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SHUTTLE SPACELAB SIMULATION USING A LEAR JET AIRCRAFT

Mission No. 2

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

Ames Research Center
Moffett Field, California 94035

January 1974

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SUMMARY

The second Shuttle Spacelab simulation mission of the ASSESS program was conducted at Ames Research Center by the Airborne Science Office (ASO) using a Lear Jet aircraft based at a site remote from normal flight operations. Two experimenters and the copilot were confined to quarters on the site during the mission, departing only to do in-flight research in infrared astronomy. A total of seven flights was made in a period of 4 days.

The experimenters chosen for this mission were relatively new to the ASO Lear Jet astronomy program, having recently completed their first flight series in an ongoing research effort. They modified their equipment for reliable operation during the ASSESS mission, with near total responsibility for design, testing, and in-flight operation within the limitations of flight safety and the Spacelab simulation guidelines.

Although notable scheduling and equipment operating problems occurred during experiment preparation and premission checkout, research operations in the simulation mission went according to plan and significant new scientific results were obtained. ASSESS related data were gathered in all phases of this activity as the basis for observations relevant to planning for Spacelab missions. These observations also draw on results from the first Lear Jet simulation mission (ref. 1) and thus represent the response of two teams of experimenters to the constraints, both inherent and imposed, associated with doing scientific research in an isolated environment.

Results show that experimenters with relatively little flight experience can plan and carry out a successful research effort under isolated and physically rigorous conditions, much as would more experienced scientists. Perhaps the margin of success is not as great, but the primary goal of sustained acquisition of significant data over a 5-day period can be achieved. Experiment preparation schedules cannot be reported as favorably; time overruns occurred when new equipment was developed and final system testing was less than desired. Experiment operations, equipment maintenance, data evaluation, and target selection were effectively handled by the experimenters. Research equipment was reasonably well suited for Spacelab application with respect to size, weight, electrical power, and cyrogenics. Automatic features as necessary for one-man operation appeared readily attainable.

INTRODUCTION

Since 1965 the Airborne Science Office (ASO) at Ames Research Center has managed programs of airborne research in which participating scientists have been directly involved in all aspects of the research. The scientist/experimenter's immediate responsibility for the development and operation of his experiment has yielded research of consistently high quality while minimizing the time and cost of program implementation.

As the Space Shuttle program moves rapidly to plan and implement the research applications of Spacelab, Shuttle planners have noted with interest the similarity of proposed Spacelab research activities to ASO airborne research programs. The recognized success of these programs in acquiring scientific results, and the potential for effectiveness and economy in space operations inherent in the management approach used, have motivated a special program to ascertain how the Airborne Science concepts may apply to Shuttle.

This special program - called ASSESS (Airborne Science/Shuttle Experiment System Simulation) - is proceeding concurrently in two phases: Phase A is a study of ongoing ASO programs and has been reported in references 2 to 4, while Phase B consists of a separate series of missions that follow the basic Airborne Science approach but are constrained to simulate Shuttle Spacelab scientific missions. Two of these simulation missions have been completed, using a Lear Jet aircraft as the flight vehicle. The first mission is reported in reference 1; the second is the subject of this report. A third Lear Jet mission and one using the replacement CV-990 aircraft (Galileo II) are in preparation.

The second Lear Jet simulation mission was conducted along the same general lines as the first. The same remote site and trailer accommodations were used, experimenters and the copilot/observer were restricted from direct contact with other personnel during the simulation period, the schedule of activities during premission week was similar, mission logistics were basically the same, and behavioral factors other than a subjective expression of experimenter fatigue were not documented. Significant new elements were introduced into the program, however, to increase the realism of the simulation and to provide exposure to circumstances not encountered during the first mission. The most important of these was the selection of experimenters with a minimum of flight experience. As before, the team was chosen from the group currently active in the ongoing Lear Jet astronomy program. However, the experimenters had flown only one previous mission with the ASO. Experimenters on the first Lear Jet simulation mission supplied and maintained the research telescope. On the second mission, the Ames 30-cm IR telescope was used for astronomical observations, and Ames personnel were responsible for its maintenance. Prior to their arrival at Ames, the experimenters did not have access to the telescope; an informal status review during the premission week served to update them on the current configuration.

New elements introduced to mission guidelines were as follows:

1. There was a 2-day "hands off" period for the experimenters just prior to the confined phase of the mission.
2. A limit was placed on the amount of spare parts, support equipment, and supplies brought "onboard."
3. Experimenter access to the aircraft was limited to a nominal 2-1/2 hr before flight.
4. Command pilot responsibility rotated among Ames pilots, who were not confined to the trailer quarters.

As will be shown, each of these new elements introduced constraints and working relationships that differed from the previous experience. From the ASSESS point of view, the experiment preparation period was given greater emphasis than in the first mission. Actual performance was compared with a "milestone" chart drawn by the principal investigator; manpower allotment to component development and testing was defined; and component characteristics and functions were documented.

The second Lear Jet simulation mission began at 1600 on April 9, 1973. A "hold" was placed on activities at about 1500 on April 12, and the mission was terminated at 1300 on April 13, as a result of the untimely accident of the ASO CV-990 aircraft, which forced cancellation of all flights from Moffett Field. Although this abbreviated simulation period had a significant impact on the amount of scientific research accomplished by the experimenters, the other ASSESS-related objectives were essentially completed as detailed in this report.

ASSESS MISSION PLAN

Guidelines

Guidelines for the second Lear Jet mission to simulate Shuttle Spacelab were established at the outset of the preparatory period as follows:

1. The experimenters would make authentic scientific measurements in infrared astronomy.
2. The Spacelab simulation period (mission) would be five consecutive days.
3. A goal of two flights per night was established, to concentrate as much experiment-operation time as possible in the 5-day mission.
4. The experimenters could modify their existing experiment to operate more effectively and more reliably for the 5-day mission.
5. The experiment preparation, aircraft installation, and flight program would be conducted in accordance with standard ASO operation; that is, the experimenter would have prime responsibility for most aspects of experiment integration.
6. The experimenter could bring on board any spare subassemblies or components considered necessary to ensure the success of the mission. Test equipment and tools would be limited to those that could be justified. Once the mission started, any additional equipment or parts vital to the success of the operation would be furnished by ASO and their use documented.
7. Two experimenters and one copilot/observer would be confined to the aircraft/trailer complex for the duration of the mission. Ames pilots would be assigned in rotation to fly the Lear Jet aircraft, as for normal ASO missions.
8. A mission control center would be housed in a separate section of the work trailer at the remote site, with the ASO mission manager coordinating "Spacelab" and Ames support activities from this location.

9. The copilot (an astronaut) would be on every flight, in part to coordinate in-flight aircraft operations with research activities, and also to serve as an ASSESS observer of experiment operational procedures.

Additional procedures were derived in support of these basic guidelines and will be described later. As with any simulation, there are natural limitations that cannot be avoided; those imposed by using aircraft to simulate Spacelab operations are recognized and their influence acknowledged.

Organization

Management- The scientific research for this simulation mission was managed, for the most part, in the manner normally followed in the Airborne Science Office (ASO) for the ongoing Lear Jet astronomy program. The regular mission manager acted as coordinator between experimenters and Ames support personnel during installation and checkout of the experimental apparatus. For the simulation period, a mission-control center was located in a separate room of the "Shuttle" work trailer and was manned 24 hr a day. All incoming contacts with the "Shuttle" crew were handled by telephone through the mission manager or his designated alternate on the night shift. With the exception of pilots, aircraft-maintenance personnel, and the mission manager, direct contact between the "Shuttle" crew and others was prohibited.

Experimenters and flight crew- The principal investigator was chosen from among those in the ongoing Lear Jet program in infrared astronomy. He and his associate had flown only once before in a Lear Jet flight series. Minimal flight experience was a primary selection factor intended to provide a contrast with the first simulation team and broaden the ASSESS data base.

Pilots were assigned in normal rotation by the Flight Operations Branch (FOB) of Ames. The copilot was a scientist/astronaut already associated with the ASSESS program, from the NASA Johnson Space Center. His presence assured flight-to-flight continuity of operations and optimum coordination of flight/research activities. He also acted as an observer during the flights to provide data on experimenter and equipment performance pertinent to the ASSESS program, and monitored the physical condition of the experimenters and their fitness for flight.

Support personnel- Experiment installation followed normal ASO practices. Experimenters were responsible for assembly and checkout in the ASO laboratory, and the Metals Fabrication and Aircraft Services Branches provided attachment to aircraft tie-points. Component assembly and installation were approved as safe for flight by the Airworthiness Engineering Group of FOB and the Inspection Branch. Supplies and equipment were provided by ASO laboratory personnel.

Flight safety precautions and the mission operating plan were reviewed and approved by the Ames Airworthiness and Flight Safety Review Board prior to flight. During the simulation period, the ASO flight planners, as well as the forenamed branches, provided support for the mission.

The Simulation Complex

The simulation complex consisted of a Lear Jet aircraft and two trailers, located in a relatively isolated parking lot well removed from other Ames flight activities and blocked off from casual traffic (figs. 1 and 2). From the site, the aircraft could be either taxied to the runway for flight or towed to the hangar for refueling and maintenance. Experiment maintenance, as well as aircraft minor maintenance and pre-flight checks were performed at this location. Flood lights illuminated the area for night work.

Aircraft- The aircraft was a model 23 Lear Jet (fig. 3). At maximum gross weight, this aircraft takes 30 to 35 min to climb to an altitude of 13.7 km, where maximum cruise time is about 1-3/4 hr at a true airspeed of 430 knots. Experimenter's equipment weight is limited to about 270 kg. The main cabin of the aircraft has a volume of about 4.25 m^3 (150 ft^3) and working space is at a premium; the baggage compartment provides another 1.13 m^3 (40 ft^3) of volume for experiment support equipment and life support oxygen bottles. Since cabin altitude can vary up to 7.6 km when the Ames infrared telescope is used in the Lear Jet, oxygen masks must be donned prior to takeoff. Figures 4 and 5 illustrate the flight research environment.

The aircraft intercom system provided the copilot/observer a "hot-mike" loop with the experimenters and a private tape recorder system, and allowed taping of all communication within and from outside the aircraft on a common recorder.

Work area and living quarters- Accommodations for the copilot and experimenters consisted of the work area and separate living quarters. The work area was a 3- by 7-m space in a standard office trailer (figs. 1 and 6 to 9). A partition separated the work area from the mission control center used by the ASO mission manager and the ASSESS observers. The living quarters were in a standard 2- by 8-m vacation trailer with four separate beds and the usual facilities. Windows were covered for daytime sleeping.

Logistics Plan

The logistics plan for the mission dealt primarily with "Shuttle" utilities, life-support systems, and aircraft operations. Logistics arrangements for ASSESS-related observations were handled by ASO personnel in the ASSESS program. All supplies for experiment maintenance were on board at the start, as specified in the mission guidelines.

"Shuttle" utilities were electrical power and cryogenics. Electrical power entered the simulation complex at the main distribution panel in the mission control center at 60 Hz and 200 V; 60 Hz at 115 V, 400 Hz at 115 V, and 28 Vdc was available to the experimenters. Power use for experiment-related activities was monitored by a chart recorder and a watt-hour meter. To satisfy "Shuttle" cryogenics requirements, liquid helium was supplied in two 25-ℓ storage Dewars (fig. 10) and liquid nitrogen in one 160-ℓ container; one bottle of helium gas at 3000 psi was available if needed for the transfer of cryogenic liquids.

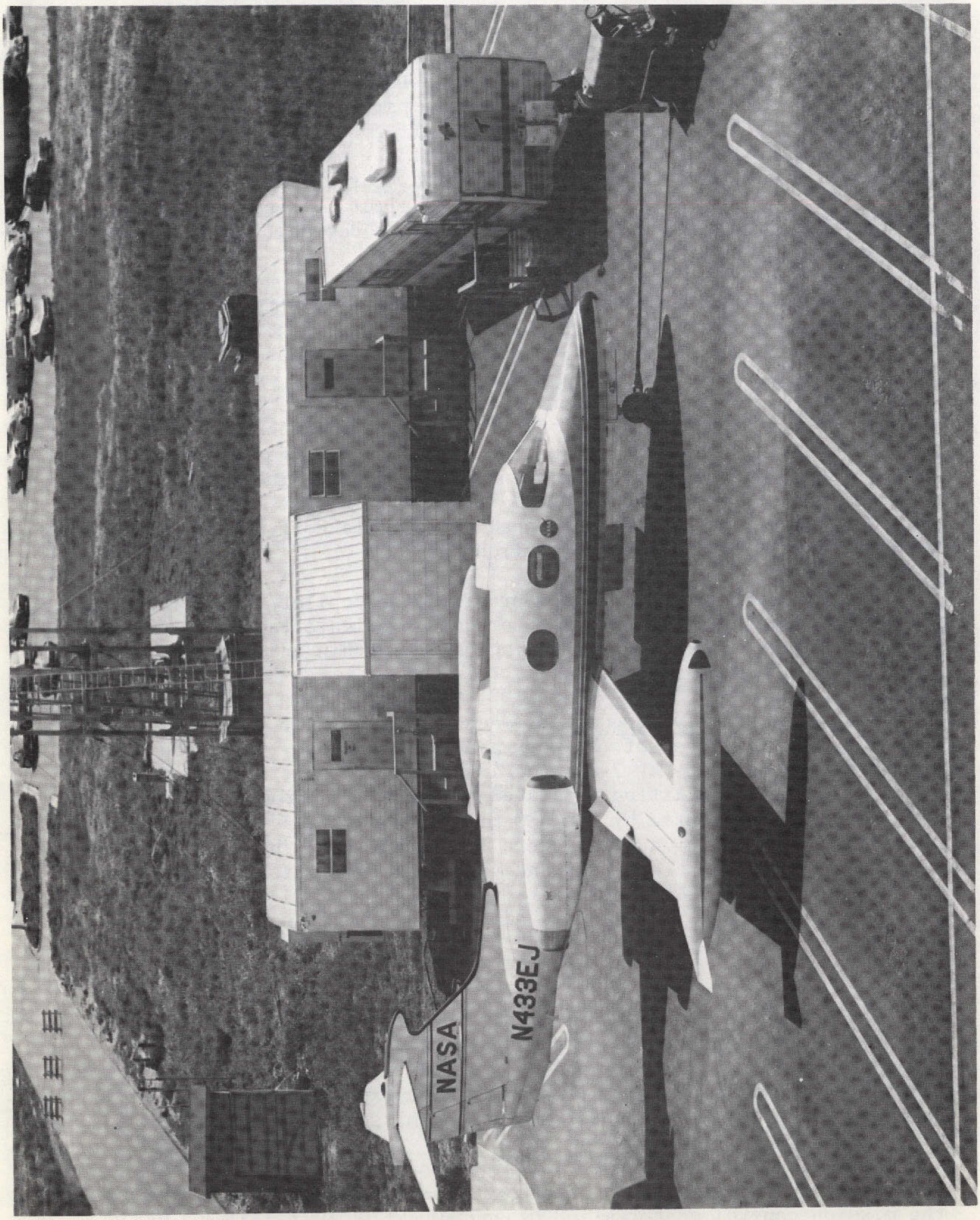

Figure 1.- ASSESS simulation site.

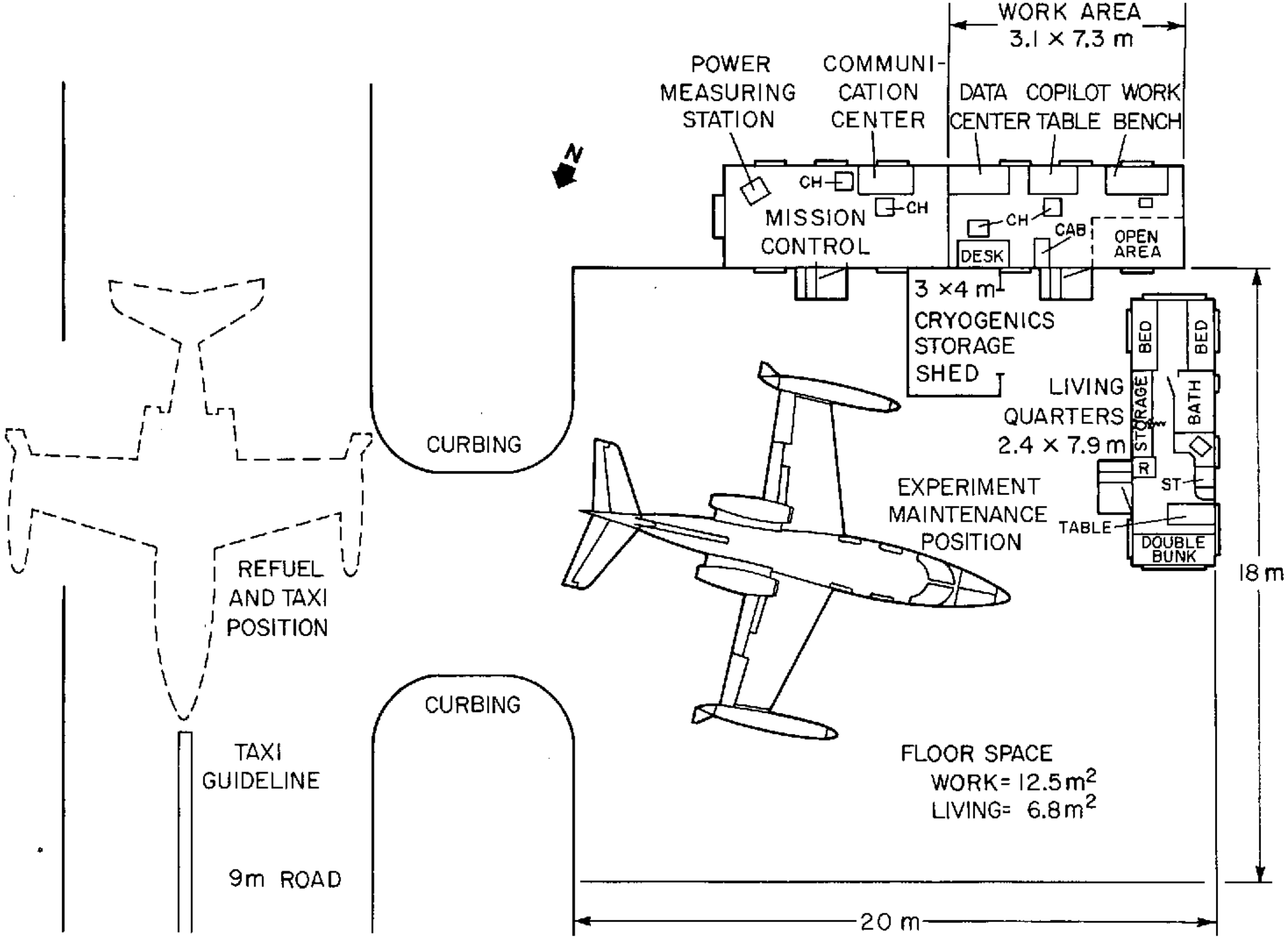

Figure 2.- Arrangement of the simulation complex.

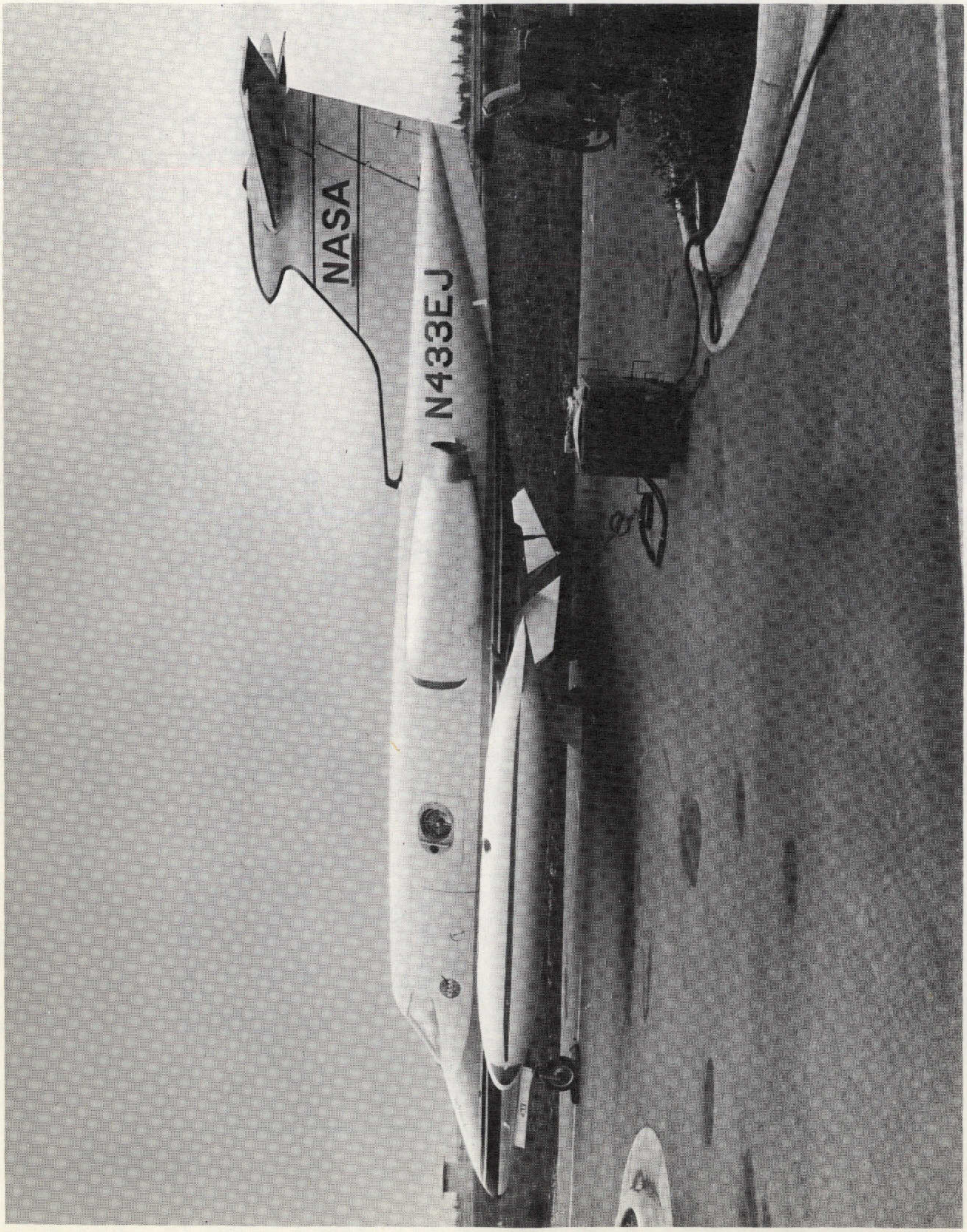

Figure 3.- Mission aircraft, Lear Jet model 23.

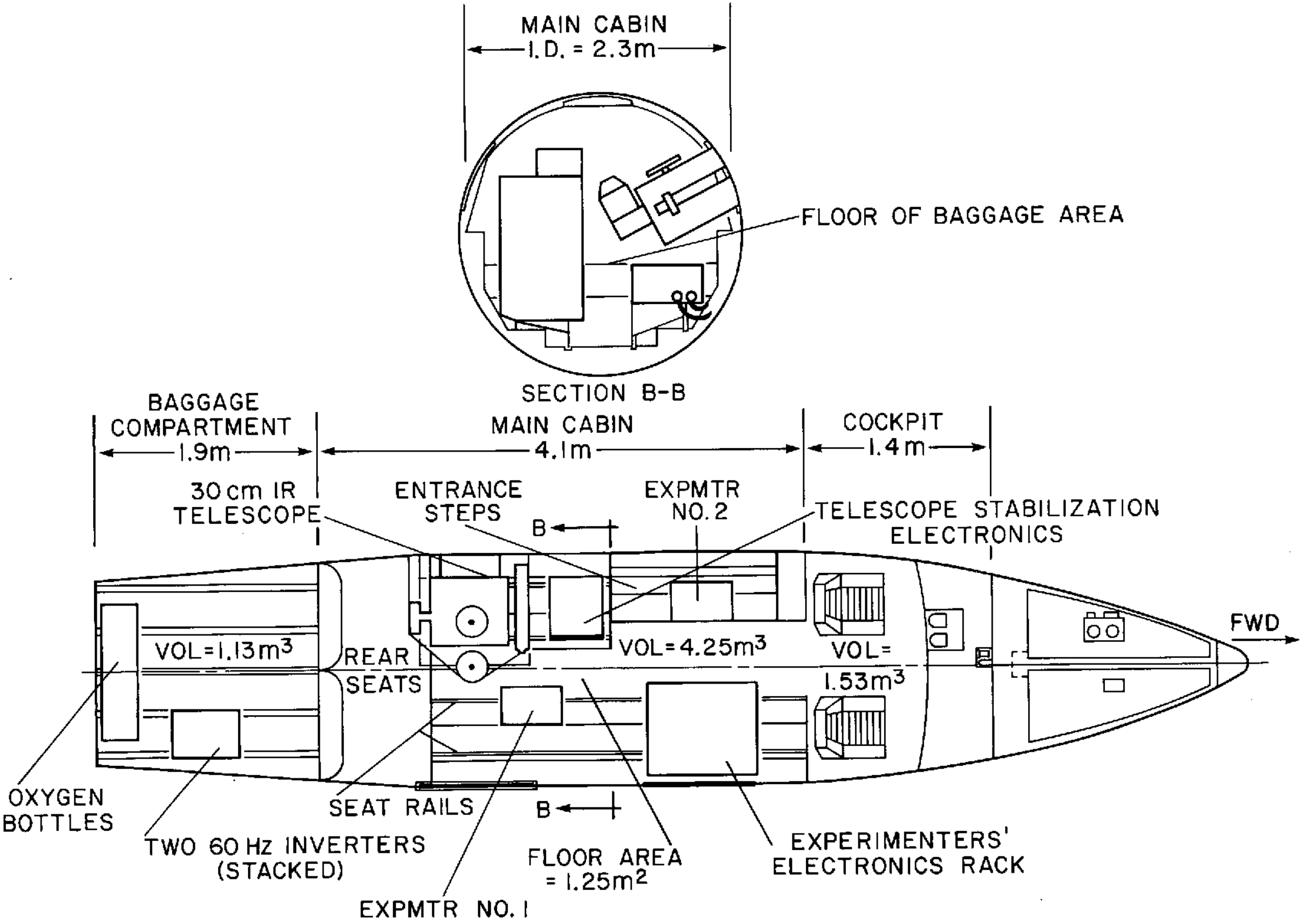

Figure 4.- Interior of Lear Jet, plan view.

