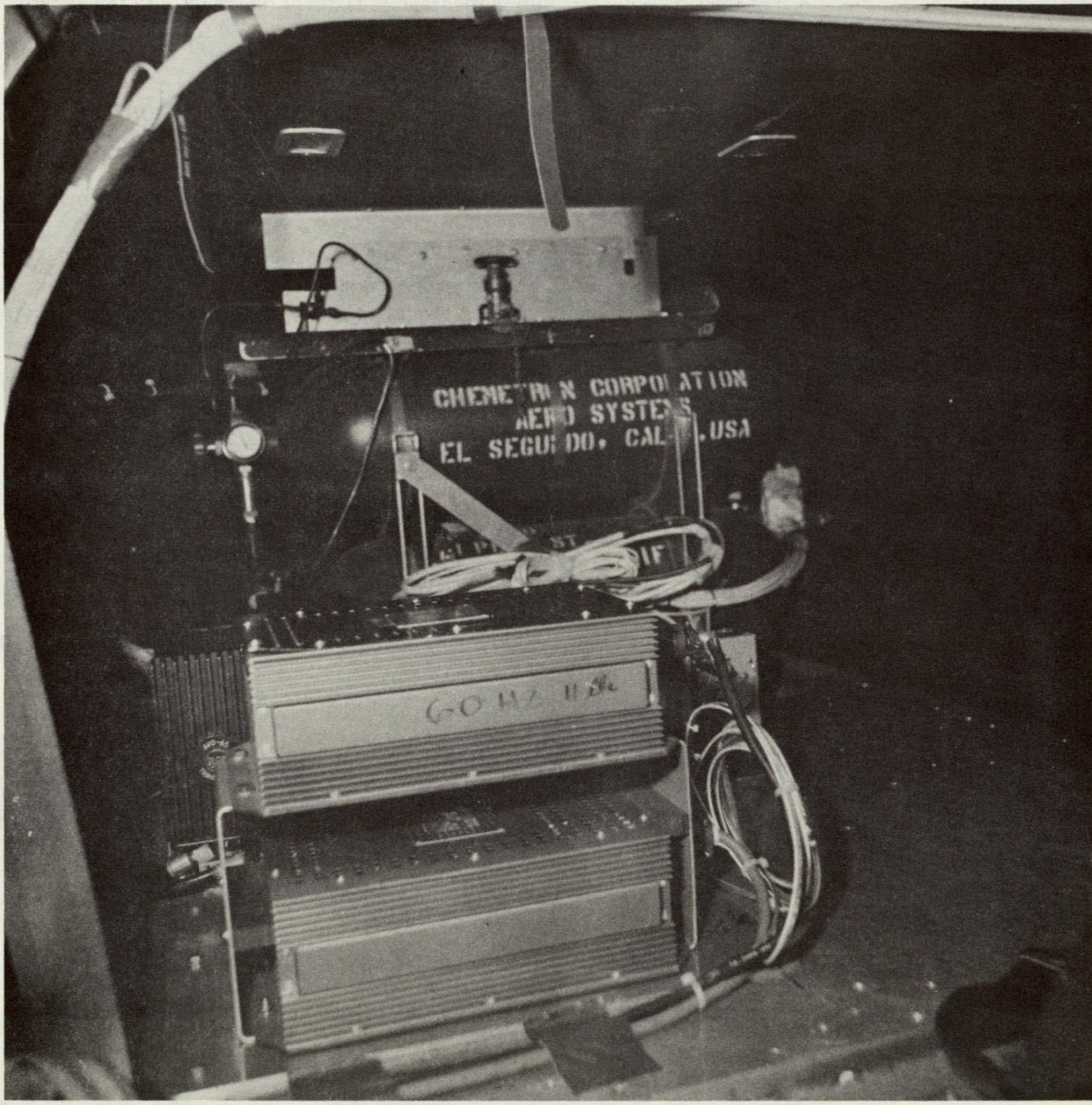

Figure 1-6. – Electronic inverters for 60-Hz power.

experiment at the experimenters' laboratory. The highlight of this period was the FRR, in which the experimenters reported on their development and testing effort to demonstrate that their equipment was in fact completed and operating reliably. Subsequently, interest focused at Ames for the checkout and flight phases of the mission.

ASSESS information was collected by (1) direct observation of trained personnel, (2) tape recording conversations of the experimenters during flight, and (3) direct interview with the experimenters. The last method was kept to a minimum during the simulation period to avoid influencing the conduct of the mission.

Two tape recorders were used to aid and complement the inflight observations of the copilot/ASSESS observer. The first was mounted in the baggage compartment and connected to the aircraft intercom system; it operated continuously so that all conversations occurring in the aircraft were recorded. The second was a hand-operated cassette recorder connected to the oxygen-mask microphone of the copilot so that his observations of the inflight activities could be recorded without interfering with the experimenters or the pilot.

To provide an accurate time base for recording experimenter activities in flight, a time-code generator was installed in the electronics rack. This device generated a signal that was input to the ASSESS tape recorder and also provided an illuminated display of time for convenient reference by the experimenters.

The copilot/observer was provided an ASSESS checklist of the major events and activities for observation and comment. Emphasis was on aircraft and experiment problems – their disposition, corrective action taken, time to resolve problems, impact on the mission, and proposed action to prevent recurrence. The experimenters also were provided a checklist of inflight events on which narrative comment was requested to aid the correlation of ASSESS information. Science objectives, changes to experimental equipment, the timing of research procedures and major flight activities, and the occurrence and disposition of equipment problems were the principal topics of interest.

Immediately following a flight, the ground-based ASSESS observer interviewed the experimenters and copilot to obtain a first-hand account of the scientific accomplishments and the experiment problems (if any). Although brief and informal, this session provided an information base to which subsequent actions could be related.

Section 2

2. RESEARCH EXPERIMENT

2.1 Experiment History

The experiment selected for the third ASSESS mission was developed in the laboratories of the astronomy department of a major university. The basic instrument was a dual-detector infrared spectrometer for scanning in the 16- to 40-micrometer (μm) region. The initial proposal to use this experiment for an ASO airborne research mission on the Lear Jet aircraft was prepared in May 1972; an existing spectrometer, developed for another NASA-sponsored program, was to be adapted for the study of infrared radiation from the planet Jupiter. The basic objective of the ASO mission was to obtain data to permit a determination of the hydrogen/helium (H_2/He) ratio in the Jovian atmosphere. Following approval of the project, the necessary electronic equipment was constructed and assembled at the university of the experimenters in the summer of 1972, leading to the first ASO flight series in November 1972.

The first flight series gave promising research results. The team was then asked to participate in an ASSESS simulation mission in April 1973 (ASSESS #2). For the ASSESS mission, a completely new spectrometer and associated electronics were constructed, with the equipment used on the previous airborne research mission relegated to backup status. Difficulties with the detectors in the new spectrometer forced a change to the backup equipment before the confined portion of the ASSESS #2 mission (ref. 5).

A third flight series took place in August 1973 utilizing essentially the same equipment as the ASSESS #2 backup equipment. Results of this mission were only partially satisfactory. The equipment flown in August represents the prime equipment for the ASSESS #3 mission.

2.2 Scientific Objectives

There were two major scientific objectives for this mission; both were extensions of previous airborne research in the 16- to 40-μm region of the far infrared spectrum. The first was to determine the thermal structure -- temperature, pressure, height -- and composition (specifically, the H_2/He ratio) of the atmospheres of two of the outer planets, Jupiter and Saturn. Such information is valuable to astrophysicists in substantiating theories of planetary formation and planetary atmospheres. In part, this objective had been pursued in the three previous airborne missions flown by this experimenter, but selective verification of the earlier results was still a priority item. During the ASSESS #3 mission period, however, Saturn was not suitably positioned for viewing, so its observation was deferred to a later mission and Jupiter was used exclusively.

The second objective was to study the thermal structure and composition of the Orion Nebula (M42), one of many H II emission regions of interest to astrophysicists. The instrument was used to map the spectral contours of this diffuse IR source. This kind of data can yield information about the constitution of such a source of radiation, both its thermal properties and the relative abundance of molecular hydrogen (and other gases) and silicate dusts. This objective had been pursued in the two previous missions with positive results; in ASSESS #3, however, far more detailed measurements were possible with the highly sensitive detector now available.

2.3 Equipment Description

For the ASSESS #3 mission, the experimenters provided a complete spectrometer system backed up with spare components to cover possible failures. An alternate spectrometer (of slightly different design than that designated as the prime unit) was provided for backup. Spares were provided for all electronic components but not in sufficient number for assembly of a completely separate backup system.

2.3.1 The Experiment

The dual IR spectrometer experiment utilizes the Ames 30-cm infrared telescope with its associated stabilization system (fig. 2-1). The spectrometer attaches to the telescope backplate and supports the Dewar, which cools the detectors (fig. 2-2). As it leaves the telescope, the infrared radiation is intercepted by a beam splitter, which reflects substantially all of the radiation to the spectrometer. A small amount of visual energy is transmitted to an eyepiece to permit guiding through the main telescope. The coaxial guide telescope (fig. 2-2) is used only for finding, but not for guiding. Figure 2-3 is a sketch of the optical paths involved.

The spectrometers utilize doped germanium photoconductors for detectors. The incident radiation excites current carriers, thus changing the resistance of the detector. (The action is physically different from that of the bolometer used by some other experimenters in which the resistance change is due to slight changes in temperature caused by the incident radiation.) Current is passed through the detector from a constant current source and the minute change in voltage across the detector resulting from changes in incident radiation provides the basic data signal.

The photoconductors need not be cooled to the minimum possible liquid helium temperatures. Actually, the temperature of the detectors under measurement conditions is not known exactly, but is estimated to be between 6° and 10° K. Such a temperature is sufficiently low to permit a good signal-to-noise ratio. The temperature of the liquid helium in the Dewar is maintained at a nominal 4.2° K by a throttle valve to control the internal pressure to approximately one atmosphere. The detector mounts are soldered directly to the base of the liquid helium container and so approach the 4.2° K temperature of the liquid helium.

2.3.2 Prime Equipment

Figure 2-4 is a block diagram of the system; figure 2-5 shows the experiment equipment mounted in the standard Lear Jet rack.

The location of each component of the system, and its dimensions, electrical parameters, weight, and costs are given in Table 2-1. The GFE portions of the system are also listed for completeness. The spectrometer and the electronics are discussed below. Spare equipment and the various displays used in the experiment are discussed in later sections.

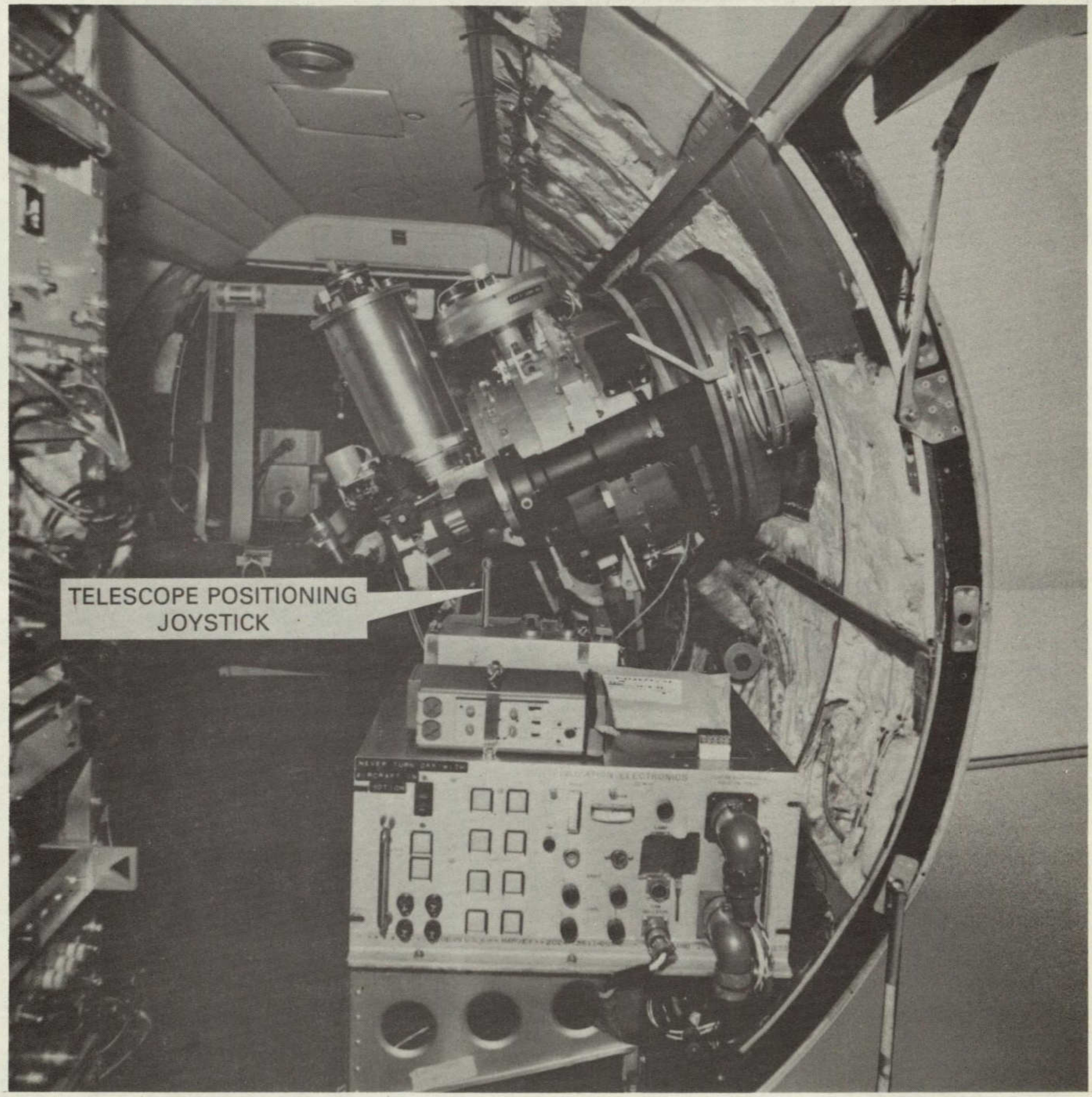

Figure 2-1. – 30-cm IR telescope with stabilization electronics.

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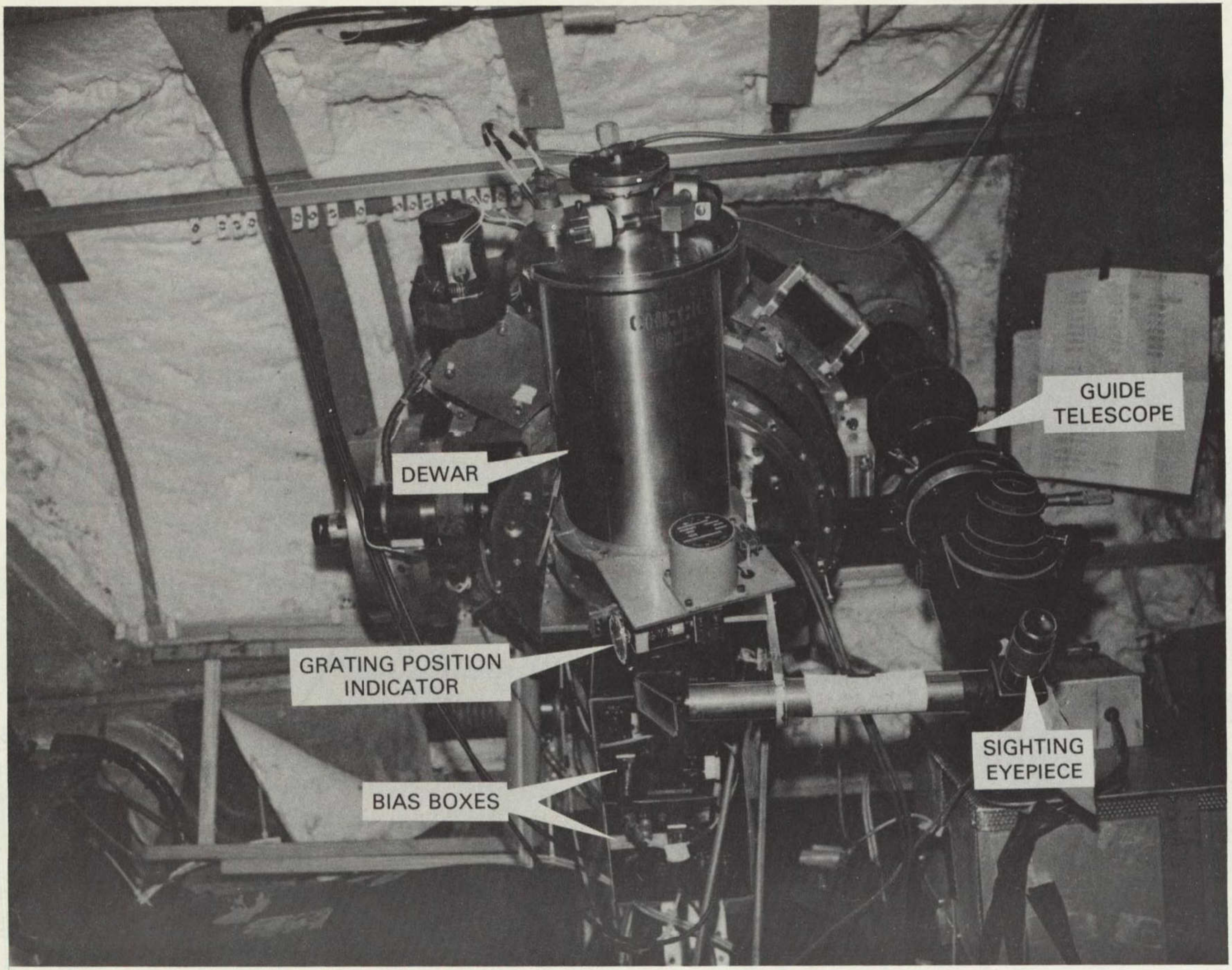


Figure 2-2. – 30-cm IR telescope installed in aircraft (side view).

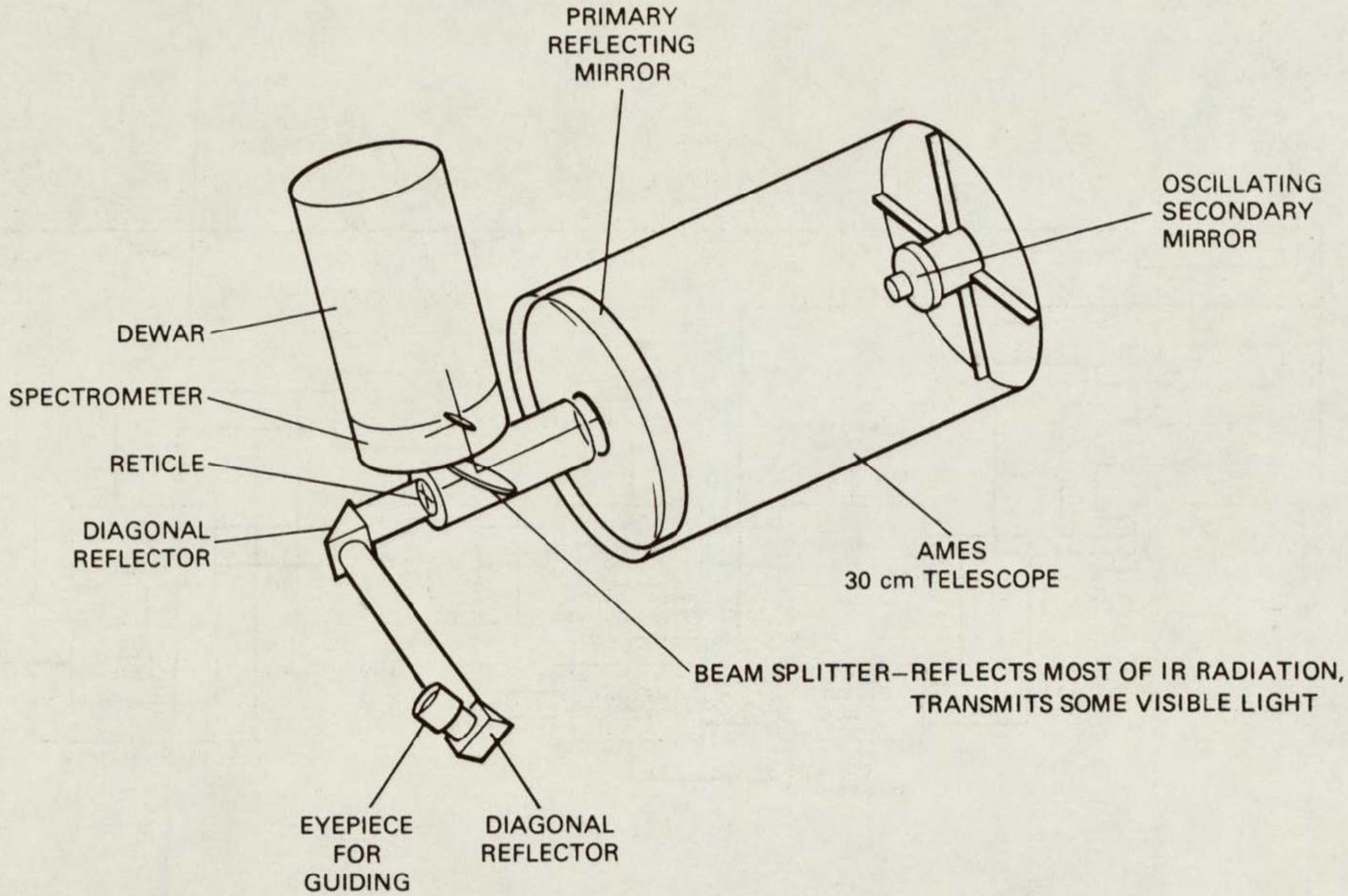


Figure 2-3. – General sketch of system optics.

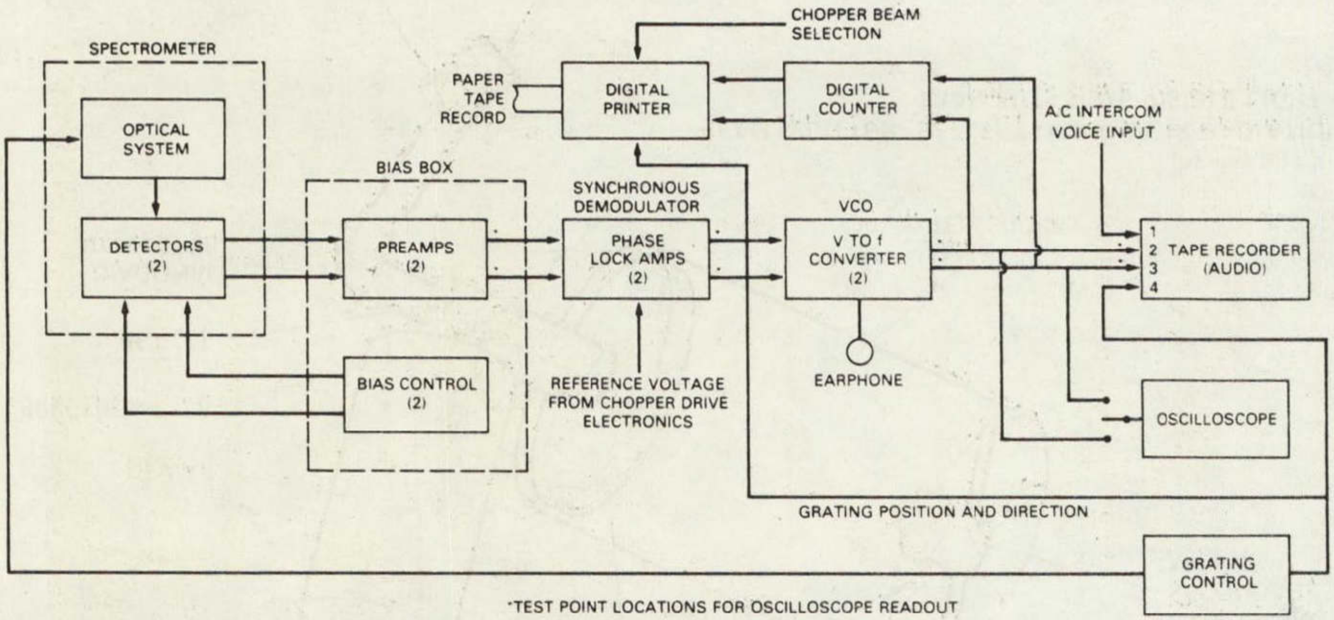


Figure 2-4. – Basic block diagram.

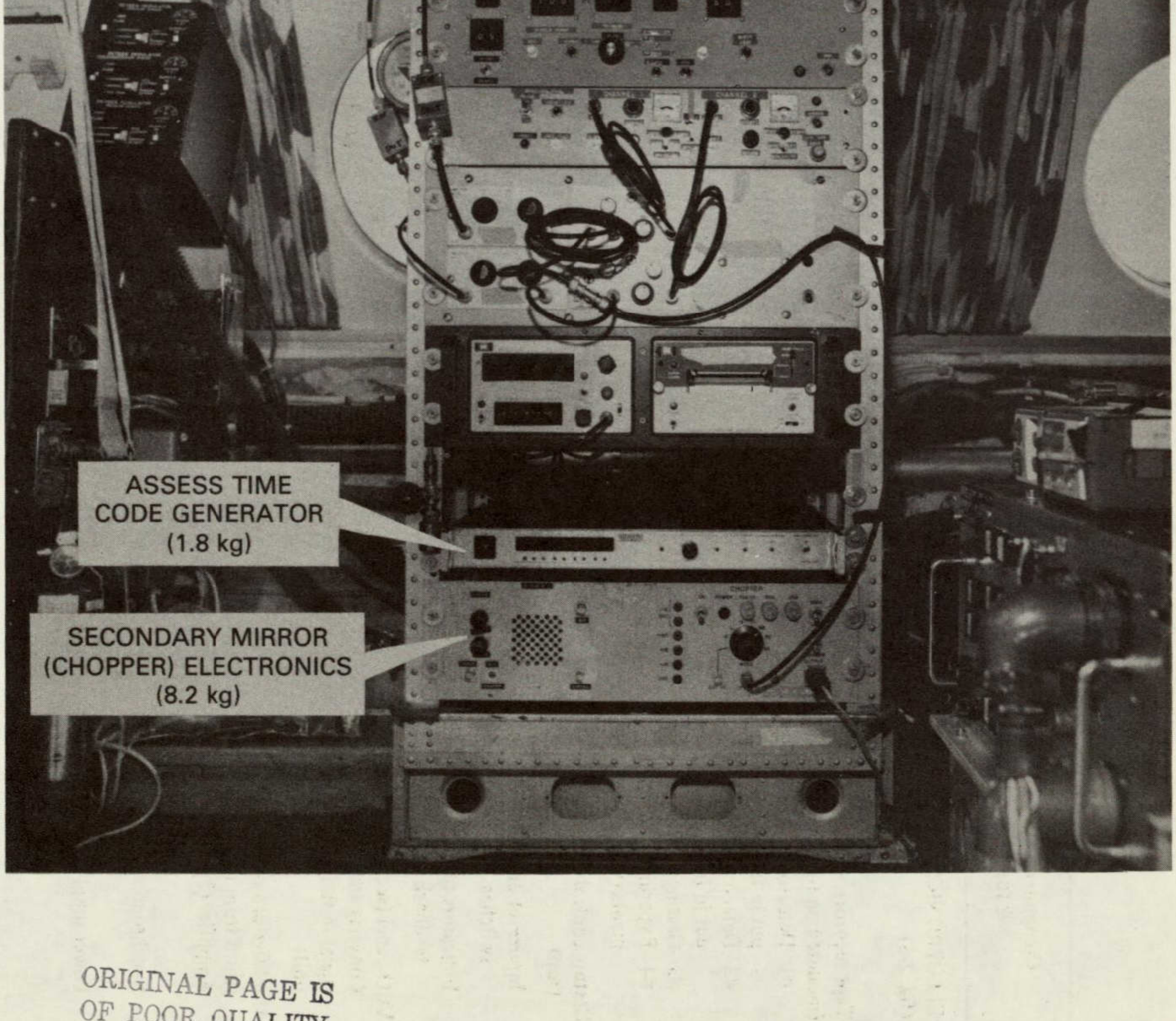


Figure 2-5. – Experimenters' electronic equipment installed in standard Lear Jet rack.