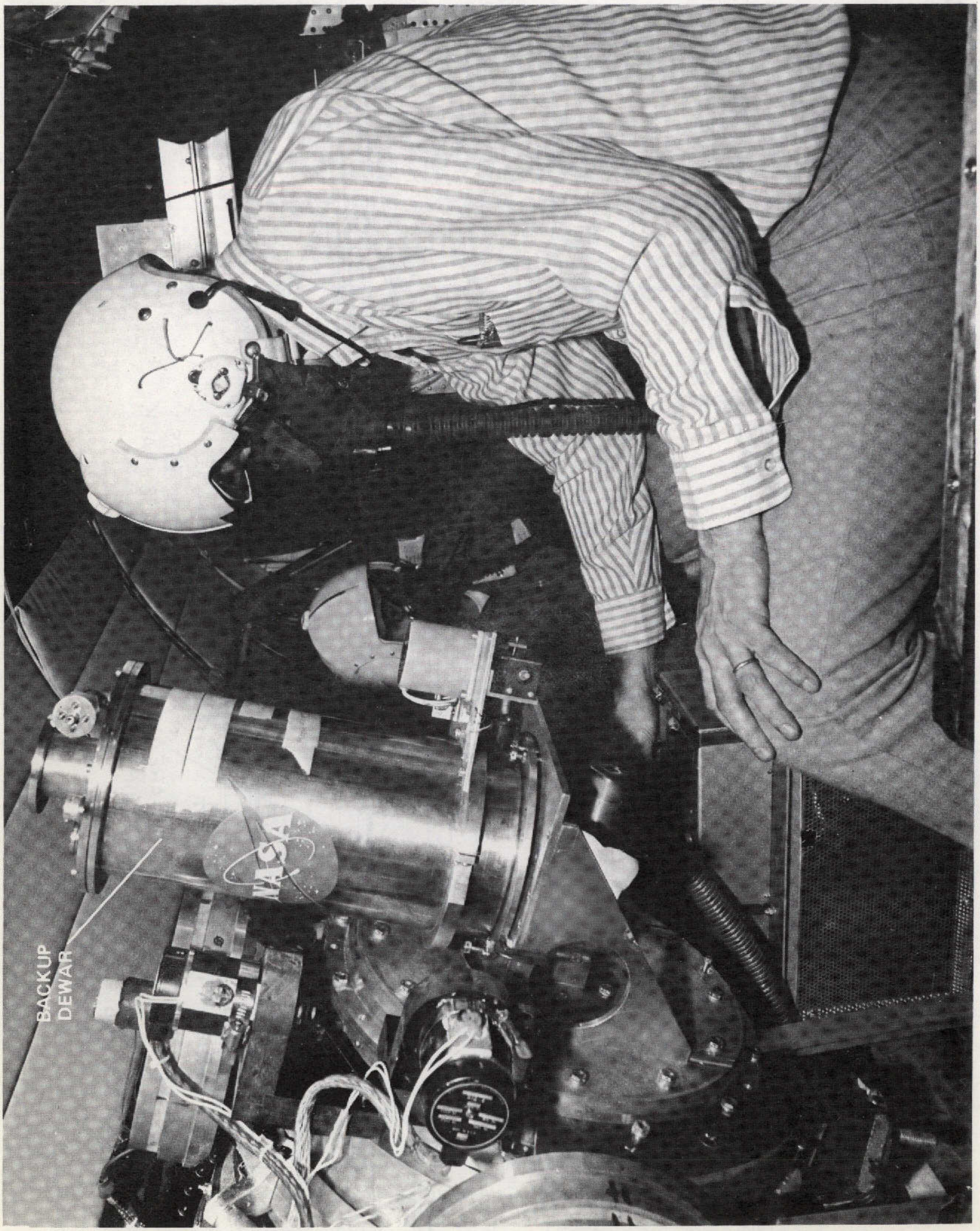

Figure 5.- Experimenters at work stations in aircraft cabin.

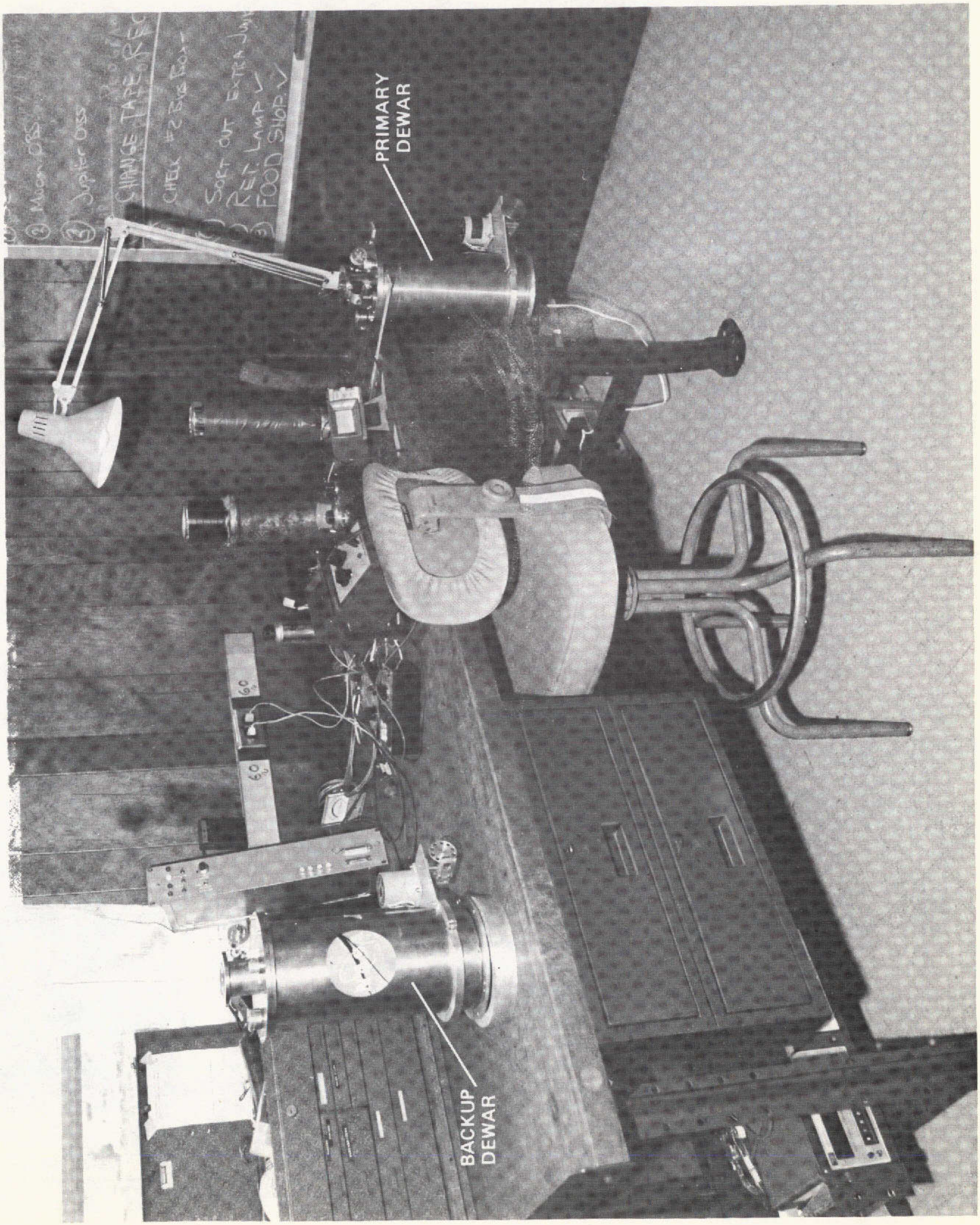

Figure 6.- Experimenters' bench in work area.

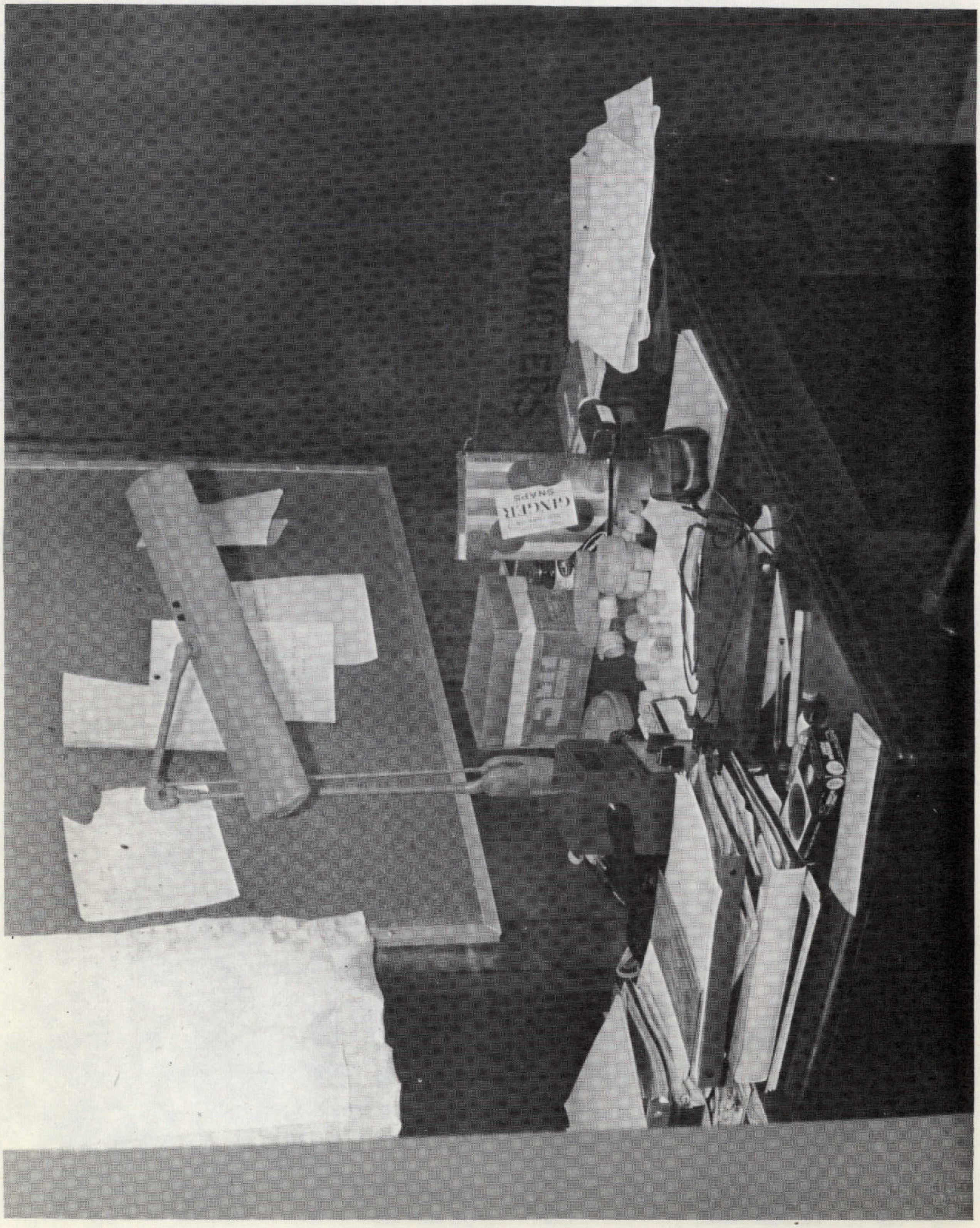

Figure 7.- Experimenters' desk in work area.

Figure 8.- Data center in work area.

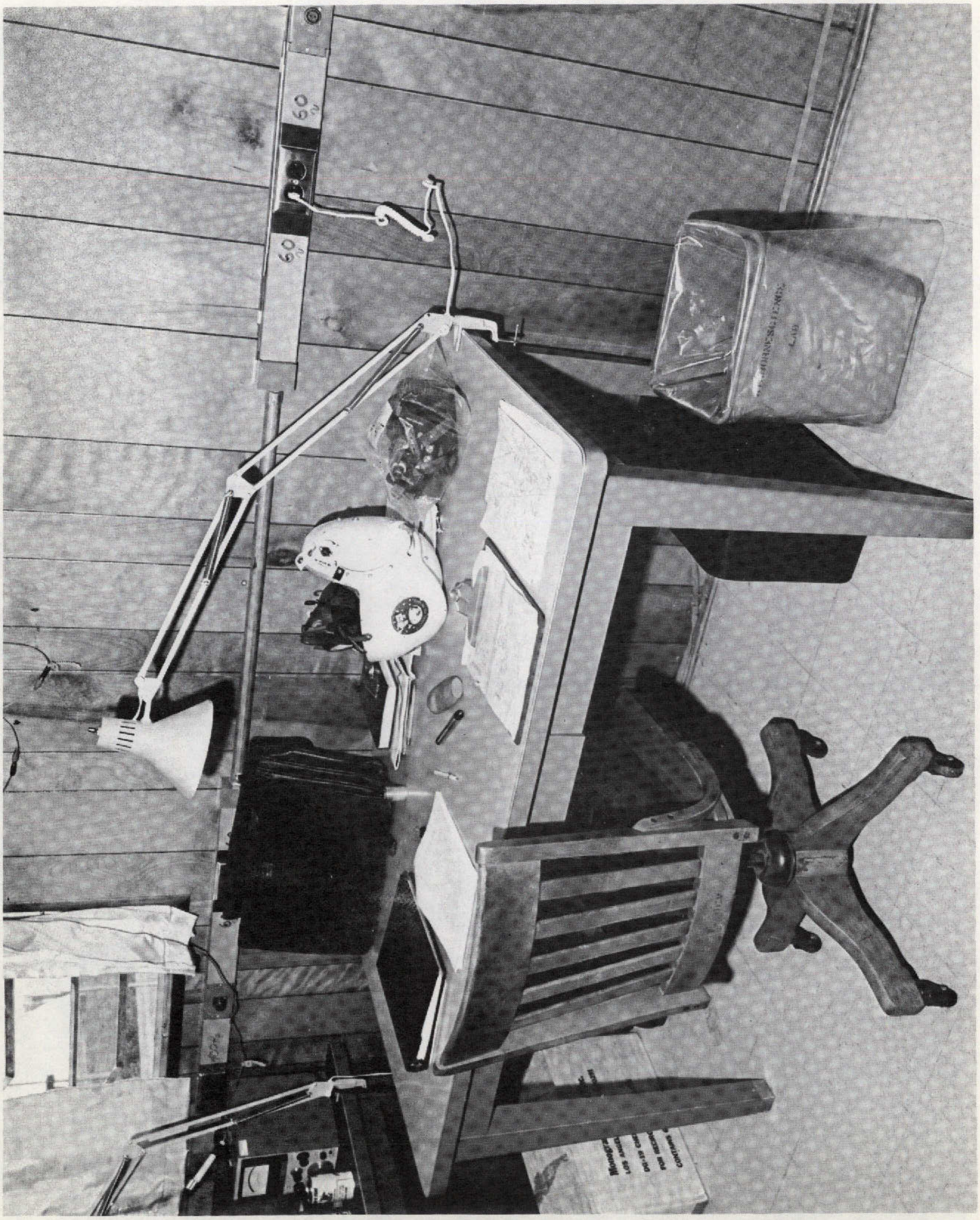

Figure 9.- Copilot's table in work area.

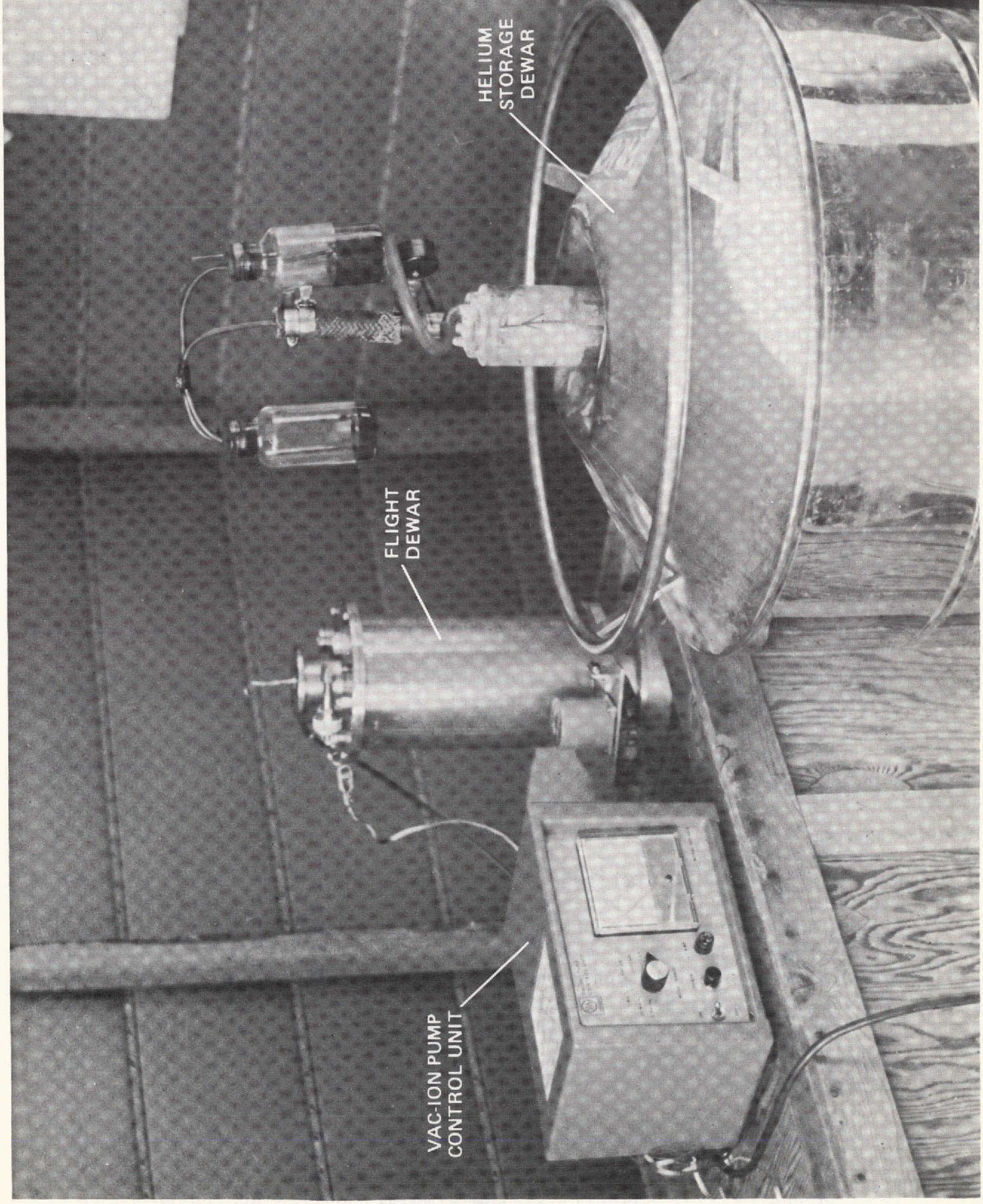

Figure 10.- Liquid helium storage Dewar and vac-ion pump for filling flight Dewar.

Life support systems installed at the simulation complex were electric power, city water, and sanitary sewer service. The living quarters and work area had separate air-conditioning and heating systems. 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. ASO personnel in the ASSESS program arranged for daily meals during the mission. A precise time schedule for eating was not established in advance, but was left to the simulation crew.

Weather permitting, all flights were to originate and terminate at the simulation complex. From there, the aircraft was towed to the hangar area for maintenance and refueling, and returned at least 2-1/2 hr prior to the next flight, to allow the experimenters to perform experiment maintenance. Final preflight inspection and occasional minor maintenance was done at the site. If the aircraft was at the hangar prior to flight, the crew could be transported there by car for the preflight checkout and returned to quarters at the completion of post-flight experiment maintenance.

Operations

Schedule- A 14-week period for experiment preparation and testing was established by ASO personnel and the experimenters. On-base activities were scheduled for a 3-week period, the first week for experiment integration and checkout flights, the second for the Spacelab simulation mission, and the third (backup) week as a contingency reserve either for the simulation mission or for a normal unconstrained flight series to obtain additional scientific data.

The dates of the simulation mission were chosen to provide viewing opportunities for the experimenters' primary targets and for in-flight calibration measurements on the Moon.

Premission period- An experiment installation and flight checkout period was scheduled for the week prior to the start of the simulation mission. Installation began on Monday, with a daytime engineering check flight and an evening science checkout flight on Wednesday. On Thursday, a rehearsal of all preflight, flight, and postflight aircraft and experiment operations was scheduled at the simulation site, with a second science checkout flight in the early evening. Friday was reserved for final tune-up of the experiment and a backup science flight in the event of an unforeseen delay. The weekend was scheduled as a 2-day "hands-off" period for rest and relaxation.

Mission activities- The plan called for the simulation mission to begin at 1400 on the following Monday with a briefing session, after which the experimenters and the copilot/observer moved personal belongings to the trailer quarters at the simulation site and based there until the debriefing meeting on Saturday morning at the end of the mission. Mission activities were coordinated through the mission control center. All contacts with the "Shuttle" crew were handled by telephone through the ASO mission manager, or in his absence, through the ASSESS representative on duty; outgoing communications were recorded in a telephone log book.

The ASO mission manager for the Lear Aircraft 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. Flight planning was handled in the normal manner by the ASO flight planner, on a day-to-day basis as requested by telephone from the experimenters. Flight plans were based on information on targets and scheduling furnished at the start of the mission, as well as current input from the experimenters, and were posted in the work area at the simulation complex.

Astronomical targets and the sequence of observations had been selected by the experimenters 3 weeks prior to the mission and were a firm part of the mission plan. A flight request for specific observation times was submitted prior to the initial briefing. The immediate preflight, inflight, and postflight activities were defined in a detailed Flight Operations Plan formulated by the aircraft operations group. The daily scheduling of experiment maintenance, sleeping, eating, and use of free time was left to the discretion of the simulation crew.

Aircraft ground operations included refueling and scheduled maintenance in the hangar area, with minor maintenance and preflight inspections at the simulation site. For departure and recovery, the aircraft taxied under power between the simulation site and the runway. Following recovery and the experimenters' postflight activities, the aircraft was towed to the hangar for servicing, and back to the simulation site either on request, or not less than 2-1/2 hr before the next scheduled flight.

Support operations- To the extent possible, the support operations plan followed the normal procedures of ongoing Lear Jet research programs, in which overall coordination is provided by the ASO mission manager, the focal point of the operation. The mission manager initiates 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 function, and the round-the-clock schedule were planned in cooperation with the ASSESS program manager and representatives of the various support groups.

The Aircraft Services and Inspection Branches serviced and maintained the aircraft on a 24-hr-a-day basis, and supplemented the normal spare parts inventory with replacements for several critical items whose failure would interrupt the mission for 1 day or more. Special preventative maintenance was done on the aircraft prior to the ASSESS mission. Standby fire protection was provided at the simulation site.

Support activities of the Flight Operations Branch were their normal functions, adjusted to the time schedule of the simulation mission. The Aircraft Operations Office is normally in radio contact with the aircraft while in flight and within radio range. The duty officer monitors local weather conditions, relays messages, advises the ground crew of expected landing time, etc. During the flight periods, the ASSESS representative on duty was to transfer to the radio communications room in the hangar.

Aircraft pilots are assigned to ASO research missions on a rotating basis by the Flight Operations Branch, at the written request of the ASO mission manager; normally, a different individual serves as command pilot for each flight. He participates actively in the operations planning for the flight, accepting responsibility for special taxiing arrangements and adherence to the aircraft activities schedule and safety procedures set forth in the Flight Operations Plan. Copilot duty for all flights of the simulation mission was the responsibility of a scientist/astronaut from Johnson Space Center.

The Ames Security Branch arranged for the use of roads for aircraft towing and taxiing, and planned traffic control measures, day-time site isolation, and night security patrols. Security guards arranged for road blockades to be set up along aircraft taxi paths during takeoff and landing.

Support for flight planning and aircraft navigation was provided by the ASO, using normal procedures. The experimenter's request to observe a specific astronomical target(s) is submitted through the ASO mission manager to the flight planner for implementation. The observation schedule for this mission was set up in advance, and the flight planner had outlined the flight requirements previously. Thus, it was necessary only for the experimenter to confirm the schedule each day and the flight planner to update for local weather conditions. When completed, the two flight plans for the next night were delivered to the command pilots and to the experimenters. After reviewing the plan and making the necessary arrangements, the pilot filed by telephone with local flight operations. Because of the prearranged flight schedule and the coordination provided by the mission copilot, the command pilots did not review plans with the experimenters prior to flight, as would normally be the case.

Safety

Flight safety is of prime importance in all ASO operations, and normal precautions for the protection of personnel and equipment are well established. Plans for this simulation mission differed mainly in procedures for handling the aircraft on the ground, with additional minor variations to allow for inflight use of a special copilot-experimenter intercom loop, and to monitor the health and safety of the experimenters both in flight and on the ground. Safety requirements applicable to experiment design followed the normal practice described in the Lear Jet Experimenters' Handbook. Key operational safety rules and contingency procedures are outlined in appendix A. The experimenter must interface with several individuals as well as specific Ames groups to ensure safe operation. First, of course, the direct participants in science flights, experimenters and pilots, have an immediate personal interest in flight safety. The ASO mission manager, with his overview of the entire flight program, also is in a unique position to identify and correct any design or operational deficiency that may be a safety hazard.

The Airworthiness Engineering Group of the Flight Operations Branch is specifically charged to review in detail the equipment design, stress analysis, and operating procedures associated with each airborne experiment and to require conformance with established safety practices. The Airworthiness and Flight Safety Review Board (AFSRB), appointed by Ames management, has overall responsibility for the flight safety of airborne missions, and its members are experts in appropriate disciplines. Unique or unusually complex experiment designs for which no precedent exists may be referred to the Board for evaluation.

The aircraft group of the Ames Inspection Branch ensures that the assembly and installation of experiments conforms to accepted aircraft standards, and inspects both aircraft and experimental equipment prior to every flight. They have the authority to suspend operations if unsafe conditions are not corrected.

Prior to every major or unique aircraft mission, a summary review is presented to the AFSRB, covering all new experiment designs, aircraft modifications, operational plans, contingency procedures, and other safety considerations. The presentation is made by the ASO mission manager, with participation by pilots, designers, ground operations personnel, representatives of the Airworthiness Engineering Group, and the experimenters as warranted. The chairman of the AFSRB must issue written approval of the aircraft mission before operations can begin. For this Lear Jet simulation mission, the review concentrated on the unique features of the experimenters' equipment, the mode of flight operation, and the arrangements for living quarters and aircraft handling at the remote site, since the infrared telescope installation and other experiment support facilities had been thoroughly reviewed by the AFSRB for previous airborne missions.

Finally, the normal safety procedures for flight training and physical fitness of experimenters were followed. Because of recent participation in an ASO Lear Jet mission, both experimenters for the simulation mission had current high-altitude flight certification from a nearby military installation and had attended local training sessions on Lear Jet life support systems and emergency procedures. In addition, both had current FAA class II flight physical certificates and a satisfactory condition of health, as verified by an examination by an Ames-approved physician immediately prior to arrival for the premission week.

Documentation

The Shuttle simulation mission followed the minimal documentation procedures normally employed in the ASO Lear Aircraft Program. Since this was not a new flight experiment, most of the information normally required of the experimenter was already on file with the ASO mission manager and/or with the cognizant safety engineers in the Airworthiness Engineering Group. This documentation included drawings of the telescope and cryogenic Dewar assembly, a cabin layout showing the location and attachment of the experiment to the aircraft structure, a stress analysis of the telescope support structure, and a listing of the experiment power requirements. The design of the experiment followed the experiment interface and design safety guidelines given in the Lear Jet Experimenters' Handbook.

Internal documentation for the ASSESS mission included an aircraft work order, issued by the ASO mission manager, for installation of the telescope and attendant electronic equipment. The work order served three functions: (1) notified the Metals Fabrication Branch of the task and authorized the fabrication of any necessary attachment hardware; (2) requested the Inspection Branch to inspect and correct or approve the final installation of all experiment-related equipment; and (3) requested the AFSRB to schedule a review of the safety aspects of the experiment and the Mission Operating Plan.

Two flight requests were initiated by the ASO mission manager, one for the checkout flights during premission week and the other just prior to the simulation mission, covering the entire flight series. This authorizing document was circulated to groups concerned with flight preparations and 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 this Shuttle simulation mission required some additional documentation. A Project Operating Plan was formulated by the ASO mission manager and the ASSESS program manager, and submitted to the Airworthiness Engineering Group for concurrence. The Flight Operations Plan used in a previous Lear Jet simulation mission similarly was reviewed. Both were approved by a full meeting of the AFSRB, and served as a guide for the simulation mission.

ASSESS Observation Procedures

The techniques, timing, and location of data collection for the ASSESS program were fully described in the Project Operating Plan, a copy of which was given to the experimenters for review and orientation. Initial activities centered on the design, assembly, and testing of experimental equipment at the experimenters' home-base laboratory. Subsequently, interest focused on the premission checkout and simulation phases at Ames.

Data collection techniques included direct observation, recorded experimenter conversations, and interviews. The primary technique was direct observation by specially trained personnel, who covered all essential activities during preparation and operation of the simulation mission except for the airborne operations, during which the Lear Jet copilot acted as observer and recorded his comments separately. To complement the direct observations, experimenters' conversations were tape recorded, particularly in those situations where the observer work load prohibited complete coverage of the activity or where the information was sufficiently important to require confirmation. To aid the analysis of timeline data from the inflight voice tapes, the copilot and experimenters were asked to describe specific events in narrative and chronological style. Although partly successful in producing narrative material, this technique yielded very little time-event information.

The aircraft intercom system provided three modes of communication. In the first mode, flight crew and experimenters were in separate, direct-talk loops with cross connection by button switches; in the second, the copilot and experimenters were in a direct three-way loop with pilot contact by button switch; and in the third, the copilot could record privately on a hand-operated cassette recorder. All conversations in the first two modes were recorded on a continuous-running voice recorder. In all modes, the command pilot was in continuous contact with ground control.

ASSESS observers documented the early stages of mission formulation and experiment development with information from the ASO mission manager and from telephone discussions with the experimenters. Component fabrication and testing were observed at the experimenters' facility and progress compared against the experimenters' milestone chart. Installation, checkout, and flight activities were monitored during the premission week by direct observation and interviews with experimenters and the copilot/observer, augmented by inflight recordings of crew communications and copilot observations.

During the simulation phase, the control center in the work trailer (fig. 1) was manned by an ASSESS duty officer and an observer at all times, except during flight when the team moved to the flight-operations radio room to monitor aircraft communications. An attempt was made to minimize direct observations during the mission and to rely on voice-powered tape recorders in the work area, copilot's recordings and written logs for sleeping and free-time activities, and brief postflight interviews with experimenters and copilots. This approach soon proved inadequate, and direct observations were gradually increased as required. The living quarters remained off bounds to the observers, however.

ASSESS observers attended briefing meetings at the start and end of the simulation period. The latter was a major source of information from the "Shuttle" crew, who not only responded fully to questions on all aspects of mission preparations and operations, but also made suggestions for the preparation of experiments for bonafide Spacelab missions.

THE RESEARCH EXPERIMENT

Scientific Method

Astronomical observations at wavelengths greater than 15 μ are severely limited by water vapor absorption in the atmosphere; above 22 μ, little radiation, if any, reaches the ground. However, just above the tropopause the water-vapor overburden is less than 1 percent of that at sea level, and 16 to 40 μ radiation can be measured with photoconductors cooled to near liquid helium temperature (4.2° K).

A Lear Jet aircraft flying above the tropopause at about 13.7 km (45,000 ft) was the airborne laboratory for this mission, in which the prime scientific objective was to record spectra of the Moon, Jupiter, and selected H-II regions (emission nebulae) in the 16- to 40-μ wavelength range. Both the hydrogen/helium ratio and the thermal structure of the upper atmosphere of Jupiter can be determined from measurements of the thermal emission as a function of wavelength in this band. Comparison of the observed hydrogen/helium ratio with that of the Sun indicates the degree of chemical fractionation involved in the formation of Jupiter and contributes to our understanding of the origin of all the outer planets. A computer program is available for determining both the hydrogen/helium ratio and the temperature structure from the observed spectra. The temperature profile should cover about a factor of 5 in pressure near the start of the convection zone in the Jovian atmosphere.

Similar measurements of the radiation from emission nebulae were first undertaken on this mission. These and succeeding data will be used to develop the thermal structure and composition of the nebulae in terms of temperature, molecular hydrogen and silicate dust particles. The Orion nebula, M42, was the selected target.

The Moon was used as an intensity calibration source for the experiment-telescope combination, in comparisons of measured spectra with those available from previous work.

Each of the two prime targets - M42 and Jupiter - required a separate flight every night, although there was some opportunity to observe both the Moon and Jupiter on a single flight. With only a single prime target to observe, the experimenters planned to make several spectral scans (first and second order), successively, on each flight, to provide verifying measurements and to allow for adjustments to peak performance. As it turned out, the experimenters made full use of the available observing time and requested an extra few minutes on several occasions.

The basic instrument was a LHe cooled grating spectrometer with a resolution of about 50, mounted with its entrance slit at the focal point of the 30-cm, open port, cassegrain telescope. Detector assemblies in the spectrometer were soldered directly to the base of the Dewar for maximum conductive cooling, and lead wires were arranged to minimize heat conduction to the detectors. Optical elements were also mounted firmly to the Dewar base to achieve as much conductive cooling as possible. Estimates of signal strength available from the telescope, compared to noise equivalent power of the detectors indicated ample signal-to-noise ratio for accurate measurements in signal integration times (~ 10 sec) commensurate with the constraints of airborne operation.

Experiment History

The experimenters for the second ASSESS simulation mission were chosen from among the participants in the ongoing ASO Lear Astronomy Program. The proposed research was in part a continuation of previous infrared observations on Jupiter in the 16-μ to 40-μ waveband, described above, with one additional scientific objective. Therefore, a part of the experimental equipment was already available. Some of this equipment, in turn, had been adapted from earlier research programs.

Active preparation of equipment for the experimenters' ongoing research effort began in June 1972 with modification of an existing sensor package, spectrometer, and photoconductors, to match the optical configuration of the Ames telescope. All the data-handling equipment was on hand except for a four-track tape recorder, which was purchased from a commercial source. Before the first flight series in November 1972, the entire experiment was operationally tested in the 1.5-m (60-in.) telescope at Mount Lemmon Observatory in Arizona.

Near the end of the first flight series, on November 15, 1972, an agreement between the principal investigator and the ASO laid the groundwork for this Lear Jet ASSESS mission. A formal proposal for the scientific research was submitted in late November, and amended in early December as more realistic estimates of the cost of experiment components needed to assure reliability during the simulation mission became available.

Soon after this, the experimenter decided to upgrade the science capability of his experiment, while at the same time providing for the reliability judged necessary to meet the constraints of the simulation mission. This decision had significant implications for subsequent events, as will be seen. The result was two experiment systems built along the same basic lines and having some interchangeable components, but with significantly different data-collecting and data-handling capabilities. The newly developed system was designated the primary mission experiment, while the older system, essentially the November experiment with slight modifications, was designated as the backup.

The decision of the principal investigator to build a new experiment to improve the science potential of the mission, rather than to make a one-to-one copy of the original, is a reflection of the flexibility and relative freedom inherent in the ASO management philosophy. Guidelines for the ASSESS mission emphasized reliability of performance and ease of maintenance; they did not require adherence to any prescribed approach.

Basic Instruments and Experiment Operation

Each experiment system consisted of a sensor package, signal-processing electronics, and data-recording equipment designed to utilize the Ames 30-cm, gyrostabilized telescope mounted in an open-port arrangement on the left side of the aircraft (fig. 3). The telescope is supported by a two-axis gimbal ring, the center of which coincides with the center of a circumferential air seal between the telescope and fuselage port. The air seal minimizes leakage from the cabin while permitting low-friction motion when the aircraft moves in roll and yaw.

Figure 11 is an external view of the telescope within the fuselage port and shows the spider-supported secondary mirror assembly within the port opening, an anti-buffet aerodynamic fence upstream of the opening, and a smaller opening for the 10-power guide telescope. At the right is a collimated light source in position for alining experiment optics.

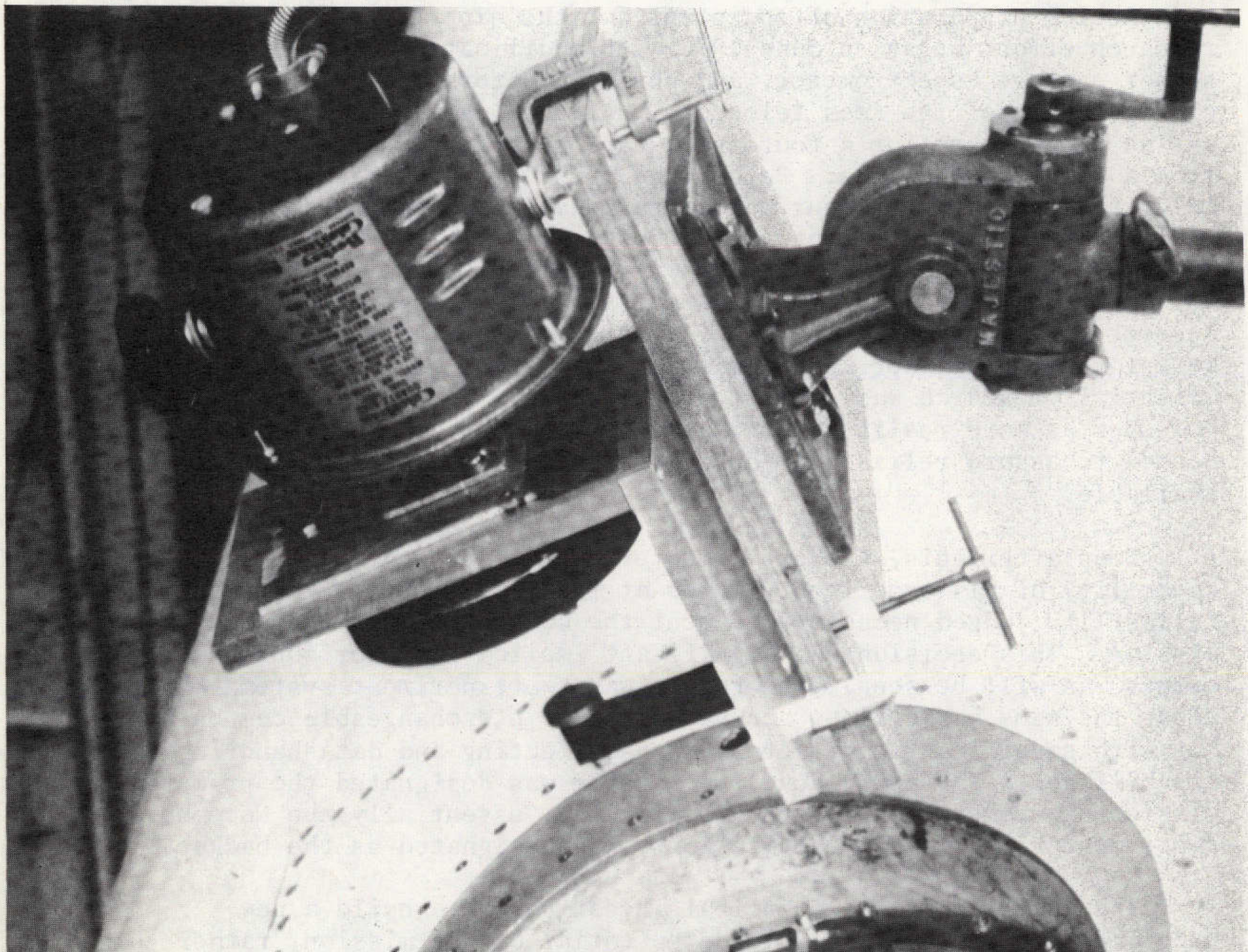

Figure 11.- External view of telescope port, with calibration light source in position.

Figure 12 shows the telescope assembly with its stabilization electronics package inside the aircraft cabin. The total weight of the telescope system is 125 kg (276 lb) of which 97 kg (213 lb) are in structure and gyro systems, 23 kg (51 lb) are in stabilization electronics, and 5 kg (12 lb) are in the manual control unit and cabling.

The primary experiment system used four closely spaced detectors in the sensor package to measure radiation in the 16-μ to 28-μ band; the detectors were copper-doped germanium wafers about 2 mm by 3 mm in size. The backup experiment system used only two detectors, one copper-doped (15 to 28 μ) and the other zinc-doped germanium (20 to 40 μ), and was designed for coverage of a 16-μ to 40-μ waveband with a similar grating spectrometer and liquid helium Dewar.

Radiation enters the spectrometer cavity, located below the Dewar, through an infrared window backed by the appropriate band-pass filter. This radiation already has been processed within the telescope so that the signal electronics can discriminate between the radiation of the astronomical target and the background radiation from the sky and from telescope surfaces. Very simply, the telescope viewing is rapidly switched (chopped) at a frequency of about 15 Hz between the target and the sky by the wobbling movement of the secondary mirror. In both positions, radiation emitted by the telescope and by the sky reaches the detectors. When the mirror is positioned to view the target, the radiant flux from this source also reaches the detectors, adding its effect to that of the background flux. Comparison of the signals from the two viewing positions by the signal electronics results in the cancelation of the telescope and sky background radiation, leaving only the voltage signal from the target.

Signal-Handling Electronics

The signal from each detector in the primary experiment was separately amplified and fed to a channel sequencer, which converted the four signals to two channels of coded, digitized data. The data were recorded on two of the four channels of the tape recorder; after processing by a voltage-to-frequency converter, the amplified output of one of the detectors was recorded on the third channel (analog channel). Experimenters' comments were recorded on the fourth channel. The two channels of digitized data were analyzed by a small computer after flight, while information on the analog channel was used for real-time audio monitoring as an aid in guiding the telescope. Figure 13 is a schematic diagram of this system.

In the backup system, the analog signal from the detectors was amplified and converted to a voltage-proportional frequency for audio monitoring and recording on two separate channels. The third and fourth channels recorded grating-position information and experimenters' comments, respectively. Data were recovered for postflight analysis by playing the two channels into a frequency counter and printing the digital output on paper tape. Figure 14 is a schematic diagram of this system.

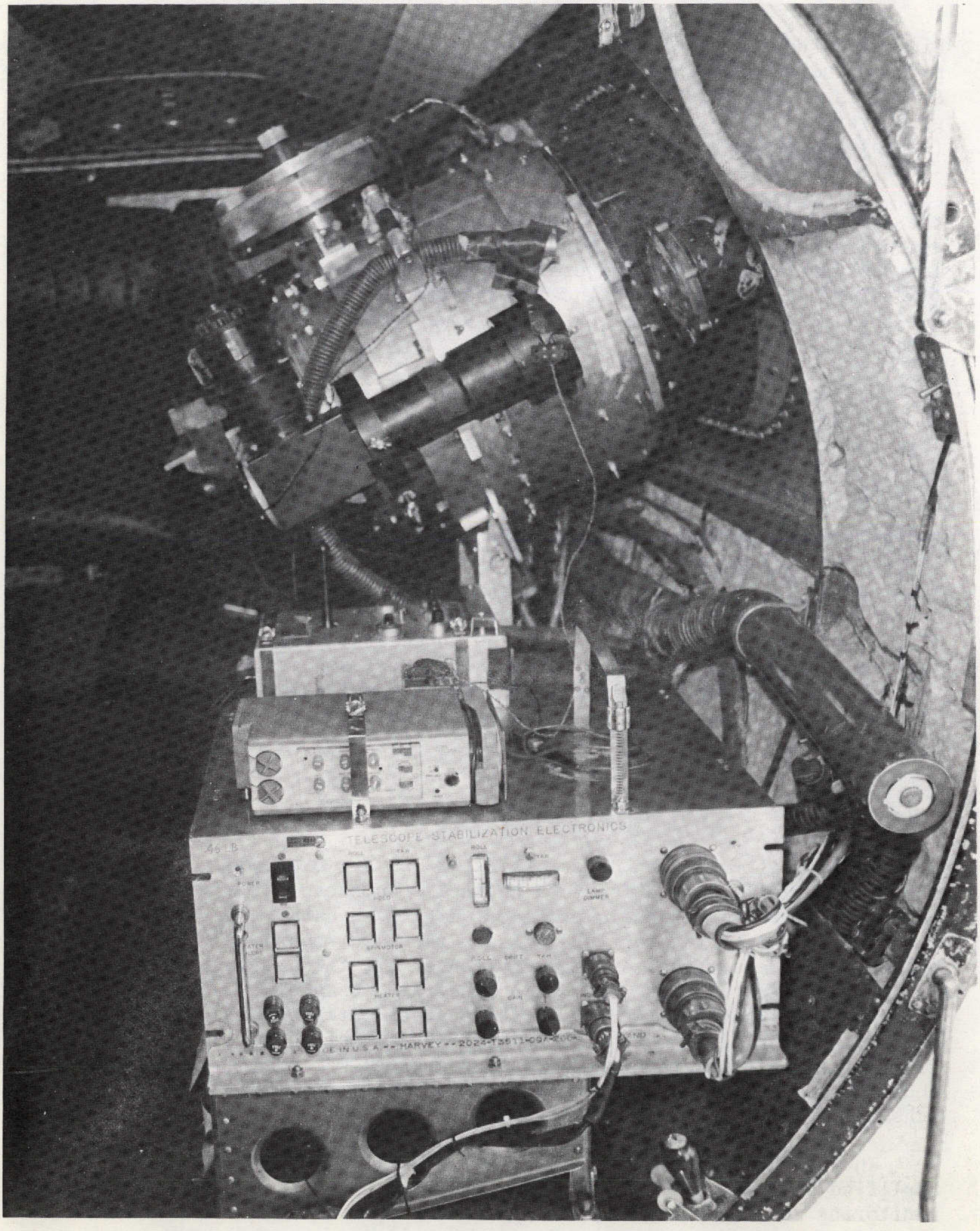

Figure 12.- 30-cm infrared telescope and stabilization electronics in aircraft cabin.

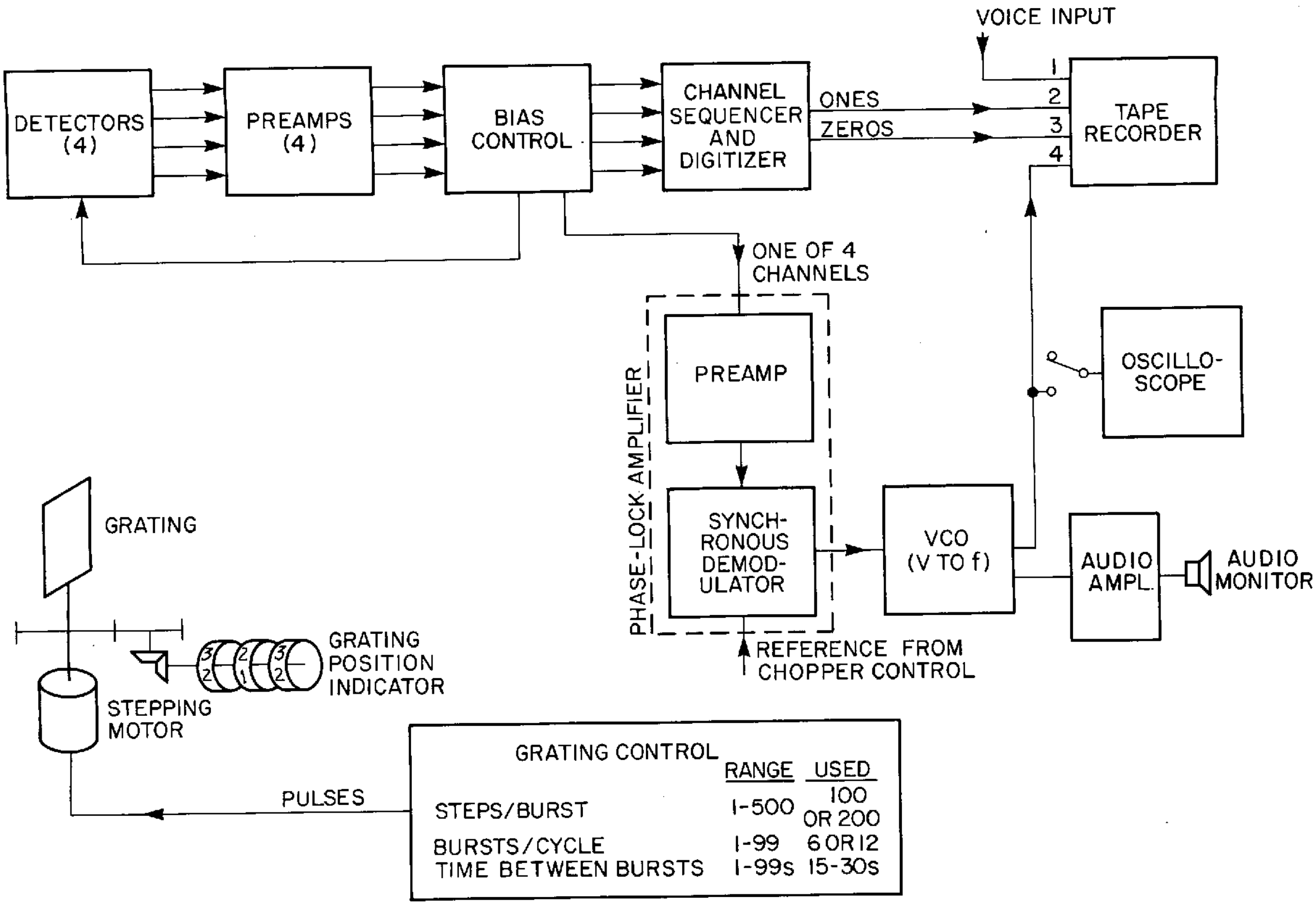

Figure 13.- Signal-handling electronics for the primary experiment.

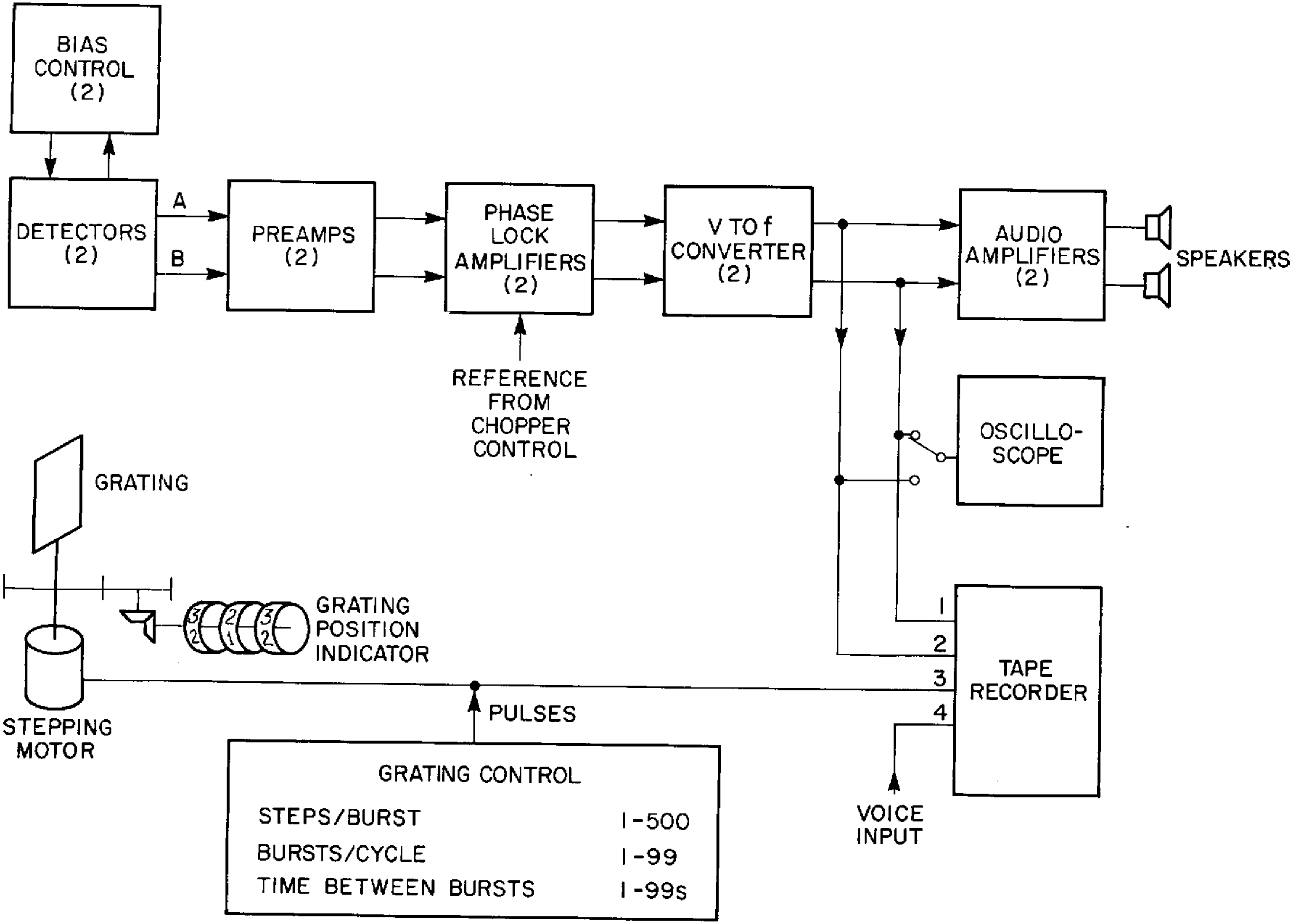

Figure 14.- Signal-handling electronics for the backup experiment.

Experiment Modifications

For purposes of the ASSESS mission, the experimenters modified their earlier Lear Jet experiment to ensure successful operation and to reduce chances of irreparable breakdown during the 5-day simulation period. As noted, they elected to achieve this objective primarily through building a second-generation experiment with enhanced scientific performance to complement their existing equipment, retaining as many components as possible common to both systems. In addition, the existing experiment was modified to improve operational procedures and data handling, and to provide several backup components. Major components built or purchased for the primary experiment are listed in appendix B. The experiment also used a data-processing computer on loan from the experimenter's organization (far left and far right units in fig. 8). This ground-based computer was programmed to accept the digital data format on flight tapes; using stored information, it could perform detailed data processing for between-flight analysis of results.

Relatively minor changes were made to the backup experiment; these are detailed in appendix B. This system used a small ground-based data-processing unit (center, fig. 8), purchased for the mission, to digitize analog frequency records on flight tapes. The unit printed out numerical results, which were manually plotted for analysis.

The primary experiment on the ASSESS simulation mission was superior to the original (backup) experiment in the following ways:

1. An improved optical filter at the spectrometer inlet.
2. Improved spectral resolution and shorter scan times with four-element detector array.
3. Greater signal strength from detectors selectively chosen for maximum sensitivity.
4. More accurate recording of basic data in digital format.
5. More complete and rapid data handling.

The use of only copper-doped germanium detectors limited observations to the 15- to 28-μ band, but the experimenters were willing to accept this restriction for the ASSESS mission.

Hardware Characteristics

Appendix C (tables C-1 and C-2) lists the components, type of construction, weight, and estimated power requirements for the primary and backup ASSESS mission experiments. Cost figures are also provided for equipment that was built or purchased as a result of funding for the mission; best estimates are given for items that were on hand or borrowed from other programs. Costs listed for the backup system were derived from current information on similar items.

About 40 percent of the components in both systems was built in the experimenter's laboratory, with the remainder almost entirely off-the-shelf units. Direct hardware costs for the primary experiment were about $10,000, and in-house design, fabrication, assembly (161 man-days for these three) and testing (30 man-days) were estimated at $15,000, for a total of $25,000. Corresponding costs for the backup experiment were $8,000 for hardware and $7500 for development and testing, for a total investment of $15,500; most of this investment had already been made for the earlier Lear Jet mission.

Thirty-two panel displays and other indicators were used to adjust and monitor operation of the primary experiment and the telescope (app. C). Sixteen were associated with the experimenters' equipment and 16 with the telescope stabilization system. The panel displays of the backup experiment are illustrated in figures 15 and 16; figure 17 shows the display for the telescope stabilization system. On the basis of his previous ASO flight experience, the principal investigator insisted that all new electronic gear have the power switch, a power indicator light, and a fuse at the right side of the front panel for ease of location at night and for rapid shutdown in the event of an emergency.

The Dewars of the primary and the backup systems are mechanically and cryogenically similar (figs. 5 and 18). Dewar preparation takes about 2 hr and involves an initial filling with liquid nitrogen, emptying, and refilling with liquid helium transferred from the storage Dewar by a hand-operated bladder pump. The internal temperature of the prepared Dewar can be held for 10 to 15 hr without further refilling. In flight, Dewar pressure is maintained nearly constant at 700 mm Hg by a hand-operated valve. Between flights it is stored under vacuum using an ion-type vacuum pump mounted on the top cover.

Except for telescope stabilization electronics, which are fan cooled, experimenter equipment and GFE are cooled by natural convection. This includes experiment-support equipment used in the aircraft and in the trailer work area.

Support Equipment

Detailed inventories of experiment support equipment, expendables, and reference materials are provided in appendix C (tables C-4 through C-9); usage of support items during the mission is indicated. The major categories of support materials are discussed below.

Tools- The experimenters were requested to limit on-board support equipment to items they considered necessary for a Spacelab mission. This constraint did not prove a deterrent for the principal investigator on the ASSESS mission, however, for he had developed a tool inventory tailored to his requirements as a result of extensive field experience at other remote installations. He supplied 177 items, nearly all of them small, commonly used hand tools (table C-4). The total estimated weight of this inventory was 22 kg (48 lb).