TABLE 2-1. – PRIME EQUIPMENT CHARACTERISTICS

Component–location & function	Type of construction	Dimensions (cm)			Power		Weight (kg)	Cost ($)	Comments
		H	W	D	Type	VA			
ELECTRONICS RACK (fig. 2-5)									Total installed weight of rack = 68 kg.
Tape recorder, 4 Channels (mounted on top of rack)	Modified commercial	11.5	46	27	115 V 60 Hz	32	*	300(1) 70(2)	Empty rack = 8.2 kg. Chopper elect. = 8.2 kg. Time code = 1.8 kg. GFE = 18.2 kg.
#1–Detector #1 signal output in frequency									*Net weight of experiment electronics in rack ≈ 50 kg.
#2–Detector #2 signal output in frequency									
#3–Grating position									
#4–Experimenter comments (voice)									No individual component weights available.
Grating control panel (top)	Experimenter built	13.5	48	15	115 V 60 Hz	57	*	600(1) 50(2)	
Inputs set on digital switches									
Indicators for displaying feedback of settings									
VCO panel (second from top) Converts analog voltage signal to frequency; two units	Experimenter built	9	48	41	115 V 60 Hz	24 both	*	50(1) 30(2)	
Amplifier-demodulator panel (third from top)		18	48	13			*		
Amplifier (2)	Off-the-shelf	6	13	13	115 V 60Hz	0.2 both		600(1) 40(2)	
Synchronous demodulator (2)	Off-the-shelf	6	13	13	115 V 60Hz	24 both		600(1)	
Power supply behind panel	Off-the-shelf	13	14	13			*		

TABLE 2-1. – PRIME EQUIPMENT CHARACTERISTICS – Continued

Component–location & function	Type of construction	Dimensions (cm) H	W	D	Power Type	VA	Weight (kg)	Cost ($)	Comments
Digital data system panel (fourth from top)		13	48	20	–	–	*		
Digital counter	Off-the-shelf	10	19	20	115 V 60 Hz	20		2000(1) 550(2)	
Digital printer Provided redundant data record (except voice)	Off-the-shelf	10	19	20	115 V 60 Hz	16			
Spectrometer with cooling Dewar (fig 2-2) Attached to backplate of telescope. Dewar filled with liquid helium cools detectors	Experimenter built				–	None	12.3	2800(1) 1100(2)	
Reflex viewing eyepiece Coupled to main telescope through beam-splitter. Permits tracking through main telescope. Includes reticle (fig 2-2).	Experimenter built				–	None	1 4	600(2)	
Bias boxes (2) Provides bias current through detectors and preamplifies signals. Placed on bracket under telescope (fig. 2-2)	Experimenter built				90 Vdc Battery	0 20	2.0 each	630(1) 860(2)	Bias boxes completely rebuilt
Pressure gauge and valve	Off-the-shelf				–	None	–	260(1)	
			TOTALS			173(3)	67.7	7840(1) 3300(2) 11,140	

TABLE 2-1. – PRIME EQUIPMENT CHARACTERISTICS – Concluded

Component – location & function	Type of construction	Dimensions (cm) H	W	D	Power Type	VA	Weight (kg)	Cost ($)	Comments
TELESCOPE SYSTEM									
Main telescope with guide telescope, stabilization system and oscillating secondary mirror (48Hz) Mounted in port passenger window (fig 2-1)	Custom – Ames	102	86	71	–	–	85	*	*Initial cost of telescope system was $86,000. Upgrading of components is a continuing process Estimated $3400 cost for this mission
Telescope stabilization electronics Mounted forward of telescope on port side of aircraft	Custom – commercial	21	48	48	28 Vdc	200 to 1120	21	*	
Joystick control Used by experimenter to control telescope tracking Mounted on stabilization electronics box.	Custom – Ames	8	15	25	–	–	5.4	*	
Chopper control Mounted in electronics rack Controls frequency and amplitude of secondary mirror motion (fig 2-5)	Custom – Ames	13	48	–	115 V 60 Hz	60(4)	8.2	*	
					TOTAL		119.6		

(1)Hardware cost incurred for a previous Lear Jet mission

(2)Estimated cost of refurbishment and testing for this mission, including backup units.

(3)To this must be added about 75 VA loss in 28 Vdc to 115 V, 60 Hz inverters.

(4)Add about 25 VA for inverter losses.

Spectrometer. – Two separate detectors, each with a different dopant, are used in the spectrometer to provide overlapping spectral coverage in the 16- to 40-μm range One detector covers half of the spectral range utilizing the second-order spectrum while the other covers 3/4 of the range with the first order. Thus, failure of either detector cannot result in a complete loss of information.

The dispersive element is a ruled grating. Rotation of this grating causes the spectrum to be scanned across the detectors. Motion of the grating is controlled by electronic circuitry driving a small electric motor Predetermined operating conditions may be set into the grating control circuitry. In addition, control conditions may be changed if required by observing conditions.

The spectrometer was built at the university by the experimenters with the aid of a local machine shop. The detectors and some of the optical components were constructed by the experimenters, who handled the entire assembly.

The construction of detectors is still somewhat of an art rather than an exact production job. The experimenters have developed techniques that result in better quality and less costly detectors than are available commercially. The process starts with slicing thin wafers from a commercially procured boule of purified germanium. The proper minute amount of doping material is added in a vacuum furnace. The art lies largely in the process of soldering leads to these small devices, which measure approximately 3 mm square. It has been found that the signal-to-noise ratio may vary by a factor of a hundred among a batch of detectors constructed at the same time. The variation is attributed to the soldering process.

Electronics. – The block diagram of figure 2-4 emphasizes the electronics portion of the equipment, which accounts for the majority of the system components. As already described, the basic data signal is a minute voltage change across the photodetector. The detectors have a cold resistance of the order of 50 to 300 megohms. The current source in the bias control unit (bias box) is a 90 V battery with an adjustable series resistor. The current through the detector is adjusted to give a useful signal with a satisfactory signal-to-noise ratio. With the value of detector resistance indicated, the current is of the order of a microampere and the voltage change is several microvolts. The signal from the detector is ac, approximating a square wave at the chopper (oscillating secondary mirror) frequency under ideal operating conditions. Leads from the bias box to the detector are carefully shielded to reduce extraneous pickup.

The detector signal is first processed by a preamplifier of adjustable gain and then synchronously demodulated by a phase-lock amplifier. The reference input is chopper-control voltage, suitably phased by an adjustable control on the synchronous demodulator panel. The dc signal from the output of the phase-lock amplifier goes to a VCO (voltage controlled oscillator, sometimes referred to as a V to f converter). The output of the VCO is a constant voltage signal with a frequency linearly proportional to the input voltage. This ac signal is recorded as an audio tone on the tape recorder, two channels of the tape recorder are used for the two separate channels of the detector signal. An earphone attached to the output of one channel permits the tone to be heard by the experimenter, who thereby can evaluate the detector signal and guide the telescope accordingly. This audio signal may also be placed on an oscilloscope for a further visual check during data acquisition.

The grating control unit is separate from the other electronic components in that it does not handle any signal data. It sends step-pulses to the motor, which positions the grating in the spectrometer. The desired step size and duration are preset on the control panel by digital switches. Associated with each of these digital switches is a neon digital readout showing the actual operation of the function desired. These readouts give the electronics operator a good picture of the adequacy of equipment performance. The grating shaft also drives a mechanical counter so that the telescope operator may have a direct readout of grating position available to him. In an emergency, the grating may be rotated by hand.

2.3.3 Spare Equipment

Alternate Spectrometer. A second spectrometer was provided by the experimenters in case of failure of the prime equipment. This second device is indicated as an alternate rather than a spare because it does not have exactly the same wavelength capability as the prime equipment. The alternate spectrometer has been designed for the ultimate installation of a multiple-detector array. At the present time it has four similar detectors, of which only two can be used with the two-channel electronic equipment. Its performance is limited to the 16- to 30-μm range. The optical paths of the alternate spectrometer differ somewhat from those of the prime instrument, although the two units are physically interchangeable.

Electronic Equipment. - The experimenters provided spare electronic equipment for all elements of their system (table 2-2). However, some units were not provided in sufficient quantity to assemble a complete backup system. An identical second tape recorder was provided. The spare grating control unit was essentially the same as the prime unit, but with only one signal strength indicator rather than two. A single spare preamplifier and synchronous demodulator were provided, a fully operating system requires two of these units. One spare bias box was supplied, two are needed for a complete system

2.3.4 Displays

Displays connected with the dual IR spectrometer experiment are listed in table 2-3. Most are associated directly with the experimental gear. Some, however, are associated with the GFE. One of these, the telescope elevation angle indicator, was added by the experimenters who found it desirable in setting up the variable angle mount.

Nearly all the displays associated with the experimental gear are integral parts of the various components. The exceptions are a small oscilloscope carried for inspection of the data signal channels; the helium pressure gage, which is attached to the back corner of the electronics rack; and a small earphone used to aid in tracking.

In flight, the displays of primary interest to the electronics rack operator are the two VCO panel microammeters giving data signal strength, and the helium pressure gage. The operator must also monitor the grating position. The other two digital readouts on the grating control panel are usually preset and require no attention in flight. Other indicators serve primarily monitoring functions

The digital counter and printer initially were intended as a redundant data system. However, this system eventually turned out to be a prime source of inflight feedback information. The counter readings were printed out and examined in flight for data adequacy and quality. The counter reading itself was not referred to.

Indicators on the GFE included the illuminated pushbuttons on the stabilization electronics, the roll and yaw meters on this same panel and those used by the pilot, and an elevation-angle indicator on the telescope. The indicators generally were not monitored by the experimental equipment operator. The roll and yaw meters were very useful to the pilot in maintaining

TABLE 2-2. – SPARE EQUIPMENT CHARACTERISTICS

Component	Type of construction	Dimensions (cm)			Power		Weight (kg)	Cost[1] ($)	Comments
		H	W	D	Type	VA			
Tape recorder	Modified commercial	See listings of prime units						300	Same as prime unit
Grating control	Experimenter built							600	Similar to prime. Identical function
Amplifier	Off-the-shelf							300	Same as prime unit
Synchronous demodulator	Off-the-shelf							300	Same as prime unit
Spectrometer	Experimenter built						~12	2000	Similar to prime unit. See text for differences (Section 3.3)
Bias box	Experimenter built						2.0	430	Same as prime unit, spare is oldest unit
Vacuum gauge	Off-the-shelf							250	Similar to prime unit
Digital counter	Off-the-shelf							2000	Same as prime unit
Digital printer	Off-the-shelf								Same as prime unit
						TOTAL		6180	
Telescope secondary mirror (chopper)	GFE							1200	Similar to prime unit.

(1)Hardware cost incurred in previous Lear Jet mission

TABLE 2-3. SYSTEM DISPLAYS

D = dedicated M = multipurpose

Experimenters' Equipment

Tape Recorder (all D)

One VU meter for each of four channels
Illuminated channel designators 1-4 (green)
End of tape indicator light (red)

Grating Control Panel (all D)

Neon Numerical Indicators

Time function	2 digits
Control function	2 digits
Grating position	3 digits (same reading as counter on Spectrometer)

Desired values are set in to the control panel by digital plots for each function. Neon indicators show actual values.

VCO Panel (all D)

Two miniature 0 100 μA panel meters to show signal strength on each data channel.

Two pilot lights (amber) over range indicators · one each channel.

One pilot light - (amber) Power on.

Spectrometer

Cyclometer counter (3 digits) geared to grating shaft. Indicates angular position of the grating shaft. Convertible to wavelength from calibration chart attached to electronics rack. (D)

Amplifier Panel

One pilot light - (red) Power on. (D)

Pressure Gage

Measures helium pressure in Dewar (0 760 mmHg absolute) and is indicator for manual adjustment of this pressure with throttle valve. Normally set for 700 mm in flight. (D)

TABLE 2-3. SYSTEM DISPLAYS - Concluded

Experimenters' Equipment – Continued

Oscilloscope

Battery operated. May be connected in flight to test points in either data channel for inspection of signal (M)

Digital Counter

Neon Numerical Readout (6 digits). Inflight signal processing. (D)

Digital Printer

Paper printout of all data except voice channel. Primary check on data in flight. (M)

Miniature Earphone

Used by telescope operator to listen to one channel of data signal. Used primarily to direct telescope to peak signal. (D)

GFE

Telescope Stabilization Electronics

10 illuminated pushbutton switches. (D)

Roll and yaw meters (±3°); telescope position relative to aircraft axes. (D)

Roll and Yaw Meters

One pair installed for use of pilot. (D)

Time Code Generator

Digital time readout (h, min, s days set to 000). (D)

Telescope

Elevation angle indicator (D)

aircraft-to-telescope alignment and thus minimizing the amount of extra tracking required by the telescope operator.

2.4 Experiment Operation

2.4.1 Normal Operation

Two experimenters are needed to operate the experiment: one operates the telescope, and the other operates the electronics. On the ground or in the flight period before observation starts, the telescope operator adjusts the variable angle mounting to the proper elevation angle to permit the telescope angle of view to contain the target. Upon starting along the observation course, the telescope operator sights first through the finder telescope to acquire the target. Then, using the joystick control, he centers the target on the crosshairs; switches his viewing to the adjacent reflex viewing eyepiece; and performs further tracking through the main telescope. The telescope observer is also aided in his tracking by the audio signal developed from the data channels by the VCO. He uses this audio tone to maximize the signal. The audio tone is a help since the maximum infrared signal may not correlate with a readily visible optical target.

The electronics operator turns on all the apparatus and monitors it for satisfactory operation during the flight. He must start the scanning process when called for by the telescope operator and must interrupt the scan whenever the target is lost due to aircraft motion. He also adjusts the throttle valve on the helium vent line to maintain the pressure in the Dewar at the desired value. He has a visual display of grating position and can inform the telescope observer at any time as to the status of the grating position and the scanning operation. He also inspects the printed data on the digital printer for quality and interpretation. An additional responsibility is to change tape recorder cartridges when necessary during the flight. The recorder was operated only during the observation period.

A spectral scan consists of some 10 to 15 steps over the waveband of interest, usually starting at the low end. Two digital counts are made in each step for both positive and negative chopper beams, each count for an exact, preset time interval depending on the source strength and selected gain settings. Integration times normally range from 10 to 20 sec, with one beam inputting a source plus background signal and the other a background signal only. Either chopper beam can be selected as the signal carrier for a given scan. Both detectors are positioned for simultaneous readings at wavelengths in their range of sensitivity.

When observations at one step have been completed, the spectrometer grating is rotated a preset amount by actuating the stepping motor drive A complete scan takes from 8 to 20 min, depending on guiding accuracy, air turbulence, etc. Successive scans on the same target are "interlaced" in wavelength to provide finer detail over the entire spectrum; alternately, the interval between steps is adjustable for fine detail in one portion of the spectrum.

2.4.2 Fallback Provisions

If ground testing showed deficiencies in any electronic component, the corresponding spare unit could be substituted with no change in recorded data and, in general, no change in operation.

If the prime system spectrometer were replaced with the alternate unit, spectral data between 30 and 40 μm would be lost as the alternate spectrometer has different detectors.

The experiment also contained provisions for fallback procedures in case of difficulties in flight. Procedures were developed for a number of contengencies, but only one was necessary during the confined portion of the mission. These special inflight procedures are outlined below.

Tape Recorder Failure. – In the event of recorder failures, voice channel information would be lost However, all the other scientific data recorded on the three remaining tape channels was also recorded in flight on the digital printer.

First-Order Detector Failure. – The grating could be rotated in flight to a predetermined location to put the first-order spectrum on the other detector and normal observations resumed. Data would be lost between 30 and 40 μm.

Second-Order Detector Failure. – No special action would be taken except that the data scan would be restricted to the area beyond 23 μm. Data from 16 to 23 μm would be lost. On the ASSESS #3 mission, this channel failed to give data for two flights, and this action was taken. (The problem was later found to be due simply to moisture in a connector.)

Grating Control Malfunction. – The grating may be moved manually by the telescope operator. A mechanical counter attached to the grating motion mechanism showed its position in the same arbitrary numerical units as shown on the grating control panel.

2.5 Data Handling

Two separate data-recording systems were provided for this experiment, an analog system and a digital system. To assist in the data reduction on the ground between flights, the experimenters also had a small electronic calculator, a slide rule, and a special radiation calculator.

2.5.1 Analog System

The analog system was a four-channel cartridge recorder The frequency outputs of the VCOs were recorded on two channels as the basic signal data A third channel was used to record the intercom comments between the experimenters. The fourth channel recorded pulses from the grating control unit so that grating position could be determined. Also multiplexed on this channel were indications of direction of grating motion, and which beam of the chopper (right or left) was being used as the signal source (the other gave a sky background reading).

As a low-cost consumer-type instrument, this tape recorder (as purchased) was not entirely satisfactory for scientific data recording. Previous flight experience indicated necessary changes. Pushbuttons to select inputs were unreliable and were replaced with hard wiring The operation of the tape cartridges also proved unreliable, and special cartridges with transparent cases were procured so that actual tape motion could be seen. An end-of-tape pilot light was added as a reminder to change cartridges. These modifications (made prior to the previous normal ASO mission) eliminated most recorder problems during this mission.

2.5.2 Digital System

Earlier in the history of this experiment some digital data-processing equipment was provided for preliminary data processing between flights. Because of past difficulties with the analog tape recorder, for this mission it was decided to fly the digital data equipment as well. The digital system provides a redundant record of all data except the voice channel.

The frequency signal from the VCO outputs also is passed to a digital counter, which counts the cycles for a predetermined time and causes the digital printer to print out the frequency reading for both detector channels (fig. 2-4). Auxiliary circuitry permits printouts of coded symbols giving direction of grating motion, grating position, and the beam used on the chopper.

The digital system, unlike the magnetic tape recorder, provides an immediately available printout of the recorded data (fig. 2-6), with an accurately-timed count of a linear function of detector signal intensity, and a grating position number that is nearly a linear function of wavelength. The experimenters found this information a primary means of checking on the performance of their experiment and the quality of the data.

2.6 Experiment Personnel

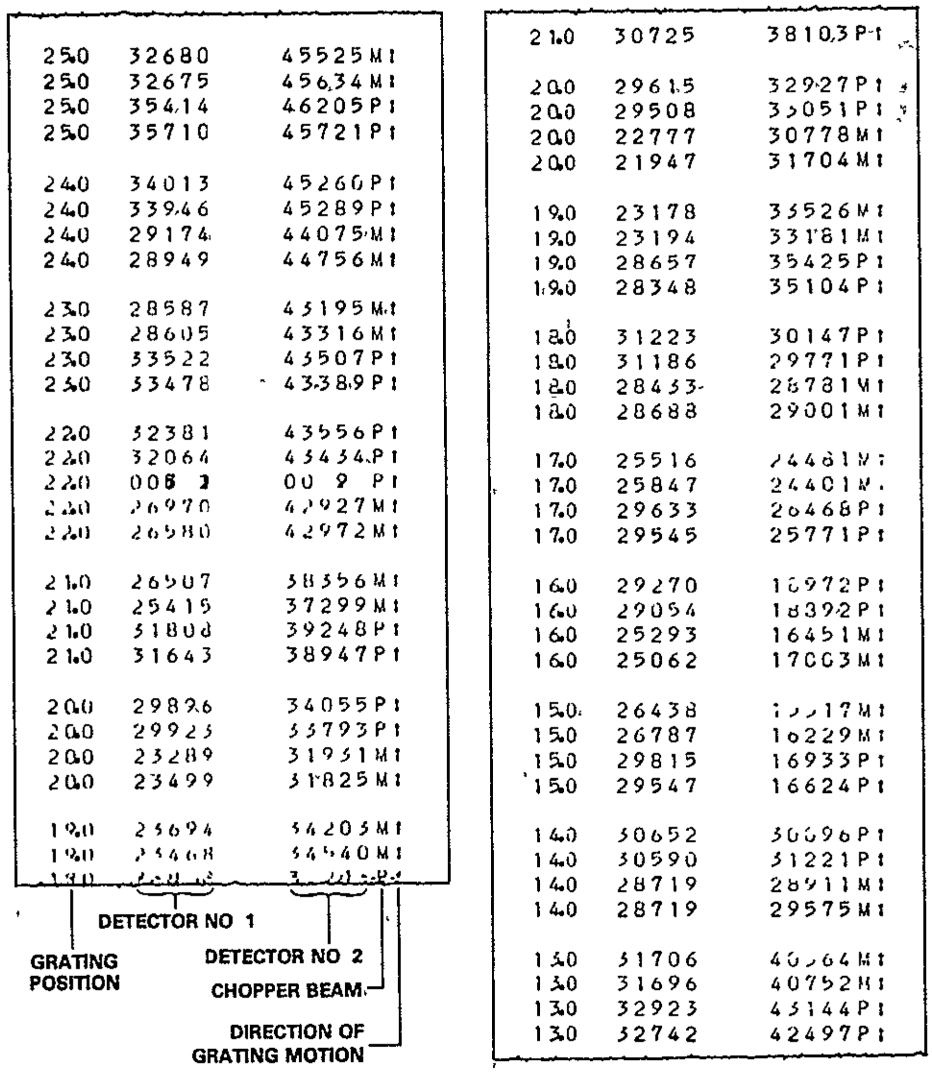
2.6.1 Principal Investigator (PI)

The PI was an assistant professor in the astronomy department of his university, with teaching assignments and other research responsibilities in addition to this project. He exercised general administrative and technical supervision over the entire experiment, designed some of the electronic components in detail, and made some of the optical equipment. His fieldwork in this mission was directed toward experiment optics and data systems. During the confined portion of ASSESS #3, he usually operated the telescope, but switched to electronics operator for the last two flights. The PI did not participate in the checkout flights before or the data flights after the simulation mission.

2.6.2 Graduate Students

The other member of mission research team, a graduate student at the university, had specific responsibility in the laboratory for some of the electronic components and for maintenance of the spectrometers. His fieldwork was oriented toward experiment electronics and cryogenic systems. He had principal responsibility for the preflight cooling and operational checking of the spectrometer. He was the electronic systems operator except on the last two flights

A second graduate student had been associated with the project for only a few months. He assisted with operations during the August mission in a ground support role, and had made some of the detectors used in the experiment. During the premission week, he operated the telescope during checkout flights as backup for the PI He and the first graduate student alternated positions during the postmission week.



25.0	32680	45525 M t
25.0	32675	45634 M t
25.0	35414	46205 P t
25.0	35710	45721 P t
24.0	34013	45260 P t
24.0	33946	45289 P t
24.0	29174	44075 M t
24.0	28949	44756 M t
23.0	28587	43195 M t
23.0	28605	43316 M t
23.0	33522	43507 P t
23.0	33478	43389 P t
22.0	32381	43556 P t
22.0	32064	43434 P t
22.0	006 2	00 9 P t
22.0	26970	42927 M t
22.0	26580	42972 M t
21.0	26507	38356 M t
21.0	25415	37299 M t
21.0	31808	39248 P t
21.0	31643	38947 P t
20.0	29826	34055 P t
20.0	29923	33793 P t
20.0	23289	31931 M t
20.0	23499	31825 M t
19.0	23694	34203 M t
19.0	23468	34540 M t
19.0	[illegible]	[illegible]

21.0	30725	38103 P t
20.0	29615	32927 P t
20.0	29508	33051 P t
20.0	22777	30778 M t
20.0	21947	31704 M t
19.0	23178	33526 M t
19.0	23194	33181 M t
19.0	28657	35425 P t
19.0	28348	35104 P t
18.0	31223	30147 P t
18.0	31186	29771 P t
18.0	28433	28781 M t
18.0	28688	29001 M t
17.0	25516	24481 M t
17.0	25847	24401 M t
17.0	29633	26468 P t
17.0	29545	25771 P t
16.0	29270	16972 P t
16.0	29054	18392 P t
16.0	25293	16451 M t
16.0	25062	17003 M t
15.0	26438	[illegible]17 M t
15.0	26787	16229 M t
15.0	29815	16933 P t
15.0	29547	16624 P t
14.0	30652	30696 P t
14.0	30590	31221 P t
14.0	28719	28911 M t
14.0	28719	29575 M t
13.0	31706	40364 M t
13.0	31696	40752 M t
13.0	32923	43144 P t
13.0	32742	42497 P t

Figure 2-6. – Sample of digital printer record on 9-cm paper tape, one spectral scan with interruption at grating position 21.

2.6.3 Scientist/Astronaut

This pilot/astronomer from Johnson Space Center flew as copilot on six of the flights in the simulation period, and as pilot on one. When copilot, he also acted as an ASSESS observer. His experience as copilot and backup experiment operator on the previous simulation mission (ref. 5) made his participation especially valuable.

Section 3

3. EXPERIMENT PREPARATION

Preparations for the ASSESS #3 mission started on July 27, 1973, when the principal investigator was notified of selection. His previous commitment to a normal ASO mission was completed August 24, and he and his associates spent the next two months making a number of improvements in the system and performing component and system tests. The equipment was returned to Ames on October 23. The bulk of the work was completed before the Flight Readiness Review (FRR) held at the experimenters' university on October 4. During the interval following the FRR and before shipment, the experimenters assembled spare parts and supplies, completed performance tests on the backup spectrometer, and made final alignment checks on the primary system. Table 3-1 gives a brief chronology of events from the first ASSESS planning meeting of May 8 until the start of experiment integration on October 29.

3.1 System Modifications

A number of significant improvements were made to existing systems during the period between the August mission and ASSESS #3 (table 3-2). Spectrometer parts were modified to assure reliable mechanical operation. Electronic components were rewired and mechanically upgraded; for example, the resistance of integrated circuit modules to vibration was increased by tie-down fixtures. The digital data system was upgraded for use in flight by adding circuitry to record all parameters except the voice channel and thus provide a redundant data record. New optical components for telescope alignment and guiding were designed and built.

3.2 Schedules and Performance

3.2.1 Experimenter Schedule

Early in the preparation period, the PI prepared a schedule of the tasks to be accomplished at his home base. These tasks, actual performance, and the man-hours spent each week are shown in table 3-3 and figure 3-1. Four individuals are covered: the two mission experimenters, an associate researcher, and an electronics technician. The agreement between scheduled and actual man-hours is remarkably good, both in rate of work done and in the total. Only 17 hr of weekend work were required in the 8-week period. After the FRR, some 75 hr were spent in minor changes to recorder circuits, final spectrometer adjustments, assembly of spare parts and supplies, and in packing and shipping.

The schedule included a full week of "slip time" just before shipment when no particular tasks were planned. One particular task, the construction of new bias boxes, was not undertaken at all. Instead, it was decided that the refurbishment of the existing bias boxes would be sufficient. As it turned out they were completely rewired, a task that consumed appreciably more time than planned. The other tasks consumed time at a rate much closer to that planned. The total direct effort was 459 man-hours.

TABLE 3-1 – CHRONOLOGY OF EXPERIMENT SELECTION AND PREPARATION

Date 1973	Event
May 8	First ASSESS planning meeting to outline mission guidelines and time frame.
June 8	Potential experimenter teams assigned order of priority. Informal telcons start.
July 2	Field narrowed to one team. Tentative acceptance by principal investigator (PI) in telcon with ASO mission manager (MM).
July 27	PI notified of selection by letter from ASO MM.
August 1	PI notified ASO MM of flight team selection (telcon).
August 13	ASO MM discusses target selection in telcon to PI.
August 16	Research proposal submitted to NASA Hdqtrs
August 13 24	Experimenters fly normal ASO mission
August 21–23	PI in planning meetings (3) with Lear Jet MM and ASSESS program manager. FRR to be held at experimenters' facilities.
August 27	Experiment preparations for ASSESS #3 begin.
September 12	PI transmits milestone chart (by letter) for preparation, premission integration, and mission periods. Telcon from PI to ASO MM requesting check on target availability; verbal progress report. FRR date fixed.
September 13	ASO MM reviews and approves research schedule.
September 18	ASO MM confirms date of FRR and proposes agenda in letter to PI.
Sepetmber 21	PI telcon for latest information on telescope modifications.
September 25	PI telcon to confirm flight plans for chosen targets.
October 1	Personnel assignments confirmed for operations on site over three-week period, in telcon from ASO MM to PI.
October 2	FRR for Ames telescope
October 4	FRR for experiment at home laboratory.
October 23–25	Equipment shipped to Ames.
October 26	PI notified by ASO MM telcon of one-week delay of "launch" due to aircraft malfunction. Assistant experimenter and associate arrive at Ames. Experiment assembly in ASO lab begins.
October 26 November 9	Assembly, integration, and checkout of experiment
November 5	Targets for mission confirmed verbally by assistant experimenter to ASO MM. Detailed flight planning starts.