Test equipment- The experimenters supplied 14 items of test and maintenance equipment necessary to ensure proper operation of their experimental gear; 11 items were furnished by the ASO at the experimenters' request (table C-5). This equipment consisted predominantly of

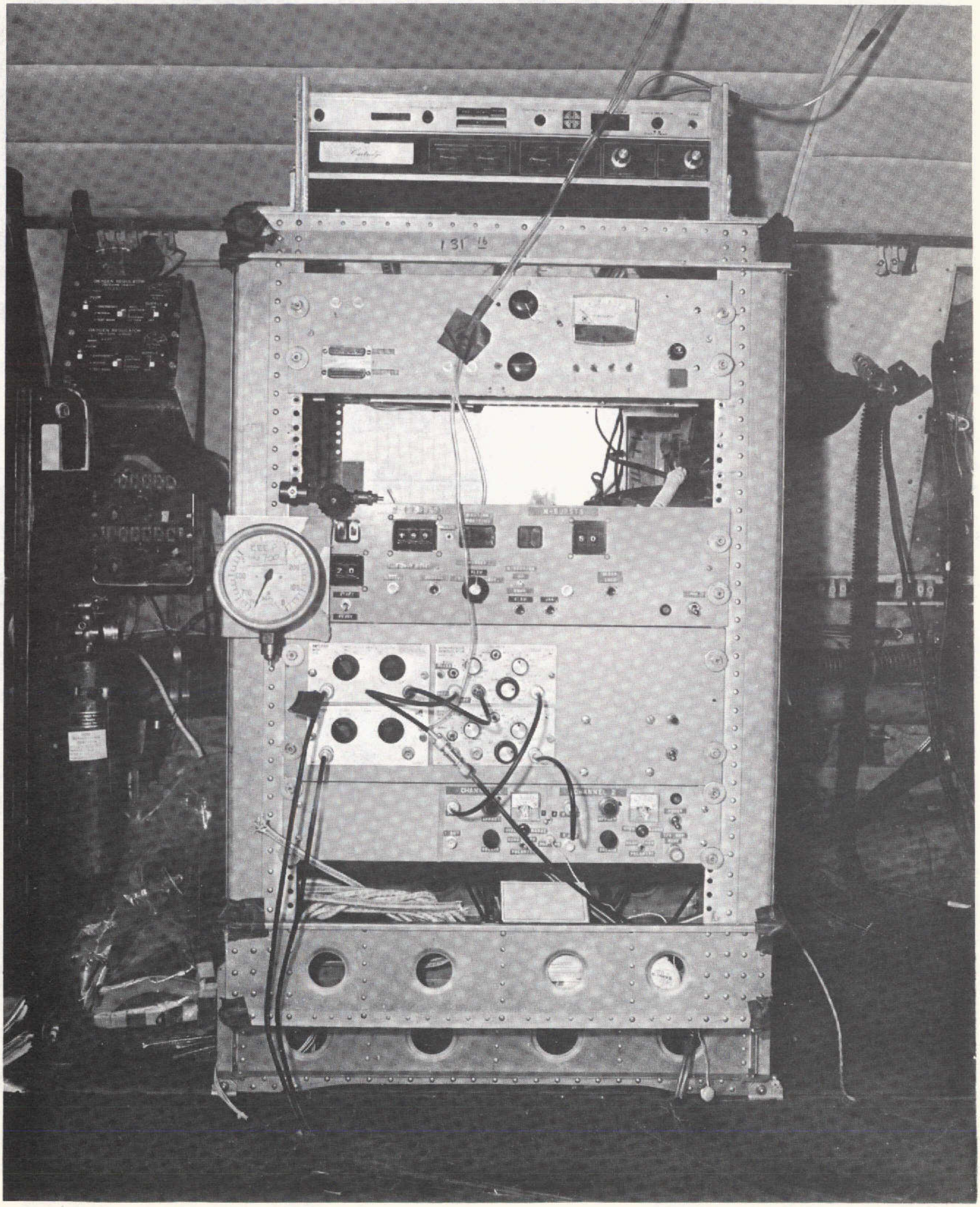

Figure 15.- Front view of electronics rack in Lear Jet, backup experiment.

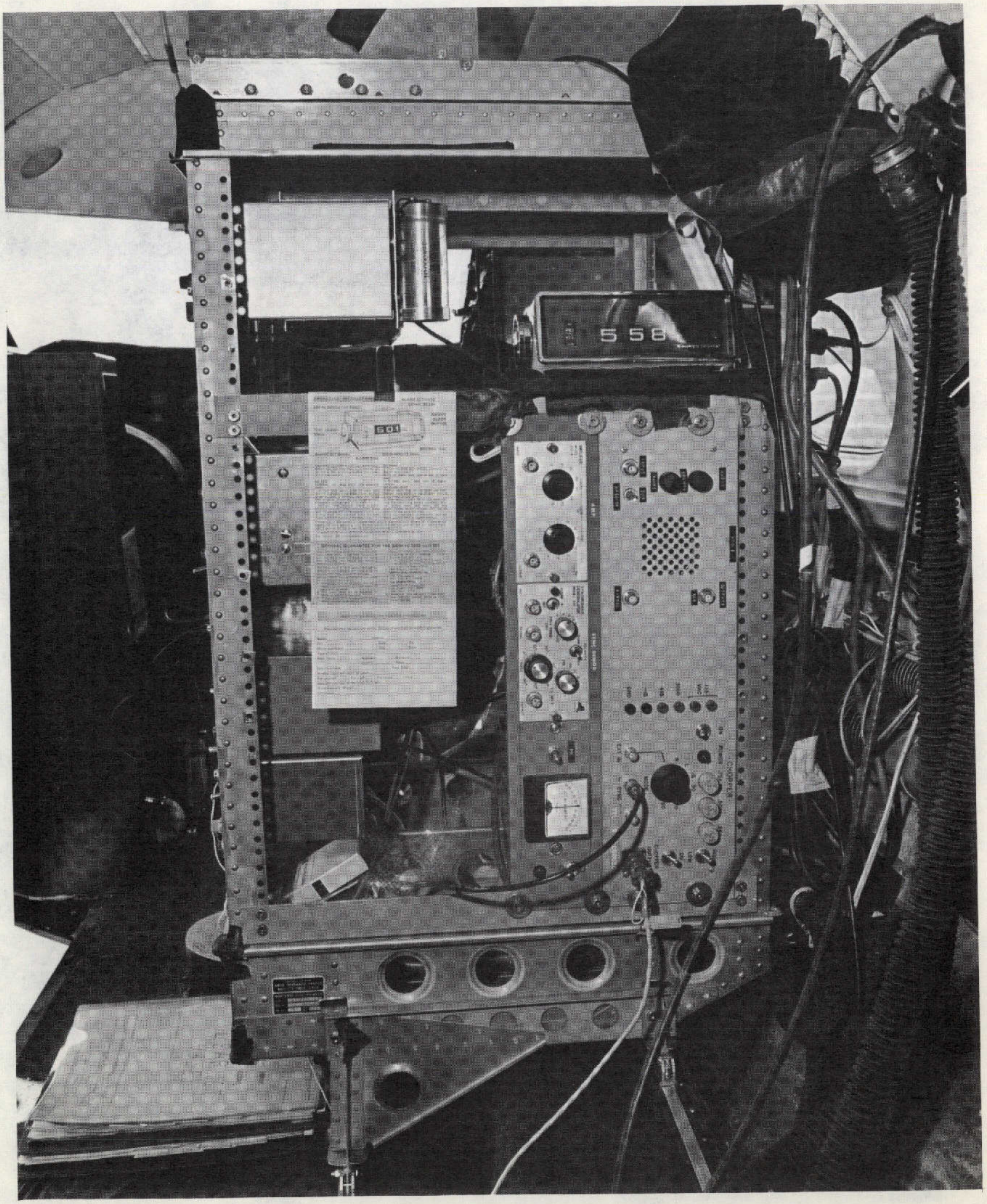

Figure 16.- Side view of electronics rack in Lear Jet, backup experiment.

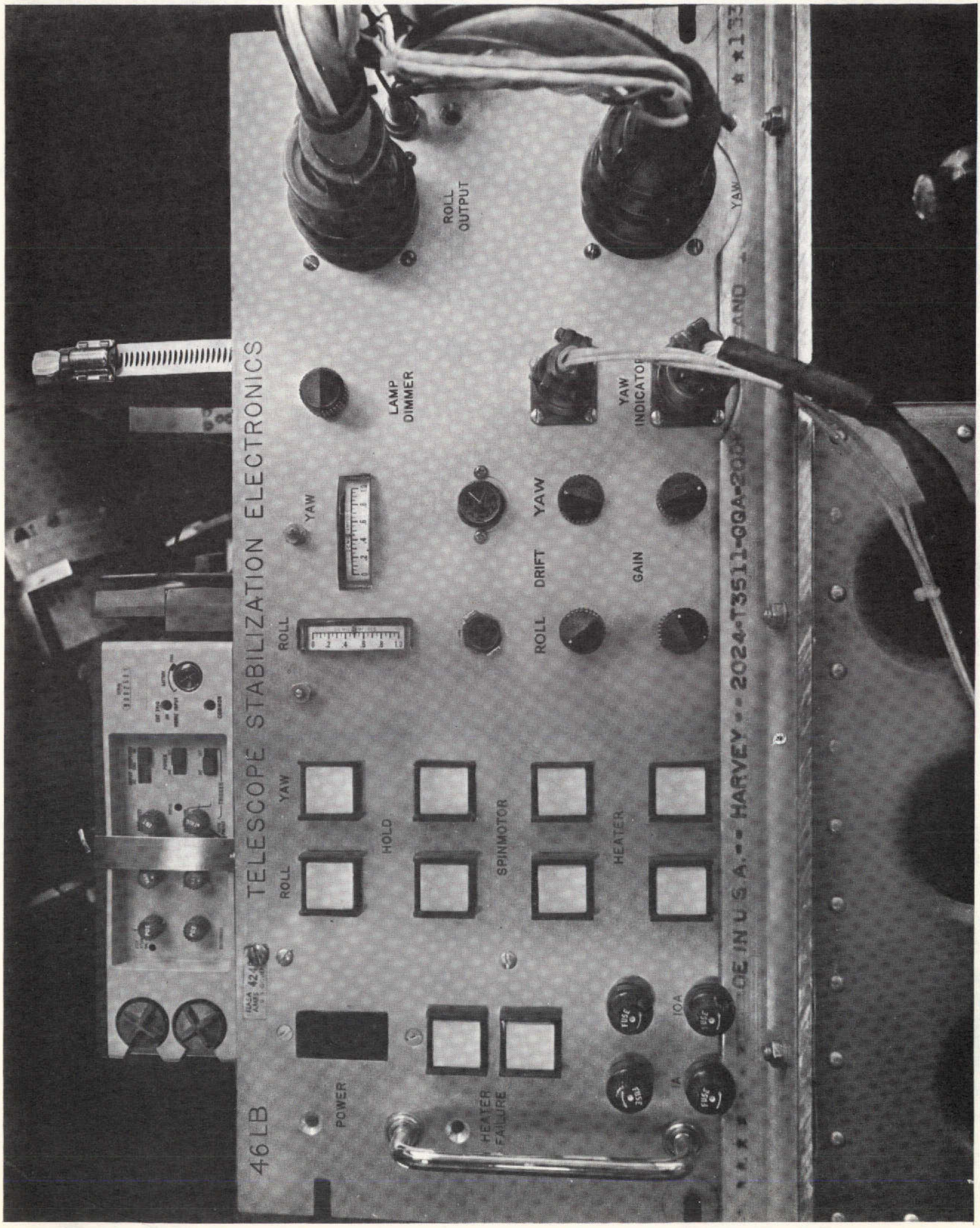

Figure 17.- Display panel for Lear Jet telescope stabilization system.

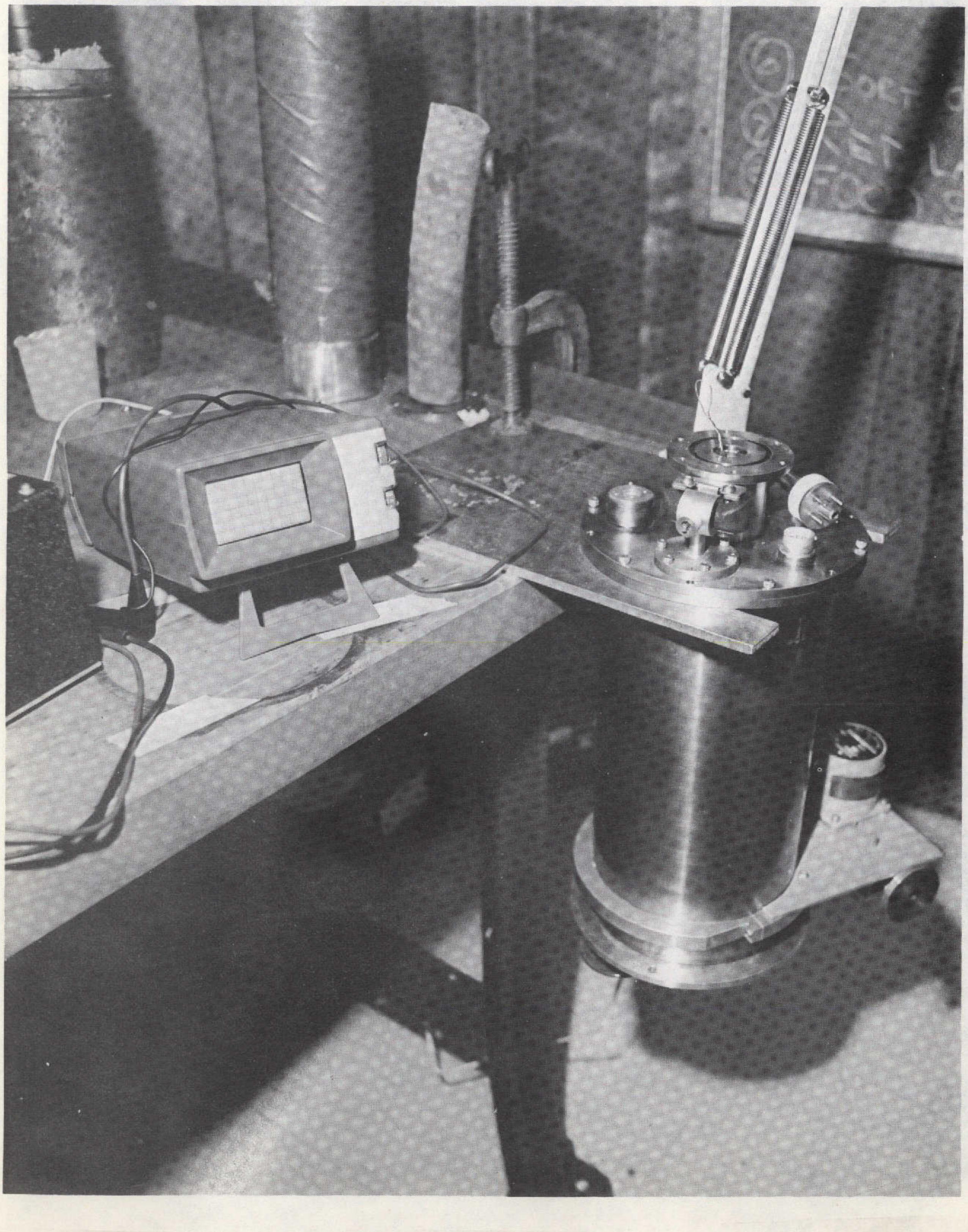

Figure 18.- Dewar from primary experiment mounted on workbench for repairs.

diagonistic devices for trouble shooting electronic circuits. Other equipment was used to aline optics of the telescope (fig. 11) or to provide dummy target sources for the experiment. Total estimated weight of the test equipment was 123 kg (270 lb). A telescope service cart was available but not used during the mission (fig. 19).

Spare parts- The availability of an almost complete backup system minimized the number of spare parts needed, and only a few were used (table C-6). The spares consisted of small mechanical, electrical, and optical items, with a total estimated weight of 3.6 kg (8 lb).

Supplies- A wide variety of supplies were brought by the experimenter (table C-7). A small part of these were expendables used in the normal conduct of the experiment. Most were intended for use in experiment maintenance, and the remainder were stationery items. Total estimated weight of these supplies was 11.4 kg (25 lb). Some expendable supplies also were furnished by ASO.

Documents- The experimenters brought several documents (table C-9). Most were provided for trouble shooting the signal electronics equipment with the remainder available as a source of astronomical data. Only a reference dealing with trouble-shooting logic circuits was utilized. Service manuals for commercial units also were furnished, as well as a schematic diagram for one of the commercial units.

Work area furnishings- Typical office furnishings were provided for the stowage and utilization of experimenter equipment in the trailer work area (table C-8). The utilization of the desks, tables, and other furnishings (88 percent) is not a true indication of possible Shuttle requirements for this type of equipment and work space. On the contrary, the experimenters tended to distribute their equipment to fill the available area or volume, noting that the surface area provided was more than adequate. In addition, only about 10 percent of the desk capacity and 50 percent of the storage cabinet (fig. 20) capacity were used. Future ASSESS missions may well incorporate some appropriate limitations on furnishings of this kind.

Utilization of support equipment- The utilization of mission support equipment is summarized below. Work area furnishings excepted, test and maintenance equipment was high with 65 percent, followed by supplies at 54 percent and tools at 37 percent. Spare parts and reference documents were barely touched, even though the original supply was very modest.

DATA SUMMARY

Item	Quantity		Percent usage
	Supplied	Used	
Tools	177	66	37
Test equipment	26	17	65
Spare parts	34	5	15
Supplies	108	58	54
Documents	14	1	7
Work area furnishings	17	15	88

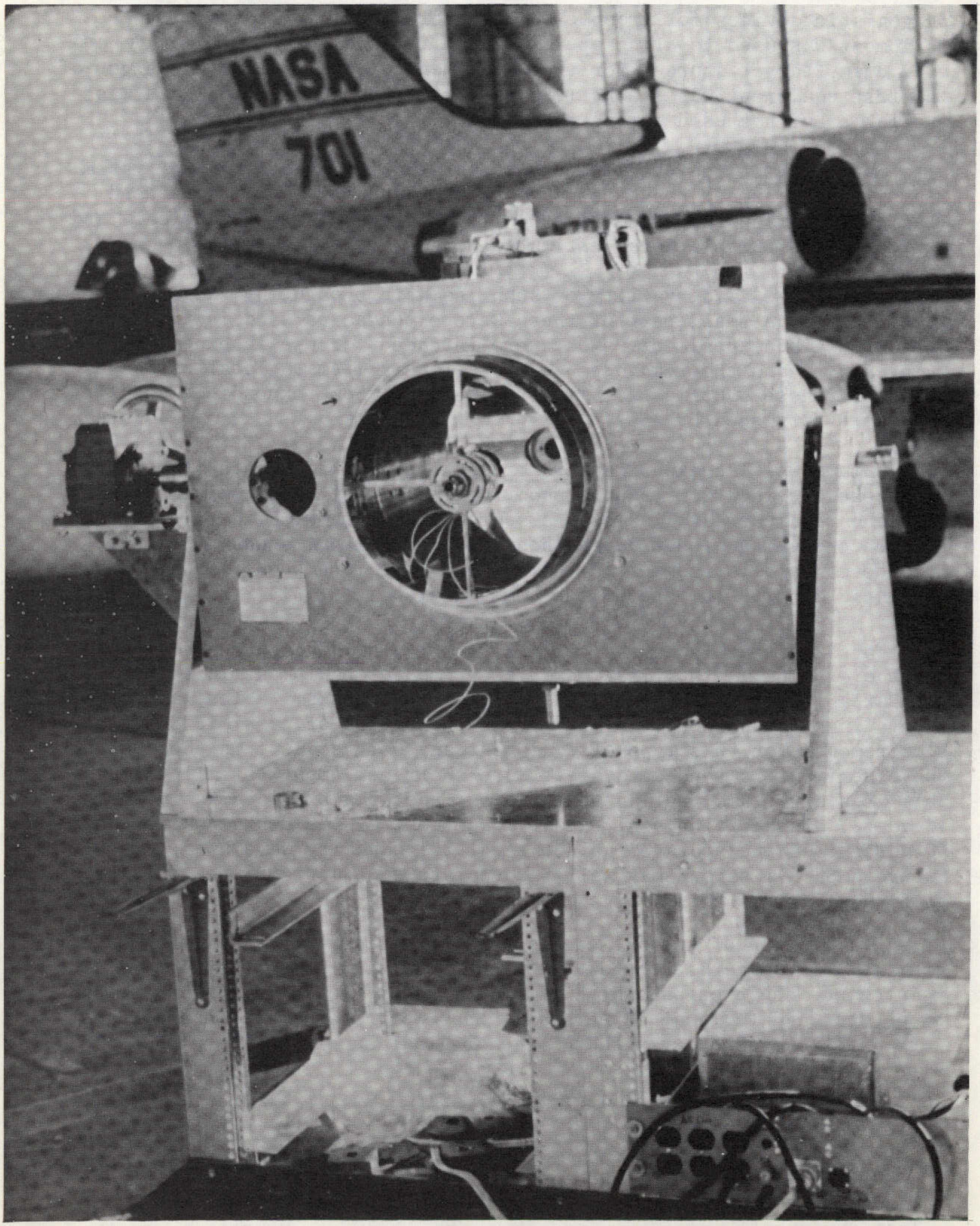

Figure 19.- Telescope service cart.

Figure 20.- Experimenters' storage cabinet.

ASSESS MISSION PREPARATION AND OPERATIONS

The scheduling of the experiment preparation, installation and checkout, and Shuttle simulation phases of the ASSESS mission is shown in the timeline of figure 21. A detailed chronology of events throughout the mission is provided in appendix D, together with supporting data on the individual mission phases discussed in this section.

Experiment Design and Assembly

The mix of experimental equipment assembled for this mission was intended by the experimenter to provide as high a probability of mission success as available time and funds would permit, and still provide an improvement in scientific capability. As a result of these requirements, both new equipment and proven existing equipment were used. Many components were interchangeable between the backup and primary equipment groups. Thus, if serious problems occurred in the primary experiment during the mission, the malfunctioning parts could be replaced with spares from the backup equipment, or the entire primary system could be replaced with the backup system.

The design and construction of new equipment for the primary system borrowed from experience gained in other programs at the principal investigator's university. The design of electronic circuits in particular followed the proven design of circuits initially fabricated for an earlier sounding rocket program. Space and weight reductions were achieved through the use of commercial integrated circuits and card-type construction (e.g., the channel sequencer unit, fig. 13).

The sensor package for the primary experiment was assembled using a commercially fabricated spectrometer body, an experimenter-built Dewar, and experimenter-built detectors for the 16- to 28-μ range. These detectors were more sensitive and less expensive than those available commercially.

The primary sensor package incorporated a number of improvements over the original (backup) system. The spectrometer had a simpler optical path in which the radiant flux was directed into a row or array of closely adjacent detectors, allowing more rapid scanning of the waveband of interest. This instrument can accommodate 16 detectors, although only 4 were available for the ASSESS mission. Another feature was the interchangeability of detectors between the backup and primary sensor packages. Although this exchange was not a simple task, it could be done without seriously impacting the observing schedule of a 5-day mission. Since detectors were hand-picked for optimum signal-to-noise ratio, the ability to transfer the best detectors to the sensor package in use was a desirable option.

An experiment preparation schedule (fig. 22) was developed by the experimenters in mid-January 1973. It reflects an ASO-approved postponement of 5 weeks in the mission starting date, occasioned primarily by an illness of the principal investigator and also by procurement lags

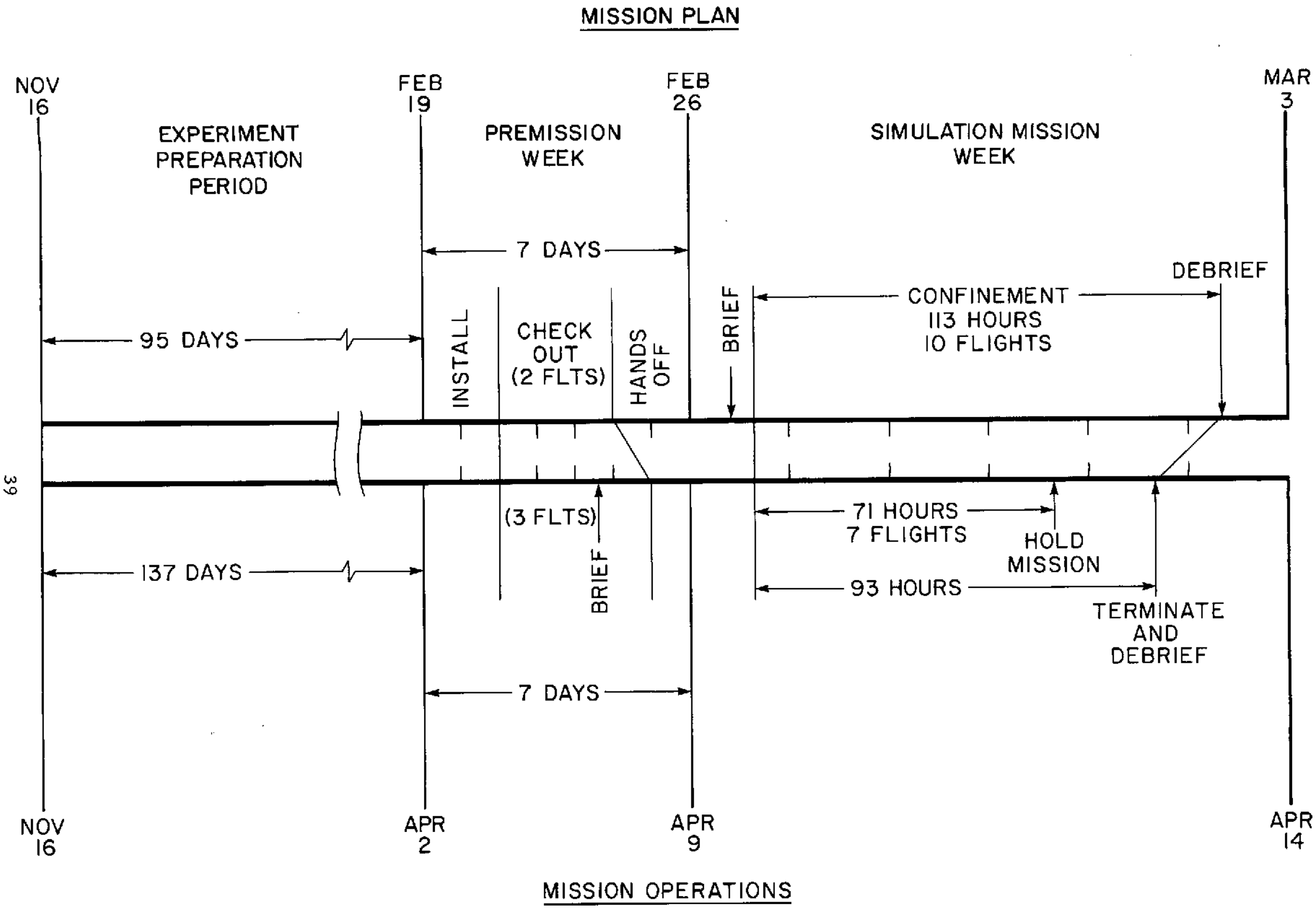

Figure 21.- ASSESS mission timelines.