TABLE 3-2. – EXPERIMENT MODIFICATIONS

Spectrometer

1. Glued all mirrors with cryogenic epoxy (1)
2. Filed detector post to prevent leads from shorting out (1)
3. Inserted taper pin into grating post to lock it in position (1)
4. Installed four new detectors (2)
5. Moved preamplifiers from inside spectrometer body to bias box (1 & 2) to facilitate maintenance

Bias Box

1. Completely rewired three bias boxes
2. Replaced one preamplifier

Voltage Control Oscillator

1. Improved the mounting of VCO modules

Grating Control

1. Remounted display lamp to prevent breakage

Guiding Eyepiece

1. Entirely new equipment designed to improve viewing, prevent misalignment, and improve reliability

Alignment of Guidescope

1. Assembled new collimator and high-intensity light source to improve accuracy of optics alignment through main telescope
2. Constructed periscope to permit use of same source for alignment of main and guide telescopes

Amplifiers and Demodulators

1. Reduced crosstalk between channels by reducing internal impedance of the power supply common to all four units

Digital Data System

1. Added circuits to record grating position, direction of grating motion, and designation of which beam used

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(1) Prime System
(2) Backup Units

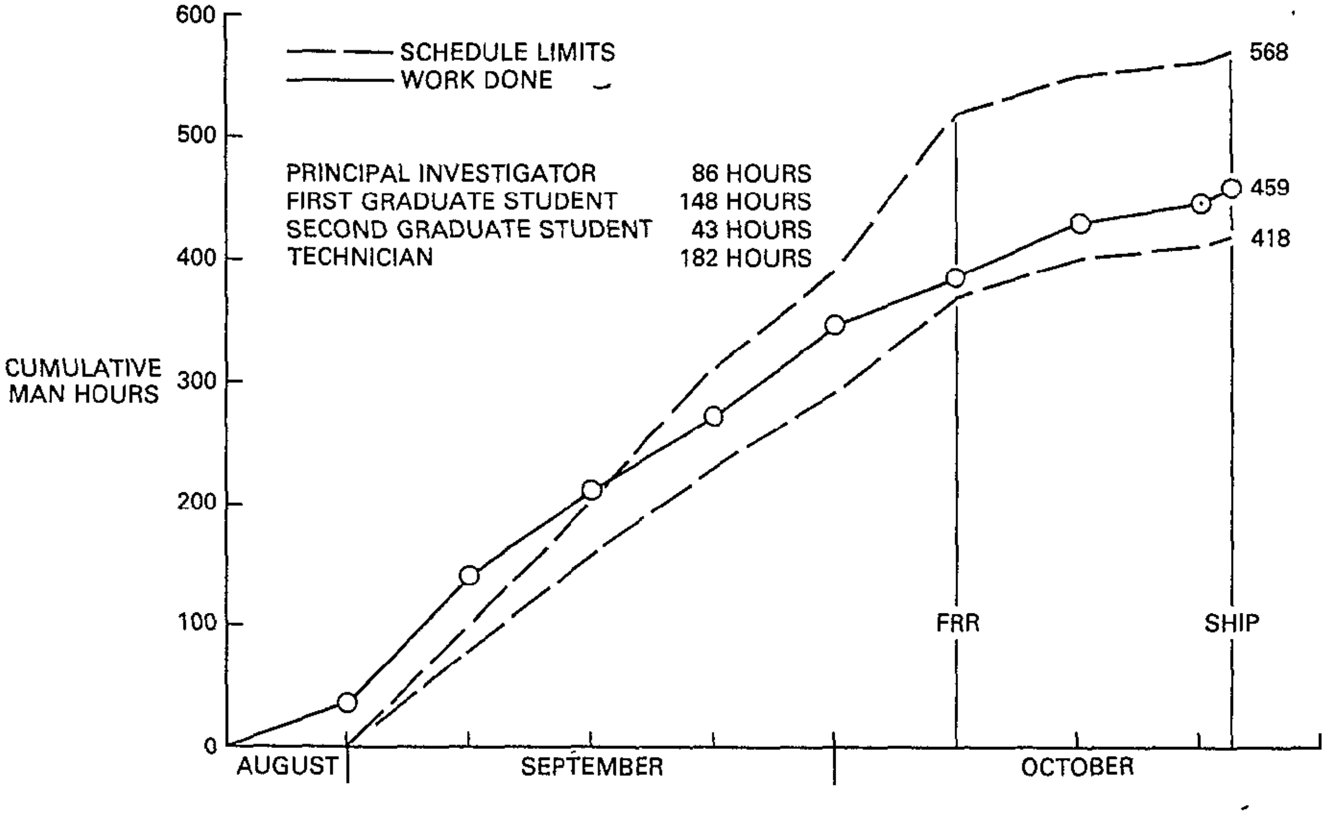
TABLE 3-3. – HOME BASE PREPARATION PLAN AND PERFORMANCE

[Total Grant Funding = $6000]

Experimenters' Schedule	Man-Hours	Man-Hours	Experimenters' Actual Work
August 27 – August 31	No est.	37	
September 3 – September 7	80–100	103	
1. Fix equipment broken in shipment			No problems – on schedule
2. Design guiding eyepiece			Completed week of September 17
3. Order parts for eyepiece			Completed week of August 27
4. Wavelength calibration of Spectrometer I			On schedule
5. Order parts for backup bias boxes (3)			On schedule
September 10 – September 14	80–100	73	
1. Establish test criteria			On schedule
2. Test new epoxy			On schedule
3. Refurbish old bias boxes (3)			Completed week of September 24
4. Disassemble spectrometer I for new epoxy, pin drive gear, and modify Ge:Ga detector mount			Completed week of September 24
September 17 – September 21	70–100	59	
1. Build and test new eyepiece system			Completed week of September 24
2. Mount new detectors in Spectrometer II			Completed week of October 1
3. Check all electronics, add lamps to VCO panel			Completed week of October 1
4. Reassemble Spectrometer I			Completed week of September 24
September 24 – September 28	60–80	73	
1. Test Spectrometer I			On schedule
2. Reassemble Spectrometer II			Completed week of October 1
3. Build backup bias boxes (3)			This task not done. Rebuilt existing boxes instead.
September 30	0	11	
October 1 – October 5	80–130	28	
1. Refurbish collimator used for ground based check of telescope			On schedule
2. Recheck ground based data processing equipment			On schedule
3. Final test Spectrometer II			Completed week of October 15
4. Final system check			On schedule
5. Readiness Review			Completed October 4

TABLE 3-3. – HOME BASE PREPARATION PLAN AND PERFORMANCE – Concluded

Experimenters' Schedule	Man-Hours	Man-Hours	Experimenters' Actual Work
October 8 – October 12	30	44	
1. Open tapes to mark reels (20)			Completed week of October 15
2. Run all tapes (20)			Completed week of October 15
3. Check replacement parts, O-rings, tools, etc.			Completed week of October 15
			Rework data system for use in flight
October 15 – October 19	10	12	
1. Slip time (3 man-weeks)			
2. Pack equipment			Packed October 23
October 21	0	6	
October 22	8	13	
1. Ship equipment			Shipped October 23
TOTALS	418–568	459	


SCHEDULE LIMITS
WORK DONE
PRINCIPAL INVESTIGATOR 86 HOURS
FIRST GRADUATE STUDENT 148 HOURS
SECOND GRADUATE STUDENT 43 HOURS
TECHNICIAN 182 HOURS
CUMULATIVE MAN HOURS
600
500
400
300
200
100
0
568
459
418
FRR
SHIP
AUGUST
SEPTEMBER
OCTOBER

3.2.2 Time Lines

Detailed time-line information is given in appendix A (table A-1) for ASSESS #3 experiment preparation between August 25, when the experimenter completed his previous ASO mission, and October 23 when equipment was shipped to Ames. The PI could spend only about half his time on the ASSESS program, with the remainder used for ongoing responsibilities as a university professor and two other research contracts. His two associates, both graduate students, similarly were limited in time spent for ASSESS preparations. One was preparing for doctoral exams and the other doing data reduction on another project. The electronics technician spent full time for several weeks on ASSESS preparations.

Data from table A-1 have been recast in figure 3-2 to show the distribution of effort during the 9-week period in experiment planning and design, fabrication, and testing. Out of the total 459 man-hours, about one-fourth were spent in planning and design, half in fabrication, and a fourth in testing. Planning and design effort peaked during the second week at close to 50 man-hours and was essentially finished in the fourth week. Fabrication built up steadily to a peak of over 55 man-hours in the fifth week, with a second notable effort the seventh week, following the Flight Readiness Review (FRR). This work, done by the electronics technician, consisted of modifications to the digital recording system to include identifying notation on the paper-tape printout (table A-1). Equipment testing accounted for about 20 man-hours in three of the first five weeks and about one-half as much thereafter. Overall peak effort occurred in the second week when the output was twice the 51 man-hour weekly average.

Subsystem Development. – Subsystem development time is indicated in table A-2. The most concentrated effort over a one-month period was on the bias boxes, which supply a small, adjustable constant current through the detector element to permit measurement of the incoming signal. Existing units had been modified several times for use in different university research projects, and their quality had progressively deteriorated. The initial plan was to refurbish three of these units and also build a new, upgraded set of three more. The design for the new set was started, while existing units were refurbished and tested in the first week. Test results were unfavorable, indicating that the existing units would have to be completely rewired. A decision was made to do this, with some design changes and new parts, and not to build the three new (backup) units. The design was changed, parts were ordered, and units were completely rewired in the following three weeks. In all, 144 man-hours were required, nearly one-third of the total preparation effort; 127 of these hours were technician time and amounted to more than two-thirds of his total contribution to the experiment.

The primary spectrometer was next in order of preparation effort (table A-2) and accounted for 102 hr, two-thirds of which were put in by the second member of the flight team. Work started with a wavelength calibration to assess current status, followed by breakdown for refurbishment of optics and detectors, and assembly and testing. These operations took 84 man-hours over a period of four weeks just prior to the FRR. Final alignment and calibration took the remaining 18 hr in the week before shipment. In contrast, the backup spectrometer required only 24 hr of work late in the preparation period.

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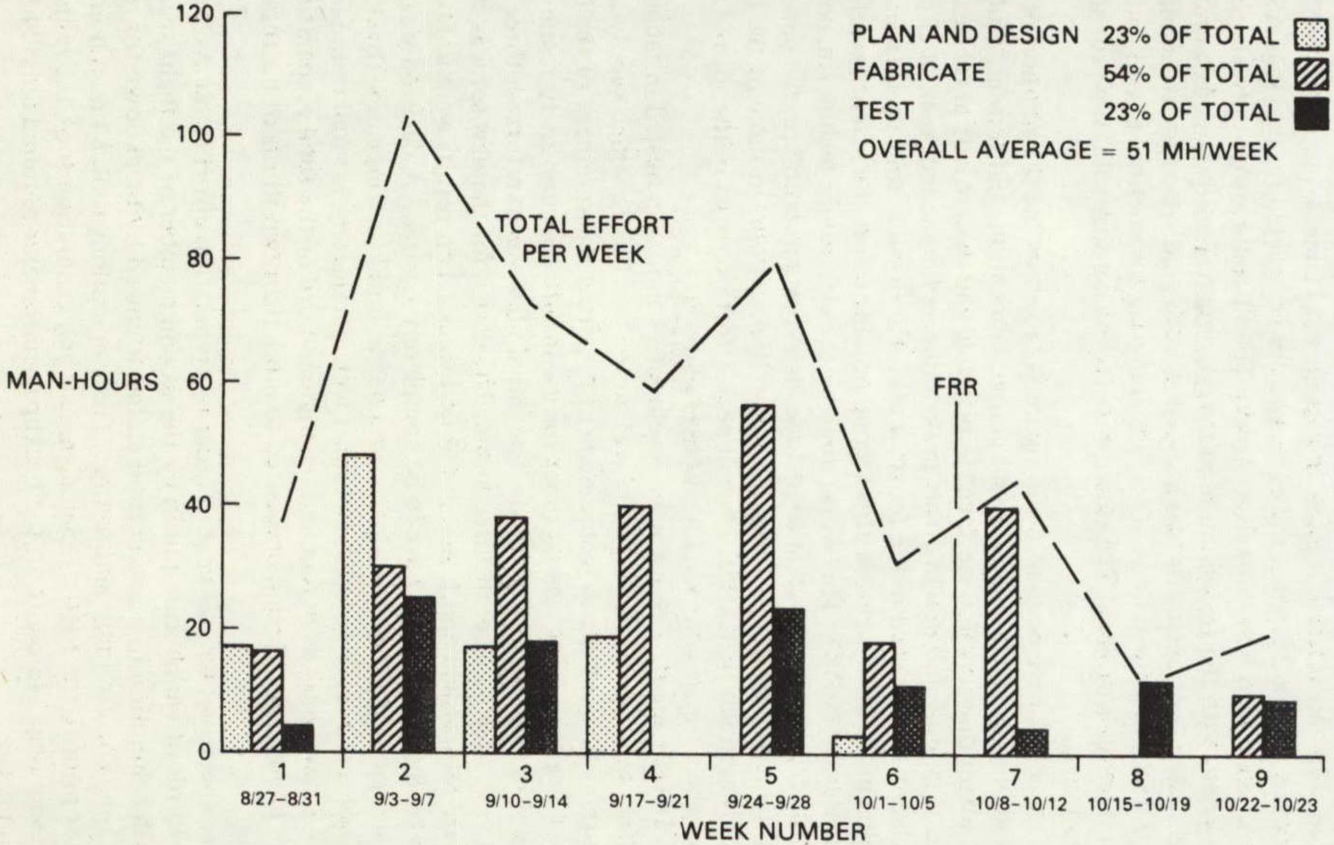


Figure 3-2. – Distribution of experiment preparation effort.

Work on the new guiding eyepiece and the new fixtures for spectrometer/telescope alignment on the ground was handled mostly by the PI. These tasks took about 50 hr, one-half of his total effort during the preparation period, and were finished in the first 4 weeks.

Preflight Equipment Handling. – Major events that define preflight equipment handling are listed in chronological order in table A-3. Very roughly, the first operation was to check the condition and make repairs on equipment shipped in from Ames. Fabrication of new components and refurbishment of existing ones followed, concurrently, while testing of primary flight units phased in at the component level and built up to the complete primary experiment, from spectrometer to data processor. Once the performance of this system had been verified on the telescope simulator, the refurbishment of backup flight units and modification of the data processor followed. The last operation before shipment was final adjustment and calibration of both spectrometer units.

Following shipment, the handling sequence was: unpack, check components for damage, assemble experiment in ASO laboratory (with electronics mounted in a standard aircraft rack [fig. 3-3] and Dewar/spectrometer on the telescope alignment simulator), and test entire system. Then the experiment was moved to the aircraft, installed, aligned optically, and given a final operational test prior to the first checkout flight. Thereafter, the experiment remained in place, except for the Dewar that was off-loaded for standby pumping and refill between flights.

3.3 Test Procedures

Test procedures in the university laboratory were much less formal than might be used for spacecraft equipment. The measurement precision required was not extreme and few highly accurate reference standards were required. The philosophy of the tests observed on this equipment was distinctly pragmatic. Most testing was a simple functional evaluation in the ambient environment commensurate with the normal temperature and low vibration levels of flight. Since none of the equipment was pressure sensitive, such tests were not considered necessary. This group of investigators has found that equipment that stands the rigors of normal shipment will operate satisfactorily in an aircraft environment.

Long-time operation of individual components to verify the reliability and stability of electronic parts was not a separate test requirement. Most equipment had been operated for many hours in previous airborne missions without problems, so that the several hours of operation during spectrometer calibration were considered adequate verification of current status. Table 3-4 summarizes test procedures and man-hours on individual components.

3.4 Flight Readiness Reviews

In the two previous ASSESS simulation missions using the Lear Jet aircraft, the start or "launch" data was delayed several weeks while finishing touches were made to new experimental eqiiipment. To avoid a similar experience with ASSESS #3, a Flight Readiness Review (FRR) was built into the experimenters' schedule, approximately one month prior to "launch." This idea was first proposed at a meeting of the ASSESS Working Group on August 2, 1973, as an initial step beyond normal ASO management procedures toward more Shuttle-like constraints. The use and content of the FRR were tentatively adopted on August 15 in an ASO/ASSESS planning session, and it was proposed to and accepted by the PI in a meeting on August 21.

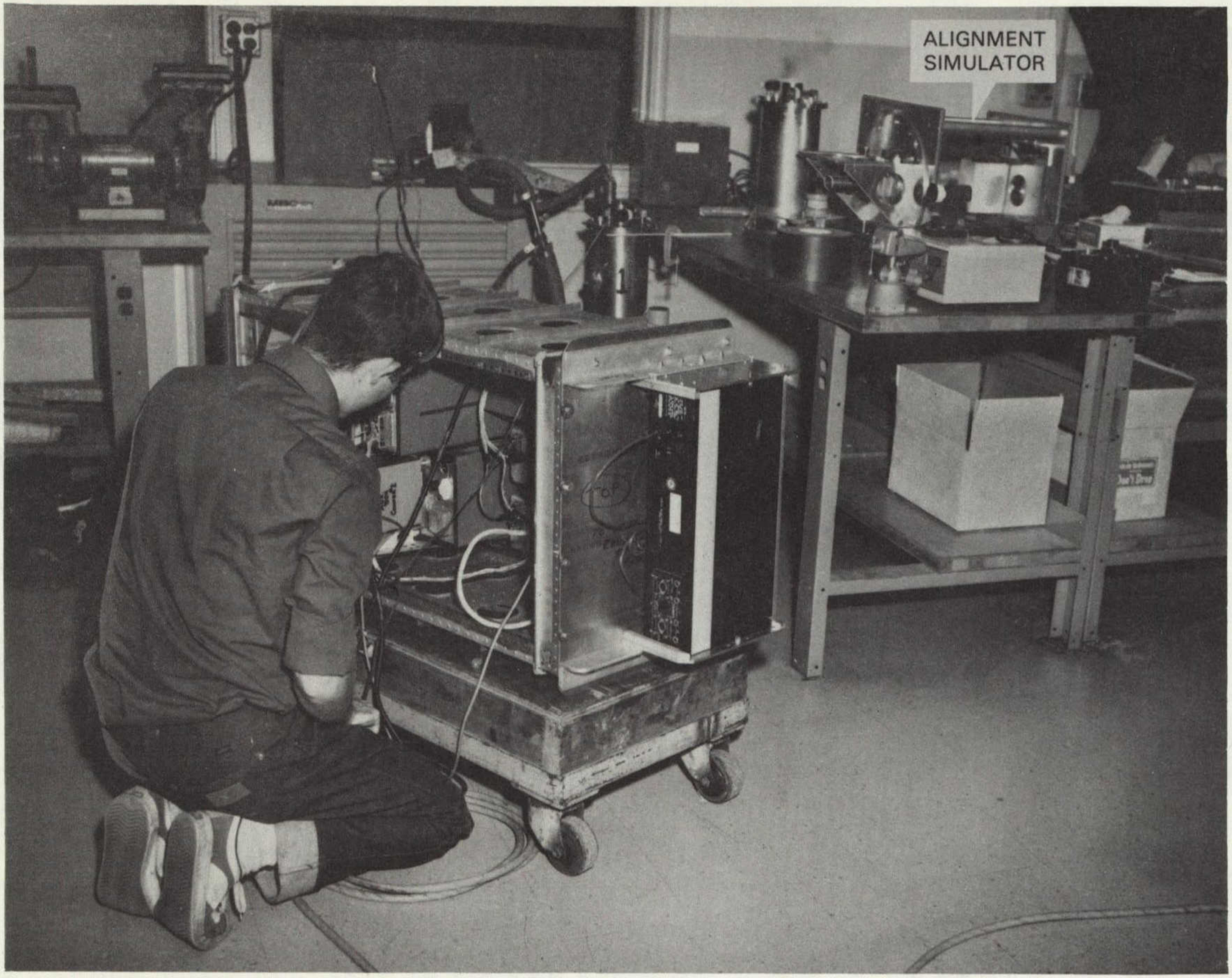


Figure 3-3. – Installing signal conditioning electronics in standard rack.

TABLE 3-4. – TEST PROCEDURES – HOME BASE PREPARATION PERIOD

Epoxy Bond at Cryogenic Temperatures – 18 man-hours

Bond a mirror to a piece of aluminum.

Dip into LN_2 and leave at room temperature.

See if bond holds.

If bond holds, dip into LN_2, then dip into LHe and leave at room temperature.

See if bond holds.

Phase-Lock Amplifier – 0.5 man-hour

Complete unit.

Apply input voltage and check output

Check to see that input polarity reverses with reverse phase of input.

Check phase-shifter for maximum output.

No cold tests or vibration tests.

No vibration mounts used.

Amplifier Section

Test consists of applying a calibrated input voltage and checking gain setting on amplifier. Calibrated oscilloscope used for input and output measures.

Oscilloscope also used at high gain to observe that noise level is satisfactorily low $\cong$ 1 mV referred to input.

No cold tests or vibration tests.

No vibration mounts used.

Voltage Controlled Oscillator – 1.5 man-hours

Apply 0–10 V dc.

Output frequency should vary from 0–10,000 Hz linearly.

Use digital counter as standard frequency measuring device.

Inspect output wave form with oscilloscope Should be reasonably smooth sine wave.

No cold tests or vibration tests.

No vibration mounts used.

IC modules are laced down to prevent disconnect under shock.

Bias Boxes

Bias Portion – 4 man-hours

Test battery voltage – 90–92 V.

Replace if voltage low.

Check series resistor with DVM.

TABLE 3-4. – TEST PROCEDURES – HOME BASE PREPARATION PERIOD – Continued

Bias Boxes – Continued

Preamplifier Section – ½ man-hour

Connect 100 k resistor across input.

Output noise must be ≤ 20 μV.

Check again – 100 ± 10%.

Check batteries – normally on charge 12.5 V (Nicads)

No cold tests or vibration tests.

No vibration mounts used.

Grating Control – 5 man-hours

Power on, run-in tests about 10 hours, testing function consists of exercising each switch and observing proper function. Procedure is OK with digital equipment.

No cold tests or vibration tests for ASSESS #3.

No vibration mounts used.

Spectrometers

Detector Quality – man-hours included below

Before mounting in spectrometer, detectors are evaluated in laboratory test Dewar for response at single wavelengths to known signal from black-body source. Selected filters used.

Wavelength Calibration of Spectrometers – 31 man-hours

Set up spectrometer and chopper wheel on test stand.

Cool down Dewar.

Use LN_2 as black-body radiation source for first approximation.

Use commercial standard black-body source for actual calibration.

Record voltages at different grating positions to go through a complete spectrum.

Insert absorption filter in front of the source; bromobenzene in plastic film bag or 0.0025-cm-thick Mylar film

Compare grating position and counter reading with known absorption lines; 23 μm for Mylar, 34 μm for bromobenzene.

Calibration results – response of detectors to input signal of known absolute intensity over wavelengths of interest; known grating position indicated by counter

Substances used for calibration: Mylar, bromobenzene, LN_2 and two interference bandpass filters.

TABLE 3-4. – TEST PROCEDURES – HOME BASE PREPARATION PERIOD – Concluded

Spectrometers – Continued

Wavelength Calibration of Spectrometers – 31 man-hours – Continued

An alternate calibration method used narrow waveband signals from a commercial spectrophotometer to set and calibrate grating position and to check relative response of system at various wavelengths. Signal intensity accurate relatively but not absolutely.

Alignment and Operational Tests – 30 man-hours

Use laser light source to illuminate entrance aperture.

Align first mirror with adjusting screws and shims so that light beam is focussed directly on the two detectors. The laser beam is visible and the adjustment is made by eye.

Check detector output signals by setting up bath of liquid nitrogen for source of known temperature Compare signal outputs with values previously obtained. Similar values confirm proper alignment

Leave all equipment energized for several hours to check stability of electronics. Check for microphonics by tapping spectrometer body.

The original plan was to meet at Ames for an oral presentation of the function and readiness for flight of the major experiment components and the completed system, followed by a review of telescope modifications and flight status by cognizant Ames personnel. Later, however, the FRR was divided into (1) an experimenters' review at their own laboratory, and (2) a GFE telescope review at Ames. Both reviews were to be conducted by the ASO Lear Jet manager. This would allow a comprehensive review of the experiment, with experimenter staff participation. On the other hand, the FRR for telescope systems would not require the experimenters' attendance, or so it appeared at the time.

The FRR for the experiment was held at the university on October 4, some 6 weeks prior to the start of the simulation mission, two FRRs for the telescope systems were held on October 2 and 24 at Ames In all cases, the reviewing groups numbered three, including the ASO Lear Jet manager as chairman. During the experiment review the PI described his system, item by item, told its state of readiness, and described the tests made to assure proper operation. (A suggested topic outline had been provided by the chairman.) In addition, the PI prepared a written summary of his presentation, essentially as shown in table A-4 and including the block diagram shown earlier in figure 2-4. The summary included a brief discussion of scientific objectives and history, followed by a description of the functional components of the experiment: problems and solutions, intended use and provision of spares, and testing procedures.

The telescope reviews covered some 23 items, mostly minor changes to upgrade operation, that were scheduled to be done between September 24 and October 12. By the final review, 17 of these tasks had been completed, 5 were not done but would have no impact on the mission, and 1 (the secondary mirror actuator or chopper) was still in preparation. Responsibility for this last item was assumed by the ASO Lear Jet manager to assure completion and checkout prior to October 29.

3.5 Premission Interactions With ASO

Communications between the experimenters and ASO personnel began in mid-June with a telephone solicitation of interest by the ASO mission manager. The responses of five candidate principal investigators to this general solicitation were evaluated against ASSESS objectives, leading to the selection and tentative acceptance of the participant on July 2. Selection was formalized by letter on July 27. These and the following premission contacts are listed in the chronology of table 3-1. Almost without exception, it was the PI and the ASO mission manager who consulted on mission plans and arrangements. A series of three meetings on August 21, 22, and 23 at ASO, attended by both principals, served to define the overall mission schedule and principal events. As noted, the FRR concept was proposed at the first meeting to the PI, who accepted this constraint on his activity as reasonable, in the context of a Shuttle simulation mission.

From August 24 to October 26 there were seven recorded communications, including the FRR, between ASO and the PI, five were initiated by the ASO mission manager. In addition to these direct contacts, a secondary loop developed through the ASO/ASSESS representative stationed at the PI's facility from early September until late October. Although the assigned function of the ASSESS representative was to observe and relay information in support of ASSESS data requirements, it soon became apparent that he was also performing (if informally) a liaison function between the PI and the ASO (perhaps another six telephone calls were made). In large part, this function served to interpret ASSESS requests and procedures, but it also was used to relay information on the operational aspects of the mission. In the postmission debriefing, the PI commented that on-site liaison (both in local discussions and by telephone calls) had provided a beneficial and timely coordination of activities between the research and operations teams, particularly in the 3 weeks just prior to the FRR. It was suggested that Spacelab research managers consider a similar liaison function in their program planning

Section 4

4. EXPERIMENT INTEGRATION

Equipment was shipped to Ames on October 23, just one day behind schedule, and arrived two days later. The assistant experimenter and his research associate reported in on the 26th, with the two Dewar/spectrometers, which had been hand-carried to avoid shipping damage. For this mission, the PI had requested an integration and flight checkout period of 11 days rather than the normal period of seven, to allow for contingencies during installation, to complete inflight calibration of the experiment before the simulation mission, and to provide flight training for the research associate.

4.1 Laboratory Assembly and Checkout

Assembly and checkout in the ASO laboratory began on schedule and was completed without incident, but installation was delayed 10 days when the aircraft was returned to the manufacturer for repair of a faulty autopilot Experiment installation resumed on Tuesday, November 6, and the first flight occurred at 1120 hours on Wednesday. Three experiment checkout flights followed, during which the experimenters became familiar with the new variable-angle telescope mount and completed inflight calibration measurements Because of the delay, this effort was completed in four days rather than six as planned, and only four of the five scheduled checkout flights were made. Events during this period are listed chronologically in table 4-1.

Two equipment malfunctions were corrected during the laboratory assembly period. The first was a faulty connection in the wiring of the data printer that, after a 5-hr search, was isolated and quickly repaired. The second was a noisy preamplifier in one of the bias boxes that was replaced in 1 hr.

During installation the only notable problem was with the telescope secondary mirror assembly that could not be positioned for proper focusing. The unit (chopper) was new and had never been flown before; minor machining in the Ames shop caused no delay.

4.2 Checkout/Calibration Flights

Table 4-2 summarizes equipment problems during the four checkout/calibration flights. Four relatively minor problems with experiment equipment were promptly resolved, as were two with GFE. By the last flight, data was being obtained full time, and following postflight repair of the digital printer, all systems were operational.

Experiences during this period are a measure of the training required to operate a flight experiment. New equipment was used – in particular, alignment optics and the telescope variable-angle mount – and a new telescope operator was trained while on his first flight series. Basic systems operation was confirmed on the first flight, mechanical difficulties with new equipment identified on the second, and optical focusing isolated as the problem on the third. Operations approached normal on the fourth flight, indicating that experiment checkout and operator training were essentially completed. Calendar time was three days, flight time about 8 hr, and observing time less than 3 hr.

TABLE 4-1. - CHRONOLOGY OF EXPERIMENT INTEGRATION AND SIMULATION MISSION

Date	Time	Event
October 25		Experimenters' equipment arrives at Ames.
		Research associate takes high altitude training course at nearby military base to qualify for flight in Lear Jet.
October 26	1500	Assistant experimenter and research associate arrive at Ames carrying primary and backup spectrometers.
		Unpack equipment and inspect for damage in shipment.
October 29 November 5		Aircraft away from Ames for emergency repairs to avionics. Integration and simulation mission delayed one week.
October 29--30		Assemble electronics in standard rack in ASO laboratory. Install primary spectrometer in alignment simulator and verify operation of all systems. Repair digital printer circuit
October 31		Verify operation of backup spectrometer in complete experiment.
November 1 4		No activity.
November 5		Telescope installed by Ames personnel. Experimenters make final ground check of flight equipment.
November 6	am	Replace preamplifier in one bias box to reduce signal noise.
	pm	Telescope stabilization electronics installed by Ames personnel at completion of bench tests. Equipment rack installed in aircraft and systems checked.
	pm	New secondary mirror assembly (chopper) interferes with telescope focusing. Remove and machine to fit at Ames shops.
	pm	Alignment, focusing and system checkout completed.
November 7	1120	Engineering check flight.
	1615	Experiment calibration flight. Targets, the Moon and Mars. Only the Moon observed.
November 8	am	Rework of telescope elevation controls by Ames personnel.
	1500	Principal investigator arrives at Ames.
	1633	Experiment calibration flight. Same targets; only the Moon observed.
		Refocus telescope after flight.
November 9	1300	ASSESS briefing meeting to review operating plans.
	1650	Calibration flight. Moon and Mars observed.

TABLE 4-1. – CHRONOLOGY OF EXPERIMENT INTEGRATION AND SIMULATION MISSION – Concluded

Date	Time	Event
		NOTE: PI did not fly during premission week.
November 10–11		"Hands-off" period for rest. PI recovers from illness (influenza). Research assistant returns to home base.
November 12	0900	Final tune-up of chopper and system focus. Decrease chopper "throw."
	1300	Move base of operations to remote site.
	1400	Simulation mission begins.
	1758	Flight No. 1, target Jupiter. Low signal strength prompts decision to delay M42 flight until 0400.
	2100	Realign optics systems and bench check spectrometer. Primary telescope mirror badly smeared and could not be cleaned.
November 13	0200	Cancel 0400 flight because of condition of primary telescope mirror and noticeable crew fatigue.
	1748	Flight No. 2, target Jupiter.
	2115	Flight No. 3, target M42.
November 14	1742	Flight No. 4, target Jupiter.
	2110	Flight No. 5, target M42.
November 15	1732	Flight No. 6, target Jupiter.
	2108	Flight No. 7, target M42.
November 16	1735	Flight No. 8, target Jupiter.
	2102	Flight No. 9, target M42.
		END OF MISSION
November 17	0800	Mission debriefing.

TABLE 4-2. – FLIGHT EXPERIENCE – INTEGRATION PERIOD

Experiment: Primary Spectrometer

	Flight type					Problem cause						Data lost						
Flight No. and Date	Check	Calibration	Transit	Data	Problem description	GFE	Experiment	Experimenter	Aircraft	A/C Equipment	Environment	None	< 25%	< 50%	> 50%	> 75%	Total	Action/comments
1 11/7	X				Grating position readout (electrical) inoperative for first few minutes–then came on and operated normally.		X					←N A→						No data recorded. No action taken. No further trouble.
					Window and mirror fogging.					X								Defog hose not installed–was done before next flight.
2 11/7		X			Telescope adjustable mount jammed at high elevation angle–could not be moved either to max. elevation or back to low angle. Experimenters not informed as to torque requirements of adjusting screw and did not have proper tool onboard for task. No position indicator installed to show limits of motion.	X										X		Obtained partial spectrum of Moon. Jamming occurred before 30–40 μm portion of spectrum reached. Mods to adjustable mount not checked in flight. Telescope could not be moved to observe Mars. Ratchet actuator and position indicator installed by Ames telescope team next day. Angle position calibrated by experimenter.
3 11/8		X			Good data on Moon. Did not see Mars because of poor focus and inexperienced operator.		X								⊢⊣			Refocused telescope after flight–1 hour time.

TABLE 4-2. – FLIGHT EXPERIENCE – INTEGRATION PERIOD – Concluded

Experiment: Primary Spectrometer – Concluded

Flight No. and Date	Flight Type				Problem description	Problem cause						Data lost						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Experimenter	Aircraft	A/C Equipment	Environment	None	< 25%	< 50%	> 50%	> 75%	Total	
4 11/9		X			Good Moon and Mars data Digital printer malfunctioned.		X					X						No data loss – tape record OK. Printer repaired after flight – no further problems.
					Offset signal high.		X					X						Adjust signal electronics in flight.
					Chopper signal not sharp.	X						X						Adjustments to chopper made Monday am before start of mission.

Section 5

5. THE SIMULATION MISSION

5.1 Flight Planning

Planning for the entire series of flights in the simulation mission was settled in advance, no major interactions were expected between one flight and another The two objects of interest, Jupiter and the Orion Nebula (M42), were programmed for two closely spaced evening flights. Since it would have been possible to observe M42 in the early morning hours as it was setting, contingency plans were drawn up for use if the second flight of the evening could not be made. None of these contingency flights was flown.

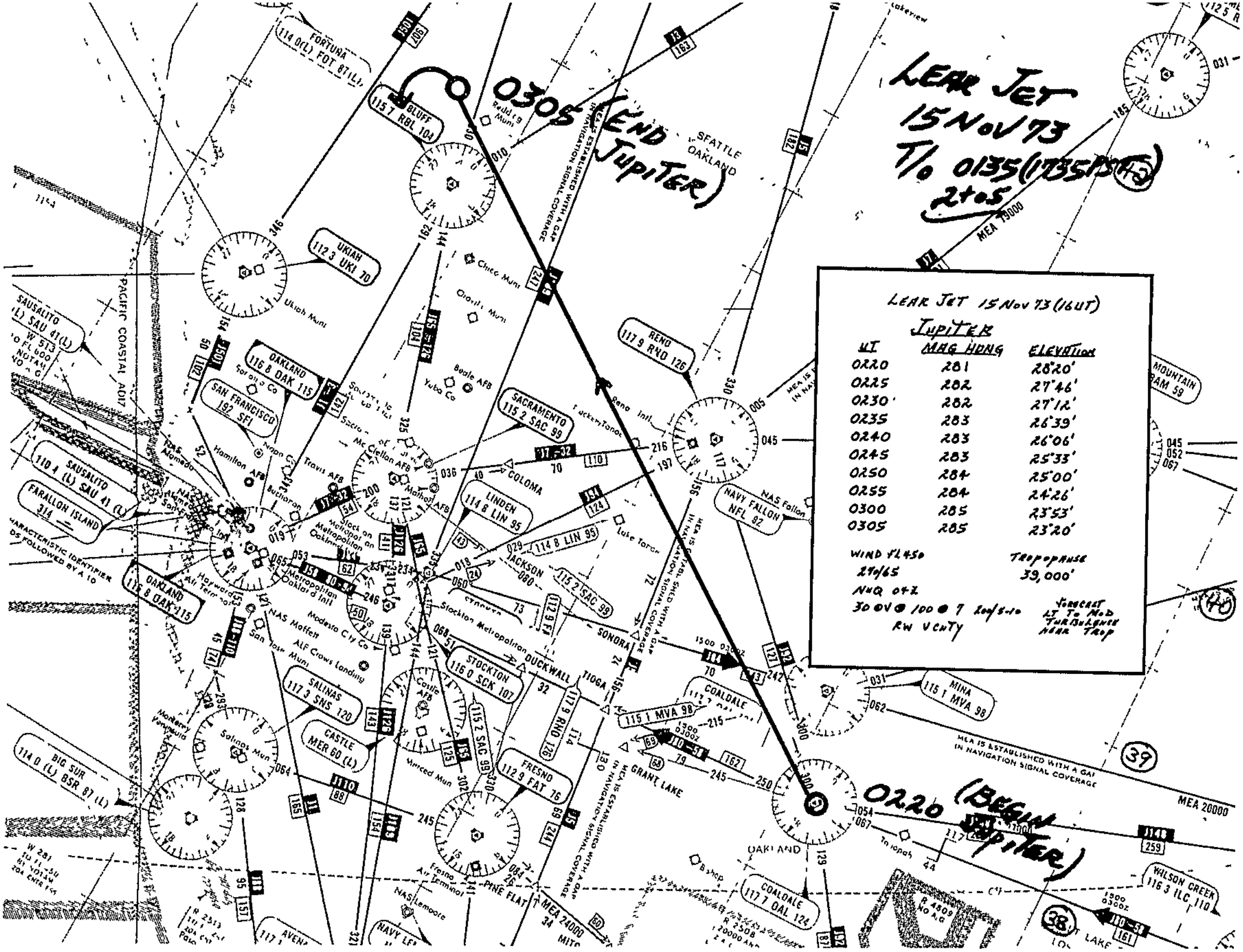
Flight plans were made up for each flight, including the early morning contingency flight, by the ASO flight planner in the early afternoon of each day. A sample plan for each of the selected targets is shown in figure 5-1. These planning sheets showed the time, aircraft heading, and target elevation for the observation leg of the flight, as well as the appropriate map segment showing the flight path. Note that the flight plans include predicted winds aloft, position of the tropopause, and estimated air turbulence From this information and the estimated total flight time, the command pilot requested adequate fuel supply and flight clearance.

5.2 Operations

The Shuttle simulation mission began at 1400 (2 pm) Monday, November 12, and ended at breakfast time Saturday morning of that same week. A debriefing followed immediately. The flight schedule called for ten flights, and nine were flown. The second planned flight was cancelled because of a combination of equipment problems and experimenter fatigue. All other flights were on schedule.

The daily flight plan called for an early evening flight at about 1800 to observe Jupiter, followed closely by a second evening flight at about 2100 to observe the Orion Nebula (M42). The quick turnaround time between flights, about an hour and a quarter, precluded servicing the aircraft at the simulation site. As it turned out, rain or the threat of rain, forced all but the first flight to originate at the Ames hangar. Thus, flight operations and aircraft maintenance were more like conventional Lear Jet flights than anticipated. However, the spirit of isolation was properly maintained for and by the simulation crew. The experimenters did little experiment servicing between flights; most of that time was spent for their evening meal.

The daily flight program, ending as it did at about 2300, permitted the experimenters to get in bed shortly after midnight. Thus, their sleep cycle was little different from normal. They used much of each day in system servicing and checkout before the first evening flight. This routine of preventive maintenance effectively minimized trouble with their own equipment in flight.



(a) Jupiter.

Figure 5-1. – Lear Jet flight plans – 15 November 1973.

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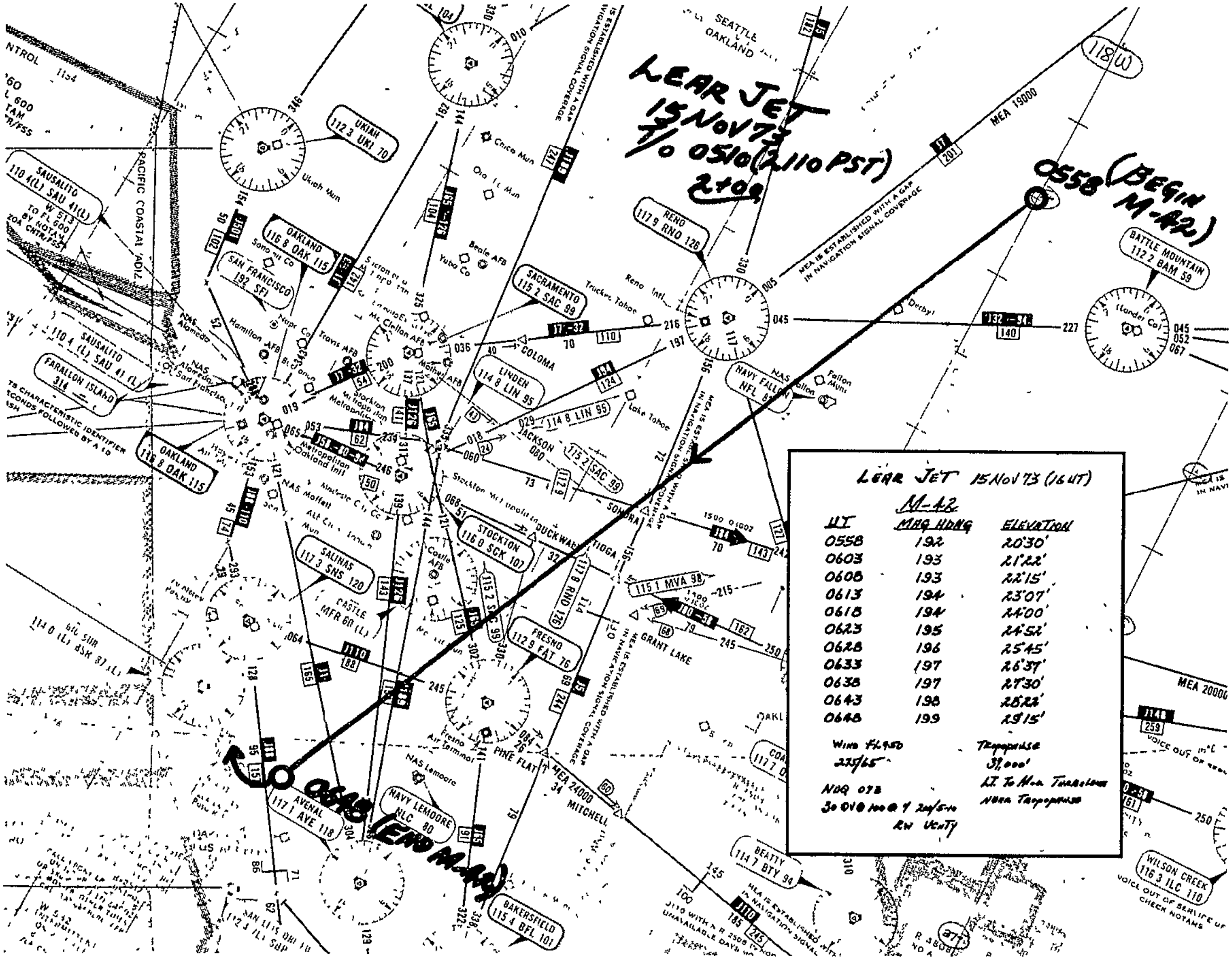


(b) M42

5.3 Data Handling

Because the two desired targets were preselected, there was no direct relation between the results of one flight and the targets for the following flights. However, previous results were examined for scatter and accuracy (signal-to-noise ratio), and subsequent scans on the same target were tailored to emphasize areas where verification or a finer-spaced scan was needed. The intent of the experimenters was to accumulate accurate, definitive data on the two targets, and this they did.

The experimenters spent some time evaluating the data in flight, and more the following day looking over the results of the previous two flights. For this purpose, they utilized the digital print-out made in flight for both real-time and post-flight judgments. Preliminary plots were made directly from the printout data. Such data examination also served as a real-time check on equipment operation.

5.4 Equipment Malfunctions and Other Problems

Equipment malfunctions and other operational difficulties, their impact on data acquisition, and their resolution are summarized in table 5-1. Only two malfunctions in experimenters' equipment caused any appreciable loss of data. The first was a partial misalignment of spectrometer optics that occurred on the first flight. This was attributed to improper torquing of Dewar mounting screws before flight, and was the direct result of shaking and vibration during taxi to the runway. Component alignment was checked after flight and the performance of all experiment systems was verified by tests on the bench and in the aircraft.

The second malfunction occurred on both Tuesday evening flights; the signal from one detector was lost, and data were obtained only in the 23- to 40-μm range. On Wednesday, the problem was identified as condensation in a connector, thereafter, a heat-gun was used to dry out the connectors in both detector circuits before each flight, and the problem was eliminated. The experimenters could also have used a light bulb for a heat source, but the heat-gun was a quicker way to troubleshoot and isolate circuit breakdowns due to condensation.

Several experiment problems of less impact were encountered, three as minor malfunctions that were accepted or quickly resolved, and others that related to experiment operations in the aircraft environment The first group were electronic in nature cross-talk between bias boxes, control-circuit interaction between digital counter unit and tape recorder, and erratic operation of grating position counter. The second group detracted from telescope guiding accuracy level of cabin illumination, glare from panel indicator lights, reticle lighting, and air turbulence. Lighting was controlled, and air turbulence was counteracted by extra guiding effort.

Two problems with the GFE telescope components and operation affected research activities significantly during the early flights. In particular, damage to the primary mirror surface and vibration (bouncing) of the secondary mirror degraded the quality of scientific data. The primary mirror had recently been realuminized at Ames and was used on the four checkout flights prior to the mission with no apparent deterioration. However, after the first mission flight the experimenters tried to remove what appeared to be a large oil deposit. Although they used approved cleaning procedures, they damaged the reflective layer. (Apparently, the aluminum layer had not been properly bonded to the glass [Cervit], and there was no protective overcoat of silicon monoxide.)

TABLE 5-1. – FLIGHT EXPERIENCE

Flight No. and Date	Flight type				Problem description	Problem cause						Data lost						Action/comments
	Check	Calibration	Transit	Data		GFE	Experiment	Experimenter	Aircraft	A/C Equipment	Environment	None	< 25%	< 50%	> 50%	> 75%	Total	
1 11/12																		Jupiter/observed
				X	• Turbulent air made telescope guiding difficult						X		X					• Affected data quality.
					• Chopper image smeared out	X						X						• Adjust after flight
					• Spectrometer misaligned, shaken by bouncing during taxi, not tightened properly when installed.			X								X		• Following flight delayed to 0400 hours to permit complete check-out of spectrometer. Results satisfactory
					• Primary mirror not hard coated as required, damaged by normal cleaning of reflective surface after flight	X						Unknown until processed						• Mirror to be realuminized at Ames next morning; 70% of surface damaged. Flight for M42 at 0400 hours cancelled at 0200 hours.
					• Rubber sleeve over air seal restricted telescope motion	X							X					
					• Reticle illumination marginal.	X						X						• Reposition lamp.
2 11/13																		Jupiter/observed
				X	• One detector out. Lost 16–23 μm data.		X						X					• No inflight fix. Checked cable between flights–no fault found. Suspect condensation in connector.
					• Mirror apparently splashed with oily water from runway						X	X						• Not cleaned between flights.
					• Chopper signal smeared out.	X							X					• No inflight fix possible.

TABLE 5-1. – FLIGHT EXPERIENCE – Continued

Flight No. and Date	Flight type: Check	Flight type: Calibration	Flight type: Transit	Flight type: Date	Problem description	Problem cause: GFE	Problem cause: Experiment	Problem cause: Experimenter	Problem cause: Aircraft	Problem cause: A/C Equipment	Problem cause: Environment	Data lost: None	Data lost: < 25%	Data lost: < 50%	Data lost: > 50%	Data lost: > 75%	Data lost: Total	Action/comments
2 11/13 (Cont)					• Rubber sleeve over air seal restricted telescope motion.	X						X						• Cut away excess material with razor blade after flight.
				X	• Telescope roll and yaw indicators difficult for copilot to see	X						X						• Suggest moving to center of pilots' instrument panel.
					• Turbulent air made guiding difficult						X		X					• Work around
3 11/13				X	Second flight of evening- short turnaround time.													M42 observed
					• No signal from one detector, 16–23 μm lost, satisfactory spectrum from 23–40 μm with other detector.		X							X				• Found condensation in connector the following day.
					• Cross-talk between detector bias boxes		X					X						• Checkout circuits; no repeat.
					• Poor condition of primary mirror.	X								Unknown until processed				• Mirror realuminized and hard coated the following day.
					• Light from pilots' compartment interfers with telescope guiding					X			X					• Work around.
					• Telescope jammed against stop.	X						X						• Work around.

TABLE 5-1. FLIGHT EXPERIENCE – Continued

Flight No. and Date	Flight type: Check	Calibration	Transit	Data	Problem description	Problem cause: GFE	Experiment	Experimenter	Aircraft	A/C Equipment	Environment	Data lost: None	< 25%	< 50%	> 50%	> 75%	Total	Action/comments
3 11/13 (Cont)				X	• Indicator lights on equipment interfere with target sighting.		X					X						• Cover with tape
4 11/14				X	Experimenters reported good data.													Jupiter observed
					Image quality not as good as desired (Chopper image smeared; adds noise to signal.)	X						X						Experimenters planned work on chopper next day.
																		Hard coating kept mirror surface in good condition. No further problems with mirror.
5 11/14				X	Good data reported.													M42 observed.
					• Image quality not as good as desired, image smear persisted	X						X						• Chopper bounce reduced following day by ASO personnel.
					• Light from pilots' compartment interferes with guiding.													• Plan to install black curtain for next M42 flight.
					• Interaction between tape recorder and digital counters; tape switch starts counter.		X					X						• Live with problem.
6 11/15				X	Good flight.													Jupiter observed.
					• Chopper giving better image.							X						• Tape placed between secondary mirror and support to damp out vibrations; quality of image held

TABLE 5-1. - FLIGHT EXPERIENCE – Continued

Flight No. and Date	Flight type: Check	Flight type: Calibration	Flight type: Transit	Flight type: Data	Problem description	Problem cause: GFE	Problem cause: Experiment	Problem cause: Experimenter	Problem cause: Aircraft	Problem cause: A/C Equipment	Problem cause: Environment	Data lost: None	Data lost: < 25%	Data lost: < 50%	Data lost: > 50%	Data lost: > 75%	Data lost: Total	Action/comments
6 11/15 (Cont)																		up and was no further problem.
					• Erratic operation of counter for grating position.		X						X					• Checkout circuit, no repeat.
					• Telescope stabilization system instability.	X						X						• Accepted.
7 11/15				X	Good data reported.													M42 observed.
					• Some mechanical problems in manipulation of variable angle adapter for telescope. (Rubber seal causes system to bind.)	X												• Pull rubber seal out of binding condition.
					• Adjusting screw on variable adapter runs into nut on telescope causing telescope to run into stop.	X						X						• Adjusted adapter screw.
					• Telescope stabilization system instability in roll axis.	X							X					• Adjusted gain in roll axis. Accepted results.
					• Difficult to operate experiment electronics in dark cabin.						X	X						• Telescope guiding improved. Electronics operator adapted to low light level.

TABLE 5-1. – FLIGHT EXPERIENCE – Concluded

Flight No. and Date	Flight type: Check	Flight type: Calibration	Flight type: Transit	Flight type: Data	Problem description	Problem cause: GFE	Problem cause: Experiment	Problem cause: Experimenter	Problem cause: Aircraft	Problem cause: A/C Equipment	Problem cause: Environment	Data lost: None	Data lost: < 25%	Data lost: < 50%	Data lost: > 50%	Data lost: > 75%	Data lost: Total	Action/comments
8 11/16				X	Good flight reported.													Jupiter observed
					• Tape recorder starts digital counter.		X					X						
					• Turbulent air makes guiding difficult						X		X					
					• Operator functions reversed for training experience Data take reduced			X					X					
					• Drift in telescope stabilization makes guiding difficult.	X							X					
9 11/16				X	Good flight reported.													M42 observed.
					• Excellent data recovery with reversed operator functions.		X					X						• Used black curtain to shield pilots' compartment, very helpful.

The following day (Tuesday) the mirror was recoated with both layers, but when cleaning was again attempted after the evening flights (to remove another deposit), the surface was too fragile to touch without damage. Again the mirror was removed from the telescope (Wednesday) and recoated after the surface had been carefully prepared by ion bombardment (a step omitted before). There was no further trouble on the last six flights.

The cause of vibration of the secondary mirror was traced to the presence of a small gap between the mirror and its support. The experimenters worked on this problem for one hour on Monday afternoon and again on Thursday with the assistance of an ASO technician. Elimination of the gap reduced the bounce and greatly improved the image quality. This was the first series of flights for the new chopper unit; thus, it took several flights before the trouble could be isolated. Had the PI flown on the checkout flights, this problem might have been identified and corrected before the mission started; with a trainee at the telescope, the problem was not recognized.

A less serious but chronic difficulty with telescope operation involved a rubber sleeve over the telescope/fuselage air seal that jammed telescope motion near the upper and lower limits of elevation. Again, this feature was part of the new variable-angle mount, which had not been flown prior to this mission. The problem was avoided rather than solved, but it remained a constant annoyance.

There is little doubt that the experimenter/telescope interface was a major problem area during this mission, and for two reasons: (1) new equipment was introduced and modifications were made that had not been tested in flight, and (2) responsibility for this equipment was not centered in the ASO, making the job of controlling the equipment very difficult. As a result, the experimenter was asked to become familiar with new devices while troubleshooting their malfunctions in flight and on the ground. His own equipment gave little trouble and, to his credit, he cooperated fully to resolve GFE problems that hindered progress toward his research goals.

5.5 Time Lines

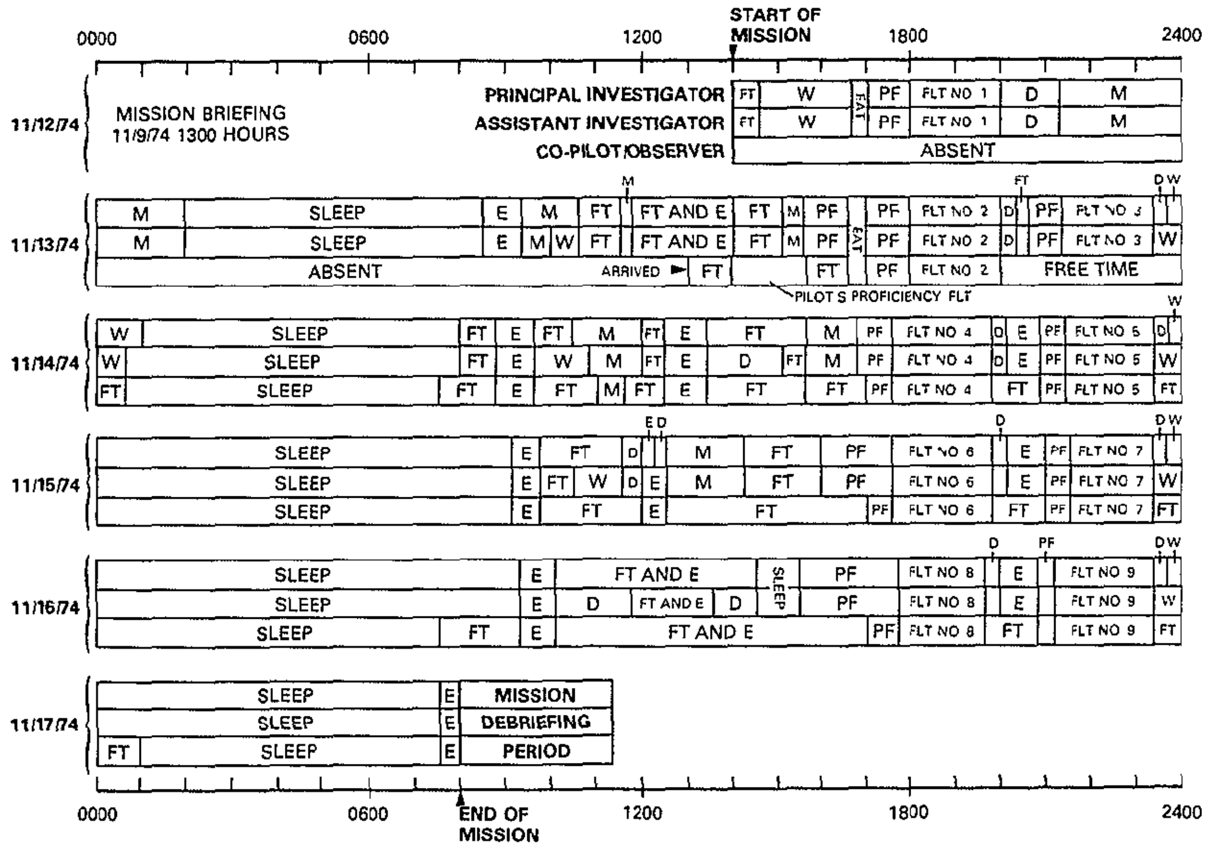
5.5.1 Day by Day

Time-line information for the simulation mission is given in figure 5-2. The period extended from 1400 on Monday until 0800 on the following Saturday, a total of 114 hr. This presentation shows the close relationship of the two experimenters and the fact that they did many tasks together. It also indicates that on this mission, unlike ASSESS #2 (ref. 5), the copilot/observer had little interaction with the experimenters.

A typical day shows the experimenters arising around 0900, having breakfast, cooling down the spectrometer, and perhaps plotting some data from the previous night's flights. About an hour before boarding the aircraft, the experimenters set up a collimator to check the alignment of the optical system. This check took 30 to 45 min each day and assured that the signal was maximized on the detectors.

The short time between the two evening flights typically was used for a late supper, and no servicing at all was done in that period. Following the second flight of the evening, the spectrometer was removed and taken to the work area for further service in the morning.

With the exception of the night of November 12–13 after the first flight, maintenance and servicing of the experimenters' equipment was quite routine and did not require extra effort beyond the time available. Considerable time was spent, however, in troubleshooting and



CODE

D = DATA EVALUATION
E = PREPARE FOOD AND EAT
FT = FREE TIME
M = EXPERIMENT MAINTENANCE
PF = PREFLIGHT EXPMT PREPS
W = NORMAL EXPMT SERVICING

Figure 5-2. – Time lines of mission participants.

maintenance of GFE telescope systems. Moderate amounts of "free time" were available for activities not related to the experiment operation, sleeping, or eating.

5.5.2 In Flight

Time-coded recordings were made of the conversations among the experimenters and pilots during all flights in the simulation mission. These records indicate that the experimenters' inflight operations were largely routine. Most of their conversations concerned the direct operation of the experiment and were couched in their own jargon. No repair or maintenance work was done. There was practically no interaction between the experimenters and the flight crew in regard to the flight operations of the aircraft, other than an occasional comment about the start of a data run or the cabin air temperature.

Each flight had a single target, first Jupiter and then M42, in the same sequence each night. This routine of scientific observations had been planned in advance, and, except for the second planned flight of the series that was cancelled, the program was carried out almost to the minute. From takeoff through the observation period, the preplanned events took place within a few minutes of schedule on all nine flights.

The observation periods were nearly identical on each target for each flight, differing in clock time by only about four minutes a day. Total flight times varied slightly depending on the direction of take off and landing. A time line typical of all flights is given in table 5-2, and the major time intervals for each flight are shown in the flight profile of table 5-3.

5.6 Telephone Communications

Telephone calls to and from the "Shuttle" crew, with three minor exceptions, were related not to the simulation mission but to future projects such as other ASO flight programs, or equipment related to other research programs at the university. Out of a total of 26 contacts, 19 originated with the PI, 6 were directed to him, and only one was made by the assistant experimenter. The copilot/observer made none. These events are summarized in table 5-4.

5.7 Experiment Support Equipment

Physical arrangements at the remote site (fig. 1-2) were relatively unchanged from previous Lear Jet simulation missions (refs. 4 and 5). Aircraft operations at the site were hampered by inclement weather, and all flights except the first originated at the Ames hangar, where the experiment preflight checks were done. However, the aircraft was available at the remote site from about 0900 until 1400 every day except Friday, so that most experiment servicing and maintenance could be accomplished there. While in the hangar area, the simulation crew observed the mission isolation guidelines to the fullest extent possible.

Floor area and furnishings in the trailer complex at the remote site were more than adequate; work surfaces and storage volumes were at least twice those needed (see fig. 1-2). Figure 5-3 shows the setup for a bench check of spectrometer optics and detector calibrations. The Dewar/spectrometer is seen mounted on the experimenters' telescope alignment simulator.