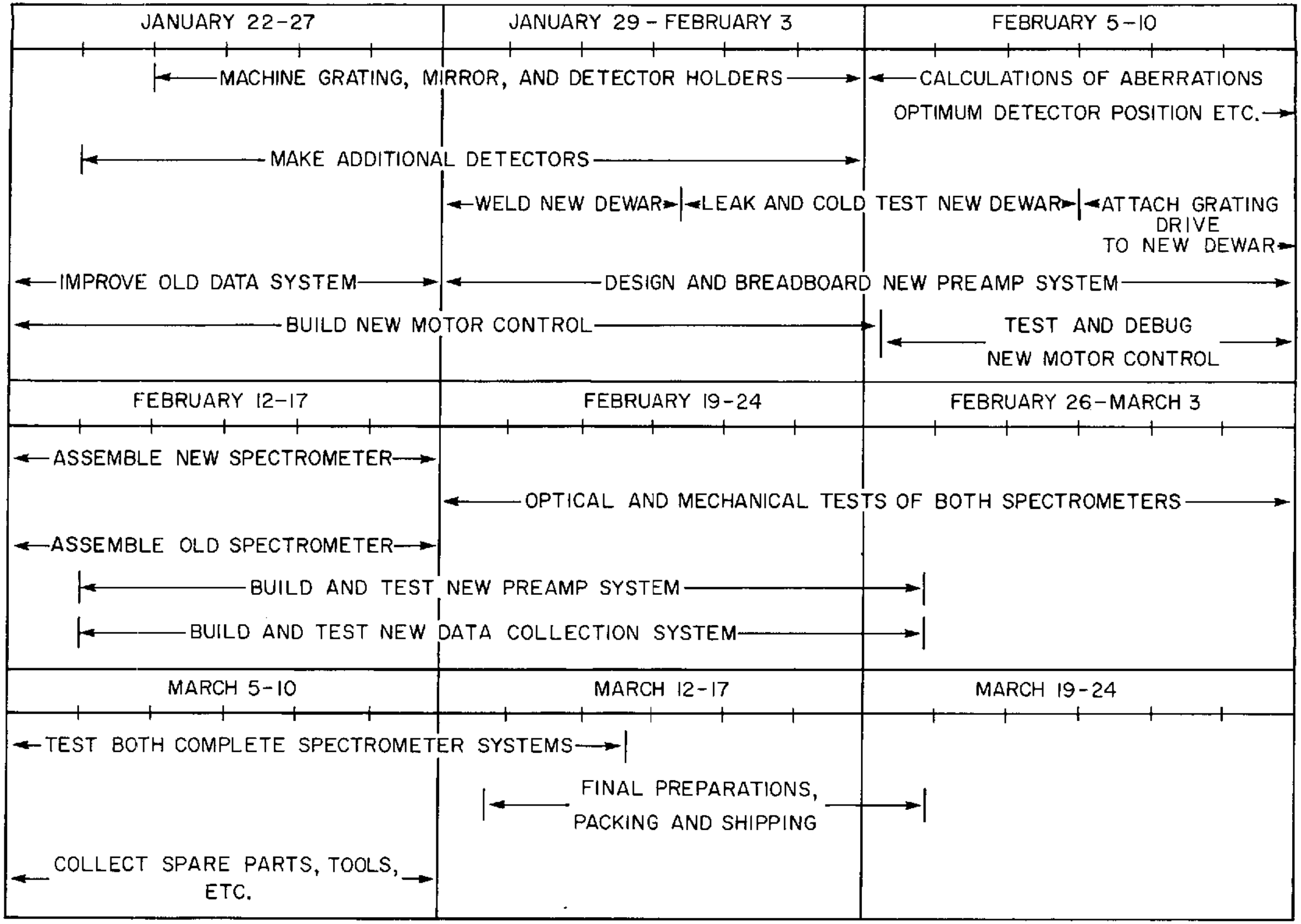

Figure 22.- Experiment preparation schedule.

traceable to grant funding delays. The revised schedule was generally adhered to, with a net slippage of 1 week at the end due to problems with the Dewar of the primary experiment.

The effort required to design, fabricate, and assemble the experiment equipment is summarized briefly below (in man-days) Detailed data on system components are provided in tables C-1 and C-2 (appendix C).

DATA SUMMARY

System	Primary experiment	Backup experiment
Sensor package	130.5	75.5
Signal electronics	27.5	10.0
Data recording and processing units	3.0	0.0
Total	161.0	85.5

Experimenter Testing at the Home Base

Testing of equipment at the experimenters' home base consisted of verifying the operation of components, subassemblies, and the completed primary experiment under normal laboratory conditions. The one exception was a stepping-motor control subassembly tested for response to power surges both at room temperature and during a cold-soak at -5°C. New components were tested against operational specifications when received from commercial sources and accepted or replaced; components (subassemblies) built up in house were tested at several stages of completion - as individual elements, as breadboard models, and as packaged units - following normal practices used in developing "one-of-a-kind" research equipment.

The new (primary) experiment was given a quantitative performance evaluation just before shipment, in which an IR signal was detected, processed electronically, recorded, and analyzed by the digital computer. About 1 man-day of effort was involved. The backup experiment was not tested as a complete system, although all subassemblies had been operationally checked and the more critical units tested individually to assure reliability.

Only normal laboratory test equipment was used in these evaluations. The experimenter noted that more extensive environmental testing (e.g., vibration sensitivity) would have been done if the appropriate equipment had been available at his home laboratory.

The experimenter's home base test effort is summarized below. Detailed data on this phase of the mission are provided in table D-2 (appendix D).

DATA SUMMARY

Component	Number of tests	Man-days of test effort
Sensor packages	9	17-1/2
Signal electronics	9	16-1/2
Data recording and processing units	5	1-1/2
Primary system evaluation	1	1
Total	24	36-1/2

Installation and Checkout

On Monday of the premission week the experimenters unpacked, assembled, and checked the operation of the primary experiment, from Dewar to digital computer. Electronic units were mounted in the standard Lear Jet rack, ready to be installed in the aircraft. In the evening, the Dewar was mounted on the Ames 30-cm telescope (in a specially constructed service cart) for focusing and alinement of the complete optical system. The system could not be properly focused, however, and considerable time was spent before it was found that the wrong spacer ring was installed in the telescope barrel (GFE). The spacer ring was replaced on Tuesday, and all equipment was installed in the Lear Jet. Optical alinement on a distant object was completed Tuesday evening. Total experimenter's effort to this point (before the first flight) was about 6 man-days, of which about 2-1/2 was testing activity.

Alinement and calibration of the primary experiment resumed Wednesday evening, following an afternoon check flight, using a small collimator and infrared source (fig. 11). Spectra were recorded both with and without a mylar filter to calibrate for wavelength. These calibrations were repeated on Thursday to verify both the procedures and the results; the additional testing time totaled about 1-1/2 man-days. During an early evening check flight, the primary experiment performed as expected, and it appeared that the installation and checkout were essentially completed. Total effort on this phase was 3-1/2 man-days of installation work, 4 man-days of testing, and about 2 man-days of effort related directly to checkout flights. (A final check flight scheduled for Friday evening required an additional man-day of effort.)

Early Friday afternoon, loss of vacuum and rapid boiloff indicated a bad leak in the primary Dewar, which was carefully examined with a GFE helium leak detector. No leak was found, and the Dewar was refilled for the evening flight in the normal manner. However, experiment performance was markedly inferior to that of the previous check flight, and noise encountered in the measurements obtained during the evening flight indicated a malfunction in the sensor package. Subsequent tests suggested the cause was a poor connection to one of the detector elements, although positive proof was never obtained.

This critical malfunction extended premission activities into the planned 2-day "hands-off" period, since the experimenters wished to isolate and correct the problem immediately. On Saturday, a side-by-side bench calibration of the primary and backup sensor packages was made; it was decided to switch to the backup experiment for the beginning of the mission and to repair the primary sensor package for later use, if time was available. Preparations for the change of experiments began on Saturday, resumed on Monday morning, and continued until time for the first mission flight. This extra effort added about 1-1/2 man-days of installation work and 2 man-days of testing to the premission total, which is summarized below.

DATA SUMMARY

Period	Installation	Testing	Flight activities
Before first check flight	3-1/2	2-1/2	0
During check flight period	0	1-1/2	3
"Hands-off" period	1-1/2	2	0
Total	5	6	3

Flight Program Planning and Execution

Planning for the overall flight program and schedule of scientific observations began with the choice of astronomical targets and definition of scientific objectives by the experimenter in his proposal for the ASSESS mission, dated November 21, 1972. At that time, the primary targets were Jupiter and "selected H II regions." By February 6, the Orion Nebula (M42) had been chosen as the primary H II source and an alternate was under consideration. On March 13, the two primary targets were reconfirmed and the experimenter requested daily observations on both targets, M42 in the evening and Jupiter in the morning. This request was validated by the ASO flight planner on March 14, and on March 26 the ASO mission manager, with the experimenter's concurrence, scheduled the installation and checkout flight activity for the premission week. These and subsequent events in the planning and implementation of the mission flight program are outlined in table D-3 (appendix D).

Checkout and installation of the experiment were completed on schedule, and the first daytime checkout/calibration flight of April 4 was successful. The evening flight of the day was aborted because of a malfunction in a GFE experiment support system, and was rescheduled to follow a second daytime calibration flight on April 5. This early flight was subsequently delayed by about 3-1/2 hr and the night flight was again put over to the following day. The flight planned for April 6 was completed on schedule.

As a result of experiment equipment problems on the last premission flight, the experimenter switched to his backup system and requested that the first flight of the simulation period be for calibration of the backup system using the Moon as the target. The remainder of the observation schedule would be flown as planned, and was so listed in a formal request to the Flight Operations Branch on the morning of April 9.

With the exception of an additional equipment checkout flight on the afternoon of April 11, the planned flight schedule was followed without event until the time of the CV-990 accident on the afternoon of April 12. Shortly thereafter the ASSESS mission was placed on "hold" status for 1 day and then terminated. Although the experimenters were ready to continue the planned flight schedule, the Ames Flight Operations Branch was directed to suspend all operations.

Scheduled and performed flight activities during the simulation period are summarized in table D-4, where planned flight initiation time, flight duration, and opportunity for scientific observation (time on track) are compared with actual events. Except for an aircraft-related problem that delayed takeoff on flight 5, all operations were carried out within a few minutes of the scheduled time. The experimenters made full use of the available observing time, although on flight 4 an experiment malfunction prevented the acquisition of any valid scientific data. On flight 5, the checkout and calibration of equipment began before the scheduled track time to allow for the desired verification of experiment performance.

On normal science flights, the experimenters averaged better than 90 percent utilization of the available observing time; on the basis of total flight time, a full 40 percent was spent collecting scientific data.

The actual sequence of observations during any given flight remained flexible, and the scan sequence primarily was based on real-time judgments of the results as they were being acquired. Although the experimenters were familiar with the operation and capabilities of their own equipment they were relatively new to the research environment. Consequently, much of the routine for in-flight observations was developed during the mission on a "learn as you go" basis. This approach contrasts sharply with the first Lear Jet simulation mission in which the experimenters, by virtue of extensive previous flight research, could follow established observation procedures and make progressive adjustments to the flight program (e.g., day-to-day selection of targets) for maximum scientific return.

During the premission week, both the ASO flight planner and the senior pilot for the Lear Jet met with the experimenters to review the planned flight schedule and discuss any special requirements. As in most ongoing flight series in the ASO Lear Astronomy Program, flight planning during the simulation period required minimum interaction between the experimenters, the ASO flight planner, and the pilots, largely because the flight schedule was set up prior to the mission.

With the two exceptions previously noted, the flight schedule was carried out according to plan. The flight planner updated each night's flights for current weather conditions, and copies were transmitted to the experimenters and the assigned pilots, who reviewed the plans, made the necessary operational arrangements (e.g., fuel load required), and filed with local traffic control. No contract with the experimenters was necessary, other than casual conversations just prior to flight. Inflight changes to the flight plan were negligible throughout the simulation mission; in only two cases were short extensions of observation time requested to complete target scans.

Experimenter Decision Points

Embedded in the chronological flow of events that comprise the preparation and performance phases of this mission is a series of experimenter decisions that gave direction to the development effort and determined the nature of the final research product. A number of these are identified in table D-5 by type (normal or mission-peculiar) and by date, with decision factors and available options. Decisions typified as "normal" were influenced mainly by quality of scientific measurements.

The major, mission-peculiar decisions that gave direction to the development effort were made in the first few weeks, while later decisions of this type were primarily concerned with schedule delays. One in particular had unique implications and far-reaching results. Near the end of the experiment preparation period it became apparent that the schedule for the primary (new) system would not be met in full. Although operation of the complete system had been verified, problems remained with the Dewar and the computer (ground based), and a second detector array was not completed. An extension of time was indicated, but outside circumstances were in opposition. Viewing opportunity on M42 was rapidly diminishing as Orion moved toward the Sun; 3 to 4 months would pass before this target was again available. Beside the impact of such a delay on the ASSESS-oriented aspects of the mission, a competitive advantage would accrue to another team of IR astronomers who were viewing M42 in the current period. A real-life decision was made by the experimenters late in March to hold to the mission schedule, utilizing their new experiment to best advantage.

Schedule Impacts

Schedule slippages during the first Lear Jet simulation mission (ref. 1) were attributed to procurement delays that were compounded by a delay in funding. It also should be noted, however, that those experimenters had elected to build a new and improved version of their cryogenic Dewar and detector system rather than refurbish or duplicate existing units. Although this decision could be defended as increasing the science potential of the experiment, this one system (both directly and indirectly) twice caused a delay in the schedule of the first mission.

To avoid a similar time constraint on this second Lear Jet simulation mission, the present experimenters were apprised of the experience of the previous team and encouraged to study the tradeoffs between reliability and science potential in their own experiment to assure that a mutually agreed time schedule could be met. As a result, the original schedule was negotiated for a period of 14 weeks from selection to "launch," essentially the same as in the first mission.

Despite the groundwork thus laid, several factors combined to cause schedule delays. Illness and funding lags were noted previously. Moreover, the experimenters again elected to develop an experiment having greater science potential, rather than merely upgrade the reliability of their existing system. As a result, about 9 weeks into the home-base development period it was necessary to postpone the mission date by 5 weeks. A second postponement of 1 week was requested just 2 weeks prior to the "launch" date, when problems arose with two major components of new equipment.

In this respect, the present and prior simulation missions are remarkably similar. That is, with relatively free choice in the use of available funding, the scientist was motivated to seek rewards in new and untried areas of research, rather than to "play it safe" with minor advances beyond accomplished results, even at the expense of much additional work and the attendant risk. It is recognized, of course, that the constraints and penalties associated with these ASSESS simulations (to date) are far less stringent than envisioned for Spacelab operations; this factor itself may encourage risk taking, since the potential scientific rewards outweigh the known penalties. In a larger sense, however, this willingness to assume risk should not be discouraged in the Spacelab era since, with flexible and frequent scheduling of orbital missions, scientists can produce experiments utilizing the most recent advances in technology to enhance their scientific potential. It is important, of course, for Spacelab planners to minimize time between experiment selection and flight date.

Schedule impacts in the early days of the premission week were due to GFE problems. Experiment installation was delayed for half a day while spacing rings were changed on the telescope, but was completed in time for the first scheduled checkout flight on April 4. The second flight of the day was aborted when an aircraft inverter malfunctioned. A practice session for ground-support personnel at the remote site culminated in a successful checkout flight on April 5, although minor GFE problems delayed the takeoff by about 3-1/2 hr.

On Friday, April 6, the experimenters encountered what at first appeared to be a leak in the primary Dewar. Experiment performance during the evening checkout flight, however, indicated a malfunction in the detector system. The potential severity of this malfunction virtually forced the experimenters to use 1 day of the "hands-off" period to seek a solution. All day Saturday was devoted to isolating the failure, evaluating the repair options, and (as a last resort) preparing the backup system for full operation. Sunday was used for rest as planned.

On Monday morning, final preparations for the simulation mission were interrupted when the second member of the experimenter team was grounded with an ear problem by the Ames medical doctor. Rather than delay the mission, a decision was made to substitute the copilot/observer as a backup experimenter operator. His extensive experience as a scientist/astronomer was valuable background training for this assignment, so much so that he quickly learned the operating procedures unique to this experiment and performed creditably on the first flight.

With no time to spare, the backup experiment was installed, the backup operator was trained, and the first flight of the simulation mission took off on schedule. At the experimenters' request, this flight was used for calibration of the backup experiment using the Moon as target, rather than the M42 data flight originally planned. After this calibration flight, the original schedule of scientific observations was resumed.

A serious malfunction of the experiment on the early morning flight of April 11 was resolved in time to add a short daytime flight at 1500 the same day to verify experiment performance after repairs; no time was lost, and the original flight schedule was resumed at 1900.

The final and most serious impact on the schedule resulted from the crash of the ASO CV-990 on April 12, which forced cancellation of the remaining four flights of the Lear Jet simulation mission. At this time, all mission activities were going smoothly and would no doubt have been completed according to plan.

The varied and serious nature of problems encountered just before and during the simulation period is viewed as a realistic test of the skill, ingenuity, and dedication of the mission experimenters. That they were able, with assistance from the copilot/observer, to meet nearly all of their planned schedule of observations is a significant indication of the potential performance of involved scientists in the Spacelab program.

ASSESS MISSION RESULTS

With the major problems of permission week resolved, the simulation mission went according to plan until the CV-990 accident forced cancellation of the last four flights. Favorable weather allowed all flights to originate from the remote site, making for a more isolated and self-contained operation than was achieved during the first Lear Jet ASSESS mission. Ten science flights were planned; six were made. The first flight was to calibrate the backup experiment, five were on planned targets, and four were cancelled for reasons external to the mission. One additional flight was initiated during the mission to verify experiment performance after a malfunction was repaired. When terminated, the mission was on schedule and operations had become routine.

ASSESS observation results on several aspects of the simulation mission are discussed in this section. Supporting data are provided in appendix E.

Experiment Performance

Performance of the experimenters' equipment during the "Shuttle" flights was generally satisfactory but by no means trouble free. During the premission checkout flights a number of problems surfaced, and the more critical of these were resolved. Other less serious problems were accepted and monitored to prevent serious effects. It is fair to say that these chronic difficulties were quickly recognized by the experimenters as equipment design limitations whose effects they had not anticipated due to inexperience in flight research. Table E-1 describes these and other problems that occurred during the premission week and the simulation mission.

ASSESS simulation missions follow the normal ASO practice of making several checkout flights prior to a Lear Jet mission, wherein both the experimenter and his equipment are exposed to the full flight environment. Significantly, the experimenters in this second ASSESS simulation mission identified 10 malfunctions or operating problems in their equipment during the 3-day checkout period, and in each case were able to effect a repair or devise an alternate solution that did not delay the simulation mission. By far the most serious malfunction was the sudden deterioration of signal from the helium-cooled IR detectors in the primary experiment during the third checkout flight. Time constraints forced the experimenters to switch to their backup system, an effort that required them to work for 1 day of the "hands-off" period and to change the first mission flight from M42 to a calibration run on the Moon. This extra effort plus the necessity of training a backup operator to replace the second experimenter who had become ill, very nearly caused the mission to be delayed or aborted.

In addition to the malfunctions in their own equipment, the experimenters had to contend with three optical problems in the GFE telescope during the premission week. Two alinement and focusing problems were promptly resolved, but the third, the reticle in the sighting telescope, remained marginal for sighting on diffuse sources even with additional illumination.

Problems of an optical nature did not occur in the first simulation mission (ref. 1) because the telescope was part of the experimenters' equipment and had been developed by them; furthermore, they had used it on numerous previous ASO missions with continual upgrading of components over a period of several years.

Problem frequency was reduced during the simulation mission as a result of the experience gained during the checkout flights. Of the four problems that occurred in the experimenters' equipment, the most serious was a faulty Dewar seal that prevented data acquisition on the fourth flight. This was an admitted oversight by the experimenters, which was rectified after flight and confirmed during the subsequent checkout flight (afternoon of April 11). Of lesser significance were two problems resulting from the changeover from the primary to the backup experiment and the limited time available to optimize the performance of the latter system. The slight optical misalinement noted on the first and second flights, and the marginal gain of the signal electronics noted on the third flight are in this category. Both were fixed after flight. A fourth and minor problem was a jammed cartridge in the magnetic tape recorder on the seventh flight, which was resolved before observations began so that no data were lost.

Only one significant GFE problem surfaced during the mission to hamper data acquisition. On the last two flights, the telescope stabilization system developed an erratic yawing motion that required close attention by the principal investigator for compensation. The problem was difficult to diagnose, but a tentative fix was made by Ames support personnel following the seventh flight; the mission was terminated before this repair could be verified. This experience is akin to that observed on the first Lear Jet mission where, despite familiarity with their own equipment, the experimenters had a guiding problem that persisted through four mission flights before being identified with a misalined yaw-axis gyroscope.

Equipment Maintenance

Maintenance activities of the experimenters in support of their own equipment (and GFE telescope optics) are detailed in table E-2, which includes a short description and the time period for each task. During the integration and checkout period there were seven electronics, four optics, and three mechanical tasks, while during the mission period there were four, three, and five, respectively. Total maintenance effort during the simulation mission averaged about 6 and 10 hr of each 24-hr period, respectively, for the principal investigator and his assistant. Work not accounted for in table E-2 is classified as minor, general maintenance of an unspecified nature.

Maintenance equipment and backup units were of critical importance to mission success. As described earlier, a malfunction of the detector in the primary experiment ultimately necessitated the last-minute substitution of the entire backup experiment. A relatively large number of tools (37 percent) and maintenance equipment (64 percent) were used in attempts to diagnose and correct this problem, including such units as electrometers, multimeters, and oscilloscopes. The experimenters' extensive research experience in the field served them well in this emergency, as evidenced by an almost exclusive use of their own tools and diagnostic units, with very minor reliance on equipment supplied by the ASO. Little use was made of spare parts, as such. The available supply was quite small (34 parts), only five of which were used (table C-6). Use of expendable supplies in maintenance activities similarly was rather modest, and of some 65 maintenance-type items available (table C-7), only 22 were put to use during the simulation period.

Power Usage

The nominal power requirements of the primary and backup experiments are given in tables C-1 and C-2. The inflight power supply is summarized below. The primary flight system used a total of 158 VA of 60 Hz power, which with an indicated power factor of 0.72 is equivalent to 114 watts. Two units were battery operated, the detector bias control and a small oscilloscope for inflight troubleshooting. On the ground, an additional 1025 VA was required to power an ion-type vacuum pump (25 VA) and the data-processing computer. Corresponding values for the backup flight system were 142 VA and 102 watts, with an additional 61 VA for the on-ground vacuum pump and data-processing units. This system was used in the simulation mission.

DATA SUMMARY

Type of power	Available volt-amps	User system	Rated volt-amps	Load (VA) Peak	Load (VA) low
60 Hz 115 V	250 Instrument supply inverters	Primary experiment	158	158	---
		Backup experiment	142	---	142
		Telescope chopper drive	60-64	64	60
400 Hz 115 V	450 Aircraft inverter	None	0	0	0
28 Vdc	1960* Aircraft generator	Telescope stabilization system	206 min	---	206
			1120 max	1120	---
		60 Hz inverter loss	87-95	95	87
			Total	1437	495

*Less that supplied to 60 Hz inverters.

The stabilization electronics and gyro drive motors of the IR telescope systems had a combined power demand that varied with driving force, from a low of 206 watts when quiescent to a high of 1120 watts at maximum torque. Power was supplied at 28 Vdc. The secondary mirror (chopper) drive required from 60 to 64 VA of 60 Hz power. No record has been made (to date) of the total energy consumed by this equipment in flight.

Energy also was lost in the form of heat during conversion of the primary supply (from aircraft generators) at 28 Vdc to 60 Hz at 115 V by inverters having an efficiency of about 70 percent. For the above case (backup experiment and chopper drive) this loss is something like 90 VA. (Other line losses have not been evaluated.)

At transient, peak load conditions in flight, the total power use could approach three-fourths of the available supply, with the GFE telescope systems using six times more than the experimenters' equipment (including inverter losses). At low load conditions only one-fourth of the supply would be used, with the telescope requiring only one and one-half as much power as the other equipment. The experimenter required only 60 Hz power for both his flight and ground-based support equipment, reflecting standard laboratory practice and extensive use of off-the-shelf components.

Power and energy for data processing and experiment maintenance in the trailer work area were measured in the mission-control area (fig. 2).

Power load exceeded 50 watts only on two occasions, one for 3 min and the other for 9 min, when the principal investigator exercised the computer system of the primary experiment and drew about 1100 watts. Total energy was recorded on a daily basis and varied from 0.62 kwh on the first day of the mission down to a low of 0.27 kwh near the end. Total energy consumed was 1.89 kwh in 4 days.

Both in power and energy demand this experiment appears reasonable for operation in the Spacelab, assuming the electrical energy for data processing and telescope operation would not be charged directly to payload. Thus the experiment operating at 0.1 kw for 50 hr on a 7-day mission would use about 2 percent of the power and 10 percent of the energy projected for payload operation (ref. 5).

Data Handling and Analysis

Data handling- The primary recording instrument in both experiments was an 8-track magnetic tape recorder. Only four channels of information were recorded at a time; the tape cartridge was automatically switched at the end of 45 min and a second record of equal length obtained. The 90-min period was usually sufficient for events leading up to and through the observation period. Signals from detector elements of the experiment systems were processed and recorded in the order shown in figures 13 and 14. Spectrometer grating position and other pertinent information were entered on the audio channel by experimenters' comments.

In the primary experiment (flown only during the premission week), two channels of digitized data were input to a small computer (after flight) for initial processing and printout; the paper-tape output could be scanned directly to evaluate results. The backup experiment (used exclusively during the simulation mission) generated two channels of analog data that were processed after flight by a frequency counter (for specific time intervals) and printed in digital form on paper tape. Manual plotting provided a meaningful display of the flight results. The quantity of data record so generated per flight with either system was about one tape cartridge, up to 10 ft of paper tape, and a few sheets of graph paper.

Data-processing equipment for the primary and backup experiments could not be used interchangeably. Thus, since only the backup experiment was flown during the simulation phase of the mission, the capability existing in the primary computer system could not be utilized. However, this unused capacity is an indication of the degree of data reduction desired by the experimenter and is meaningful to Spacelab planners for this reason. The computer memory (8K of 16-bit core) permits the reduction of a relatively large number of channels of multidigital information to absolute quantities and their multiplication by any programmed correction pattern desired. General utility programs are available, for example, to generate a black-body spectrum at any temperature for quick checks of system calibration. In addition, the aircraft heading, observation time, etc., can be derived for a single astronomical target, or more than one, a valuable assist in flight planning. In fact, the experimenter used this feature in his home laboratory in preparing for the ASSESS mission. Lack of time precluded this use of the computer for exploratory studies of possible supplemental targets during the mission.

Data analysis- The experimenters planned to analyze their data after each flight to assure results before the next observation of the same target. Heavy demands on experimenter time during the checkout flight period and a chronic malfunction of the flight recorder precluded any runthrough of this operation; replacement of the primary experiment just before the mission prevented its realization. In the simulation period the extent of data analysis also was curtailed, in part, by time-consuming maintenance of experimenters' equipment and the GFE telescope, and by the limited capability of the backup data-processing units. All that could be done under the circumstances was a preliminary check of the data after each flight to make sure that test equipment was operating correctly and that all levels (wavelengths) were recording properly. The extent and impact of data analysis following flights 1 through 7 is summarized below. In most cases, data analysis was handled by the principal investigator while his assistant performed other postflight activities. Only 30 to 60 min was required to evaluate the quality of results from a given flight.

DATA SUMMARY

Flight	Amount of data analysis (min)	Effect on observation schedule
1	30	Decision to resume scheduled flight plan
2	35	None; minor misalinement of Dewar optics noted
3	None observed	Dewar optics realined after flight
4	60	Flight plan changed to add checkout flight
5	45	Decision to resume scheduled flight plan
6	50	None; results show telescope stabilization malfunction
7	30	None; telescope stabilization malfunction impacts data acquisition

Mission Personnel

Responsibilities- For the second Lear Jet simulation mission, experimenters comparatively new to the Aircraft Science program were selected to determine whether flight experience was a strong contributor to trouble-free mission operation. The principal investigator had only one previous flight experience in the ASO science program although he had considerable in-the-field experience with rocket-borne experiments. The assistant experimenter, a graduate student and competent scientist in his own right, had no field experience except for one previous flight series with the ASO.

Seven different pilots were provided by the Ames Flight Operations Branch; three served as command pilots and four as copilots. The initial copilot assignment was given to a scientist/astronaut from the Johnson Space Center; he also acted as observer during the mission to provide inflight data on various aspects of experimenter and equipment performance pertinent to the ASSESS program. However, during the first four of the seven flights made during the confined portion of the ASSESS mission, he served as experiment operator (the assistant experimenter was grounded with an ear problem). The copilot position during these flights was filled by four Ames pilots. After the fourth flight, the scientist/astronaut returned to his copilot role.