TABLE 5-2. – TYPICAL TIME LINE – IN FLIGHT

Hours	Activity
0h00m	Board
10	Adjust variable-angle telescope mount
20	Close door
30	Takeoff
40	Climb and transit – turn on telescope stabilization electronics
50	Turn on experiment electronics
1h00m	Experiment checkout and tune-up
10	Observation – one target per flight
20	
30	
40	
50	
2h00m	
10	Turn off electronics
20	Descend and transit
30	Evaluation of data
40	
50	Land and taxi to ramp
3h00m	

TABLE 5-3. – FLIGHT PROFILES

Target	No. of scans	Flight No.	Boarding time (Δ min)	Door time (Δ min)	Air time (Δ min)	Prep. time (Δ min)	Time on track: Checkout & service time (Δ min)	Time on track: Observation time (Δ min)
Jupiter	2	1	1735 7	1742–2006 144	1757–2002 125	1802–1832 30	1832–1845 13	1845–1914 29[a]
Jupiter	2½	2	1710 40[b]	1750–1950 120[a]	1800–1945 105[a]	1805–1820 15[a]	1834–1842 8	1842–1915 33
M42	2	3	2100 5[a]	2105–2314 130	2114–2312 118	2116–2202 46[b]	2202–2220 18[b]	2220–2251 31
Jupiter	3	4	1710 16	1726–1951 145	1741–1948 127	1750–1820 30	1820–1826 6 Background calibration	1826–1910 44 1910–1918 8
M42	3	5	2045 6	2051–2315 148	2109–2310 121	2132–2200 28	2200–2208 8	2208–2251 43
Jupiter	2	6	1700 16	1716–1945 149	1732–1940 128	1755–1815 20	1815–1832 17	1832–1907 35
M42	3	7	2045 6	2051–2312 141	2106–2305 119	2133–2158 25	2158–2203 2220–2225 10	2203–2248 45
Jupiter	2	8	1700 20	1720–2003 163[b]	1735–1956 141[b]	1740–1816 36	1816–1824 Practice operation 8	1824–1903 39
M42	3	9	2045 19	2104–2347 163	2119–2339 140	2122–2203 41	2203–2207 4[a]	2207–2300 53[b]
Totals Average	22½ 2.5		135 15	1303 145	1124 125	291 32	92 10	360 40

min[a] max[b]

TABLE 5-4. – SUMMARY OF TELEPHONE COMMUNICATIONS WITH CONFINED PERSONNEL

Date	Contact	In/Out	Purpose of call		
			Mission	Other business	Personal
November 12	Assistant Experimenter	Out		1	
	PI	Out			1
November 13	PI	Out	2 (Ames) Telescope mirror		1
November 14	PI	In	1 (ASO) Aircraft logistics	1	1
November 15	PI	In	1 (ASO) Cryogenic supply	1	1
		Out		5	
November 16	PI	In	1 (ASO) Chopper performance	2	
		Out		6	1
November 17	---	---	None	None	None
		Totals	5	16	5

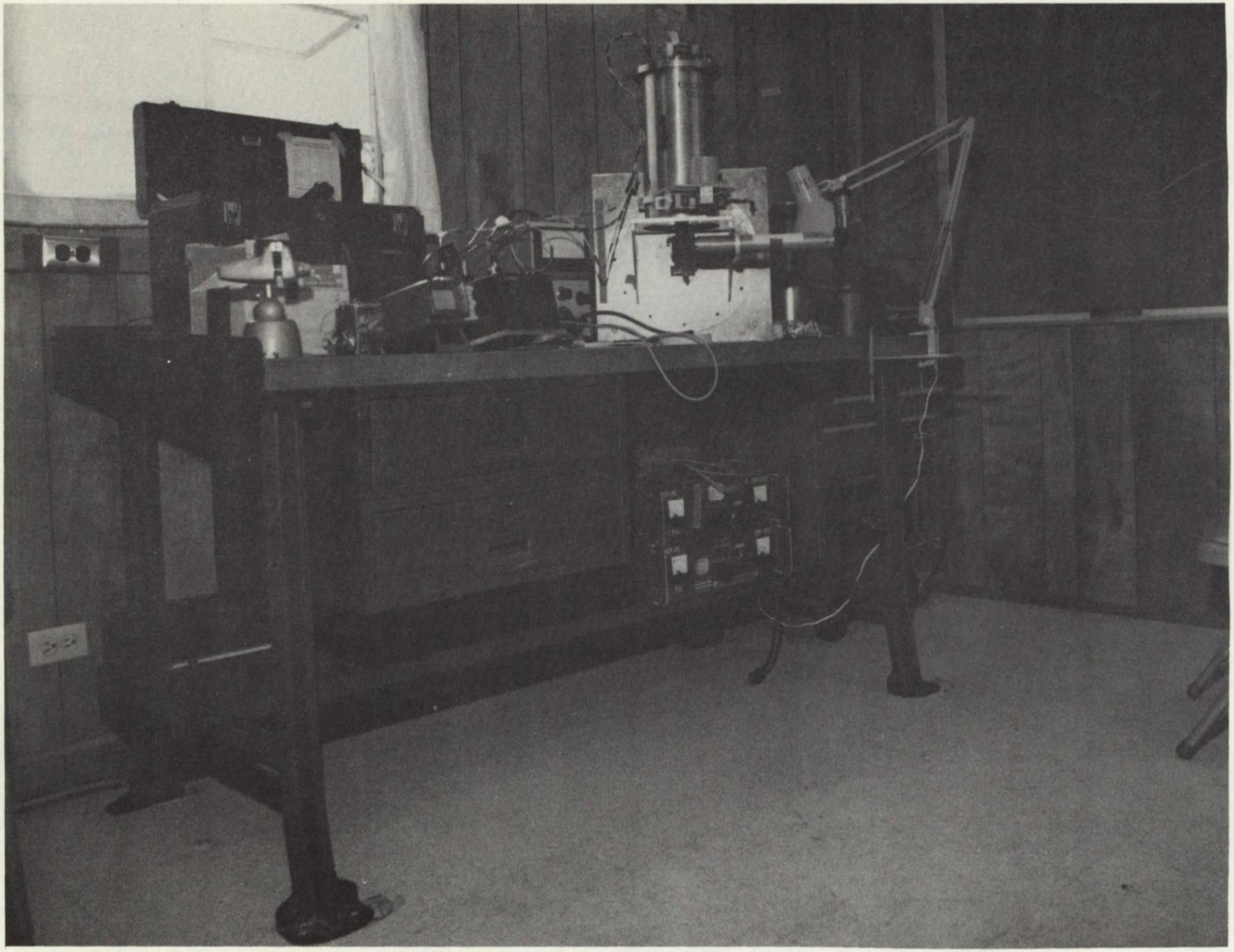


Figure 5-3. – Bench setup for check on optical alignment of spectrometer.

5.7.1 Experimenters' Inventory

The experimenters provided essentially the same tools, references, small spare parts, and test equipment as for the earlier ASSESS #2 mission in which they had participated (table 5-5). Tool utilization was about half that for ASSESS #2, because very little experiment maintenance was done, and was limited to hand tools needed for routine servicing.

The supply and use of test equipment was similar for the two missions, with two notable exceptions. For ASSESS #3, the experimenter brought the telescope simulator jig he had built to align and check performance of Dewar optics and detectors on the bench (figs. 5-4 and 5-5). This unit was part of the new alignment equipment acquired after the ASSESS #2 mission to reduce time and uncertainty in experiment integration with telescope optics in the aircraft. After the mission had begun, the ASO furnished the "heat gun" used to drive out moisture from cable connectors in the detector circuits.

The supply and use of small parts was the same as before, while expendable supplies and reference material were reduced on the basis of previous experience. Detailed inventories of the tools, test equipment, and supplies is given in tables B-1 through B-5.

5.7.2 Ames Support Functions

Ames support of experiment operations during the simulation mission was handled by the ASO mission manager, who was responsible for aircraft and experiment-related GFE servicing. maintenance, and logistics, including pilot support. Facilities at the remote site were handled by the ASSESS program manager.

Problems with the primary and secondary mirrors in the GFE telescope had a direct impact on experiment operations and required both telephone and personal consultations among the mission manager, the PI, and Ames support personnel to resolve. On three occasions, the PI's experience with IR optical systems and his evaluation of current telescope performance were utilized in the selection of maintenance and repair options that would satisfy the science requirements of the experiment within the time constraints of the mission flight schedule. This personal interaction was vital to the science goals of the mission, and is perhaps analogous to a similar GFE malfunction in Spacelab.

Electrical power for the experiment was supplied by two 115-V, 60-Hz inverters from the 28-Vdc aircraft generators, and directly to the telescope stabilization system as 28-Vdc. A small amount of 90 Vdc was furnished by batteries. Power used by the various experiment components is shown in table 2-1; overall distribution is summarized in table 5-6.

Less than 1 kWh of 60-Hz energy was used for experiment maintenance and servicing in the "Shuttle" work area during the entire 5-day mission. Experiment problems were minimal, and between-flight activities were primarily routine checkout and servicing of the equipment in and around the aircraft; little bench work was required. Furthermore, postflight data analysis used the digital records processed and printed out during inflight observations; no additional machine processing was done on the ground and no energy was consumed.

TABLE 5-5. – UTILIZATION OF MISSION SUPPORT EQUIPMENT

Comparison Between ASSESS #2 and #3

Item	Number supplied		Number used		Percent used	
	#2	#3	#2	#3	#2	#3
Hand tools	177	175	66	33	37	19
Test equipment (Including ASO-supplied)	26	24*	17	17	65	71
Spare parts	34	34	5	5	15	15
Expendable supplies (Experimenter-supplied)	108	91	58	53	54	58
Reference material & data aids	14	11	1	6	7	55

*One item supplied during simulation mission.

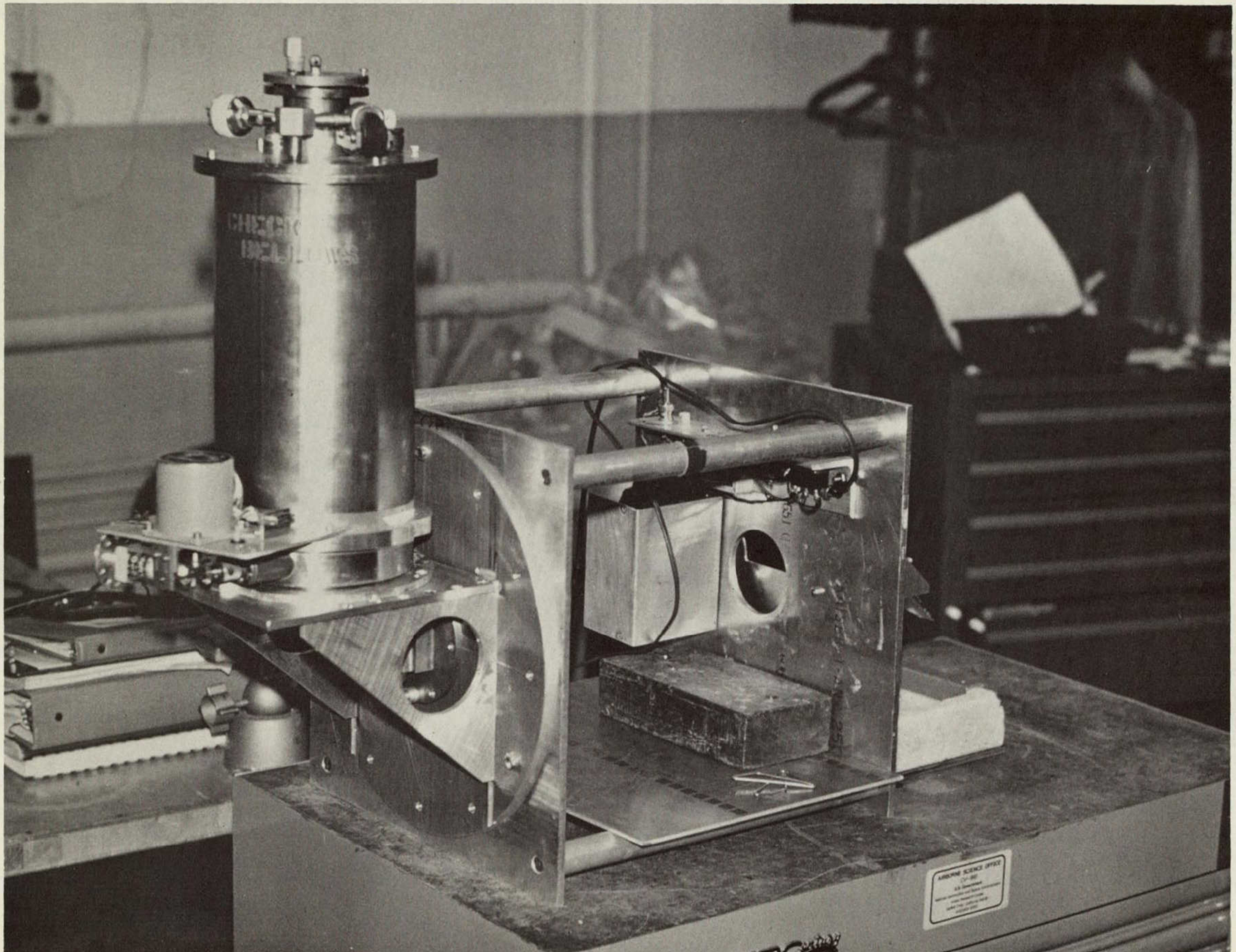


Figure 5-4. – Front view of telescope simulator with Dewar mounted.

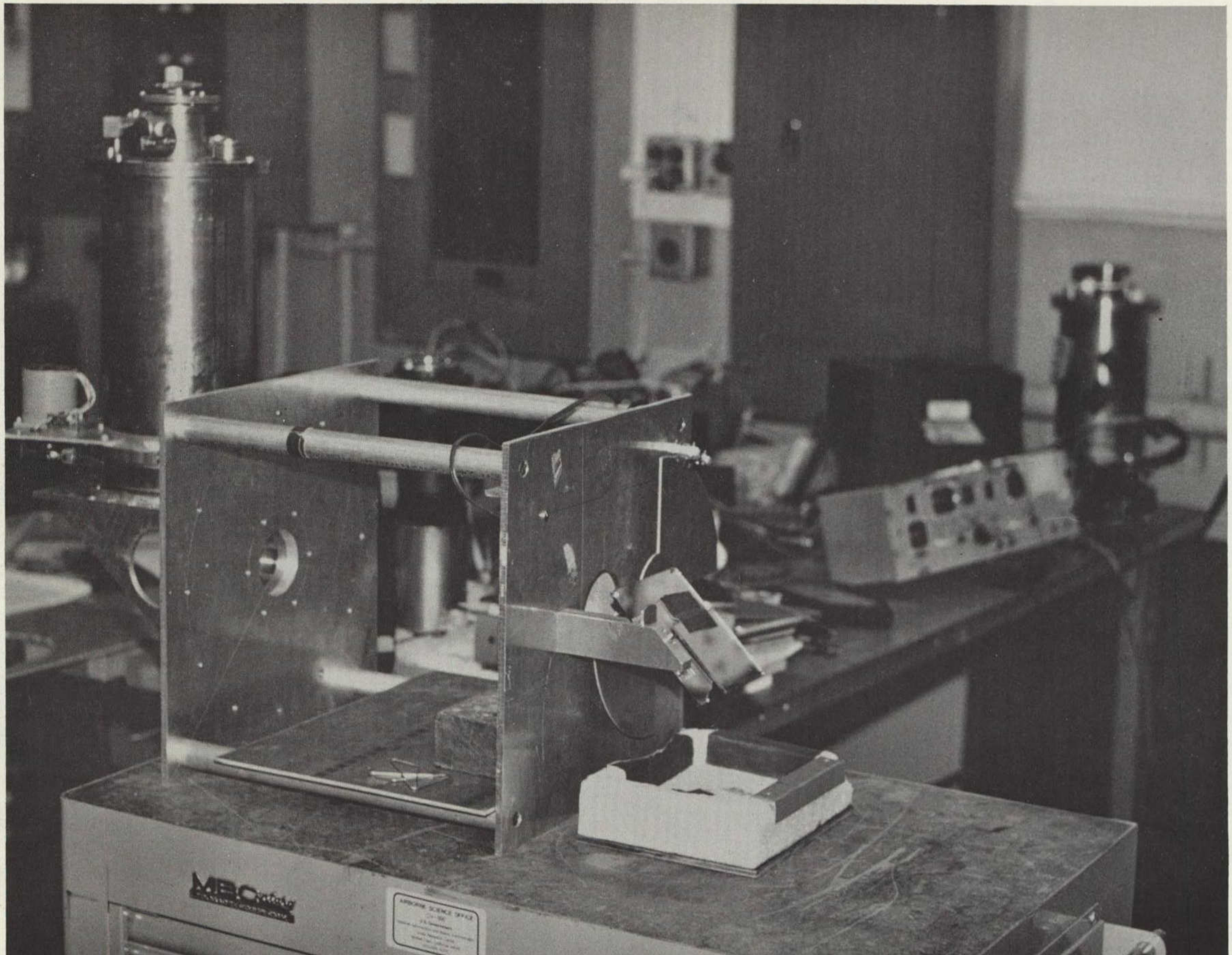


Figure 5-5. – Rear view of telescope simulator with chopper wheel and liquid nitrogen tray.

TABLE 5-6. – DATA SUMMARY

Type	Available in aircraft, VA	Distribution of power	
		Amount, VA	Used for
115 V, 60 Hz	250	173	Experimenters' equipment
		60	Telescope chopper drive (GFE)
28 Vdc	1710	200 (min) 1120 (max)	Telescope stabilization electronics (GFE)
		100	60 Hz inverter losses (GFE)
90 Vdc	----	0.20	Experimenters' equipment
Totals	1960	533 (min) 1453 (max)	All units

No accurate record was kept of energy used in normal servicing of the experiment in the aircraft. However, estimates have been made using nominal power ratings and observed time durations of servicing activities, as summarized in table 5-7 at about 0.64 kWh per day. Thus, overall energy consumption for experiment maintenance and servicing, including that used to check out onboard systems between flights, was about 0.8 kWh per day

TABLE 5-7. – DATA SUMMARY

Event	Equipment	Power use	Average time per day	kWh energy per day
Optical alignment	Collimator	< 100 W	0.6 h	<0.06
	Experiment electronics	~ 100 W	2.0 h	0.20
	Inverter loss	~ 35 W	2.0 h	0.07
	Secondary mirror drive & inverter loss	~ 60 W	<0.6 h	<0.04
Telescope systems checkout	Stabilization electronics	200 W	0	0
Dry out connectors	Heat gun	1500 W	0.04 h	0.06
Dewar storage	Vac-ion pump	14 W	15 h	0 21
			Total	<0.64

Section 6

6. DISCUSSION OF RESULTS

The ASSESS #3 mission involved the same team of experimenters and the same basic experiment as the second mission. Equipment modifications were made to improve experiment operations and servicing, and to provide inflight data processing and display Primary components were tested to assure reliable operation, proven backup units were available as replacements, and special equipment was developed for precise instrument calibration during the mission.

As a result of his experience in the ASSESS #2 mission, the principal investigator scheduled a longer integration/checkout period at Ames and assigned those tasks to his team associate and an alternate As planned, they completed inflight calibration of the experiment in this time period, so that all mission flights were devoted to observations of the primary targets. The principal investigator phased into the operations a few days prior to the start of the simulation period.

A new mission element, the Flight Readiness Review (FRR), encouraged the experimenters to plan well in advance and to complete preparations on schedule. Aircraft problems delayed the "launch" by one week, when the mission resumed, the experiment performed reliably, and 9 of 10 scheduled flights were completed. Results in specific areas of interest are discussed in this section.

6.1 Synopsis of First Experimenters' Meeting

The first meeting of the principal investigator (PI) with the ASO Lear and ASSESS program managers was held at Ames on August 21 An early agenda item was the proposed FRR, its purpose and content, and its impact on the timing of experiment preparations In particular, the ASSESS guidelines allowing no equipment changes after the FRR, one month prior to flight, was viewed by the PI as a serious constraint on his normal mode of operation. In fact, with this constraint, he could not complete his proposed upgrading of the IR detector array in time for a November 5 "launch" date His initial mission plan included the custom-commercial fabrication of a 16-detector array, which he proposed to check out in flight one month before the ASSESS mission and then continue to improve until final shipment to Ames (Here again, as in the first two Lear ASSESS missions, the experimenter was motivated to improve the science capability of his experiment in anticipation of future research beyond the immediate mission.)

Because the FRR was designed for the very purpose of eliminating last-minute changes, and was considered a vital part of the ASSESS program, the PI was asked to reconsider his research plan. Agreement ultimately was reached: the November 5 "launch" date was confirmed, the FRR adopted, and the PI outlined his revised plan of action and the level of support he required. The existing experiment would be used, with upgrading and testing of primary and backup components as required to achieve fully reliable operation in the context of Lear Jet operations; equipment modification and testing would be targeted for completion by the FRR date in early October; scientific observations would be planned to make optimum use of research equipment on 10 mission flights. ASO was requested to monitor ongoing telescope (GFE) modifications and to keep the experimenters posted on progress, as well as any changes that could impact experiment operating plans, inflight checkout of telescope performance after modification was recommended. The meeting was adjourned

It is only fair to note that the ASO/ASSESS constraints on mission scheduling and resources caused the PI to substantially modify his original plans during the course of this three-session meeting He did so in a reasoned manner, through discussion of options and negotiation toward his larger objective – a viable, continuing program of IR astronomy in his chosen area of specialization.

6.2 Actual versus Planned Schedule

July 30 marked the beginning of preparations for the third ASSESS mission, although until August 25 the experimenters were occupied with a normal ASO Lear Jet mission and did little more than prepare the research proposal. A total of 104 days was available, with 5 reserved for the simulation mission The principal investigator allotted 11 days for integration and checkout at Ames, with the remaining 88 for home base preparations and shipping. These are shown in time-line form at the top of figure 6-1, along with a more detailed breakdown for the integration period

Preparations were completed within one day of schedule (lower part of fig. 6-1), and bench assembly at Ames commenced on October 26. Aircraft problems delayed installation by more than a week, so that six rather than two days were occupied with assembly and testing in the ASO laboratory, and four were available for rest and relaxation. GFE problems stretched experiment installation from one to two days, compressing the checkout flight schedule from five to three days and eliminating the final one-day period planned for clean-up activities The scheduled hands-off period was observed. In all a total of 17 days elapsed between the arrival at Ames and the start of the simulation mission. Confinement was just short of a full 5 days and with one exception, all flights were on schedule.

The exemplary way in which the experimenters achieved their experiment preparation and flight plans is in sharp contrast to the previous two ASSESS Lear Jet missions (refs 4 and 5) in which delays in preparation of three and six weeks, respectively, forced corresponding slippages of the "launch" dates. In all three cases, the target time for preparation was nearly the same, about 90 days. In the present mission, three factors were responsible for this improvement – experience in a previous ASSESS mission, use of an existing experiment, and the FRR. Perhaps the FRR was the prime mover that caused the experimenters to evaluate research plans with more realism and in the light of their projected workload, both for the mission and otherwise. Early plans to build a new detector system were revised in favor of more reliability in existing equipment. Work was carefully scheduled to meet the FRR date, and started early with good momentum.

Previous ASSESS experience was not only a valuable guide in work scheduling, but also hastened the acquisition of optical devices that greatly simplified the alignment of telescope and spectrometer systems, reduced the inflight workload, and influenced the time and manpower allotments during the premission checkout period The overall result derived from experience, experiment choice, and the FRR was a relatively well planned, smoothly functioning research effort

6.3 Experimenter Decision Points

Planning for ASSESS #3 began about 3 months after the ASSESS #2 mission, a short enough interval for past experience to influence current decisions significantly In a certain sense this was the second half of a two-part research experience, with an intermediate period (a normal Lear Jet mission in August) for evaluating equipment changes resulting from ASSESS #2.

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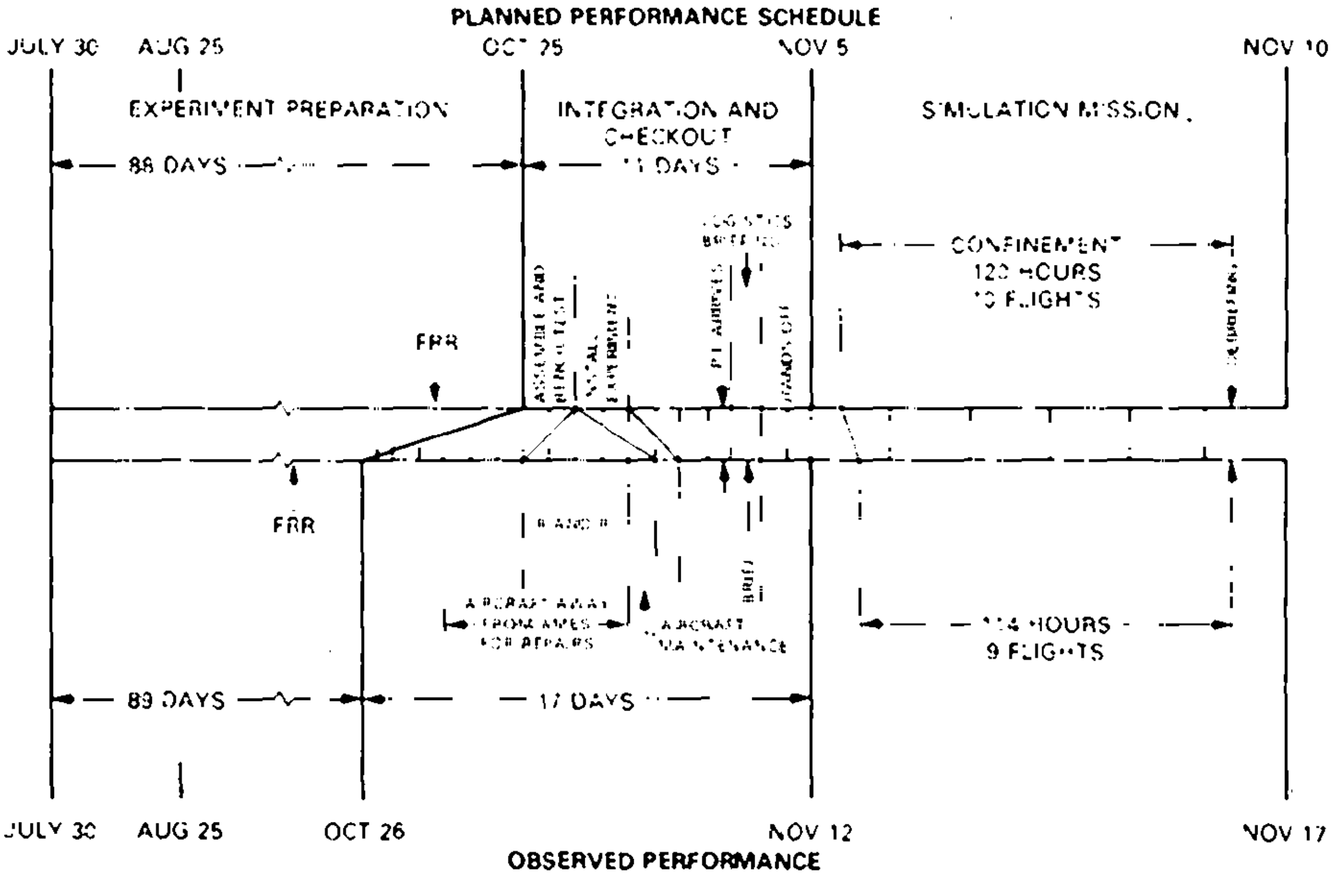

Figure 6-1.- Overall time-lines for ASSESS #3.

Table 6-1 summarizes experimenter decisions, each identified as normal (N) or mission specific (MS) by its relation to normal practice in ASO research or to the unique constraints of a Shuttle simulation mission. The first three decisions shown grew out of the ASSESS #2 experience; these were implemented and then tried out in the August mission several weeks after the experimenters were selected for ASSESS #3. A comparison of table 6-1 with the corresponding table D-5 for ASSESS #2 (ref. 5) indicates a more timely resolution of early, basic decisions and a more carefully planned program, both of which contributed to the realization of the proposed schedule and the reliable performance of the experiment throughout the ASSESS #3 simulation mission.

The basic decisions that gave direction to the overall effort were made in a 4-week period following submission of the research proposal in mid August. Research and simulation program elements were coordinated at the first experimenters' meetings of August 21 to 23, and the principal investigator completed his milestone chart for experiment preparation and research operations on September 12. Thereafter, until the mission began 2 months later, the monitored activities balanced well against the schedule, with only minor adjustments within the overall time frame. Similarly, during the simulation period, the day-to-day decisions, with one exception, were implemented without affecting the flight schedule.

Of all these decisions, perhaps the choice of detector array for the primary experiment (August 21 to 23) was of the greatest significance. This was the focal point of both research plans and ASSESS schedules. Since early July, the experimenter had been considering the development of a 10-element array to improve the resolution and data-gathering capability of his equipment. By August 21, his thinking had progressed to 16 elements in one array, and this he proposed at the first experimenters' meeting. However, when estimated development time indicated substantial delay and schedule conflicts on both sides, a decision was made to use existing detector arrays and improve other components of the experiment Although an unpalatable decision in response to real constraints, its major impact was to reduce quantity rather than quality of data return.

6.4 Science Planning and Accomplishment

Table 6-2 summarizes science planning for ASSESS #3 in terms of targets, objectives, and flight schedules. Research objectives were fixed at the outset as a continuation of previous work, while a flight frequency of two per night was the accepted standard. In his research proposal, the PI defined his primary targets as Jupiter and M42, the same targets observed on several previous missions, and Saturn. Three weeks later, the milestone chart defined the sequence of calibration and data flights planned for the checkout period and the simulation mission, Saturn was dropped from the plans.

With the approach of the checkout period, GFE delays and operator training plans prompted the deletion of Jupiter and M42 from the flight plan for the premission week, and the calibration target Mars was joined by the Moon. At about the same time these two sources were deleted as optional sources on the last mission flight.

Several days before the mission period, the PI requested that flight plans be prepared for a morning flight on M42 each day, as a contingency if the second evening flight was aborted for any reason. Final plans were a Jupiter flight about 1815, an M42 flight at about 2200, with the contingency flight at about 0400 the following morning Nine of the ten regular flights were completed; both regular and contingency flights on M42 were cancelled on November 12 because of GFE problems.