This constant changing of command and copilot personnel was distinctly different than the first simulation mission, where one Ames command pilot was confined with the copilot and experimenters, and participated in all mission flights. Obviously, he was far more involved with the science crew and could work with them in flight planning and postflight evaluation of results. For this present mission there was little preflight and no postflight coordination between pilot and science crew, yet operations went smoothly because the premission flight plan developed by the principal investigator and the ASO mission manager was known to the pilots and was closely followed.

The principal investigator and his research assistant were responsible for the content of the research program, the design and testing of all research equipment, the operation and maintenance of the flight experiment, and data reduction and analysis. Problems at the aircraft-experiment interface were resolved with the ASO mission manager who was also responsible for arrangements for aircraft operations, maintenance, and logistics.

The observation sequence planning, telescope guidance, and data evaluation functions were done primarily by the principal investigator. A larger share of the daily experiment preparation and the inflight operation of the electronics systems were handled by the research assistant. While the principal investigator tracked the desired astronomical target by use of the guide telescope and a "joy stick" control, his assistant was fully involved with (1) stepping the spectrometer grating through the spectral band, holding for a predetermined time at each wave length; (2) monitoring signal output; (3) maintaining the desired pressure within the sensor package; and (4) watching the tape recorder and replacing cartridges as needed. Functions such as troubleshooting, maintenance, and optical alinement, that could cause flight delays, were usually worked on together to effect the quickest solution.

The copilot/observer was in direct contact with the experimenters during the inflight preparation and observation periods. He followed the progress of the research activities, working with both the experimenters and the pilot to achieve the best flight attitude and the longest track time for reviewing the target. A personal tape recorder was available for his comments relative to research operations.

The copilot/observer recorded his observations at his earliest convenience for the flights on which he served as experiment operator.

He also monitored the safety of the experimenters, particularly in the use and proper functioning of the life-support oxygen system. On the ground, the copilot/observer aided ASSESS observers as requested to document personal activities (e.g., sleep time) of the simulation crew.

The command pilot and the copilot used a two-mode flight pattern developed in the first Lear Jet mission. In the departure-recovery mode both acted as pilots; in the observation mode, the command pilot handled all aircraft responsibilities, and the copilot coordinated research activities and the flight profile.

Inflight communication- The major inflight interaction between the flight and science crews, and between experimenters, was communication to provide real-time operational support to the experiment. Communication interchanges between the groups started off slowly during the few minutes following takeoff and more than tripled during the 30- to 45-min experiment preparation period. During the observational phase lasting from 40 to 60 min, the conversation rate between members of the science crew increased again, typically reaching about 2 to 3 per min, and dropped off for the last 15 to 30 min of the flight as the aircraft returned to base. Generally, the rate of conversation between the experimenters themselves was from about two to five times that between the flight and science crews. Figure 23 illustrates conversation rates in terms of interchanges per minute.

The need for communication between the flight and science crews was minimized by the pilots closely following detailed flight plans, and by the use of aircraft attitude indicators which presented to the pilots the position of the aircraft relative to the stabilized telescope in roll and yaw. The lower conversational rate between the flight and science crews appeared to be sufficient for needs of this mission. Besides small talk, these interchanges were mostly concerned with timing milestones; aircraft attitude; and flight parameters of altitude, speed, and temperature. On the other hand, the two experimenters kept up a constant stream of conversation during the observation period as they worked together to achieve their scientific measurements.

Outside communications- Communications between the "Shuttle" experimenters and "ground personnel" fall in one of two broad categories: experiment operations or data management. In Spacelab terms, these two correspond to a voice-contact link and a data downlink, respectively. During the present mission, as for the first Lear Jet simulation, all communications with the outside world were of the experiment-operations type; no transfer of data took place.

Three means of communication were available to the confined "Shuttle" crew; inflight radio contact with the ground, a telephone with FTS access in the simulation complex, and direct contact with the "ground-based" mission manager. Of these three, the last was used most frequently, partly out of convenience but also because the research effort was essentially self-contained with the principal investigator "onboard."

Aircraft-to-ground radio was not really a viable means of communication for the experimenters since no other associated research

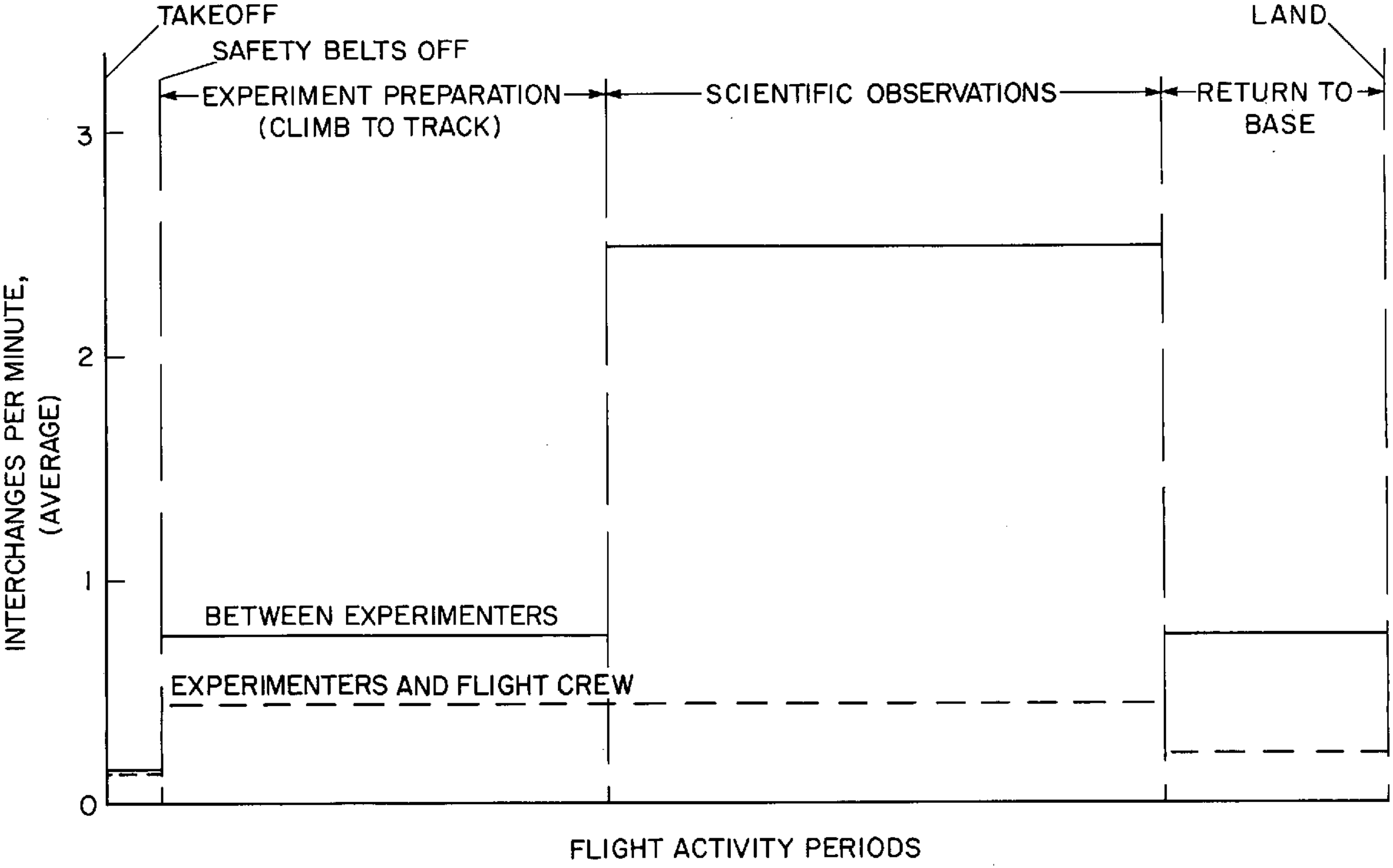

Figure 23.- Frequency of inflight communications.

personnel were on hand at Ames for consultation, and more distant contacts would be unlikely to yield useful results within the constraints of remaining flight time. The link was exercised by the pilot on only four occasions. Of a total of 15 phone calls, only four concerned experiment operations, six concerned unrelated business activities, and five were personal calls.

Direct communications with the ASO mission manager relative to experiment operations and flight planning occurred at a rate of about four a day, for a total of 18 recorded events. A majority originated with the principal investigator, some as informal progress reports (6), and others (5) requesting some form of ground support, such as navigational planning and telescope troubleshooting. In the first Lear Jet mission, the control center was located some distance from the simulation complex and contacts of this type were made via telephone.

With one exception, communications relative to flight planning were minimal, since the planned flight schedule was closely followed. Daily confirmation by the experimenter was relayed to the flight planner by the mission manager; flight plans were returned several hours before flight. The one exception to routine, the experimenters' request for a daytime checkout flight, was coordinated and implemented by ASO and flight operations personnel in less than 3 hr.

The complete absence of data-related communication with the outside world follows from the same features that characterized the first Lear Jet simulation mission: the principal investigator was "on board" to make real-time decisions; data quantity and format were amenable to rapid evaluation using "onboard" equipment; and there were relatively few experiment problems requiring support information from an outside source.

Personnel Work Cycles

Science crew timelines- The mission participants' work cycles and the division of time in various activities are summarized in the timelines of figure 24. This information was gathered primarily by observing the flow of activities at the simulation complex, using personnel stationed in the mission control center. The experimenters also were briefly interviewed, both after flight and following major rest periods.

The timelines in figure 24 cover the entire mission period from 1600 on April 9 until 1300 on April 13; for study purposes, the significant time period closed at 1500 on April 12 when a "hold" status was invoked. Such minor activities as hygiene and housekeeping are included in the free-time category. After the first flight on April 9, daily mission activities quickly assumed a regular pattern with two roughly 4-hr intervals centered on the morning and evening flights. Since the same targets were observed each night, the flights occurred about the same time. Sleep was divided into two periods: about 3 to 4 hr between night flights and 4 to 5 hr between daylight and noon, such that a near normal amount was obtained in each 24-hr period. There is some evidence, however, that under the pressure of a heavy work schedule, these short sleep periods were only marginally adequate. The principal investigator

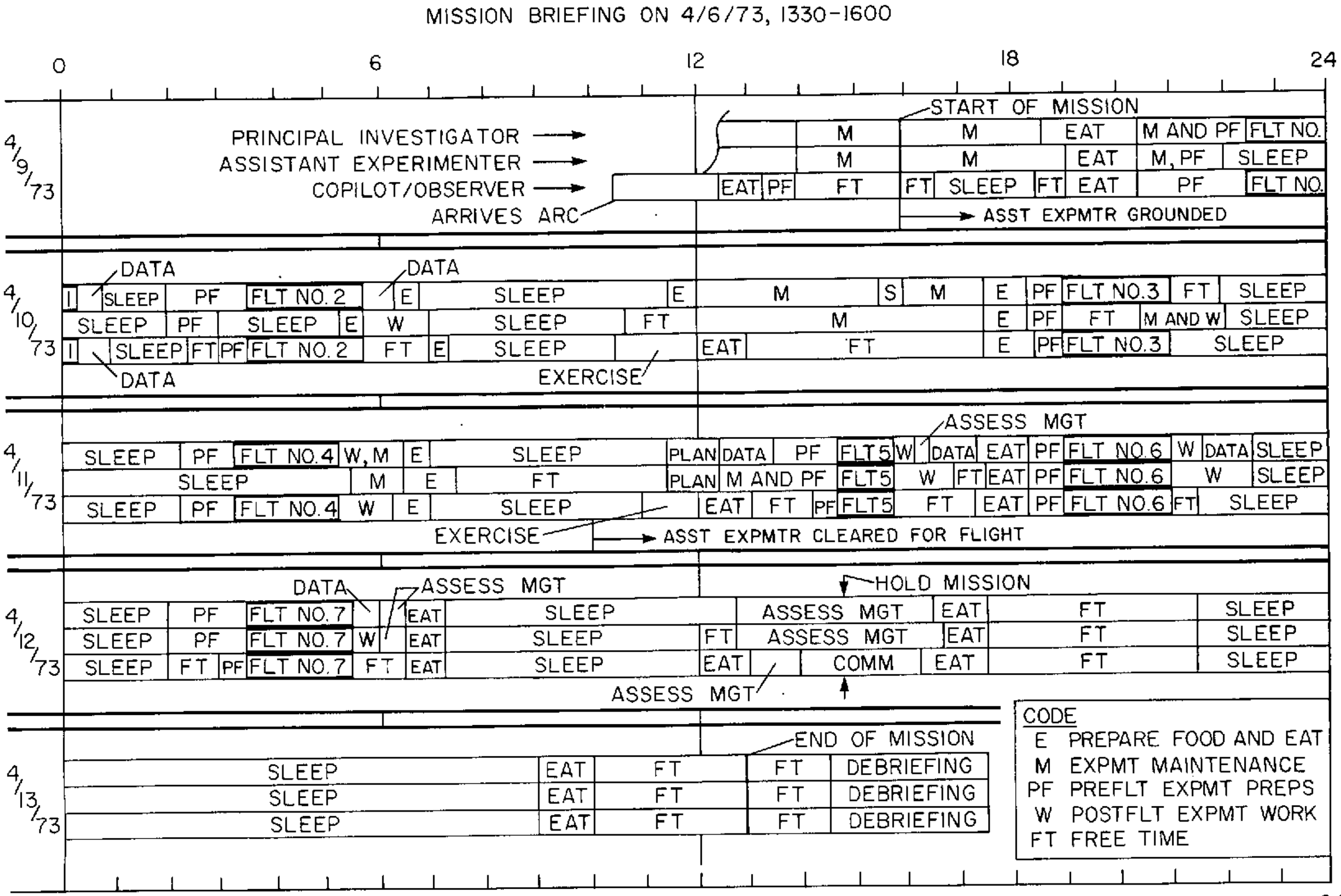

Figure 24.- Timelines of mission participants.

in particular had essentially no free time during the entire mission and, with his assistant grounded for the first four flights, he carried a larger than normal share of inflight responsibility. As the week progressed he became noticeably fatigued, even though his assistant carried a larger share of the postflight operations and experiment maintenance activities. The assistant experimenter accumulated more sleep and free time early in the week while he was grounded and so was in somewhat better shape later on. Both men slept about 11 hr straight on the night of April 12 to 13.

The large difference in free time between the first and second Lear Jet simulation missions, 25 percent of the day on the first mission as compared to less than 10 percent on the second, apparently had a significant impact on the experimenters' overall well being.

Eating patterns quickly developed into a two-meal-a-day cycle, similar to that observed on the first mission. A large breakfast followed the night's work, with snack food at mid-day and a self-prepared (airline-type frozen dinner) meal before the evening flight.

The copilot/experimenter/observer followed a similar sleep pattern but had considerably more free time than the experimenters (over 20 percent). Despite his demanding flight duties and his significant contribution of time to experiment operations early in the week, he was apparently able to adjust to the split schedule with no unusual fatigue. In contrast to the experimenters he maintained a food cycle of three meals a day. Also, he was the only one who engaged in physical exercise (jogging), probably because of his established schedule of training as an astronaut.

Experimenters' activity summary- Experimenter activities during the 71-hr period of normal mission operations are summarized in figure E-1. As would be expected, the largest amount of time was experiment related, over 50 percent for the principal investigator and over 40 percent for his assistant. The latter's role in flight was assumed by the copilot/observer for 2 days, while he assumed a larger responsibility for experiment maintenance and had somewhat more free time. Otherwise the two experimenters had a similar division of time, 30 to 35 percent was used for sleeping, 7 percent for food preparation and eating, and a few percent for miscellaneous purposes.

Experiment-related activities are detailed in figure E-2 for each experimenter. The three major divisions are flight time, experiment maintenance time (reaction to an experiment problem), and scheduled activities (planned work functions). Forty-two percent of the principal investigator's experiment-related time was spent in flight; about one-fourth of his flight time was used for observation (data acquisition), one-fourth for experiment preparation, a small amount for inflight maintenance, and the remainder in takeoffs and landings. Twenty-five percent was used in maintenance, and nearly 34 percent in various scheduled tasks such as data evaluation (11 percent) and flight planning (7 percent). In contrast, his assistant spent a larger fraction of his experiment-related time in maintenance and less in flight, as noted earlier, and performed a noticeably larger fraction of the postflight work.

The experimenters managed to spend about a tenth of their overall work time in the acquisition of IR astronomical data. This relatively modest period of productivity was, of course, limited by the flight time available with the Lear Jet, where with a maximum flight time of 2 hr the time available for viewing was at most 45 to 60 min.

Copilot/observer activity summary- Use of time by the copilot/observer is shown in figures E-3 and E-4. As a full-time member of the confined "Shuttle" crew, his daily activities were keyed to the flight schedule (fig. 24) and his sleep pattern was similar. His active participation as an experiment operator in the first four flights accounted for about 21 percent of the total time and piloting the aircraft on the last three flights another 11 percent. Free time was still 22 percent of the total, compared to 5 and 12 percent for the experimenters, a definite indication of underutilization of manpower. It was evident that copilot/observer's time could have been used to better advantage, both to relieve some of the experimenter work load and to prevent boredom. Although also true of the first Lear Jet simulation mission, underutilization of copilot's time on the second was particularly unfortunate because he was a trained astronomer with a keen interest in the research program.

Nearly two-thirds of the copilot/observer's experiment-related activity was flight activity, of which more than one-half was direct support of the experiment (fig. E-4). The remaining one-third comprised ground activities, including flight planning, data evaluation, and other activities in support of experiment operations.

Flight crew activity- The support given by Ames pilots to the ASSESS simulation mission is compared with the work time of the experimenters in figure E-5. During the base period of 71 hr, the principal investigator and assistant worked a total of about 67 hr; total pilot hours were 59, of which the copilot/observer contributed 22, and seven pilots and copilots 37. Note that Ames command pilots spent about 40 percent of their time in preparation for flight and 60 percent in flight operations.

Influence of Mission Constraints

The constraints applied to Shuttle simulation missions are similar in kind but not in degree to those in normal ASO research. In a normal flight series the experimenter has a nominal flight date and designs his experiment to meet facility requirements. When on site, he operates in a semi-isolated location far removed from his home laboratory, and must depend largely on his own devices to achieve his research goal. ASSESS constraints strive for the limiting conditions - a fixed-time schedule, design for high-reliability performance, and complete functional isolation of the experimenter and his research effort from outside influences other than verbal communications. The impact of these time and isolation constraints significantly alters the normal processes - planning, preparation, and operations - posing a greater challenge to the experimenter as well as providing the added incentive of program visibility. The result is a unique research experience with real scientific goals, having many of the same program elements that will be part of Spacelab missions.

Mission time constraints were a specified "launch" date and a stated goal of ten flights in 5 days. In his first ASO flight series, the experimenter prepared for flight in about 4 months; for the simulation mission, 14 weeks was mutually agreed on as a realistic preparation period. As it turned out, this time was not sufficient to complete the development of a new, higher-potential measuring system, and the "launch" date was delayed by 6 weeks. The time constraint imposed by two flights per 24-hr period appears to have been beneficial, mainly because it prompted the experimenter to develop a research program with two objectives: to augment previous measurements and to open a new area of research, thereby increasing the science potential of the mission. The flight schedule was achieved despite serious problems just prior to the mission, and the necessity to train an alternate operator on short notice.

Experimenters considered the constraints of the semi-isolated environment beneficial to the conduct of the mission, just as had been observed on the first Lear Jet mission. The proximity of living quarters, work space, support equipment, and the aircraft allowed more time for experiment preparation and maintenance. In fact, without this convenience, it would have been extremely difficult to sustain the heavy flight schedule.

On several occasions, however, postflight servicing was not completed in time to return the aircraft to the site with the specified 2-1/2-hr lead time before flight. As a result, experiment preparations piled up and last-minute adjustments disrupted the usual preflight routine and noticeably increased the experimenters' fatigue level during flight.

Pilot procedures were changed for this mission. In the first Lear Jet mission, one individual was assigned as command pilot for the entire operation; he participated in the premission checkout flights, and lived and worked as a member of the confined "Shuttle" crew during the simulation period. The copilot/observer was similarly involved. The result was a highly effective research team; both flight and science crews had a working knowledge of the entire operation, and the planning and conduct of research flights were coordinated for maximum effectiveness. For an isolated event such as a Spacelab mission, this approach was judged beneficial in terms of quality and amount of research product. Within the larger context of Ames pilot workload and scheduling in support of other programs, however, this approach was unduly restrictive and could not be justified for the second simulation mission. Therefore, it was decided to use Ames pilots on a rotating basis as for normal Lear Jet missions and to include only the copilot/observer in the confined "Shuttle" crew.

The results were generally favorable. The planned flight sequence was carried out, and scheduled observation times were attained or exceeded. Apparently there was sufficient flight-crew continuity from the copilot/observer who was on all flights (including premission checkouts), and adequate pilot familiarization during the premission week, to achieve the desired flight goals without delaying incident. The copilot's extensive background in astronomy (as in the first mission) and the preplanned flight sequence chosen by the experimenters were positive factors in this achievement.

On the other hand, available information suggests that the experimenters had to push a little harder to keep to the schedule, with the pilot not available for on-site planning and coordination. On balance, however, without the serious experiment problems just prior to the mission and the concurrent illness of one experimenter, this added effort probably would not have been noticeable.

Experimenter fatigue surfaced as a discussion topic in the mission debriefing and deserves special comment. Experiment problems near the start of the mission appreciably reduced the value of the 2-day "hands-off" period for rest and relaxation. Premission time on Monday, already filled with the task of installing the backup experiment, was further complicated by special preparations for a substitute experiment operator. Although the demands of this very tight schedule were successfully met, both experimenters had expended considerably extra effort and began the confined period under considerable pressure. Whereas the "grounded" experimenter apparently recovered to normal in the next day or two, the pressure on the principal investigator continued above average, and combined with an abnormal, interrupted sleep pattern to prevent his full recovery. Although conditions remained tense for several days, at no time did experimenter fatigue affect the mission schedule. With the assistant experimenter back onboard for the last three flights, crew operations were normalized and the research effort continued under less stressful conditions.

In one instance, an awkward arrangement of equipment resulted in experimenter fatigue. The GFE telescope guidance system required vertical viewing from above for extended periods of time. With the helmet and oxygen mask normally used as head gear, maintaining this position soon became very tiring; the use of lighter head gear allowed cabin noise to interfere with audio signals required for proper guidance. No satisfactory solution was found to this human-engineering problem, and it remained a minor but constant source of irritation.

Scientific Accomplishments

The quantity of research data collected in this mission was much less than had been anticipated at the outset. Ten flights were planned, five to augment previous IR measurements of Jupiter and five to provide new information on the Orion nebula (M42). Only five were actually made, however, and these were with the backup experiment, which had less sensitivity and resolution than the primary experiment, as well as a far inferior capability for data reduction. It is to the credit of the experimenters that they continued working, despite all setbacks, to achieve the best results possible with the resources and time available.

Data gathered during two observation periods on the Orion nebula and two on Jupiter (no valid data on one Jupiter flight) yielded the following scientific accomplishments:

1. Unique infrared measurements of M42 at wavelengths from 16 to 40 μ, for the determination of thermal structure and composition.

2. Measurements in the 16- to 40-μ waveband of Jovian radiation to substantiate those previously made, permitting a finer resolution of the upper atmosphere thermal structure as well as a more precise evaluation of the hydrogen/helium ratio. The experimenters consider these new data sufficient to justify a technical publication.

In more general terms, the mission experience also served to prove several new experimental methods, which will enhance the effectiveness and quality of results in future flight programs:

1. A new signal-handling system that outputs digital information suitable for real-time evaluation of results and, potentially, for input to an onboard mini-computer for detailed processing.
2. New spectrometer optics and a multielement detector array with improved spectral resolution, having an inherent growth potential well beyond that demonstrated.

Finally, the experience gained by this relatively new (to flight research) team of experimenters will enable them to plan more effectively for future flight opportunities. Improved methods of optical alinement, telescope guidance, and source scanning were already being planned before the end of this simulation mission.

Comparison of Mission Elements

The first and second ASSESS simulation missions are compared here in terms of basic, quantitative elements illustrative of the scope and effort involved. Bear in mind that the constrained part of this mission was effectively ended after less than 4 of the 5 days that had been scheduled. The overall timelines of figure 25 show major work periods; the present effort covered 148 days and the first 127, with 137 and 109 days for experiment preparation, respectively. Both premission checkout periods (7 and 13 days, respectively) included three check flights; both simulation missions achieved seven "Shuttle" flights.

Although the number of flights was the same, the type of research activity was significantly different, as shown in the following data summary. The second science team flew less and observed fewer targets, but for longer times. During the first Lear Jet mission, there was a total of 1.7 hr between observation periods while the aircraft was repositioned for the start of a new track. Available observing time on both missions was tailored to the data requirements and scientific goals of the research team; the first required comparative results from a selection of targets, and the second, extensive and detailed data on only two.

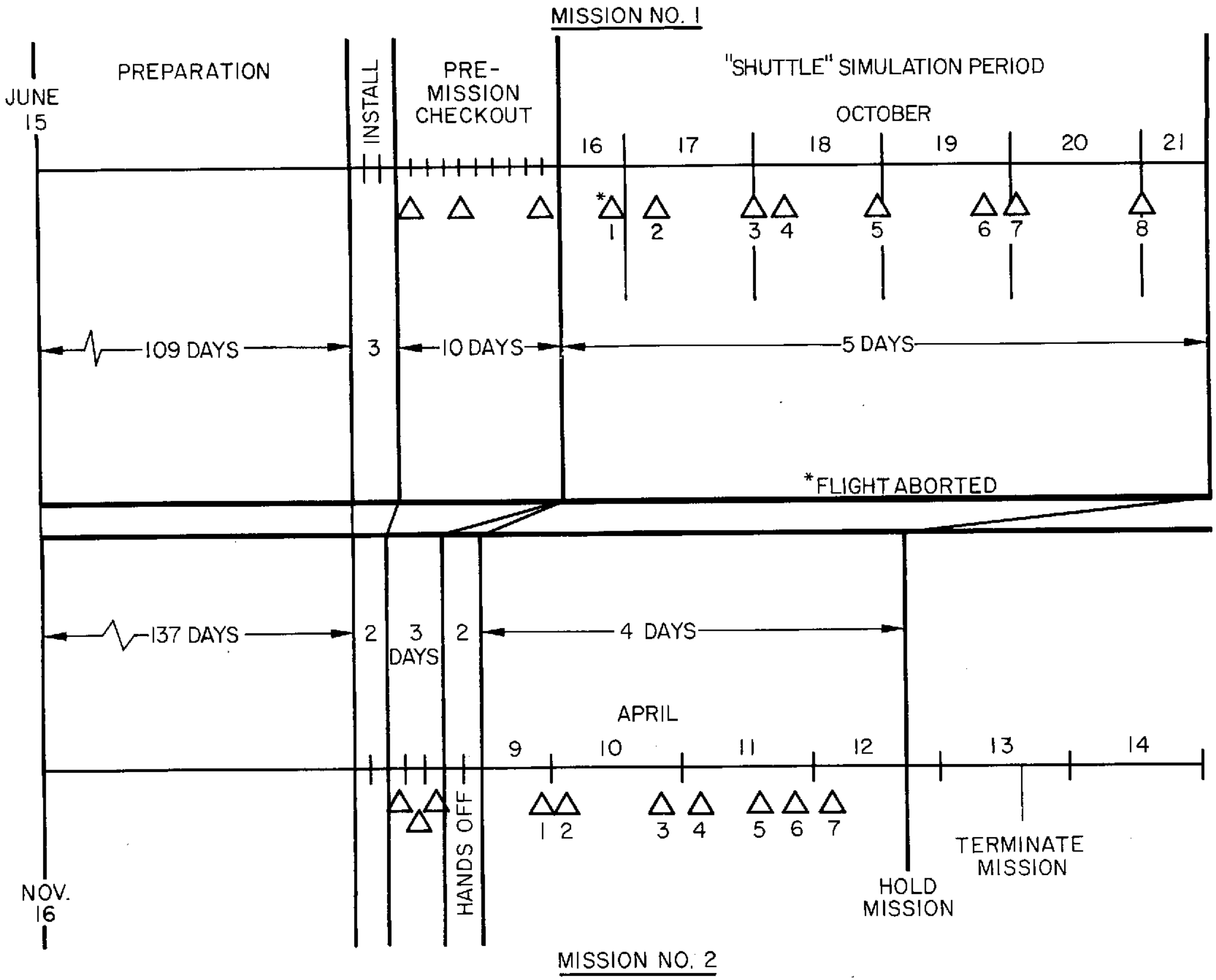

Figure 25.- Timelines for Lear Jet/Shuttle simulation missions.