TABLE 6-1. – EXPERIMENTER DECISION POINTS, NORMAL (N) OR MISSION SPECIFIC (MS)

Decision	Date and type	Decision factors	Options
Build optical simulator for telescope (portable)	April 14 N	Bench-align Dewar optics, reduce maintenance time, bench calibration at remote site.	Align after installed, troubleshoot Dewar in aircraft, calibrate in aircraft, no cold source
Upgrade experiment components	April 15– August 10 N	Preamps pick up 400 Hz noise, vibration loosens detectors, detector sensitivity.	Isolate from telescope ground, move preamps inside spectrometer housing, cryogenic cement, replace 20–40 μm detector
Test grating control electronics at reduced temperatures	April 15– August 10 N	Possible temperature sensitivity, impact of malfunction on data	Test conditions and criteria, response to malfunction.
Participate in ASSESS mission if selected	July 2 MS	Impact on ongoing programs, funding and manpower, experience in ASSESS #2	Continue normal schedule with existing equipment, request funds to upgrade experiment for ASSESS #3.
Flight team selected	August 1 MS	Premission activities, mission schedule, experience in ASSESS #2	Train new operator, vary inflight roles.
Research proposal formalized	August 16 MS	Science objectives, funding required, reliability desired.	Target selection, primary waveband, experiment configuration.
Use 2-detector array in primary experiment, 4-detector array as backup	August 21–23 MS	Science potential, procurement time, reliability of new units.	10 unit array } procure from 16 unit array } outside source 2 and 4 unit arrays (existing)
Use proven experiment with backup components and upgrade critical units	August 23 MS	Time for preparation, science potential, inflight data display.	Alternate, noncompatible electronics as separate backup system.
Mission schedule agreement	August 23 MS	Flight Readiness Review, availability of targets, constraints of weather.	Extended preparation period to develop new detectors, checkout flights part of FRR.

TABLE 6-1. – EXPERIMENTER DECISION POINTS, NORMAL (N) OR MISSION (MS) – Continued

Decision	Date and type	Decision factors	Options
Decisions on experiment modifications and test procedures	August 27–September 12 MS	Reliability of components, time for in-mission servicing, equipment calibration, data processing.	Refurbish or replace, build new alignment units, test required
Rebuild bias boxes to incorporate preamps	September 6 MS	Result of tests on reconditioned units, preamp accessibility for maintenance.	Fabricate new units as planned, retain existing as backups.
Milestone schedule formalized	September 12 MS	Available manpower, task priority, FRR objectives, checkout and mission flight goals	Division of preparation tasks, allowance for contingency, assigned premission roles and schedules of tasks.
Adjust work schedule as required to meet FRR date	September 12–October 4 MS	Ames participation in FRR, ASO liaison at university, promised cooperation.	Continue development of hardware after FRR.
Ship equipment to Ames	October 23 N	Checkout flight schedule, status of experiment, operator training in flight.	Delay several days for final tuneup.
Change targets for checkout flights to meet operator training and calibration requirements	October 29 MS	Train backup operator, inflight calibration of experiment, GFE delay of schedule.	Observe as planned on Mars, Jupiter and M42.
Change target of last checkout flight	November 9 N	Illness of PI, new operator training.	Continue calibration and training, cancel flight.
Cancel second flight of mission	November 12 MS	Experiment malfunction, problem not isolated, flight results questioned.	Contingency flight.
Cancel am contingency flight	November 13 MS	Problem resolved, primary mirror degraded, fatigue.	Make flight but with data questionable.
Primary mirror must be recoated	November 13–14 N	Unknown effect on data, can be done at Ames, ASO responsible for job.	Risk data quality, cancel one or more flights if necessary.

TABLE 6-1. – EXPERIMENTER DECISION POINTS, NORMAL (N) OR MISSION SPECIFIC (MS) – Concluded

Decision	Date and type	Decision factors	Options
Chopper signal not acceptable	November 15 N	Marginal signal quality, adjustment takes temporary improvement, ASO job.	Continue operation, ASO trouble-shoot and repair, replace with old model.
Inflight decisions on data quality during first flight	November 12–15 MS	Evaluation of printout, target scans done, problems encountered.	Second or contingency flight.
Post-flight decisions of scan pattern for repeat flights on targets	November 12–15 MS	Data quality, definition of critical areas, comparison with previous results.	Repeat same scan to verify results, offset step sequence, change step size.

TABLE 6-2. – SCIENCE PLANNING FOR ASSESS #3

Date	Targets and objectives	Observation schedule
July 30	Planning starts; continue previous research.	––
August 13	PI and ASO mission manager discuss target selection.	Two flights each night, the accepted standard.
August 16	PI submits proposal; defines objectives and tentative targets as Jupiter, Saturn and M42.	Saturn not available in mission time frame.
September 12	PI submits milestone chart, optional targets for premission checkout flights are Jupiter (2), Mars (3) and M42 (1). Targets for mission flights are Jupiter (5), M42 (5), Mars (1), Moon (1). Mars and Moon are calibration targets.	PI requests ASO flight planner check target availability. Targets ordered by days during checkout and mission periods
September 25	Availability of prime mission targets confirmed, both Jupiter and M42 each night.	PI informed of observation times on prime targets.
November 5	Targets selected for premission checkout/calibration flights, both the Moon (3) and Mars (3) each flight. Prime mission targets, Jupiter and M42 reconfirmed by experimenter	Flight plans completed for premission week and Flight Request Record submitted for 4 flights (one daytime flight for engineering checkout)
November 6	Jupiter and M42. Optional calibration targets, the Moon and Mars, deleted from last mission flight.	Detailed planning begins for 10 mission flights.
November 8	PI requests daily am flight on M42 as contingency if late pm flight is aborted.	ASO planner adds second M42 flight to daily schedule.
November 12	Jupiter and M42.	Flight Request Record submitted for 10 mission flights and 5 contingency flights
November 12	Mission flight #1, target Jupiter.	Late pm and am contingency flights on M42 cancelled by PI.
November 13–16	Mission flights on Jupiter and M42	On schedule, eight flights carried out as planned.

Scientific accomplishments on this mission can be stated in several ways. Superficially, the quantity of valid data recorded is one measure of success, table 5-3 shows a total of 22-1/2 spectral scans, 11 on M42 and 11-1/2 on Jupiter, with 80 percent of the available track time utilized for data acquisition Allowing for GFE and experiment problems that reduced data quality on the first three flights (6-1/2 scans), the confirmed scientific yield was 16 out of 22-1/2, or 71 percent. More to the point, however, the PI stated at the mission debriefing that his planned scientific objectives had been accomplished, despite the loss or reduction of data quality on the first four flights.

At the mission debriefing meeting, the principal investigator also assessed scientific accomplishments in the context of his total flight program This was the fourth and probably the last flight series to study the composition and thermal structure of M42 and the Jovian atmosphere. Taken as a group, these data are unique – the first astronomical observations made with a liquid-helium cooled spectrometer, and the first spectrometer results in the 16- to 40-μm waveband. Several publications are in preparation to describe the instrumentation and the Jupiter and M42 findings. ASSESS #3 results are unique to the group, moreover, since observations on Jupiter were tailored to substantiate several unexpected features, first encountered in the August mission, that are not explained by existing theory. With these new Jupiter data, and the M42 data obtained during the mission to augment previous results, the flight program has been essentially completed.

The PI requested three or four additional flights on M42 during the postmission week; two were made. This contingency option is offered to all participants in ASSESS simulation missions; it was used here for the first time, and apparently indicates that some aspect of the research problem was not fully resolved in the 5-day mission period In part, this was because of the events that occurred early in the week when one M42 flight was cancelled On the other hand, the stated reasons go beyond this explanation into the areas of data analysis and laboratory checkout of eqiupment. Both were done in more detail before the postmission flights than was possible while the mission was underway, with particular attention to one portion of the M42 spectrum where results were not entirely consistent. Further flight observations were then tailored to answer the remaining questions

This sort of time extension is common in normal Lear Jet missions, where schedules often can be adjusted to accommodate the experimenter. In this light, it is reasonable that the anomalous M42 result was recognized earlier but deferred until after the mission, in favor of completing the overall research objectives.

6.5 Data Management

ASSESS #3 was the fourth flight series in the ASO Lear Jet for this team of experimenters. On the first three, the basic approach to data management was to process the flight record with ground-based equipment, in sufficient depth to judge its value and to plan for the next flight. Real-time monitoring of data quality was limited to visual indicators and audio signals of the results being recorded on magnetic tape. Although these instantaneous outputs served to guide research observations in real time, there was no record available for review while in flight.

On ASSESS #2 (their second flight series), the experimenters decided to upgrade their on-ground processing capability with a preprogrammed microcomputer for in-depth evaluation of scientific results. Time constraints and equipment problems before and during that mission prevented more than a cursory exercise of this computing capability.

For the present mission the emphasis shifted from on-ground to inflight processing, apparently to make more effective use of the limited observation time available on Lear Jet flights. To this end, the experimenters modified their original ground-based counter/printer system for airborne use; for each grating position (wavelength) a 15-digit line of print defined the average signal during the integration interval, nominally 10 sec (see fig. 2-6). With this on-line capability, they planned real-time evaluation of results to guide data acquisition during the flight, postflight analysis of the same record for internal consistency and for comparison with previous results as a guide to flight planning, and final computer processing at the home base after the mission was over.

In practice, this data management plan proved effective. Real-time monitoring provided a quick estimate of telescope guiding fluctuations (guiding noise) and the need to repeat an observation, as well as a continuous indication of overall system performance. When observations were completed, the record was reviewed for 20 min or so during the return to base; signal strength, instrument and guiding noise, and signal-to-noise ratio over the spectrum were examined. During the early evening flight, these results were the basis for a decision to "go with" the second scheduled flight of the night or switch to the contingency flight This decision was radioed to the ground to set in motion the between-flight activities of the ground crew and to alert the command pilot for the second flight.

Immediately after flight there was a 10- to 15-min review of the results for internal consistency and for comparison with previous data. During another period of evaluation and analysis the next day, spectra were plotted, unusual features studied, and the detailed observation schedules planned for the next two flights. This took an average of about 40 min full time, with intermittent attention for another 60 min. The result was a decision on the scan interval, step offset, and step size to be used on the next observation of each primary target.

Time spent in data evaluation is summarized in table 6-3, exclusive of real-time monitoring. During the mission, almost 17 man-hours were spent in data evaluation, 6 in flight and 11 on the ground; the PI contributed about 40 percent of the total effort and his associate the remainder.

Postmission analysis at the experimenters' laboratory was expected to follow the original plan, with special attention required to determine whether the spectral scans obtained with a damaged mirror surface were valid.

Experimenters' comments in the mission debriefing gave further insight into data handling during the simulation mission, with application to Spacelab planning. The first expressed the need for a visual analog record in real time of detector response while fine-guiding the telescope for target acquisition and observation. Such a record would assist the location of dim targets and provide a measure of the guiding stability during the observation interval at each wavelength.

The second comment concerned data evaluation for unusual, detailed features. These could could not be studied to the desired extent during the mission and still keep up with the experiment servicing and checkout for the ongoing flight schedule [1] As a result, additional flight time was requested after the mission, with an interval of several days for in-depth analysis and planning for definitive observations. In Spacelab context, this time constraint might be resolved in one of two ways: a longer duration mission would decrease the impact of reduced effectiveness early in the mission while the experimenter worked into a routine, and allow time for response to unexpected scientific findings; or more rapid and automated data processing could supply timely answers to implement the ongoing observation schedule. Both viewpoints have validity and possibly could be combined for best results

[1]In effect this was the case. However, in reality, the reason was perhaps not so much a lack of time as of motivation, brought on by physical isolation, routine activities, and the availability of a postmission flight opportunity.

TABLE 6-3. - DATA SUMMARY

Data	Time for evaluation of data, min					
	Principal investigator			Associate experimenter		
	Inflight	Postflight	Next day	Inflight	Postflight	Next day
Monday	Average 20	75	–	Average 20	75	–
Tuesday	per flight	Average 10 to 15	0	per flight	Average 10 to 15	0
Wednesday	(9 flights)	(8 flights)	0	(4 flights)	(8 flights)	105
Thursday	↓	↓	30	↓	↓	45
Friday	↓	↓	0	↓	↓	165
TOTALS	180	175	30	180	125	315

The third comment addressed the value of a data downlink in the Spacelab for this type of experiment. In the opinion of the PI, his present system augmented by a real-time display (e.g., a CRT screen) of the data would provide the necessary information for him to run the experiment. By inference from the previous comment, there may well be some need for a modest processing and plotting capability to augment manual data handling for an experiment of this type in the Spacelab, since daily opportunities for observation will be more frequent than in this simulation exercise and multiple-experiment responsibility may be required. But for the relatively small amount of data record generated, and with the processing capability now available in the experiment, it appears that onboard facilities could easily provide all the support necessary and no data down link would be needed if the experiment were present

On the other hand, if a less experienced operator were in orbit and the PI were on the ground, a data downlink would likely be requested to permit the PI to evaluate new features exhibited by the data, to direct observations to verify such findings, and to input his judgment and experience to all aspects of the research effort for maximum effectiveness. Thus, in this particular case a Spacelab data downlink would function primarily to compensate for an onboard experiment operator in place of the PI.

6.6 Impact of Flight Readiness Reviews

In both previous ASSESS missions there were delays in experiment preparation that caused significant slippages of the scheduled flight dates. As a result of these experiences, the FRR concept was introduced into the ASSESS program on the recommendation of the ASSESS Working Group, an advisory group with representatives from NASA Headquarters and from several NASA centers. The purpose of the FRR was to assure that both the experiment and the GFE support equipment would be fully operational by the scheduled "launch" date. To this end, FRRs were held one month in advance, with the stipulation that equipment modifications and testing be completed and documented by this time. (In Spacelab context, this review would be the basis for a decision to "go with" an experiment or switch to an alternate, backup experiment.)

The primary benefit of the FRR for the experiment was to prompt careful, realistic planning of experiment preparations. With a known cutoff date, the experimenters made early decisions about what could and could not be done, matching the manpower available to the estimated task requirements in a detailed milestone chart (table 3-3). Then they worked hard to keep to their schedule, with the result that all primary components were completed and tested by the FRR date. As a consequence, the experimenters had time to complete the conversion of their ground-based data processing system for flight use, a task they originally had not expected to complete for this mission.

A similar but less formal review for the Ames 30-cm telescope systems produced less favorable results; the responsible parties were not directly related to either ASO or the ASSESS program. Although most changes were completed and checked out on the ground, there was no opportunity to verify their behavior in the flight environment or for the principal investigator to fit-check his equipment before the premission week. The result was a number of installation and operations problems that continued into the simulation period and adversely affected the conduct of the mission. In the opinion of the experimenters, most of these could have been avoided if a representative of the user group had participated in telescope reviews.

In summary, the FRR appeared to exert a low-key but very beneficial influence on the experimenters' preparation for the mission; schedules were carefully planned and kept, testing was perhaps more extensive than before, and extra time was available for fine tuning the experiment. The few experiment problems that did surface during the mission were related to equipment operation rather than to component failure and could be quickly resolved. Reviews for GFE were not effective, because responsibility was not properly located within the program office and the user was not directly involved.

6.7 Management-Experimenter Liaison

Normal ASO programs are noted for direct contact between the experimenter and the ASO mission manager. This single point of contact in the program office reduces time and documentation to a minimum (ref. 2). In ASSESS #3, an unplanned but effective liaison developed between experimenter and ASO mission manager in the person of an ASSESS representative stationed for six weeks at the home laboratory as an observer. Most of this liaison effort was related to the simulation aspects of the mission and the information being collected to document preparations, rather than directly to science planning and implementation. Even so, the communication with ASO/ASSESS management and the interpretation of their plans, guidelines, and specific requests was a welcome assist to the principal investigator, particularly in his preparations for the FRR. The liaison augmented rather than substituted for direct communication between the principal investigator and the ASO mission manager.

In Spacelab context, the experimenters were certain that on-site liaison would benefit their preparations for an orbital mission by providing information and coordination relative to hardware and operations constraints. As a single-point contact with Shuttle management, the NASA representative might be delegated this responsibility by a Spacelab "mission manager" in much the same manner as an assistant manager is assigned to support the multiexperiment payloads in current ASO CV-990 missions.

6.8 Allocation of Participant Time

The time-line information of figure 5-2 is summarized in figures 6-2 through 6-4 in terms of major activities, and these results are compared to ASSESS #2 in table 6-4. In the present mission, the experimenters spent nearly one-half of their time in experiment-related activities, about one-third in sleep, and the remainder in free time and eating (fig 6-2). Both experimenters spent about 40 percent of their experiment-related time in flight, 20 percent in experiment and GFE maintenance (troubleshooting and repair in response to problems), less than 15 percent in routine servicing of owned equipment (on-the-bench or in-the-aircraft checks of detector calibration, electronic systems response, and optical alignment), and some 17 percent in immediate preflight preparations (fig 6-3).

For data evaluation, however, there was a notable time difference between the two, with the PI spending only about 3-1/2 hr (7 percent) of on-ground time at this task and his assistant nearly 7-1/2 hr (13 percent).

Out of a total of about 21 hr of flight time, over 6 were utilized in target observation, about 3 in data evaluation, and almost 7 in equipment preparation and minor servicing (adjustment). Based on total mission involvement, about 13 percent of the time was spent in active scientific

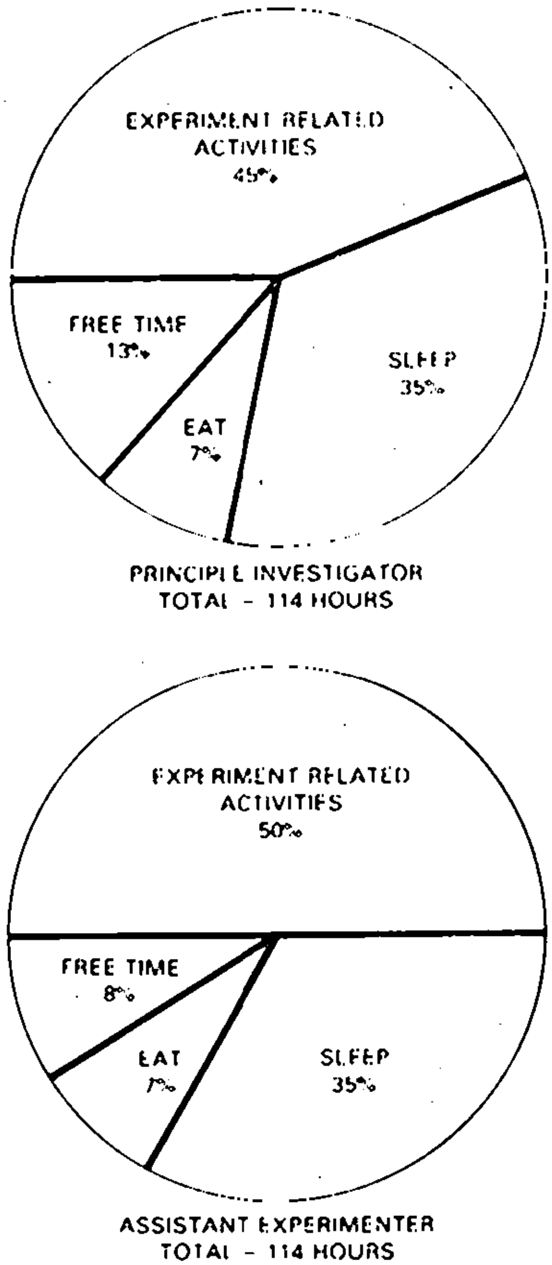

Figure 6-2. Experimenters' mission activity charts.

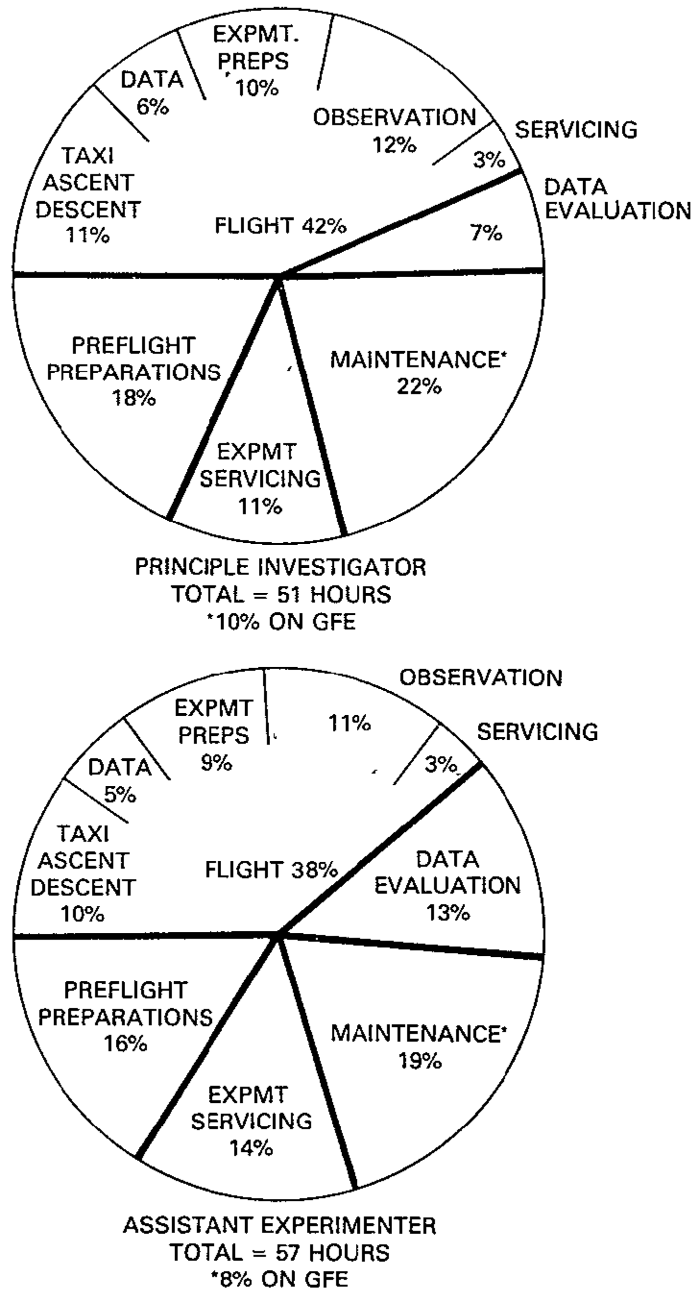

Figure 6-3. – Experiment-related activities.

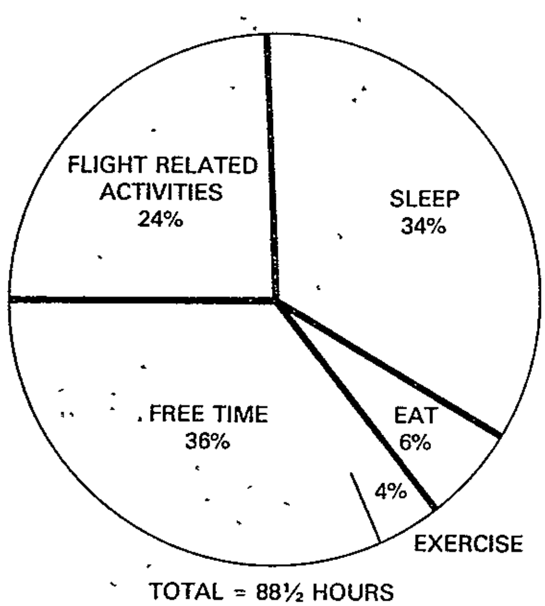

Figure 6-4. – Copilot/observer's mission activity chart.

TABLE 6-4. – TIME ALLOCATION BY EXPERIMENTERS IN SPACELAB SIMULATION MISSIONS

(Average for two men)

Activity	Fraction of total time, percent		
	Lear Jet No. 1	Lear Jet No. 2	Lear Jet No. 3
Planning, acquisition, and evaluation of data	8	12**	13
Upkeep of equipment	26	27	30
Life support functions	34	44	42
Unscheduled free time*	25	9	11
Flight time not utilized	7	8	4

*Includes interactions with ASSESS personnel

**Includes direct support by copilot/observer.

pursuits - planning, acquiring and evaluating astronomical data. By comparison, about 30 percent was equipment upkeep and about 5 percent was flight time that could not be utilized for research. The sum of these is analogous to a 12-hr work period each day in the Shuttle Spacelab. In fact, the overall work/rest time allotments are a reasonable simulation of the anticipated regimen for in-orbit research.

Experimenters' time allocations on this ASSESS #3 are compared in table 6-4 with those for the two previous Lear Jet simulation missions (refs. 4 and 5). It should be noted that division of time was at the discretion of the participants; they decided what needed to be done and when to do it. All missions had a common guideline for scientific operations two flights a night for IR astronomy -- and involved somewhat similar equipment and research methods. Thus, it is not surprising that time allocations were also roughly the same.

For all three missions, close to one-half of the day was spent in work and one-half in personal activities. The work time was roughly 3/4 equipment handling and nonproductive flight time, and 1/4 data related activities. The largest difference is in unscheduled free time between the first and the latter two missions; in ASSESS #2 and #3, the experimenters required more sleep and spent more time in data-related activities and equipment upkeep. For ASSESS #3, an onboard computer system allowed postobservation evaluation of the data in flight for a better utilization of flight time.

The copilot/observer's activities are summarized in figure 6-4, he joined the mission one day late and was an active participant for a shorter period. During this time only one-fourth of his effort contributed directly to the conduct of the mission. There was no ready use for his free time since no plans had been made in advance, it was quite apparent that he would have welcomed the chance to make a larger contribution. This experience points to the analogous problem of pilot utilization in the Spacelab, where the ineffective use of available, scientifically trained personnel would impose a more severe penalty

6.9 Factors in Experiment Performance

6.9.1 Experiment Modifications

Experiment modifications for ASSESS #3 had three purposes: ensure reliable operation, improve data management, and simplify equipment servicing. These are normal objectives in any airborne research, but here there were visible differences in the extent and depth of preparation The number of changes made (table 3-2) and the amount of testing done (table 3-4) were calculated to meet the constraints of the simulation mission · operational isolation and a fixed "launch" date.

With few exceptions, the experimenters held to their research plan. Equipment handling problems early in the mission caused some loss of data, but these were eliminated by revising preflight checkout procedures. No component failures occurred, and none of the backup units was used. (One preamplifier was replaced during the premission checkout period to reduce electronic noise.) Reliable operation during the mission was an accomplished fact.

Data handling was greatly improved by incorporating the counter/printer into the flight equipment. The experimenters monitored their results in real time and tuned equipment or adjusted observation routine to optimize data acquisition. On the return flight leg, they reviewed the printed record to assess experiment performance and plan for the next flight; immediate postflight comparisons with previous results verified data quality and indicated what, if any, equipment servicing was required. This new capability for data evaluation thus enhanced mission performance by improving real-time interaction with the experiment and permitting early planning for future observations.

Experiment modifications to improve optical alignment, calibrate detectors, and facilitate target viewing were notably successful. Impetus for these changes originated in the ASSESS #2 experience, in which alignment of Dewar and telescope optics was a time-consuming, imprecise activity, detector response to known signals was difficult to verify; and target viewing was a fatiguing exercise Before their normal ASO mission in August, the experimenters built a telescope optical simulator for aligning Dewar optics and calibrating detectors; in ASSESS #3, this simulator was used before the first flight each day to bench check spectrometer performance, and once on Monday evening to troubleshoot an apparent malfunction. Both functions were performed quickly, with precision, and with a high level of confidence.

For this mission, the experimenter also built optical components – a precision collimated source, a periscope for accurate alignment of guide telescope relative to main telescope, and a beam-splitter eyepiece for guiding through the main telescope (fig. 2-3). Taken together, these units reduced servicing time and assured accurate positioning of optics, alignment was checked daily prior to the first flight. This new capability removed the need for flights before or during the mission using the Moon as a source for precise alignment of optics.

Experiment modifications for ASSESS #3 achieved the stated purposes of reliable operation, improved data management, and time-effective servicing. With operational parameters in firm control, the experimenters could devote more time to planning and evaluation of scientific results, to the end that the full potential of the experiment was realized.

6.9.2 Premission Checkout Flights

In lieu of a separate ground-based simulation facility the ASSESS program uses the Lear Jet aircraft for premission checkout of the experiment. For ASSESS #3, checkout flights were made during a 5-day period between November 5 and 9 (table 4-1). Telescope installation (by Ames personnel) began on November 5 and was completed on November 6; the experiment equipment was installed, aligned, and completely checked out on November 6.

On the following morning, the required safety and engineering checkout flight was made, followed by three calibration flights on successive evenings. The four premission flights served to (1) test the operation of the modified telescope systems, (2) verify the performance of the experiment equipment, (3) calibrate the experiment systems on astronomical targets, and (4) train an associate scientist for inflight experiment operation.

Telescope. – Telescope systems gave the most trouble during the checkout flights. System modifications had not been flown before, and operating instructions provided by the responsible organization were sketchy at best On the first evening flight, most of the data were lost when the telescope jammed against the upper stops and could not be freed. Although this problem was alleviated the next day by the addition of a ratchet actuator and position indicator, the tendency to jam against a pressure-sealing rubber sleeve persisted into the mission flights as an annoying hindrance to telescope operation

On the last checkout flight, the signal from the oscillating secondary mirror was fuzzy, to the detriment of data quality. This problem may have existed before but was obscured by other events. When it was identified, only minor adjustments were believed necessary to correct it; in fact, however, the severity of the problem was not recognized and its solution was delayed into the mission period. Had the primary experimenter been onboard during the last checkout flight, this problem might have been uncovered earlier and corrected before the mission began

Experiment. – Several minor problems were uncovered in the experimenters' equipment during the checkout flights (table 4-2), necessitating repairs to the digital printer and some adjustment of optical focus, as well as a few adjustments to electronic units. None was critical or time consuming and might well have been resolved during the mission itself.

Calibrations. – Inflight calibrations on astronomical targets were accomplished during the checkout flights so that all mission flights could be devoted to observation of the primary science objectives, Jupiter and M42

Operator Training. – Operator training was completed successfully and, although not a mission requirement, made available a backup person to assure that the mission "launch" date and flight schedule would be met. A second and real advantage of the backup operator was to relieve the PI of day-to-day tasks during the premission checkout period and thus allow him to be fully rested at the start of the simulation period. The second experimenter's workload was thereby increased, of course, just prior to the mission. As it turned out, however, this arrangement may have been a vital factor in the success of the mission, since the PI recovered from a bout with the flu just in time to begin the simulation.

In summary, the checkout flight period had a major, beneficial impact on mission performance Most of the maintenance effort was directed to telescope systems that had not been flight tested after modification, only minor and easily correctable faults were found in experimenters' equipment.

6.9.3 Mission Constraints

This section is concerned primarily with the effect on performance of the constraints imposed to simulate Spacelab operations during ASSESS #3. The discussion also includes the scheduling constraints posed by a series of unplanned problems with the aircraft during the experiment installation and checkout period.

Firm FRR and Launch Dates. – The establishment of firm "launch" and FRR dates was one of the major ways in which the third ASSESS simulation mission differed from the previous two missions As a constraint, the fixed launch date had a significant positive effect on the achievement of overall mission goals.

To meet the two deadlines, the experimenters were motivated to evaluate closely what experiment development could be done in the time available, and the amount of work required to achieve it Decisions were made to limit new equipment development and to improve the existing equipment Manpower assignments, premission inflight calibration and operator training goals were established and carried out

The launch-date constraint had no impact on the research objectives of the science program. However, the decision to use existing detector arrays as opposed to development of a 16-element array had a quantitative effect on the data-gathering capabilities.

Aircraft Repair. – The 10-day delay of equipment installation caused by unplanned aircraft repair at the beginning of the integration and flight checkout period acted as an additional time-restricting constraint relative to the launch date. The mission schedule was slipped for only 7 of the 10 days: one day was cut from the installation period, one from the premission flight period, and one day planned for final cleanup prior to beginning the mission was eliminated. As a result, one premission flight (to observe a primary target) was cancelled and a secondary mirror (chopper) problem that emerged late in the checkout flights was misjudged to be minor, and was not solved until after the mission period began.

Flight Schedule: – Flight scheduling for the ASSESS #3 mission was very different from the two previous ASSESS missions. The first two ASSESS missions consistently had one flight scheduled for early evening, followed by another in the early morning of the following day, with from 4 to 6 hr between the two flights. ASSESS #3 flights were scheduled for early and late evening of each day, with about one and one-quarter hours between the two flights.

The two different flight schedules had contrasting effects on the experimenters' accommodation to their work (and sleep) cycle, as well as having an impact on experiment servicing and data management. In the earlier ASSESS missions, the experimenters had a split work/sleep cycle. In the current mission, the daily flight program permitted the experimenters to maintain their normal sleep cycle.

There was ample time during the day for servicing, checks, and maintenance of the experiment before the first evening flight, but not between the two evening flights. Preventive maintenance therefore was critical to the equipment's ability to endure for two flights The upgraded component reliability effectively minimized experiment problems during the mission.

Another important factor in ensuring reliable experiment operation was the calibration, alignment, and boresight equipment built by the experimenters between ASSESS #2 and #3. The use of this support equipment, especially the periscope, avoided the stress of the time pressures encountered by the experimenters in ASSESS #2, and gave them the time in ASSESS #3 to perform routine preventive maintenance checks to ensure trouble-free flights.

Data management also was affected by the short turnaround time between evening flights. The flight record could not be processed in sufficient depth for the experimenters to judge its value and plan for the next flight. However, the on-line, hard-copy capability that was developed for ASSESS #3 permitted real-time monitoring of inflight results and overall system performance. During their return to base from the first evening flight, the experimenters could decide, on the basis of inflight results, whether to continue with the second flight as scheduled or to switch to the contingency flight.

Flight scheduling per se had no discernible effect on the accomplishment of the mission science objectives except to the extent that the length of the mission might be considered as part of the scheduling. Additional flights were requested during the postmission week, indicating that some areas of the research program were not fully resolved during the mission.

Aircraft Support and Location. – Aircraft support had no particular impact on the research aspects of the mission other than those resulting from the one-week delay for aircraft repair at the beginning of the mission. However, constraints posed by the semi-isolated location indirectly added to the impact of the GFE support problems on the mission performance. During the postmission debriefing, the experimenters indicated that GFE telescope maintenance was a problem, because telescope support services were not provided on the night shift.

Physical Isolation. – Physical isolation began to have an effect on the experimenters after the second day of the mission period. Apparently, the range of tasks facing the experimenters was too limited to occupy their full-time interest. Increased equipment reliability resulted in an absence of further experiment problems; normal servicing of the experiment became very routine; and there was an absence of interesting stimuli from the unchanging surroundings

Except for the lack of stimuli noted above, the experimenters considered the constraints of the semi-isolated environment generally beneficial to the conduct of the mission. The proximity of living quarters, work space, support equipment, and the aircraft allowed more time for experiment preparation and maintenance. Similar benefits were acknowledged by the experimenters on both previous ASSESS missions

ASSESS Observations and Documentation. – The ASO mission manager and ASSESS observers performed surveillance and documentation throughout the mission. Although minimum interference was the rule, the experimenters' activities were identified and recorded during their working hours while they conducted maintenance checks, experiment servicing, and data evaluation in the work trailer. There was no noticeable adverse effect on the experimenters, probably because it was expected, and because they were used to similar but less time-related observations during the course of normal ASO missions.

Section 7

7. APPLICATION TO SPACELAB PLANNING

The results discussed in this section reflect primarily the experience and aptitude of the two-man team of experimenters on the third Lear Jet simulation mission. This same team also flew on the second simulation mission as experimenters relatively new (at that time) to airborne research. In the report for the second mission (ref 5), they were contrasted to the more experienced experimenters of the first mission. By the third mission, however, they had also flown several normal ASO missions and were considered to be experienced and to have settled into a fixed pattern of activity. Where appropriate, results from the first two missions are used to augment or to contrast these findings.

7.1 Management of Research Programs

Under past ASSESS policy for managing Spacelab simulation missions, the PIs for the first and second simulation missions were responsible for the content of their research program, design and testing of their research equipment, operation and maintenance of the first flight experiment, in-mission selection of flight objectives to optimize research results, and the reduction and analysis of the data. The ASO was responsible for operation of the aircraft, for the engineering aspects of the experiment and aircraft/experiment interface as they related to airworthiness and safety, and all mission-specific support functions.

Under this management approach of wide latitude and independence for the experimenter, each PI of the previous two ASSESS missions made a decision to upgrade the capability of his experiment significantly. As a result, the schedules of both missions were seriously affected by "launch date" delays of several weeks. Even so, time ran out and the experimenters were unable to complete their test program in the laboratory. In both cases, a critical failure occurred during premission checkout, one delayed the launch and the other required a major substitution of backup components. An attempt was made during ASSESS #2 to monitor the experimenters' progress relative to a self-imposed "milestone" schedule, but it was not implemented early enough to avoid a significant delay near the beginning of the preparation period.

To avoid the occurrence of similar delays in the current mission, the FRR was introduced as a new mission element to motivate the experimenters to plan well in advance and to complete the preparations in time to meet a firm "launch" date for the simulation mission. Under the FRR concept, the PI had the same responsibility for preparation and operation of his experiment as before, but was now asked to review its status and verify his readiness for flight well in advance of the "launch" date.

For all three ASSESS missions, the same length of time (about 3 months) was scheduled for experiment preparation. However, for ASSESS #3, the requirement for proof of flight readiness as the prerequisite to mission approval on the FRR date rather than on the mission launch date resulted in a marked improvement. Faced with a commitment to this deadline, the experimenters set up their equipment objectives and a realistic milestone schedule for timely completion of the work required to achieve these objectives.

The progress of the experimenters during the preparation period was monitored by mission management via telephone, observed by onsite ASSESS representatives, and reviewed periodically against the milestone schedule. No conditions were imposed on the experimenter as a result of this activity. Some monitoring by ASO management during experiment preparation is normal practice, but not to the depth exercised here; onsite observation is unique to the ASSESS program for informational purposes.

ASO had responsibility for aircraft operations, safety and airworthiness, and mission support functions as before, but also accepted specific responsibility for monitoring of ongoing telescope (GFE) modifications, for keeping this effort on a timely schedule, and for keeping the experimenters posted on progress and on any changes that could affect the experiment. An FRR was also scheduled for the telescope Unfortunately, the personnel responsible for the telescope changes and its FRR were not part of ASO, nor were they directly involved with the ASSESS program. As a result, certain installation and operational problems were not disclosed by the FRR and had to be dealt with during the simulation period.

These problems were not critical from the standpoint of time required to resolve, but still had an adverse effect on the conduct of the mission at the beginning – at a time when the experimenters were trying to work into a routine and least needed problems from the experiment-related support equipment. In a Spacelab context, responsibility for review of GFE (telescope) should be placed directly within the program office. The experimenters also were convinced that a representative of the user group should be directly involved in the review as a hands-on participant.

It is apparent that in addition to the motivation provided by an informal status review, an FRR, and a fixed launch date, both the past experience of the experimenters and the complexity of the experiment development (or modification) are extensively involved in the ability to meet the schedule. The contribution of each of these factors should be examined closely when the length of the preparation period for a Spacelab experiment is established.

In normal ASO programs, reliability of operation is the responsibility of the experimenter, and is built in by him to the level required to satisfy his own needs. A lower level of reliability (at less cost) is usually satisfactory under these circumstances since the time and resources are available between flights to correct equipment failures. In Spacelab programs, experiment reliability is envisioned to remain the responsibility of the experimenter, although he may be provided with guidelines as to how a higher desired level of experiment reliability might be obtained.

7.2 Performance of Planned Research

7.2.1 Objectives and Schedules

The PI for ASSESS #3 had two major scientific objectives and two primary astronomical targets, both of which had been studied before. The objective for one target was selective verification of previous results; for the other, more detailed measurements were now possible with a more sensitive detector. A single, well-tested experiment was provided for the mission, with an alternate spectrometer provided as a backup for the primary unit. Each target was to be observed five times, one target per flight, on a total of ten scheduled flights. Contingency flights were scheduled each day in the early morning against one of the primary targets.

Inflight calibration of the experiment was scheduled for the premission week, with two calibration targets, so that all mission flights could be used to observe primary targets. Premission flights would also serve to train an associate scientist for inflight operations and relieve the PI of direct participation in most premission activities. Experimenters would also learn to use the new variable-angle telescope mount. Only the final checkout flight would directly involve the PI in "dress rehearsal" observations on a primary target.

7.2.2 Accomplishments

Checkout Flights. - Adequate calibration data were obtained during three checkout flights, although of the two calibration targets, only the Moon was used as a target during the first two flights. Operator training was completed successfully. Schedule changes forced cancellation of the final "dress rehearsal" flight, so that no observations of a primary target were possible before the mission began.

Mission Flights. The PI was able to accomplish his selected research objectives on both targets during the nine mission flights, an indication that his program was (1) sized to the available flight opportunity, (2) ordered by priority of measurements, and (3) perhaps somewhat redundant. Thus, even though one flight was cancelled and three others were affected by a defective primary mirror, basic objectives were satisfied.

On the other hand, the PI requested several postmission flights on one of the targets, M42, because there were certain regions of the M42 spectrum that he wanted to scan in finer detail (smaller grating steps). This suggests either a planned task of lower priority or a current result requiring further evaluation, in either event, a mission of longer duration would have been required to complete the study. In basic astronomical research, however, there is seldom an end to the questions to be answered and there are always additional observations to be made. The argument would be academic in a Spacelab context, regardless, because there would be many more observation periods available in a Spacelab mission than in a Lear Jet mission simulation. The question in Spacelab would be whether there was sufficient time to do the desired additional data analysis between observation periods If this were a problem, it would be more cost-effective to solve it by providing faster analysis methods than by extending the mission time

7.2.3 Data Management

On-line data processing capability allowed the experimenters to do real-time evaluation of results to guide data acquisition during the flight -- to know if an area had been adequately defined or if an observation needed to be repeated Postflight analysis of the same records was a guide to flight planning The analysis performed while returning to base from the early evening flight was the basis for a decision to make the second scheduled flight or to fall back to the later contingency flight.

Direct analogies of the above procedures apply to Spacelab. The time between observation periods in Spacelab will be the same or less than between the two evening flights on ASSESS #3. An on-line data processing capability could be the basis for experimenter decisions to repeat target scans, add new scans, or even skip the following observation period. This last decision would be analogous to cancelling the late evening simulation flight in favor of the contingency flight.

For an experiment like the one flown on ASSESS #3, the real-time requirement for data processing in Spacelab could easily be met by a local integrated unit, while more complex operations (analogous to the between-flight evaluation done here) would be handled by a central computer. Alternately, this latter function might be programmed for intermediate or off-shift periods when onboard capacity might be less fully occupied. As a last resort, ground support systems could be employed for higher levels of processing, or for basic information if the PI does not accompany his experiment in flight. In any event, data management must be sufficiently automated to be timely and to avoid the dulling routine of manual processing encountered in this simulation mission.

7.3 Operational Procedures for Spacelab

7.3.1 Premission Simulation

In the debriefing sessions for both ASSESS #2 and #3, the experimenters emphasized the value of experiment integration and checkout in a Spacelab simulator well in advance of final preparations for flight. In a manner of speaking, such premission simulations are conducted prior to Lear Jet ASSESS missions. ASSESS experimenters fly their experiment repeatedly in the normal ASO astronomy program. After completing a flight series, they routinely make changes in their equipment at their home laboratory to improve its capability prior to their next flight series. In a Spacelab context, this practice would be analogous to an advanced try-out in a simulation facility to qualify the experiment, and would allow time for required changes prior to final integration for a Spacelab mission.

In ASSESS #3, the integration and full-up simulator experience occurred the week prior to the mission itself and served to accomplish final checkout and calibration for the equipment. In the Spacelab this final premission trial would assure that the experiment was ready for space flight.

The PI for the third ASSESS mission stated unequivocally that two such premission simulations would be essential to first-time success for experimenters new to space research, particularly if their experiment also was new and untried. In his opinion, an experimenter who was experienced in airborne research and had a flight-proven experiment could meet Spacelab qualifications with perhaps no more than an FRR prior to final checkout and integration.

7.3.2 Duty Cycles and Workload

Duty Cycles. - No guidelines or constraints were applied to the experimenters' use of time during the mission. The sole limitation was imposed by the planned schedule of flight observations, which was fixed by his choice of astronomical targets. Approximate flight times and, therefore, available sleep periods were known weeks in advance. Because the two daily flights were both in the evening and closely spaced in time, the experimenters were able to choose a single sleep period of 8 hr from about 1.00 a.m. to 9.00 a.m. – a period that approximated their normal sleep habits. This regular pattern for the two experimenters and the copilot/observer contrasts with the first simulation mission in which sleep periods frequently were not concurrent and with the second in which the sleep pattern was concurrent but split into two periods. In ASSESS #2 there was a noticeable incidence of fatigue associated with the split-period rest cycle, whereas with the present schedule adequate rest was obtained.

Workload. Experimenter workload was noticeably lighter for this ASSESS mission than for the previous one, except at the beginning when there were difficulties with the telescope. Although the time allocation to major areas of activity (by percent of total time) was roughly the same (table 6-4), there were notable changes in the approach to routine servicing, preflight checkout, and inflight routines For example, the time required for daily calibration and alignment activities was reduced and the precision of these operations improved by the use of new equipment acquired for this purpose. Also, data management for this mission was partly automated by an onboard data processing system, allowing post-observation evaluation of the data in flight, for a better utilization of flight time.

As a result of the improvement in the above areas, as well as the absence of experiment problems, the experimenters had more time for data-related activities and equipment upkeep, and still had more unscheduled free time. This had been their intent from the beginning. to improve the effectiveness of normal experiment servicing, to minimize the impact of equipment failure, and to allow more time for planning and contingencies. Experience in ASSESS #2 was the incentive for this time-effective approach, which worked so well that mission activities soon became routine and free time excessive

For a number of reasons, it is doubtful that the lack of stimulus and resulting boredom experienced by the experimenters during the simulation mission would be encountered in a Spacelab environment. First, the Lear Jet mission involved one experiment designed for two-man operation, whereas Spacelab is anticipated to have a number of experiments to be operated by two to four people, featuring time-sharing and cross-training in backup assignments Second, there were only two flights or "observation periods" during each 24-hr period. These flights were closely spaced in time, with a relatively long unstructured period before the next evening's flights. In addition to eating, sleeping, and other housekeeping chores, the time was set aside for experiment servicing and for maintenance contingencies that never materialized. In Spacelab, on the other hand, the available observation periods will be much more frequent, and with more than one experiment to service and maintain, the experimenters will have more demands made on their time and a larger range of tasks to hold their interest.

The inflight workload for ASSESS #3 was greater than in the second mission. As in previous missions, the equipment was designed for two-man operation, and during observation periods there was no time available for operating other equipment. About the same percentage of time was utilized in this and the second mission for experiment preparation and observations (one-fourth each) before each data run. For the current mission, however, some post-observation flight time was occupied with data evaluation, whereas in ASSESS #2, there was free time for other experiment-related activities once the primary observations were completed and while the aircraft returned to base.

In a Spacelab context, a similar short period of data evaluation by the experimenter may be required between observations, but with automatic data processing to a level suitable for rapid comparisons and timely decisions, this activity should not seriously reduce the time available to operate other experiments. In addition, it is reasonable to postulate a periodic (perhaps daily) review of results in greater depth, analogous to the daily analysis and planning sessions in this simulation mission With processed data available in a condensed format this additional effort (per observation) may not greatly exceed that expended in the initial quick-look evaluation.

There is also the distinct possibility that the experimenter could be saturated with data from his own experiment before the end of a Spacelab mission, and would have additional time to operate other experiments. Under these circumstances a flexible time-sharing plan would permit adjustments to be made throughout the mission to fulfill the data requirements of each experiment.

7.3.3 Science Crew/Flight Crew Interactions

The confined crew in ASSESS #1 consisted of two pilots and two experimenters. There was considerable interaction among the crew both before and during flight; flight planning was flexible, and new targets were selected daily. In ASSESS #2 and #3, only the two experimenters and the copilot were confined, and there was little or no preflight interaction with the pilot.

Communications in flight were by a three-way loop between experimenters and copilot, who in turn relayed requests to the pilot. During the first two missions, the copilot was in direct contact with the experimenters most of the time, monitoring the research progress, providing information on aircraft position, time on track, and flight parameters, and implementing experimenter requests for minor changes in flight attitude. During the current mission, there was much less interaction between the experimenters and the flight crew concerning flight operations of the aircraft, other than information provided about the time of arrival at the start and end of the observation run.

Time-coded voice recordings show that the experimenters' operations were largely routine during flight. "Routine" is considered the probable key to differences between ASSESS #2 and #3 in terms of crew interactions. Each flight had a single target, in the same sequence each night. The routine of scientific observations had been planned in advance, and from takeoff through the observation period on all nine flights, the preplanned events took place within a few minutes of schedule. The observation periods were essentially identical on each target for each flight, differing in clock time by some 4 min per day. Furthermore, the copilot had flown with the experimenters on ASSESS #2 and knew their routines and needs. He was familiar with the experiment because he had acted as experiment operator during the first four flights of ASSESS #2. The bulk of the experimenters' conversations were concerned with operation of the experiment, from his background as an astronomer, the copilot understood what was taking place.

As an indicator of Spacelab crew interactions the present simulation gave decidedly optimistic results. That is, the circumstances surrounding the research effort represented a near-ideal situation, and a minimal level of interaction sufficed to carry out the program. Thus, both the flight and science teams were well seasoned in flight, the experiment was operated by the PI and experienced associate, and detailed flight plans were known in advance and closely followed. Furthermore, the copilot was ideally suited (by virtue of training and experience) to coordinate flight plans and operations with science activities, and did so effectively. To the extent that these elements can be achieved in a Spacelab mission, the amount of crew interaction necessary to support the research activities would similarly be reduced.

7.3.4 Outside Technical Support

Outside technical support is defined here as experiment- or mission-oriented support, and is not meant to include normal aircraft servicing or maintenance. The point of contact for planned or unplanned technical support was the ASO mission manager, and the support to be furnished was verbal, hardcopy, manpower (including equipment if required), or combinations of these. With the exception of the assistance that was required to solve the GFE telescope problems at the start of the mission, there was only one instance of outside equipment support that was not preplanned or anticipated – namely, the heat gun used for drying moisture from selected experiment equipment connectors, a precaution that was subsequently exercised before every flight.

Resurfacing of the primary mirror surface was not chargeable to experiment operations since the telescope was GFE and under mission guidelines was an ASO responsibility. In a Spacelab context, outside technical support would of necessity be verbal or hardcopy (teletype). A problem with telescope optics, such as encountered here, would spell disaster for the mission unless onboard resources sufficed to correct it. The lack of experiment problems requiring outside support in contrast to the GFE experience, demonstrates the value of having designed-in reliability for *both* experiment and GFE equipment.

7.4 Design Considerations for Spacelab

7.4.1 Data Recording and Processing

Historically, flight experiments need data-handling systems that make accurate, permanent records and also have a quick-look capability. In this mission, the experimenter was responsible for data handling and provided the necessary units as part of his own equipment. As for the previous simulation mission, his permanent record of raw data was on magnetic tape. The quick-look record was a time-integrated, digital data printout that could be monitored in real time to provide a check on the quality of the data and a continuous indication of overall experiment performance. After observations were completed, the printout was immediately reviewed (in flight). After flight, it was again reviewed for internal consistency and for comparison with previous data. The same record was used the next day to plot spectra; unusual features were studied, and detailed observation schedules were made for the next day's flights.

As a result of his experience in this mission, the PI expressed a need for a real-time, visual analog record of detector response to assist the acquisition of dim targets and indicate the fine-guiding stability of the telescope during observations. The analog record would augment rather than replace his digital printout which was an integration of detector response over a selected period of time.

A similar, two-step approach to data handling is suggested for experiments of this type in Spacelab. An analog recorder and a microcomputer integral with the experiment would provide local control for guiding observations and quick-look review, and would also reduce the quantity of data flow to a central computer system for additional processing onboard. If there were insufficient onboard capacity or clock time between observations for second-level processing, or if the experimenter were occupied with other tasks, the processing and evaluation might require ground support personnel. Regardless, for an experiment of this type, planning for successive observations requires some quick-look processing during the mission.

The principal investigator in this mission was of the opinion that a data downlink would not be necessary to conduct scientific research with this experiment in Spacelab, provided that adequate data-processing facilities and an experienced operator were on board. In his opinion, the necessary information for *him* to run this one experiment would be provided if the present system capability were augmented by a real-time analog display of the raw data. Nevertheless, considering that observation opportunities on Spacelab will be more frequent, and multiexperiment responsibilities will likely be required, he thought even the most experienced operator of this equipment would need to depend on computer support for additional data processing and plotting. Alternatively, for him to direct operation of this experiment from the ground with maximum effectiveness, with another operator on board, presumably less experienced, he concluded that a data downlink would be necessary.

7.4.2 Experiment Power and Cooling

Power requirements for the flight experiment on ASSESS #3 were about 125 W of 60-Hz, 115-V power. Since the digital records processed and printed out during inflight observations were used for postflight analysis, no additional machine processing was required on the ground and no energy was consumed. Telescope systems power and the 60-Hz inverter losses were not directly chargeable to experiment power. The telescope systems required an average of 660 W of 28 Vdc and about 45 W of 60-Hz power, 60-Hz inverter losses amounted to about 70 W. No 400-Hz power was required.

Energy used for experiment maintenance in the work area averaged about 0.64 kWh per day. Thus, this experiment (exclusive of the GFE telescope) could be operated for 50 hr and maintained for 5 days at an expenditure of about 9.5 kWh, a little more than one-sixth of that projected as the primary payload supply from the Shuttle Orbiter power system. This energy expenditure was about 25 percent greater than that of the same experiment and over the same length of time during ASSESS #2 (ref. 5). This increase resulted from the addition of the inflight data processing equipment, and two pieces of experiment ground support equipment – the optical alignment collimator and the heat gun for drying out connectors.

Cryogenic coolants were required to support experiment operations 7 liters of liquid nitrogen for initial cooldown of the primary Dewar, and about 20 liters of liquid helium for final cooldown and "hold" at steady-state conditions for the 5-day mission period. The total consumption of 27 liters was a third less than the previous estimate for this experiment (ref. 5) and about the minimum required for continuous operation; no Dewar malfunctions were encountered, and it was not necessary to cool and service the backup unit as a standby replacement. For a 7-day Spacelab mission, a minimum cryogenic budget of 40 liters would be required for the primary equipment, and an additional 40 liters to maintain backup equipment in a standby status.

The telescope electronics was fan-cooled; all other equipment operating and support equipment was cooled by natural convection and would require forced-air cooling in Spacelab.

7.4.3 Experiment Support Equipment

As in ASSESS #2, the experimenters were requested to bring on board only those items that could be justified as necessary to maintain the experiment operational, as if on a Spacelab mission. The total number of all mission support equipment items was reduced slightly for the current mission. The usage of the support equipment on the two missions was about the same except for hand tools, which in this case were essentially limited to those needed for routine servicing. Because very little experiment maintenance was done on ASSESS #3, tool usage was half that for ASSESS #2. Thus, overall, about one-third of the items supplied in this mission were used in routine servicing, and the remainder were insurance against equipment malfunctions.

The bulk of test equipment and tools used for servicing and maintenance in a Spacelab mission could be shared by several experimenters. One notable mission-specific exception was the new optical and detector simulation and alignment equipment. Use of this equipment saved a great deal of time, and also reduced uncertainty, both in the alignment of spectrometer optics and calibration of detector sensitivity, and in the integration of experiment with telescope optics in the aircraft.

7.4.4 Government-Furnished Equipment

Dissimilar but related problems with GFE occurred with the same experimenters on both the second and third simulation missions. Both were related to the experimenter having the responsibility for operation of major equipment (the telescope) with which he was not entirely familiar.

In the previous mission, the problems were related to alignment and sighting, and corrective design actions were proposed after the mission. In the current mission the problems were with the primary and secondary mirrors. The solutions to these problems required personal contact and interaction among the experimenters and support personnel. The secondary mirror malfunction could have been repaired in space, but the primary mirror problem could not have been solved by experimenters in Spacelab. The points are made again that (1) it is important to place the responsibility for GFE within the appropriate program office, and (2) the PI or other knowledgeable experimenter who will use the equipment should be in the GFE loop earlier in the mission schedule to become familiar with the systems, to go over details of equipment changes, and to make recommendations.

7.4.5 Workspace and Accommodations

As in previous Lear Jet missions, the quantitative simulation of Spacelab working conditions was not a guideline in the current mission. However, information with possible application to the design of counterpart areas in Spacelab was noted during the mission.

Living accommodations for the two experimenters and copilot/observer were adequate with respect to size. An observation was made that sleep areas are best when isolated from the work area and the living/eating area, particularly if the experimenters work on different schedules. The work area in the trailer was more than adequate, particularly since the level of maintenance work was very low. The work surface (5.6 m^2) and the storage volume (1.0 m^3) were the same as in ASSESS #2, and both were at least twice as large as needed.

Work space in the aircraft cabin was unchanged (4.25 m^3) and still considered minimal but adequate for the experimenters' research activities for the average 2-hr flight. For this mission, the telescope operator again sat on a camp stool and viewed downward into the sighting scope. Each operator sat facing his portion of the experiment in a space about 1 by 1.5 m^2. It is expected that even if the space allocated for operating an experiment in Spacelab were the same, the configuration would be more convenient for working since the space would be designed-in rather than added-on to existing structures.

8. APPENDIX A

SUPPORTING DATA FOR EXPERIMENT PREPARATION AT HOME BASE

This appendix provides tabular data in support of text discussions of the experiment preparation period. Table A-1 provides original time-line information for the four direct participants during preparation at the university. Table A-2 outlines the stepwise development of five experiment subsystems, with calendar dates and man-hours of effort. Table A-3 is a brief chronology of pre-flight equipment handling that blocks out major functional tasks; and table A-4 consists of material prepared by the principal investigator for the Flight Readiness Review of October 4, with minor annotations for completeness.