DATA SUMMARY

ASSESS Mission	Total flight period, hr	Total observation period, hr	Number of targets	Targets per flight (flights)
Lear Jet no. 1	17.4	4.6	6	1 (2) 2 (4) 3 (1)
Lear Jet no. 2	12.8	5.2	3	1

The division of experimenters' time during the simulation periods of the two missions is compared in table 1. In the second mission, more sleep was needed, more work was done, and less than half as much time was available for personal use. Timely resolution of health and equipment emergencies demanded nearly full-time attention, as well as the assistance of the copilot/observer.

The two flight experiments are compared in table 2 by cost, source of components, electrical power, and manpower for preparation. In general, the similarity shown between experiments merely points up the features they have in common - the telescopes were developed from a common source and for the same aircraft, while the remaining systems in both cases were developed in university laboratories for somewhat similar applications.

Experiment support equipment and its utilization for the two missions are summarized in table 3. Recall that both teams of experimenters had been active "in the field" prior to the "Shuttle" missions and thus were familiar with remote operations. In the first ASSESS mission there were no restraints on support equipment; in the second, it was recommended that such equipment be limited to justified needs. The unexpected result of this admonition was a greater number and variety of small items like hand tools and expendable supplies, and a marked decrease in reference documents; quantities of test equipment and spare parts were virtually the same for both missions. In effect there was little control over the amount of support equipment provided; the standard complement consisting of "most everything we own" was brought. Experiment problems during the second mission resulted in the use of substantially higher fractions (up to two-thirds) of the available support hardware. Even so, no shortages were observed, and many items were not needed.

TABLE 1.- MISSION TIME ELEMENTS

[SCIENCE CREW AVERAGE]

Element	Fraction of total time, percent	
	ASSESS Lear Jet no. 1	ASSESS Lear Jet no. 2
Experiment activities*		
Flight	18.5	19.4
Maintenance	11.3	14.0
General	12.2	18.3
TOTAL	42.0	51.7
Sleep	19.0	32.1
All other	39.0	16.2

*Includes contribution of copilot/observer to experiment operations.

TABLE 2.- EXPERIMENT CHARACTERISTICS

Item	ASSESS Lear Jet no. 1	ASSESS Lear Jet no. 2		Differences between missions 2 and 1
Cost				
Telescope	100,000 (existing)	86,000 (GFE)		Total ~11 percent less
All other	17,000	18,000		
TOTAL	117,000	104,000		
Source by %				
Off-the-shelf	47	57		Off-the-shelf ~10 percent less
Experimenter-built	40	40		
Other	13	3		
Power, volt-amps		Primary	Backup	Backup expmt. approximately equal
Telescope	1205	1500 (GFE)	1500 (GFE)	
Other flight units	505	158	142	
Data reduction units	---	1025	61	
TOTAL	1710	2683	1703	
Preparation effort, man-days		Experimenter	GFE	
Fabr. & assy.	---	247	---	Total ~15 percent less
Testing	---	35	---	
TOTAL	337*	282	<5	

*Experimenter's budget estimates.

TABLE 3.- SUPPORT EQUIPMENT UTILIZATION

Item	ASSESS Lear Jet no. 1		ASSESS Lear Jet no. 2	
	No. supplied	% used	No. supplied	% used
Hand tools	114	18	177	37
Test equipment	23	35	26	65
Spare parts	35	3	34	15
Expendable supplies	39	44	108	54
Flight planning and reference material	39	26	14	7

APPLICATION OF RESULTS TO SPACELAB

DESIGN AND PROGRAM PLANNING

Airborne science research, like scientific research in an orbiting Shuttle Spacelab, permits the use of special investigative techniques and gives access to phenomena not available to ground-based observers. By virtue of this generic similarity, many of the elements of airborne research programs have counterparts in planned Spacelab operations, and although the vigor and precision of orbital research may be more demanding, the ASSESS simulation studies provide valuable guidelines for Shuttle planners.

The results discussed in this section reflect primarily the experience and aptitude of the second two-man team of experimenters. In contrast to the first team, they were relatively new to airborne research and had not settled into a fixed pattern of activity. Where appropriate, results from the first simulation mission are used to augment these findings.

Management of Research Programs

In keeping with established ASO management policy, the principal investigator was responsible for the content of the research program, design and testing of his research equipment, operation and maintenance of the flight experiment, in-mission selection of flight objectives to optimize research results, and the reduction and analysis of the data. (The ASO mission manager was responsible for aircraft operations up to and including the aircraft-experiment interfaces.) This independence of the principal investigator in ASO programs typically has produced a timely and reliable experiment at relatively low cost (ref. 3). In the second simulation mission, however, two obvious difficulties occured. The "launch" date was delayed 6 weeks (in part, due to illness and procurement delays) by experiment preparations; and the primary experiment had a critical failure that could not be quickly repaired, forcing use of the backup system for the entire mission. In general, this experience was quite similar to that of the first simulation mission, and in "Shuttle" context, the schedule of both missions was seriously affected by an experimenter's decision to upgrade his experiment significantly.

These two experiences indicate that, in its present unstructured form, the ASO approach to experiment preparation for the Lear Jet does not always assure completion on schedule. The single team of Lear Jet experimenters tends to overestimate schedule flexibility to meet valid contingencies, as compared to an ASO CV-990 mission, which involves several teams and requires more rigid timing. In this regard, the single-experiment mission does not adequately simulate the multiteam situation of Spacelab, and some added incentive may be required in future simulation missions to meet a fixed "launch" date. For example, an experimenter's progress could be monitored relative to a self-imposed schedule and/or a mutually acceptable "ready" date could be established far enough in advance of the mission to permit substitution of an alternate experiment. The first concept was attempted in this second mission, but it was not implemented early enough to avoid an initial delay of several weeks. Later on, the "milestone" schedule did prove to be a valuable (but not sufficient) incentive for the timely completion of experiment preparations.

In the ASO tradition, equipment test procedures are the responsibility of the experimenter. In the present case, a testing effort of 36 man-days produced both a primary and a backup experiment, each with the required scientific capability. Again, however, time ran out before a spare detector array for the primary experiment could be tested and, by chance, this was the element that failed just prior to the mission. In the first mission, time also was short and operational checkouts of the primary Dewar were not completed. In both cases, therefore, the planned test schedule was cut short and the impact was potentially serious. The fault (if it can be called that) lay not in the content of the test program but in its timing. Clearly the target date for completion should be set well in advance of the "launch" date to avoid this last-minute rush, particularly when new equipment must be evaluated and integrated as in both simulation missions.

Operator training was not a planned exercise in this mission, except for the normal exchanges between the principal investigator and his assistant. Fortunately, it was possible to observe the training of the copilot/observer by the principal investigator as a replacement for the second experimenter. This training was successfully accomplished on a time-available basis in the 12 hr prior to the first flight; with about 3 hr of instruction and familiarization, the new operator was able to perform his assigned duties in flight with real-time guidance from the principal investigator. Although data acquisition was slower than normal, valid scientific results were obtained in good quantity. On succeeding flights, the research effectiveness of the team continued to improve but remained below that of two experienced men. In particular, the principal investigator found his telescope guidance task more difficult without real-time comments from his assistant on the response of the experiment systems to the incoming signal. Despite this restraint and his extra workload of equipment preparation during flight, the principal investigator was generally satisfied with the results. Thus, it was demonstrated that with minimal training a scientist in a related field, who was familiar with the flight environment, could function adequately as a substitute for one member of a two-man team.

Research Plans and Performance

How well was the principal investigator able to carry out his planned research? He proposed to make full use of the opportunities available for scientific observation by choosing two primary targets, each of which would be observed five times. Observations of the first target would provide new and more detailed results in a familiar area; observations of the second would be his first attempt in a new field. To make the best use of this research opportunity, he designed and built a new experiment of greater science potential then the earlier one, and used his existing equipment as a backup experiment to ensure reliability. His checkout flights prior to the mission were used to calibrate the new experiment using the Moon as the target, so that all mission flights could be used to observe the prime objects.

The mission plan thus involved two research goals, two well-tested experiments, and completion of all calibration flights prior to the mission. What was the observed performance? Adequate calibration data were obtained on the primary system in the premission week, but a critical failure late in this week required a switch to the backup system and an additional calibration flight at the start of the mission. The planned flight schedule was then resumed and continued until its forced cancelation. In essence, then, the planned observation schedule was met. Although only two observation periods were achieved on each prime target, the results were valid scientific data of substantial importance. Had the mission been completed, the 5-day period would have satisfied the full data requirements. With one exception caused by experimenter error, the equipment operated reliably during the mission and only minor adjustments were required.

Even though relatively new to flight research, the principal investigator carried out his flight program successfully, despite a number of serious obstacles and interruptions. In relation to Spacelab, both the experienced team of the first simulation mission and the nearly new team in the second mission flew an IR astronomy experiment of their own design and obtained new and unique scientific results. However, the newer team worked longer hours to achieve results, they had less time for data analysis, and practically no time was available for alternate research efforts.

Operational Procedures for Spacelab

Premission simulation- In their debriefing session, the second team of experimenters emphasized the value of Spacelab premission simulation periods. As a result of their experience in this ASSESS mission, they considered two such periods to be desirable for Spacelab: the first some weeks before final integration to permit any necessary equipment changes; and the second similar to that provided in the ASSESS mission in which they participated. In both cases, the premission simulation experiences should be as close to the real environment as possible; in ASO missions, both would be most useful if actual flights were involved. Since many Spacelab experimenters would be new to space research, such simulations were thought to be absolutely essential for first-time success.

Duty cycles, workload, and fatigue- No guidelines or constraints were applied to the experimenter's use of time during the mission. The sole limitation was imposed by the planned schedule of flight observations, which was fixed by the experimenter's choice of astronomical targets. Approximate flight times, and therefore available sleep periods, were known weeks in advance. The experimenters chose two periods, one of about 3 hr duration between flights and a second of about 5 hr after the morning flight. This became a regular pattern for the three "Shuttle" crew members, in contrast to the first simulation mission in which sleep periods often were not concurrent. Although marginal at first, the split schedule was adequate once the mission routines were established.

Experimenter workload was noticeably heavier for this mission than for the first, especially at the beginning when the backup experiment was being brought "on line." The principal investigator was busy with experiment-related activities nearly 13 hr a day and had essentially no free time, while his assistant and the copilot/observer (who replaced him on four flights) together averaged 15 hr a day. By contrast, in the first mission the experimenters' workload totaled 20 hr a day, nearly one-third less. Although the emphasis gradually shifted away from direct maintenance activities to more routine operations and data evaluation, the principal investigator remained too busy with flight preparations to have time for much of the data analysis he had planned.

Inflight workload was about one-fourth experiment preparation and one-fourth observations. While acquiring data, the experimenters were fully occupied and in constant communication. One guided the telescope to keep it centered precisely on target, while the second operated the spectrometer grating and monitored the signal electronics and overall system performance. As in the first mission, the equipment was designed for two-man operation, and there was no time available to operate other experiments while the aircraft was on track. Every available minute was spent on data acquisition, and even more time could have been used to good advantage. Once observations were completed, there was time for other activities while the aircraft returned to base. This suggests the possibility of a second, semiautomated experiment that could be tuned up prior to the start of observations, left to run unattended while on track, and operated and/or monitored during the last flight leg. Beyond this, the experimenters thought it reasonable to provide automatic features in their own experiment to release the second operator for other duties. When put in the context of Spacelab operations, such alternatives were acceptable to the experimenters, at least for observation periods not greatly different in duration or frequency than those experienced here.

There were several indications that the science crew had to push hard to keep the program on schedule. The lack of free time and the minimal opportunity for data analysis showed that little margin was left for contingency situations. Two flights a night appear to be an upper limit on extended research activities with a fully manned experiment in the Lear Jet environment, at least for this relatively new science crew. With the potential of eight observing periods in each 12-hr time span on Spacelab, it is apparent that equipment operation and data handling must be much less time consuming if viewing opportunities are to approach full utilization.

Science crew/flight crew communications- The confined "Shuttle" team in the first Lear Jet mission consisted of two pilots and two experimenters. Interaction between crews both before and during flight had a notably favorable effect on the research product; flight planning was kept very flexible with new target selections daily. In the second mission, only the two experimenters and the copilot were confined, and there was little or no preflight interaction with the pilot. This approach appeared to work satisfactorily for two reasons: First, the flight schedule had been planned in advance and was closely followed; second, the confined copilot functioned (informally) as a mission coordinator, giving continuity to the flight/research effort in which seven Ames pilots participated. His background in astronomy and his experience as experiment operator on the first four flights ideally suited him for the job.

Communications in flight were by a three-way loop between experimenters and copilot, who in turn relayed requests to the pilot. Except during takeoff and landing periods, 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. On the average, he exchanged comments with the science crew about once every 2 minutes during experiment preparations and scientific observations. This two-way flow of information coordinated all flight efforts for maximum research effectiveness. The same inflight procedures yielded equally positive results in the first mission and prompted a recommendation that Spacelab support systems include real-time displays for the experimenters of orbital and vehicle parameters of interest, as well as the option of direct verbal contact with a mission coordinator or member of the flight crew.

Communications outside the mission- Experimenter teams participating in ASO programs are characteristically small in size. In this case, the two experimenters made up the entire research team. With both on board, the loop was essentially closed and there was little need for outside communications. Only four telephone calls had direct bearing on the mission; one to the ASO flight planner, one to the home laboratory about an equipment problem, and two to commercial firms requesting technical information on electronic parts. No communications relative to data or scientific results were necessary. Data quantity and format were planned for rapid "onboard" processing to sufficient depth that the principal investigator could evaluate results.

Communications with the ASO mission manager were more frequent, at least four times a day, but were either informal progress reports or requests for servicing of experiment-related systems furnished by ASO.

Design Considerations for Spacelab

Data recording and processing- Flight experiments need data-handling systems that make accurate, permanent records and also have a quick-look capability. In this mission, as in normal ASO Lear Jet programs, the experimenter was responsible for data handling and provided the necessary units as part of his own equipment. His permanent record was on magnetic tape; for a quick look at his results, he processed this tape between flights, retaining the original record for final, detailed processing after the mission was over. The quantity of recorded data was small, requiring one or two tape cartridges per flight. Quick-look processing required less than 1 hr and was sufficient to assure that all elements of the backup experiment were operating properly and to give an overall indication of the scientific results. Had the primary experiment with its more advanced processing capability been operational, the experimenter would have had more detailed, quantitative results at hand for direct comparison with prior research work.

This approach to data handling appears suitable for Spacelab with perhaps only minor modifications. For an IR astronomy experiment of this type, the quantity of data to be processed, the onboard computer needed, and the time required for preliminary analysis seem reasonable for the work schedule of one experimenter, in at least the opinion of the principal investigator on the second ASSESS mission. He favors a moderate computer system (on board the Spacelab) that permits variations in target observing plan to best suit current conditions, rather than adherence to a rigid plan dictated by the programming of a ground-based computer. Alternatively, of course, if he were occupied with experiment maintenance (as in part of this mission), or operated more than one experiment, the processing and evaluation of the data might require ground support personnel. In either case, for the present type of experiment, planning for successive observations apparently can be guided by quick-look processing during the mission, with final processing left until return to the home laboratory.

In contrast, the principal investigator in the first Lear Jet mission, who had considerably more flight experience, opted in favor of a ground data link. He reasoned that this capability would allow him to concentrate on data acquisition (for multiple targets as during his ASSESS mission) while an assistant on the ground handled the processing and analysis. It should be noted, however, that his opinion was prompted in part by a need for some rather complex data processing to suppress noise in signals from very weak sources. Thus, it appears that both onboard processing and data transmission to the ground could serve a useful purpose, depending on the type of experiment and the goals of the principal investigator.

Experiment power and cooling- Power requirements for the experiment flown on the second ASSESS mission seem reasonable in comparison to the projected Spacelab supply. The flight experiment used about 102 watts of 60-Hz, 115-V power, and the associated data processing unit another 26 watts (36 VA). Telescope systems were GFE and were not directly chargeable to experiment power; they required an average of 660 watts of 28 Vdc and about 45 watts of 60-Hz power. No 400-Hz power was used in either experiment or telescope systems.

Energy used for data processing and experiment maintenance in the work area averaged about 0.5 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 7.6 kWh, about one-seventh of that projected as the primary payload supply from the Shuttle Orbiter power system.

The primary coolant requirements were for liquid nitrogen and helium, the former for initial cooldown of the Dewar and the latter for steady-state observations. With a stated holding time of about 12 hr, the estimated steady-state use of LHe in this Dewar is roughly 5 ℓ per day. Initial cooldown takes about 4 ℓ of LN_2 and 5 of LHe. Allowing for two cooldowns in a 5-day period, a Spacelab cyrogenic budget of about 40 ℓ is indicated for equipment like that used in the ASSESS mission. All other experiment operating and support equipment (except for telescope electronics) was cooled by natural convection and would require forced air cooling in the Spacelab.

Experiment support equipment- In contrast to the first Lear Jet simulation mission where there was no restriction on support equipment, experimenters on the second mission 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. In the absence of any positive weight limit, however, there was little incentive for the principal investigator to reduce the variety and weight of equipment below that normally carried on field trips. As noted earlier, the available inventory was greater than for the first mission (table 3).

There is little doubt that the experimenter can predict what support equipment he will need to keep operational; experience in the flight environment apparently tends to assist him in determining an adequate lower limit. Of perhaps greater significance for Spacelab, however, several experimenters on board generally can share test equipment and tools except for those unique to an experiment. On the second Lear Jet mission, experiment-specific support equipment accounted for well below 10 percent of the total support equipment weight and about one-fourth the weight of the experiment itself, exclusive of the GFE telescope systems.

During flights on the Lear Jet (analogous to observing periods on Spacelab), the experimenters' support equipment was minimal, consisting of a small battery-powered oscilloscope, spare tape cartridges, and a small bag of basic tools, weighing in all perhaps 10 lb. This equipment was sufficient for minor inflight maintenance aboard the Lear Jet; if more was required, it was unlikely that the problem could be resolved in the remaining flight time.

Government-furnished equipment- A somewhat different class of problems can develop when GFE is part of the total experiment package. In the second simulation mission, the experimenter was expected to operate and/or monitor the performance of a major, active system (the telescope) with which he was not too familiar yet which was critical to the success of his experiment. In fact, without frequent and active contact with a mission scientist/coordinator who is completely familiar with the design and use of the GFE, the experimenter may not design his own experiment to optimize overall performance. To some extent, notably in alinement and sighting, such difficulties occurred in the present mission. These were highlighted in the mission debriefing, and corrective design actions were proposed, some for changes in GFE and others in experimenter's equipment. This experience is pertinent to the design of Spacelab experiments, since most investigators will be new to the research facilities and similar integration/operation problems could impact individual research efforts.

Workspace and accommodations- The simulation of Spacelab working conditions was not a guideline in either this or the previous Lear Jet mission. Even so, certain observations on space and arrangement may be useful. First, the living quarters that were uncomfortably small for four occupants in the previous mission were found adequate for three. Second, the work area was overly generous, even though the level of maintenance work was somewhat higher. Both work surface area (5.6 m^2) and storage volume (1.0 m^3) could easily have been cut by one-third or more.

Work space in the aircraft cabin was minimal (4.25 m^3) for the experimenter's research activities, but it was deemed adequate for the average 2-hr flight. In the previous mission, the average flight approached 3 hr, and the telescope operator was cramped for leg space while sitting on the floor for end-on sighting in the finder telescope. In the second mission, the operator used a camp stool and viewed downward into the sighting scope, thereby transferring the cramp from legs to neck. As before, except for takeoff and landing each operator sat facing his portion of the equipment in a space about 1 by 1.5 m. Even with the added restraint of life-support oxygen equipment, this limited space apparently did not hinder the research effort.

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APPENDIX A

ASSESS MISSION OPERATIONAL SAFETY RULES AND CONTINGENCY PROCEDURES

Safety Rules

Key operational safety rules applied to this ASSESS simulation mission are as follows (normal and mission-specific items are denoted by N and MS, respectively).

1. Aircraft will not depart on a flight if the weather forecast makes return to base questionable (N).
2. Alternate recovery sites will be chosen before flight, to be used if adverse weather conditions or other emergencies develop (N).
3. Radio operator in Flight Operations Office will monitor the aircraft communication frequency during flight (N).
4. Pilot not flying the aircraft will report on life-support oxygen systems every 5,000 ft during climbout (N).
5. Whenever the copilot/observer is switched into the experimenters' communications loop, the command pilot will monitor the life-support oxygen systems (MS).
6. The command pilot will be responsible for operation and maintenance of aircraft life-support systems (N).
7. The command pilot will evaluate the physical condition of copilot and experimenters and will cancel the upcoming flight if excessive fatigue becomes apparent (MS).
8. A flight surgeon will be on call at all times and will receive daily medical reports from the copilot/observer (MS).
9. Security guards will provide traffic control on roadways during aircraft towing operations, and a safety vehicle will accompany the aircraft when towed, or during taxi to or from the designated taxi strip (MS).
10. The aircraft will be connected to the safety ground rod whenever located at the simulation site (N).
11. Crash and fire crews will be notified of aircraft parking locations, taxi and tow routes (MS).

Contingency Procedures

Contingency procedures were part of the Project Operating Plan. Weather conditions, fatigue or illness, major aircraft maintenance, and recovery from a remote base were considered of particular importance for flight operations. The contingency arrangements were:

1. In the event of a major maintenance problem, or rain, the aircraft will be <u>stationed in</u> and <u>depart from</u> the hangar. "Shuttle" crew will be taxied from the simulation site to the hangar by car for each flight.
2. The command pilot can elect to:
   a. recover to the hangar in case of bad weather or a safety problem, or
   b. cancel the upcoming flight in case of over-fatigue of pilots or experimenters.

3. In the event of illness of either the pilot or the copilot/observer, he will be replaced by the assigned Ames backup pilot. If either of the experimenters becomes ill, the upcoming flight will be cancelled and rescheduled.

4. Alternate landing fields will be used in emergencies. If an emergency landing is made at a nearby airport, the ASSESS duty officer will retrieve the "Shuttle" crew, and available Ames' pilots will be assigned to recover the aircraft. In the case of a remote airport, the effect of the emergency on the simulation mission and plans for subsequent operation will be evaluated and decisions made accordingly.

5. Any decision to cancel the mission will be made by the ASO mission manager in consultation with appropriate personnel.

6. If an experiment malfunction should require some part or item of test equipment that is not available "on board," the item will be supplied if it is considered necessary to the success of the mission.

Other contingencies related to aircraft operations and ASSESS facilities were handled by the ASO mission manager and the ASSESS duty officer, respectively.

APPENDIX B

ASSESS MISSION EXPERIMENT MODIFICATIONS

Primary Experiment

Following are the major components built or purchased for the primary experiment on the ASSESS simulation mission:

1. A new sensor package consisting of four detectors, a rotating grating spectrometer, four preamplifiers, and a Dewar for liquid helium. The spectrometer was designed to accommodate multiple-element detector arrays for improved spectral resolution; ultimate capacity, 16 elements.
2. A spare four-element detector array (this unit was built but not tested and not available for the mission).
3. Four spare preamplifiers for the sensor package.
4. A channel sequencer unit to convert the preamp outputs from analog to a coded digital form. This format also serves to enhance data accuracy by relaxing the requirement of constant tape speed in the recording instrument.
5. A four-track tape recorder identical to the existing unit. Applicable to either experiment.
6. Stepping motor and control box to actuate spectrometer grating, similar to existing unit. Applicable to either experiment.
7. A four-channel bias control unit to supply a known constant current to detectors, similar to existing two-channel unit. Applicable to either experiment.

Backup Experiment

Relatively few changes were made to the backup experiment, as follows:

1. The unit used to generate a 10-Hz reference signal for the third channel of the tape recorder was removed.
2. Pulse information from the grating control unit was recorded on the third channel of the tape recorder.
3. A digital-readout gratiòn position indicator was added to the panel displays.
4. Spare detectors (two of each type) were obtained.
5. A backup voltage-to-frequency converter was built.
6. A backup phase-lock amplifier was purchased, which was applicable to either experiment.

APPENDIX C

ASSESS MISSION EXPERIMENTAL HARDWARE, DISPLAYS, SUPPORT EQUIPMENT, AND DOCUMENTS

Experimental hardware for the ASSESS mission primary and backup experiments is given in tables C-1 and C-2, respectively, by type of construction, weight, and estimated power requirements. Costs are also noted. Table C-3 lists the various displays and indicators used in monitoring and adjusting operation of the primary experiment and telescope.

From previous research experience at remote installations, the principal investigator had assembled an impressive tool inventory (table C-4). Experiment test and maintenance equipment was furnished by the experimenter and ASO (table C-5). Spare parts and expendables supplied by the experimenter are listed in tables C-6 and C-7, respectively; quantities of liquid helium and nitrogen and helium gas, all supplied by ASO, are also indicated in table C-7. Work area furnishings supplied by ASO, are listed in table C-8.

The principal investigator supplied a variety of documents, including reference materials and equipment service manuals; these are listed in table C-9.

TABLE C-1.- PRIMARY EXPERIMENT HARDWARE

Equipment	Type of construction	Weight (kg)	Power (VA)	Cost[1] ($)	Effort[2] (man-days)
Sensor package and associated equipment					
·Spectrometer	Experimenter-built (except for final welding)	15.0	None	1,100	10
·Spectrometer grating control	Experimenter-built		57	600	40
·Detector, Cu:Ge array of four	Experimenter-built		None	20	40
·Detector bias control (4)	Experimenter-built		90 V battery	100	5
·Preamplifiers (4)	Experimenter-built		0.4	100	20
·Dewar (liquid helium)	Experimenter-built		None	700	15
·Pressure gage and valve	Off-the-shelf		None	260	1/2
·Ion vacuum pump and control[4]	Off-the-shelf	---	25	475	0
·Helium transfer lines[4]	Experimenter-built	---	None	300	---
Signal electronics					
·Digital channel					
Channel sequencer	Experimenter-built	52.6	40	500	20
·Analog channel					
Amplifier and synchronous demodulator	Off-the-shelf		12	1,000	0
Voltage control oscillator (volts to frequency)	Experimenter-built		12	50	7-1/2
Data-recording or data-display equipment					
·Four-channel cartridge recorder	Off-the-shelf		32	300	0
·Oscilloscope (used sometimes)	Off-the-shelf		15 V battery	545	0
·Audio amplifier and speaker	Off-the-shelf		5	50	3
Data-processing equipment					
·Computer[4]	Off-the-shelf	---	1,000	4,000	0[3]
Expendables					
·Miscellaneous[4]	Off-the-shelf	---	None	500	0
	TOTALS	67.6	158.4 (flight) 1183.4 (all)	10,000	161

TABLE C-1.- PRIMARY EXPERIMENT HARDWARE - Concluded

NOTES: [1]Material costs only.
[2]Includes design, fabrication, and assembly.
[3]Original design took about 80 man-days; not charged to this effort.
[4]Not used in flight.