TABLE A-1. – TIME LINES FOR HOME-BASE PREPARATION

(A) Principal investigator

Date	Activity	Man-hours charged to ASSESS #3
8/25/73	Left Ames for home	0
8/26–8/27	No ASSESS #3 activity	0
8/28	Ordered lenses for new guiding eyepiece	2
	Ordered new gauge for monitoring He pressure in Dewar	2
8/29	No ASSESS #3 activity	0
8/30	Ordered replacement gauge for vacuum meter	1.5
	Ordered metal tubing for guiding eyepiece	1.5
8/31–9/2	No ASSESS #3 activity	0
9/3	Began unpacking equipment from Ames trip	2
	Tape recorder lost – returned 9/11	
9/4	Unpacked equipment	3
	Ordered material for new tripod legs for spectrometer alignment	
9/5	Supervised undergrad making new supports for telescope simulator	2
9/6	Worked on data from August flight series	4
9/7	Helped calibrate Spectrometer 1	2
9/8–9/9	No ASSESS #3 activity	0
9/10	Wrong eyepiece tubing delivered – had to reorder	1
	Had new idea on how to focus telescope	1
	Made up milestone chart	6
9/11	Got hardware idea together to focus telescope	4
9/12	Determined hardware would have to be built – could not be bought off-the-shelf	1
For the 9/5–9/12 period, add 12 hours total for design and parts order for bias boxes.		
9/13	Made drawings of parts for guiding eyepiece	2
9/14	Took drawings, guiding eyepiece, and new parts for Dewar pump to outside shop for machining	4
	Talked to ASSESS observer	4
9/15–9/18	No ASSESS #3 activity	0
9/19	Worked on drawings for fixture to align telescope	1

TABLE A-1. – TIME LINES FOR HOME-BASE PREPARATION – Continued

(A) Principal investigator – Concluded

Date	Activity	Man-hours charged to ASSESS #3
9/20/73	Worked on drawings for guiding eyepiece	3
	Cut off piece of replacement brass tubing for guiding eyepiece and took to outside shop	1
9/21	Took alignment drawings and stock to outside shop	1
	Picked up vacuum gauge at outside shop	1
	Worked on vacuum gauge	1
9/22–9/23	No ASSESS #3 activity	0
9/24	Took drawings of collimator to outside shop and discussed them with machinist	3
9/25	Worked on guiding eyepiece	6
9/26	Worked on guiding eyepiece and made a new adapter in response to information from Ames	2
9/27	Made a bracket to secure guiding eyepiece to telescope simulator	3
9/28	Tested tape recorders	4
	Tested Spectrometer 1	2
9/29	No ASSESS #3 activity	0
9/30	Tested guiding eyepiece system	1
	Cleaned vacuum pump	2
	Worked on collimator	1
10/1–10/3	No ASSESS #3 activity	0
10/4	Flight Readiness Review	8
10/5	Work on data system	3
10/6 – 10/7	No ASSESS #3 activity	0
10/8	Answer questions on ASSESS	1
10/9–10/23	No ASSESS #3 activity	0

(A) Data summary

Experiment preparation, 86 man-hours

Planning, analysis, design	50%
Fabrication related	37%
Testing	13%

Direct ASSESS, 13 man-hours

TABLE A-1. – TIME LINES FOR HOME-BASE PREPARATION – Continued

(B) Graduate student (1); member of flight team

Date	Activity	Man-hours charged to ASSESS #3
8/25–9/2/73	No ASSESS #3 activity	0
9/3	Read and plot data tapes from last flight series	6
9/4	Read and plot data tapes from last flight series	6
9/5	Read and plot data tapes from last flight series	6
9/6	Read and plot data tapes from last flight series	6
9/7	Performed wavelength calibration on Spectrometer 1	11
9/8–9/10	No ASSESS #3 activity	0
9/11	Prepared for test of cryogenic epoxies	8
9/12	No ASSESS #3 activity	0
9/13	Test cryogenic epoxies	4
9/14	Finished epoxy tests	6
9/15–9/20	No ASSESS #3 activity	0
9/21	Took Spectrometer 1 apart	6
9/22–9/23	No ASSESS #3 activity	0
9/24	Glued mirrors on posts with new epoxy	8
9/25	Reassembled Spectrometer 1	8
9/26	No ASSESS #3 activity	0
9/27	Reassembled Spectrometer 1	5
9/28	Reassembled Spectrometer 1, pumped it down, made preliminary test of both detectors, tested operation of grating control and VCO	8
9/29	No ASSESS #3 activity	0
9/30	Made additional tests of both detectors in Spectrometer 1	7
10/1	Realign Spectrometer 1 and test	3
10/2	Spectrometer 2 assembly started	6
10/3	Complete assembly of Spectrometer 2	5
	Tested preamplifiers and phase-lock amplifiers	1
10/4	Flight Readiness Review	4
10/5	Align and check Spectrometer 2	6
10/6–10/7	No ASSESS #3 activity	0
10/8	Test Spectrometer 2	4

TABLE A-1. – TIME LINES FOR HOME-BASE PREPARATION – Continued

(B) Graduate student (1); member of flight team – Concluded

Date	Activity	Man-hours charged to ASSESS #3
10/9–10/10/73	No ASSESS #3 activity	0
10/11	Reduce data from August mission	0
10/12	Reduce data from August mission	0
10/13–10/14	No ASSESS #3 activity	0
10/15	Reduce data from August mission	0
10/16	Reduce data from August mission	0
10/17	Build alignment light source	4
10/18	Study alignment of Spectrometer 1	4
10/19	Study alignment of Spectrometer 1	4
10/20	No ASSESS #3 activity	0
10/21	Adjust Spectrometer 1	6
10/22	Make new bias cable–calibrate both spectrometers	6
10/23	Pack and ship	4

(C) Graduate student (2), ground support assistant

8/26–9/3/73	No ASSESS #3 activity	0
9/4–9/5	Performed wavelength calibration on Spectrometer 1	12
9/6	Reduced data from Ames flight of 8/23	5
9/7	Calculated the 16 μm to 40 μm Jupiter spectrum	8
9/8	Calculated the 16 μm to 40 μm Jupiter spectrum	
9/9	Calculated the 16 μm to 40 μm Jupiter spectrum	
9/10–9/16	No ASSESS #3 activity	0
9/17	Reduced the data from Spectrometer 1 wavelength calibration	15
9/18	Reduced the data from Spectrometer 1 wavelength calibration	
9/19	Reduced the data from Spectrometer 1 wavelength calibration	
9/20	Reduced the data from Spectrometer 1 wavelength calibration	
9/21–10/3	No ASSESS #3 activity	0
10/4	Flight Readiness Review	4

TABLE A-1. – TIME LINES FOR HOME-BASE PREPARATION – Continued

(C) Graduate student (2); ground support assistant – Concluded

Date	Activity	Man-hours charged to ASSESS #3
10/5–10/21/73	No ASSESS #3 activity	0
10/22	Assist in spectrometer calibrations	3

(B) & (C) Data summary

Experiment preparation, 191 man-hours

Planning, analysis, design	25%
Fabrication related	30%
Testing	45%

Direct ASSESS, 8 man-hours

(D) Electronics technician at university laboratory

8/27–8/31/73	Refurbished three bias boxes used during August flight series and tested operation	20
	Helped design new bias boxes for ASSESS #3	10
9/1–9/3	No ASSESS #3 activity	0
9/4	Repaired battery charger damaged in transit from Ames	6
9/5	Repaired battery charger damaged in transit from Ames	5
9/6	Rebuilt three bias boxes used during August flight series	5
9/7	Rebuilt three bias boxes used during August flight series	5
	Between 9/5–9/7 3 hours on redesign of bias box circuits	3
9/8–9/9	No ASSESS #3 activity	0
9/10–9/14	Rebuilt three bias boxes used during August flight series	27
	Work on redesign of bias box circuits	3
9/15–9/16	No ASSESS #3 activity	0
9/17–9/21	Rebuilt three bias boxes used during August flight series	30
9/22–9/23	No ASSESS #3 activity	0
9/24–9/27	Rebuilt three bias boxes used during August flight series	24
9/28–10/4	No ASSESS #3 activity	0
10/5	Check grating control in attempt to find cause of failure of manual advance to operate properly – nothing found	4
10/6–10/7	No ASSESS #3 activity	0

TABLE A-1. – TIME LINES FOR HOME-BASE PREPARATION – Concluded

(D) Electronics technician at university laboratory – Concluded

Date	Activity	Man-hours charged to ASSESS #3
10/8–10/12/73	Add circuitry to digital data recording system to record grating position, grating motion direction, and chopper beam used	40
10/13–10/23	No ASSESS #3 activity	

(D) Data summary

Experiment preparation, 181 man-hours

Planning, analysis, design	9%
Fabrication related	86%
Testing	4%

TABLE A-2. – SUBSYSTEM DEVELOPMENT

Date	Guiding eyepiece	Man-hours
8/28, 8/30, 9/10	Order parts	4.5
9/5–9/12	Develop design ideas	9
9/13	Made engineering drawings	2
9/14	Take parts to outside machine shop and place order	4
9/20	Finish drawings and take parts to outside shop	4
9/25–9/27	Assemble and mount on telescope simulator	11
9/30	Tested completed system	1
		35.5
	Bias boxes	
8/27–8/31	Refurbish existing units	16
8/27–8/31	Initiate design of improved bias circuit for backup units (3)	10
8/28–8/30	Tested refurbished units. Results not acceptable. Units must be rewired.	4
9/5–9/12	Complete circuit design and order parts	18
9/6–9/27	Rewire existing units with new parts to upgrade performance as per design, with preamplifiers in same box; test for operation as completed.	96
		144
	Spectrometer #1	
9/4	Wavelength calibration	12
9/7	Wavelength calibration	13
9/17–9/21	Reduce calibration data	15
9/21	Take spectrometer apart to refurbish	6
9/24	Install new mirrors	8
9/25–9/28	Assemble and test	20.5
9/30	Test detectors	7
10/1	Realign and test	3
10/17–10/19	Study alignment	8
10/21–10/22	Final adjustment and calibration	9.5
		102

TABLE A-2. – SUBSYSTEM DEVELOPMENT – Concluded

Date		Man-hours
Spectrometer #2		
10/2–10/3	Assemble components	11
10/5	Align and test	6
10/8	Continue tests	4
10/22	Final calibration	3.5
		24.5
Spectrometer/telescope alignment systems		
9/4	Ordered material for tripod support	1
9/10–9/12	Investigate new idea for focusing and alignment	6
9/19	Made drawings for alignment fixture	1
9/21	Took drawings and stock to outside shop	1
9/24	Took collimator drawings to outside shop and discussed with machinist	3
9/30	Assembled collimator parts and tested alignment system	1
10/17	Built alignment light source for final spectrometer tests	4
		17

TABLE A-3. – PREFLIGHT EQUIPMENT HANDLING

Date	Activity
8/27–8/31	Unpack, refurbish, and test bias control units
9/3–9/5	Unpack remaining equipment, check, and repair damage incurred in shipping from Ames to experimenters' base
9/4–9/7	Wavelength calibration of primary experiment; spectrometer, electronics, and data handling units
9/7–9/25	Refurbish optics and electronic components, fabricate new components; both primary and backup units. Begin component testing.
9/25–10/1	Complete testing of primary components; assembly and test primary flight systems
10/2–10/8	Complete testing of backup components; assemble and test backup spectrometer in complete system
10/9–10/16	Modify and test data processing system for use in flight
10/17–10/22	Final adjustments and calibration of both spectrometers with experiment in flight configuration
10/23	Pack for shipping
10/23–10/25	Shipment to Ames
10/26	Unpack and check for shipping damage
10/29–10/30	Assembly experiment in ASO laboratory. Installation delayed by aircraft problem until 11/5. Operational tests of components and entire experiment.
10/31	Operational tests of components and entire experiment
11/5–11/6	Install and check out experiment in aircraft
11/7	First checkout flight

TABLE A-4. – FLIGHT READINESS REVIEW

October 4, 1974

Scientific objectives

1. Determine thermal structure of planetary atmosphere of Jupiter and Saturn
   a. Pressure, temperature, height
   b. Composition H_2/He ratio
2. Thermal structure of Emission Nebulae
   a. Temperature
   b. Composition (H_2)
   c. Silicate dust particles

Observational requirements

1. Coverage of 16–40 μm spectral region
2. Medium spectral resolution

History of 16–40 μm infrared spectrometer program

Design initiated	June 1972
First flight	November 1972
Second series (ASSESS #2)	April 1973
Third series	August 1973
Fourth series (ASSESS #3)	November 1973

Component: Spectrometer 1 – two dissimilar detectors

1. Primary XX Backup
2. Purpose – To disperse incoming radiation and detect discrete wavelengths
3. Any previous problems
   a. Mirrors coming loose from mounting
   b. Detector post coming loose
   c. Shorted detector lead
4. How were they resolved
   a Mirrors glued with cryogenic epoxy
   b. Post soldered with low temperature solder
   c. Filed off sharp corner on detector mount
5. Why chosen as primary or backup
   a. Most experience with this particular instrument
   b. Does 30 μm or 40 μm region, other unit does not reach this far

TABLE A-4. – FLIGHT READINESS REVIEW – Continued

Component: Spectrometer 1 – two dissimilar detectors – Continued

6. When is repair improbable
   a. If Dewar leaks – replace with backup
   b. Broken optical components – replace with backup
7. How is component tested
   a. Check Dewar for leak using He leak detector
   b. Align spectrometer using a Helium Neon laser
   c. Using a standard light source, check detector output
   d. Calibrate wavelength
8. What are criteria for OK
   a. Strong signal from detector
   b. Output spectrum compares favorably with standard spectrum
9. What are criteria for rejection
   a. Small or no signal from detector – check alignment
   b. If output spectrum does not match standard spectrum – check grating drive

*10 Date tested —September 4, 7, 28, 30, and October 1, 22

*11. Man-hours for test
   a. 20 operation
   b. 28 calibration

Components: Spectrometer 2 – two similar detectors

1. Primary   Backup XX
2. Purpose – To disperse incoming radiation and detect discrete wavelengths
3. Any previous problems
   a. Lost vacuum
   b. Noisy detectors
4. How were they resolved
   a. Installed new detectors
5. Why chosen as primary or backup
   a. Less experience with this particular instrument. Only covers 20 μm to 30 μm region. Only used for ASSESS #2.
6. When is repair improbable
   a. If Dewar leaks
   b. Broken optical components

*Completed after FRR.

TABLE A-4 – FLIGHT READINESS REVIEW – Continued

Component: Spectrometer 2 – two similar detectors – Continued

7. How is component tested
   a. Check Dewar for leak using He leak detector
   b. Align spectrometer using a Helium Neon laser
   c. Using a standard light source, check detector output
   d. Calibrate wavelength
8. What are criteria for OK
   a. Strong signal from detector
   b. Output spectrum compares favorably with standard spectrum
9. What are criteria for rejection
   a. Small or no signal from detector – check alignment
   b If output spectrum does not match standard spectrum – check grating drive

*10. Date tested – October 5, 8, and 22

*11. Man-hours for test
   a. 10 operation
   b. 3 calibration

Component. grating control

1. Primary XX   Backup
2. Purpose
   a. To position the grating
   b. Time the observations
   c. Display the grating position
3. Any previous problems
   a. Damaged in shipping from Ames
4. How were they resolved
   a. Remounted broken display lamp
5. Why chosen as primary or backup
   a. Better reliability and control
6. When is repair improbable
   a. In case of massive electrical short – replace with backup
7. How is component tested
   a Operationally at room temperature
   b. At 32°F (0°C)

*Completed after FRR.

TABLE A-4. FLIGHT READINESS REVIEW – Continued

Component: grating control Continued

8. What are criteria for OK
    a. Proper stepping and slewing of grating
    b. Proper readout of grating position
    c. Proper timing of stepping
9. What are criteria for rejection
    a. Failure of any of the above
    b. Intermittent operation
10. Date tested – September 28
11. Man-hours for test
    a. Operational test – 1
    b. Observed and used for several hours during test of Spectrometer 1

Component: bias box

1. Primary - 2 Backup - 1
2. Purpose
    a. To supply bias to the preamplifiers
    b. Amplify detector signal
3. Any previous problems
    a. Intermittent operation
    b. Bad preamplifier
4. How were they resolved
    a. Completely rewired
    b. Replaced preamplifier
5. Why chosen as primary or backup
    a. Backup is shared with ground-based project
6. When is repair improbable
    a. A replacement preamplifier and batteries are included in spare parts
7. How is component tested
    a. Operationally at room temperature
8. What are criteria for OK
    a. Noise from the preamplifier must be $\leq 20\ \mu V$ RMS for 100 kΩ load resistor
9. What are criteria for rejection
    a. Failure of above or intermittent operation

TABLE A-4. – FLIGHT READINESS REVIEW – Continued

Component: bias box – Continued

10. Date tested
    a. August 28 and 30 (after replacing preamplifiers)
    b. September 28, and October 1 and 21
11. Man-hours for test
    a. 4
    b. Used and observed during tests of spectrometers

Component: preamplifier

1. Primary – "A", "B"   Backup – "C", units interchangeable
2. Purpose – Amplifier detector signal
3. Any previous problems – Slight cross-talk
4. How were they resolved – Improved power supply
5. Why chosen as primary or backup – Convenience of gain control
6. When is repair improbable – For almost any failure – spare available
7. How is component tested – Operationally at room temperature
8. What are criteria for OK – Unit meets manufacture specification
9. What are criteria for rejection
    a. Failure of above
    b. Intermittent operation
10. Date tested – October 3, 1973
11. Man-hours for test – 1/4 man-hour, noise and cross-talk OK (Note: Cross-talk less than –90 dB)

Component: phase-lock amplifier

1. Primary – "A", "B"   Backup – "C", all units identical
2. Purpose – To convert AC signal from detector to DC voltage
3. Any previous problems – Slight cross-talk between channels
4. How were they resolved – The power supply was improved
5. Why chosen as primary or backup –
6. When is repair improbable – For almost any failure – spare available.
7. How is component tested – Operationally at room temperature
8. What are criteria for OK – Unit meets manufacturer's specifications
9. What are criteria for rejection
    a. Failure of above
    b. Intermittent operation

TABLE A-4. – FLIGHT READINESS REVIEW – Continued

Component: phase-lock amplifier – Continued

10. Date tested – October 3, 1973
11. Man-hours for test – 1/2 man-hour. The phase shifter, time constant gain, noise and offset were checked

Component: tape recorder (cartridge)

1. Primary – Old   Backup – New (both same model)
2. Purpose – To record experimental data
3. Any previous problems
   a. No tape advance
   b. Complicated setup
   c. Poor end-of-tape indicator
4. How were they resolved
   a. Used semitransparent tape cartridges
   b. Hard wire to 4 channels
   c. New end-of-tape indicator light

   Note: completed for August mission
5. Why chosen as primary or backup – "old" recorder has had fewer tape advance problems
6. When is repair improbable – In case of motor burn-out or record amplifier failure – replace with backup
7. How is component tested – Operationally at room temperature
8. What are criteria for OK
   a. Proper tape transport
   b. Proper recording amplitude
   c. Proper recording playback
   d. ⩽4% frequency shift
   e. ⩽50% amplitude change
9. What are criteria for rejection – Failure of any of above or intermittent operation
10. Date tested
    a. Extensive use in playback mode since August flights
    b. Record amplifiers checked September 28, 1973
11. Man-hours for test – 4 for record amplifiers and frequency check

Component: voltage controlled oscillator

1. Primary – 2 signal level meters   Backup – 1 signal level meter
2. Purpose – To convert output of the lock-in amplifiers to frequency signal for recording on tape.
3. Any previous problems – Intermittent response in channel #2 due to shipping damage

TABLE A-4. – FLIGHT READINESS REVIEW – Continued

Component: voltage controlled oscillator – Continued

4. How were they resolved – Improved the mounting of the VCO modules
5. Why chosen as primary or backup
   a. Quality of wiring
   b. Overload indication
   c. Adjustable offset
6. When is repair improbable – Spare parts, including VCO module, are available
7. How is component tested – Operationally at room temperature
8. What are criteria for OK
   a. Over and under voltage at 0 and 10 Vdc
   b. Output frequency 0–10 kHz
9. What are criteria for rejection – Failure of any of the above or intermittent operation
10. Date tested – September 28
11. Man-hours for test – 1/2 hour per unit (estimated)

New component features for ASSESS #3

Component	New features for ASSESS #3	Testing completed
Spectrometer 1	All mirrors glued with cryogenic epoxy	2 October
Spectrometer 2	Installed two new detectors	After FRR
Bias box	Completely rewired. Replaced preamplifier.	30 August
Voltage control oscillator	Improved mounting of VCO modules	After FRR
Grating control	Remounted display lamp	28 September
Guiding eyepiece	Entirely new	30 September

Requested ground support GFE

Liquid helium	60 liters/week
Liquid nitrogen	100 liters/week
Vacuum pump (mechanical)	
Power supplies (2)	(0–60 volts @ 1 ampere)
Small oscilloscope	
Small signal generator	

TABLE A-4. – FLIGHT READINESS REVIEW – Continued

Task	Estimated man-hours	Actual man-hours	Reason for difference
Miscellaneous			
*1. Fix equipment broken in shipment	40–60	12	This estimate included some work on bias boxes
2. Refurbish collimator used for ground-based telescope check	20–30	4	Task not completed
*3. Establish test criteria	10	––	Not recorder
*4. Check replacement parts	10	5	Task not completed
Spectrometer accessories			
*1. Design guiding eyepiece	10	17	
*2. Order parts for eyepiece	10	6.5	Less trouble than usual
*3. Build and test new eyepiece system	10	12	
Bias boxes			
*1. Design and order parts for backup bias boxes	10	32	
2. Refurbish old bias boxes	40–60	112	Bias boxes had to be completely rewired
3. Build backup bias boxes	40–60	0	Task not started; decided to rebuild existing units
Spectrometer			
*1. Wavelength calibration of Spectrometer 1	10	25	
*2. Disassemble Spectrometer 1 for new epoxy, pin drive gear and modify detector mount	20–30	7	Increased facility with experience
*3. Mount detectors in Spectrometer 2	20–30	1	Used existing detectors
*4 Reassemble Spectrometer 1	20–30	30	
*5 Reassemble Spectrometer 2	10	14	

*Completed at time of review.

TABLE A-4. – FLIGHT READINESS REVIEW – Concluded

Task	Estimated man-hours	Actual man-hours	Reason for difference
Testing			
*1. Test new epoxy	10	18	
2. Check all electronics, add lamp to VCO panel	20–30	10	Electronics tests complete
*3. Test Spectrometer 1	10	20	
*4. Recheck data processing equipment	20–40	24	
5. Final test of Spectrometer 2	20–30		Task not started
6. Final systems checks	20–30		Task not started
7. Mark and run tapes	20		Task not started

*Completed at time of review.

9. APPENDIX B

SUPPORTING DATA FOR EXPERIMENT SERVICE AND MAINTENANCE EQUIPMENT

Tabular data are provided in support of text discussions of experiment equipment for the simulation mission. Tables B-1 through B-5 list hand tools, test and maintenance equipment, spare parts, expendable supplies, and reference documents. Utilization of this equipment is recorded in these tables and summarized in table 5-5 of the text.

In reviewing the tables, note that tools and test equipment are limited by mission guidelines to those justified as necessary by the experimenter. In practice, this request was not enforced with sufficient rigor to have any real meaning, minor reductions of these and other support items (compared to ASSESS #2) were voluntary, and a result of experience on the prior ASSESS mission. Test equipment consisted primarily of general-purpose diagnostic devices normally used in the laboratory for troubleshooting electronic circuits, and was complemented by circuit diagrams for experimenter-built units and service manuals for commercial experiment components. In the total of number of 24 items of test equipment, only 5 were experimenter-built specifically for this experiment (table B-2).

Spare parts for the experiment consisted of the items listed in table B-3, and the major assemblies (components) listed in table 2-2 of the main text. Not listed are replacement parts for telescope systems – gyroscopes, modularized printed-circuit boards, and a spare secondary mirror assembly – which were held in reserve by the ASO Lear Jet manager.

TABLE B-1. – EXPERIMENTER-SUPPLIED HAND TOOLS

Brown tool box – 51 X 22 X 34 cm (11.4 Kg empty)

Item	Quantity	Used		Quantity used
		Yes	No	
Longnose pliers	3	X		3
End cutter plier	1	X		1
Small wire stripper	1		X	
Tweezers	3		X	
Screwdrivers; flat blade, 0.32 to 0.64 X 10 cm	6	X		4
Screwdrivers; Phillips blade, small, #1, #2	3		X	
Offset screwdrivers				
Regular	1		X	
Phillips	1		X	
Set small screwdrivers	8 pieces	X		1
Allen screwdriver set	9 pieces		X	
Nut driver set	10 pieces	X		3
Nut driver	1		X	
2 sets Jeweler's screwdrivers	12 pieces	X		1
1 set hex key wrenches	10 pieces	X		6
1 set long hex key wrences	10 pieces		X	
Ratchet wrench	1	X		1
Adjustable wrenches; 10, 15 (2), and 20 (2) cm	5		X	
Tap wrenches	3		X	
Allen wrenches, very-small to small	7		X	
Solder gun, 1-1/2 amps	1	X		1
Small soldering gun	1		X	
Small soldering iron tip	2		X	
Nozzle for torch plus gas cylinder	1		X	
Swiss jeweler's files	5		X	
Flat files	5		X	
Half round file	1		X	
Knife blades	2	X		2
Small saw blade	1		X	
Glass cutter	1		X	
Pair small scissors	1		X	
Pair shears	1		X	

TABLE B-1. – EXPERIMENTER-SUPPLIED HAND TOOLS – Concluded

Item	Quantity	Used: Yes	Used: No	Quantity used
Scribe	1		X	
Prick punches	2		X	
Heavy duty punch	1		X	
Twist drills; tap & clearance drills	16	X		1
Set twist drills; 9.16 to 0.41 cm	13		X	
Electric drill motor	1	X		1
9 taps, sizes 0 to 10	9		X	
Hand reamers, tapered	2		X	
Rubber hammer	1		X	
Micrometer; 21.5 cm	1	X		1
Wooden blocks used as fulcrum for removal of radiation shield*	3		X	
Tubing clamps	5	X		5
C clamps; 2.5 cm	2	X		2
Hacksaw	1		X	
TOTALS	175			33

*Experimenter built.

TABLE B-2. – TEST AND MAINTENANCE EQUIPMENT

Supplied by experimenter

Item and type construction		Used	Not used
Electrometer – off-the-shelf		X	
Battery tester – off-the-shelf		X	
Telescope simulator (dimensionally equivalent mount to check spectrometer) – experimenter-built		X	
Dummy IR source with chopper wheel – experimenter-built		X	
Digital multimeter – off-the-shelf		X	
Multimeter – off-the-shelf		X	
Earphones – off-the-shelf			X
Test probe – off-the-shelf			X
Vacuum gauge – off-the-shelf		X	
Laser – off-the-shelf			X
Vacuum pump (ion-impact, 14 watts) – off-the-shelf		X	
Collimator, 40-power telescope, and IR source – modified-commercial and experimenter-built		X	
Dewar for liquid nitrogen (1 liter) – off-the-shelf		X	
Liquid helium transfer tube – experimenter-built		X	
Periscope (used to align guide telescope) – experimenter-built		X	
Battery charger and checker (for nicads) – experimenter-built		X	
Supplied by ASO			
2 power supplies – 0–15 V, 2 A			X
Function generator			X
Vacuum pump (fore pump)		X	
Heavy tripod (used to hold collimator)		X	
Heat gun – 1500 W maximum*		X	
Oscilloscope (small, low frequency)			X
Liquid helium depth gauge (failed after initial use)		X	
TOTALS	24	17	7

*Supplied after mission started.

TABLE B-3. – EXPERIMENTER-SUPPLIED SPARE PARTS

Item	Quantity	Used		Quantity used
		Yes	No	
Mechanical				
Tubing adapters	2	X		1
Envelope of O-rings (9)	9	X		1
Loose O-rings – large (2.5 to 15 cm diameter)	10	X		2 (5 cm dia)
Electrical				
Electronic component board	1		X	
Spare circuit boards – empty	2		X	
Box assorted electronics parts – resistors, integrated circuits, etc.	1	X		1 (bias box pre-preamplifier)*
Optical				
Extra grating (higher resolution)	1		X	
Optical & IR filters	2		X	
Spare small flat mirrors	6		X	
TOTALS	34			5
Components				
Spare components for direct replacement of experimental gear are listed in table 2-2				

*Installed prior to constrained period.

TABLE B-4 – EXPENDABLE SUPPLIES

Supplied by experimenter

Item	Quantity	Used: Yes	Used: No	Quantity used
Experiment maintenance & servicing				
Epoxy patch kit	1	X		
Tube thread-locking compound	1		X	
Tube cement	1		X	
Tube polish	2		X	
Tube RTV coating	1		X	
Roll clear electric tape (plastic)	1	X		
Roll black electric tape (plastic)	1		X	
Bottle varnish	1		X	
Bottle varnish thinner	1		X	
Bottle metal rubber cement	1		X	
Bottle acetone (1/2 liter)	2	X		1/4 liter
Bottle bromobenzene (for calibration)	1		X	
Roll of Mylar film (for calibration)	1	X		0.1 m^2
Bottle methyl alochol (1/2 liter)	1	X		1/4 liter
Hookup wire (30 m spools)	3	X		About 2 ft
Silver solder flux (vial)	1		X	
Silver solder (25-cm rod)	1		X	
Bottle soft solder flux	1		X	
Roll 60/40 solder (0.5 Kg)	1	X		30 g (estimate)
Boxes assorted spare screws, etc.	2	X		1 box (15 screws)
Assorted test leads	–	X		–––
90-V battery	2	X		1
Lengths 0.32 cm diameter plastic rod	1		X	
Coaxial cable (15 m)	1		X	
Light bulbs	2	X		1
Small can vacuum greast (60 g)	1	X		1
160 g plastic dispenser Teflon	1		X	
30 g can oil (light machine)	1	X		1 application
1 tube rubber cement	1	X		1

TABLE B-4. – EXPENDABLE SUPPLIES – Concluded

Supplied by experimenter – Concluded

Item	Quantity	Used		Quantity used
		Yes	No	
Miscellaneous				
2 pads paper	2	X		2
Tape cartridge	20	X		15
Pencils	2	X		2
Ballpoint pens	1	X		1
Felt writer	1	X		1
Package note paper	1		X	
Experimenters' notebooks (22 X 28 cm)	3	X		3
Computation notebook	1	X		1
Wooden ruler (15 cm)	1		X	
Plastic ruler (31 cm)	1	X		1
Wooden ruler (46 cm)	1	X		1
Plastic air syringe (small)	1	X		1
Wool cap	1	X		1
Pyrex beakers	4		X	
Nalgene beakers	2	X		2
Eye dropper	1	X		1
Spare plastic bottle	1	X		1
Artists' paint brush	2		X	
Pencil flashlights	2	X		2
Wrist watch	1	X		1
Plastic funnel	1	X		1
Bottle vitamin C pills	1	X		---
TOTAL	91			53

Supplied by ASO

Liquid helium (2 Dewars)	50 liters	X		20 liters
Liquid nitrogen for precooling flight Dewar (2 Dewars)	50 liters	X		7 liters

TABLE B-5. – EXPERIMENTER-SUPPLIED REFERENCES, TECHNICAL MANUALS, AND DATA EVALUATION AIDS

Item		Used	Not used
Experimenters' reference files (2)		X (2)	
Astronomical reference data reprint (experimenter assembled notebook)		X	
Norton's Star Atlas			X
Digital printer – service manual			X
Schematic diagram for ion-impact pump			X
Audio magazine recorder operator's manual			X
Audio magazine recorder service manual			X
Electronic calculator, pocket size		X	
Slide rule		X	
Radiation calculator		X	
TOTALS	11	6	5

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