TABLE C-2.- BACKUP EXPERIMENT HARDWARE

Equipment	Type of Construction	Weight (kg)	Power (VA)	Cost[1] ($)	Effort[2] (man-days)
Sensor package and associated equipment					
· Spectrometer	Experimenter-built	16.3	None	1,100	10
· Spectrometer grating control	Experimenter-built	↓	57	600	40
· Detectors (2); Cu:Ge and Zn:Ge (and spares)	Experimenter-built and custom-commercial		None	1,000	0
· Detector bias control (2)	Experimenter-built		0.2	50	10
· Preamplifier (2)	Off-the-shelf		0.2	580	0
· Dewar (liquid helium)	Experimenter-built		None	700	15
· Pressure gage and valve	Off-the-shelf	↓	None	260	1/2
· Ion vacuum pump[3]	Off-the-shelf	---	25	125	0
Signal electronics					
· Amplifiers (2) · Synchronous demodulators (2)	Off-the-shelf	49.9	24	600	0
· Voltage control oscillator (2) (volts to frequency)	Experimenter-built		24	50	10
Data-recording and data-display equipment					
· Four-channel cartridge recorder	Off-the-shelf		32	300	0
· Oscilloscope (used sometimes)	Off-the-shelf		15 V battery	545	0
· Audio amplifier and speaker	Off-the-shelf	↓	5	50	0
Data-processing equipment					
· Digitizer and printer[3]	Off-the-shelf	---	36	2,000	0
	TOTALS	66.2	142.4 (flight) 203.4 (all)	7,960	85-1/2

NOTES: [1]Material costs only.
[2]Includes design, fabrication, and assembly.
[3]Not used in flight.

TABLE C-3.- PRIMARY EXPERIMENT DISPLAYS[1]

Display	
Tape recorder	
One VU meter for each of four channels	
Illuminated channel designators 1-4	
Channel sequencer	
0-50 A panel meter, measures signal strength	
Red pilot light, on-off indicator	
Grating control panel, neon numerical indicators	
Time between bursts[2]	2 digits
Bursts per cycle	2 digits
Steps per burst	3 digits
Desired values are set into the control panel by digital pots for each function	
VCO panel	
Two miniature 0-100 A panel meters to show signal strength per channel	
Oscilloscope (battery operated)	
Used for signal channel indication; readily removable for lab use	
Small loudspeaker	
Also handles signal channel signal; provides signal indication to experimenter while his eye is on the tracking telescope	
Telescope stabilization electronics	
12 illuminated pushbutton switches	
Roll and yaw meters	
Roll and yaw meters (installed in pilots compartment)	
Grating position indicator	
Mechanical counter (3 digits) geared to grating shaft; indicates angular position; convertible to micrometers with calibration	
Pressure gage	
Measures and indicates pressure in Dewar for manual adjustments	

NOTES: [1]All displays are a direct part of the experiment equipment except for the oscilloscope which can be removed and used for other tasks.

[2]A burst is a selected number of individual small steps of the stepping motor.

TABLE C-4.- EXPERIMENTER TOOLS AND USAGE DURING MISSION

Item[a]	Quantity	Used Yes	Used No	Quantity used
Longnose pliers	3	X		3
End cutter plier	1	X		1
Small wire stripper	1	X		1
Tweezers	3	X		2
Screwdrivers (flat blade, 1/8" to 1/4")	5	X		3
Screwdrivers (Phillips; small, no. 1, no. 2)	3	X		3
Offset screwdrivers				
Flat blade	1		X	
Phillips	1		X	
Set small screwdrivers	8 pieces	X		3
Allen screwdriver set	9 pieces	X		6
Nut driver set	10 pieces	X		3
Nut driver	1	X		1
2 sets Jeweler's screwdrivers	12 pieces	X		3
1 set hex key wrenches	10 pieces	X		6
1 set long hex key wrenches	10 pieces		X	
Ratchet wrench	1	X		1
Adjustable wrenches (4", two 6", two 8")	5	X		2
Tap wrenches	3		X	
Allen wrenches - very small to small	7	X		2 very small
Solder gun, 1-1/2 amp	1	X		1
Small soldering iron	1	X		1
Small soldering iron tip	2	X		1
Nozzle for torch plus gas cylinder	1		X	
Swiss jewelers files	5	X		2
Flat files	5	X		2
Half-round file	1		X	
Knife blades	2		X	
Small saw blade	1	X		1
Glass cutter	1		X	
Pair small scissors	1	X		1
Pair shears	1	X		1
Scribe	1	X		1
Prick punchs	2		X	
Heavy-duty punch	1		X	
Twist drills (tap and clearance drills)	16	X		4
Set twist drills (1/16" x 1/4")	13 pieces		X	
3/8" electric drill motor	1	X		1
9 taps - sizes 0 to 10	9		X	
Wooden blocks - spacers for Dewar filling	3		X	
Hand reamers - tapered	2		X	

TABLE C-4.- EXPERIMENTER TOOLS AND USAGE DURING MISSION - Concluded

Item[a]	Quantity	Used Yes	Used No	Quantity used
Rubber hammer	1	X		1
1-in. micrometer	1		X	
Wooden blocks (custom built) used as fulcrum for removal of radiation shield	3	X		1
Tubing clamps	5	X		5
1-in. C clamps	2	X		2
Hacksaw	1	X		1
TOTALS	177			66
Estimated net weight, 22 kg (48 lb)				

[a]Items stored in 20x8-1/2x13-1/2 cm tool box, weight 11 kg (24 lb).

TABLE C-5.- EXPERIMENT TEST AND MAINTENANCE EQUIPMENTS AND USAGE DURING MISSION

Item	Used	Not used
Electrometer (measures volts, amp, ohms, coulombs)	X	
Battery tester	X	
Dummy IR source with chopper wheel (experimenter-built)	X	
Digital multimeter	X	
Oscilloscope (battery operated)	X	
Multimeter	X	
Pair earphones	X	
Test probe	X	
Vacuum gage (used in helium filling)	X	
Helium transfer lines (2)	X	
Battery charger	X	
Laser (alinement of optics)		X
Vacuum pump (used to pump down Dewar)	X	
Microphone		X
Miniature earphone	X	
Camera tripod (ASO)		X
Collimator and IR source (for telescope alinement in aircraft) (ASO)	X	
Oscilloscope (battery operated) (ASO)		X
Two power supplies (0-15 V @ 2A) (ASO)		X
Function generator (ASO)		X
Vacuum pump (mechanical) (ASO)	X	
High pressure regulator (ASO)		X
Helium transfer line (ASO)	X	
LN_2 Dewar (1 liter) (ASO)	X	
Telescope service cart (ASO)		X
TOTAL	17	9
Estimated total weight, not including telescope service cart, 123 kg (270 lb)		

TABLE C-6.- EXPERIMENT SPARE PARTS AND USAGE

Item	Quantity	Used Yes	Used No	Quantity used
Mechanical				
Tubing adapters	2	X		1
Envelope of "O" rings	9		X	
Loose "O" rings, large (1" to 6" dia.)	10	X		2 (2" dia.)
Electrical				
Electronic component board	1		X	
Spare circuit boards, empty	2		X	
Box assorted electronics parts, resistors, etc.	1	X		1
Detectors	4	X		1
Optical				
Extra grating (higher resolution)	1		X	
Optical and IR filters	2		X	
Spare small flat mirrors	2		X	
TOTAL	34			5

Estimated total weight, 3.6 kg (8 lb)

TABLE C-7.- MISCELLANEOUS EXPERIMENT SUPPLIES AND USAGE

Item	Quantity	Used Yes	Used No	Quantity used
Epoxy patch kit	1		X	
Epoxy glue, small tube	1		X	
Tubes 600 adhesive	2	X		1
Tube thead locking compound, 633	1		X	
Tube plastic cement	1		X	
Tubes metal polish	2		X	
Tube RTV coating	1		X	
Roll elec. tape	1	X		1
Roll plastic elec. tape	1		X	
Bottle varnish	1		X	
Bottle varnish thinner	1		X	
Bottle metal rubber cement	1		X	
Pint methyl alcohol	1	X		1
Hookup wire, 100-ft spools	3	X		About 2 ft
Vial silver solder flux	1		X	
10" silver solder	1		X	
Bottle soft solder flux	1		X	
Roll 60/40 solder, 1 lb	1	X		1
Boxes assorted spare screws, etc.	2		X	
Assorted test leads	-	X		-
45-volt battery	2		X	
12.6-volt battery	4		X	
90-volt battery	1		X	
Lengths 1/8" dia. plastic rod	3		X	
Coaxial cable, 50 ft	1		X	
Light bulbs	2	X		1
Small can vacuum grease, 2 oz	1	X		1
10-oz plastic dispenser teflon	1		X	
1-oz can of 3-in-1 oil	1		X	
1/2-oz tube anti-seize	1		X	
Two pads paper	2	X		2
Abrasive paper, fine	2		X	
Package black paper	1	X		-
Magnetic tape cartridges	26	X		26
Package aluminum foil	1	X		
Tube rubber cement	1	X		
Box absorbent tissues	1	X		
Pencils (lead)	7	X		2
Ballpoint pens	2	X		2
Felt writer	1	X		1
Ballpoint pens	5		X	
Package note paper	1		X	
Experimenters notebooks (8-1/2" x 11")	3	X		3
Computation notebook	1	X		-
Experimenter's reference files	2	X		2
Scales (6", 12", 18")	3	X		2
Plastic air syringe, small	1	X		1
Wool cap	1	X		1

TABLE C-7.- MISCELLANEOUS EXPERIMENT SUPPLIES AND USAGE - Concluded

Item	Quantity	Used		Quantity used
		Yes	No	
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	
Pocket watch	1	X		1
Plastic funnel	1	X		1
Bottle nasal spray	1	X		1
0.6 fl oz nasal mist	1		X	
Bottle vitamin C pills	1	X		1
TOTAL	108			58
Estimated total weight, 11.4 kg (25 lb)				
ASO-supplied expendables:				
Liquid helium (2 Dewars)	50 liters	X		> 25 liters
Liquid nitrogen (1 Dewar)	160 liters	X		< 25 liters
Helium gas (1 cylinder)	215 SCF		X	

TABLE C-8.- INVENTORY OF FURNISHINGS IN THE WORK AREA AND USAGE

Item	Size	Used
Work bench	1.58 m^2	Yes
Storage cabinet	0.79 m^3	|
Desk		|
Surface	1.31 m^2	|
Storage	0.19 m^3	|
Work tables (2)	1.31m^2 ea.	|
Chairs (3) and stool	---	|
Blackboard	2.23 m^2	|
Bulletin board	1.67 m^2	↓
Fire extinguisher	---	No
First aid kit	5x15x25 cm	No
Desk lamps (4)	---	Yes
Telephone	---	Yes
TOTAL, 17 items		Total used, 15 (88%)

TABLE C-9.- REFERENCE MATERIALS AND RELEVANT EQUIPMENT

SERVICE MANUALS

	Used
Logic equipment catalog	Yes
Semiconductor cross reference guide	No
Technical data books: synthetic optical crystals (2)	↓
Astronomical reference data reprint	
ASSESS report, TM X-62,283	
Equipment service manuals	
Digital printer (2 models)	
Strip chart recorder (4 models)	
Phase-lock amplifiers (3 models)	
Oscilloscope	
Digital multimeter	
Electrometer	
Schematic diagram for vac-ion pump	
Audio magazine recorder operator's manual	

APPENDIX D

DETAILED ASSESS MISSION CHRONOLOGY AND SUPPORTING DATA

This appendix provides a detailed chronology of ASSESS mission events between November 15, 1972, when the experimenter team was selected, through the mission debriefing on April 13, 1973 (table D-1). Supporting data are also provided for text discussions of the major phases of the mission (tables D-2 through D-5).

TABLE D-1.- ASSESS MISSION CHRONOLOGY

Date	Time	Event
		Premission activities:
Nov. 15, 1972		Experimenter team chosen. Mission dates Feb. 26 to Mar. 3.
Nov. 27		Experimenter submitted proposal for ASSESS mission
Dec. 8		Experimenter submitted ammended proposal for additional funding to increase redundancy of electronic components. Request approved.
Dec. 18		ASSESS operational guidelines formulated. Experimenter asked to forward a GFE list.
Jan. 9, 1973		Grant funds forwarded to experimenter.
Jan. 17		Experimenter requested to develop proposed schedule of experiment preparation activities. ASSESS logistics plan approved.
Jan. 22		Illness of principal investigator delays preparations; mission dates slipped to April 2 to 6. Experimenter asked for and agreed to furnish GFE list.
Feb. 6		Experimenter's home base visited by ASSESS observer. Experimenter phoned in GFE list. Preparation of experiment on schedule; backup system testing completed, primary system 80% completed.
Feb. 12 to Mar. 7		AD converter fails in primary system; new unit ordered. Late delivery of digital counter delays assembly. Production of printed circuit cards in channel sequencer exceeds time estimate. Fabrication of preamplifiers delayed by other work. New Dewar develops He leak and delays testing.
Mar. 8		Experimenter home base visited by ASSESS observer. Preparations behind schedule on Dewar and data collection system of primary experiment. Shipping still estimated 3/16.
Mar. 13		Orion nebula (M42) and Jupiter chosen as mission targets. Copilot/observer accepted assignment.
Mar. 14		Operational test of primary experiment system. ASO flight planner/navigator calculates takeoff times for Orion and Jupiter. Flights to be 1 hr + 40 min for both targets.
Mar. 20		Problems with computer and Dewar of primary system. Experimenter plans to arrive at Ames March 26, on schedule.
Mar. 21		Experimenter asked for schedule delay of 1 week; computer fixed but Dewar still giving trouble. Mission dates reset to April 9 to 13.
Mar. 29		ARC telescope being tested; completion date April 2.
		On-site preparation week:
Apr. 2		Principal investigator and assistant arrive and begin installation of equipment on aircraft racks.
Apr. 3		Telescope spacing ring replaced to allow for proper focusing. Preliminary flight schedule defined. Telescope focused in evening.

TABLE D-1.- ASSESS MISSION CHRONOLOGY - Concluded

Date	Time	Event
Apr. 4, 1973		Equipment installation completed. Airworthiness and Flight Safety Review Board briefing; operation plan approved. Crew physician assigned.
	1500	Engineering checkout flight.
	1930	Copilot/observer familiarization and data flight aborted due to aircraft malfunction.
Apr. 5	1500	Experimenter equipment moved to trailer site.
	1824	First data flight from trailer site. Moon used as calibration target. Results satisfactory.
Apr. 6	1300	Dewar appears to be leaking, but no leaks indicated by test.
	1400	ASSESS briefing meeting.
	1921	Second data flight from trailer site. Targets were the Moon and M42. Tape recorder not operating properly. Experimenter developed ear problem. Experiment malfunction indicates damage to detector system.
Apr. 7	0800	Experimenters worked to resolve noise problems identified on last flight. Planned "hands-off" period could not be realized.
Apr. 8		One-day "hands-off" period for rest and relaxation.
Apr. 9	0800	Assistant experimenter grounded by Ames medical doctor.
	1600	Confined phase starts at trailer site. Backup experiment system installed.
	2227-0020	Flight no. 1 from trailer site. Target Moon. Copilot/observer replaces experimenter who is grounded with ear trouble for ASSESS flights no. 1-4, inclusive.
Apr. 10	0340-0545	Flight no. 2 from trailer site. Target Jupiter.
	1905-2105	Flight no. 3 from trailer site. Target M42.
Apr. 11	0338-0520	Flight no. 4 from trailer site. Target Jupiter. Serious experiment malfunction.
	1446-1548	Flight no. 5; check flight from trailer site to verify experiment performance. Assistant experimenter back on board. Target Moon.
	1901-2103	Flight no. 6 from trailer site. Target M42.
Apr. 12	0340-0533	Flight no. 7 from trailer site. Target Jupiter.
	1450	CV-990 crashed. Flights cancelled. Mission holding.
Apr. 13	1300	Mission terminated.
	1415	Mission debriefing.

TABLE D-2.- EXPERIMENT HOME BASE TESTING

Component	Extent of tests	Type of test	Test equipment used	Problem highlights	Test effort (man-days)
Sensor package					
Helium Dewar (new)	Measurement of helium loss and leak	Operational	Flow meter and leak detector	None	1
Helium Dewar (backup)	Measurement of helium loss and leak	Operational	Flow meter and leak detector	None	1
Detectors (4) (new)	Tested separately for output noise and sensitivity	Operational	Standard Dewar, preamplifier, oscilloscope, wave analyzer	None	14
Dewar and detectors (2) (old)	Tested as complete cryogenic-optical system for beam pattern, detector noise, and output response	Operational	Oscilloscope, wave analyzer black body, and filters	None	1
Laboratory					
Test Dewar	Find leak		Helium leak detector	Leak repaired but too late to complete tests of four-element detector arrays	1/2
Electronics					
Preamplifier	Tested separately for gain and noise	Operational	Square-wave generator and oscilloscope	Small development troubles	2
Signal channel electronics	Tested separately to check gain and battery condition	Operational	Oscilloscope and meter	Small development troubles	4
Phase reference amplifier	Chopper voltage measured	Operational	Oscilloscope and signal generator	Small development troubles	2
Stepping motor control	Room temperature and and -5° C	Power surges, cold soak	Voltmeters, counter	Small development troubles	8
Voltage control oscillator (VCO)	(1)Test for function (breadboard model) (2)Cursory checkout flight unit	Operational	Oscilloscope and signal generator	(1)Failed and replaced (2)None noted	1/2 (est)

TABLE D-2.- EXPERIMENT HOME BASE TESTING - Concluded

Component	Extent of tests	Type of test	Test equipment used	Problem highlights	Test effort (man-days)
Recorders and data processors					
Magnetic-tape recorder	Recorder operated	Operational	Pre-recorded cassette and computer	None	1/4 (est)
Computer	Test with data tape; repeat after replacement	Operational	Data tape	Front panel failed and replaced	1 (est)
Counter	Test with frequency signal; repeat after replaced	Operational	Signal generator	Failed and replaced	1/4 (est)
Primary experiment	Response of entire system	Quantitative performance evaluation	IR signal source, data processing computer	Minor adjustments	1
					Total 36-1/2

TABLE D-3.- PLANNING FOR ASSESS MISSION INFLIGHT OBSERVATIONS

Nov. 21, 1972 - Experimenter's Proposal

Prime objective is to obtain spectra on the Moon, Jupiter, and selected H II regions, in the 16 to 40-μ band.

Feb. 6, 1973

Principal astronomical objects will be M42 (Orion Nebula) and the planet Jupiter. μ Cephei will be observed if time permits and α Orionis (Betelgeuse) will be used as a calibration star.

March 13

Jupiter and the Orion Nebula reconfirmed as primary targets, with the Moon as a calibration source. Daily observations planned for the two primary targets, M42 in the evening and Jupiter in the morning.

March 14

Preliminary flight plans (ASO) validate timing of Orion and Jupiter flights.

March 26

Schedule for experiment installation and checkout flights during preparation week as follows:

April 2 and 3 - experiment installation
April 4 - daytime equipment checkout flight; evening data flight
April 5 and 6 - backup data flights if needed

April 2, 1973 - Premission week begins at 0800

April 2 to 4

Detailed flight planning (ASO) for observations of M42 and Jupiter during ASSESS mission.

April 4

Daytime checkout flight (at 1500) completed. Evening data flight (at 1930) aborted due to aircraft problem.

April 5

Calibration flight using Moon at 1500; delayed to 1824. Data flight on M42 (at 1930) delayed until April 6 because of time conflict with first flight.

April 6

Data flight on M42 and Moon at 1921.

April 9

0800-Experimenter requests calibration flight on the Moon and Betelgeuse (in place of M42) as first flight in ASSESS mission.

1000-Request for Ames support of ASSESS flight 2 through 10 formalized by Ames Flight Request Record by ASO mission manager as per planned schedule of March 13.

April 9

1600-Start of Shuttle simulation period

April 10

Two scheduled science flights completed.

April 11

Scheduled early morning science flight completed.

1300-Flight schedule revised by addition of experiment checkout flight at 1400, using the Moon as calibration source. Scheduled evening science flight completed.

TABLE D-3.- PLANNING FOR ASSESS MISSION INFLIGHT OBSERVATIONS - Concluded

April 12, 1973
Scheduled morning science flight completed.
1500-Crash of CV-990 forces cancellation of two science flights. Mission in "hold" status.
April 13
1300-Mission terminated; remaining two science flights cancelled.

TABLE D-4.- EFFECTIVENESS OF FLIGHT PLANNING AND RESEARCH OPERATIONS DURING SHUTTLE SIMULATION PERIOD

			Flight request April 9, 1973		Final flight plan						Flight operations					Research effectiveness							
Flight number	Date	Astro. target	Time of takeoff	Flight duration (est.), min.	Date prepared	Time of takeoff	Time on track Start	Time on track Finish	Time on track Min.	Flight duration, min.	Time of takeoff	Time on track Start	Time on track Finish	Time on track Min.	Flight duration, min.	Observation period Start	Observation period Finish	Observation period Min.	Obsv. time / Track time	Background scan Start	Background scan Finish	Background scan Min.	Obsv. time / Flight time
1	4/9	Moon	2227	110	4/9	2227	2300	2340	40	115	2227	2300	2338	38	113	2310	2338	28	0.74	2343	2348	5	0.29
2	4/10	Jupiter	0342	115	4/9	0342	0429	0519	50	115	0340	0420	0523	63	123	0420	0523	63	1.00	None		0	0.51
3	4/10	M42	1905	110	4/10	1905	1938	2023	45	110	1905	1938	2023	45	120	1941	2025	44	0.98	None		0	0.37
4	4/11	Jupiter	0338	115	4/10	0338	0425	0515	50	120	0338	0424	0510	46	102	0424	0505	41	0.89	None		0	0.40
5	4/11	Moon	Not planned		4/11	1400	1440	1520	40	115	1446	1516	1537	21	62	1456	1537	41	1.95	None		0	0.66
6	4/11	M42	1901	110	4/11	1900	1934	2019	45	110	1901	1934	2024	50	122	1935	2024	49	0.98	None		0	0.40
			Flight 5																				
7	4/12	Jupiter	0335	115	4/11	0335	0422	0512	50	120	0340	0419	0512	53	113	0425	0512	47	0.89	None		0	0.42
			Flight 6																				
Cancelled ↓		M42	1857	110	4/12	1857	1930	2015	45	110		Cancelled ↓											
			Flight 7																				
		Jupiter	0331	115	4/12	0332	0419	0509	50	120													
			Flight 8																				
		M42	1853	110		Not prepared																	
			Flight 9																				
		Jupiter	0327	115		Not prepared																	
			Flight 10																				

NOTE: Flight altitude to be above tropopause during observation period; nominally 13.7 km (45,000 ft).

TABLE D-5.- EXPERIMENTER DECISION POINTS - NORMAL (N) OR MISSION PECULIAR (MP)

Decision	Type	Date	Decision factors	Options
Participate in ASSESS simulation mission	MP	11/15/72	Impact to ongoing program Availability of astro. targets Flight schedule, two a night Availability of funding, manpower	Continue research on normal flight schedule
Science goals and experiment equipment for ASSESS mission	MP	11/21/72	Science results to date in airborne research Time for preparation Experiment reliability	Extend or diversify research effort Use existing equipment or build new
Obtain back-up units for most experiment components	MP	Before 12/8/72	Experiment reliability Checkout and testing required Manpower available	Duplicate existing units Upgrade component design Two separate systems or one with backup
Build new primary experiment	MP	Before 1/1/73	Improved science potential Time and manpower to develop Availability of funding Interchangeability of units	Upgrade existing experiment Develop new data system Use new detector concept Make or buy
Selection of detector array for primary experiment	N	Before 1/15/73	In-house fabrication ability Quality of data return Testing and calibration required Commercial availability	Use existing array Number and material of elements Make or buy
Request delay of one month	N	1/22/73	Required development time Delays in delivery from commercial sources Available manpower	Contract out fabrication Fly without new experiment Reduce reliability testing
Select astronomical targets	N	2/6/73	Meet research goals Available to observe Intensity of source Sensitivity of detectors	Alternate targets for calibration and prime sources One or two targets per flight
Replace all existing cabling and LHe transfer lines	MP	Feb. 1973	Time available for in-mission maintenance Ready availability In-house capability	Use existing hardware and repair as required Buy reliability in low cost items

TABLE D-5.- EXPERIMENTER DECISION POINTS - NORMAL (N) OR MISSION PECULIAR (MP) - Concluded

Decision	Type	Date	Decision factors	Options
Request delay of one week	N	3/21/73	Fabrication and testing of new system delayed Problems with Dewar and computer systems	Use untested experiment Fly with only backup system
Hold to revised schedule	MP	3/28/73	Time required to complete testing of detector arrays Availability of targets Competition of other scientists	Fly with existing detectors Delay mission and complete replacement arrays Reschedule when astronomical targets available (3 to 4 mo.)
Do not repair detectors during the mission	N	3/28/73	Science potential of backup system Safety hazard of repair procedure	Use backup system if failure occurs Replace detector array with lower quality backup
Replace primary experiment with backup	MP	4/7/73	Time required for repair Research potential of backup system Problem not isolated	Delay or cancel mission Replace or repair defective parts during mission Fly with backup experiment
Use copilot/observer as backup for experimenter	MP	4/9/73	Asst. experimenter grounded for indefinite period Skill and training required Copilot is an astronomer	Delay mission
Make calibration flight with backup experimenter	N	4/9/73	Verify optical alinement Optimize system performance Train backup experimenter	Fly backup experiment without flight calibration As-you-go training
Omit calibration flight on realined experiment	N	4/10/73	Loss of research time Results of last flight	Delay scheduled observations Rely on ground-test procedures
Make daytime checkout flight	N	4/11/73	Validate problem solution No delay of scheduled observations	Omit flight checkout of experiment

APPENDIX E

ASSESS MISSION RESULTS

This appendix provides supporting data for text discussions and data summaries on observed experiment performance (table E-1), equipment maintenance activity (table E-2), and participant activity cycles (figs. E-1 through E-5). Relevant supporting data in other appendixes, notably appendix C pertaining to hardware and support items, are cited in the text discussion, as appropriate.

TABLE E-1.- PROBLEM DESCRIPTIONS

Problem	Origin			When detected	Symptom	How fixed	Comments
	Expmtr. equip.	GFE	Other				
Primary Dewar optics		x		4/2	Could not be alined with telescope	Rederived equations for telescope chopper motion	Furnished equations incorrect
IR telescope		x		4/2	Could not focus	Experimenters replaced rings in telescope barrel	Wrong rings had been installed
Signal electronics	x			4/4 P. M. 1	400-Hz pickup in data signal	Built and installed low band-pass filters	Noise from telescope gyro drive
Experimenters' intercom		x		4/4 P. M. 1	Experimenters' tape recorder blanks intercom channel	Missing unit installed by ground crew	Impedence mismatch
Voltage-to-frequency converter	x			4/4 P. M. 1	Switch malfunction	Corrected wiring error	No delay
Aircraft inverter		x		4/4	Failure	Replaced by ground crew	Abort flight
Digital computer	x			4/4	Data recording malfunction (on ground)	Internal adjustments	No delay
Tape recorder	x			4/5 P. M. 2	Failed to switch channels	Postflight test worked okay	Has happened before
Signal electronics	x			4/5 P. M. 2	Strong signal from Moon saturates amplifiers	Inserted 10/1 attenuator during	Required recalibration after flight
Experimenters' intercom		x		4/5 P. M. 2	Interface from aircraft communications	Principal investigator switched out of "hot-mike" loop	Serviced by ground crew

TABLE E-1.- PROBLEM DESCRIPTIONS - Continued

Problem	Origin			When detected	Symptom	How fixed	Comments
	Expmtr. equip.	GFE	Other				
Tape recorder	x			4/6	Audio channel garbled	Change input impedence	Intercom interference
Primary Dewar	x			4/6	Rapid boil-off on bench	Tested for leaks, none found	Dewar recooled in normal way
Tape recorder	x			4/6 P. M. 3	Did not switch channels	Replaced with backup	Recorder not rated for altitude operation
Experimenters' intercom		x		4/6 P. M. 3	Aircraft communication override bothers principal investigator	Switch out of "hot-mike" loop	Serviced by ground crew
Detectors in primary Dewar	x			4/6 P. M. 3	Weak, unsteady signals	Remove 10/1 attenuator, increase gain. Switch to backup	Very high noise level in signal
Sighting telescope		x		4/6 P. M. 3	Reticle not adequate for weak sources	Experimenters build and install illuminator	Still only marginal for weak sources
Digital clock		x		4/6 P. M. 3	Timing lost when engines started	Replaced with hand-wound timer	No delay
Grating position indicator	x			4/6	Needed for use by backup experimenter	Designed and built new indicator	Not ready for flight M. 1
Start of simulation period							
Roll and yaw indicators		x		4/9 M. 1	Target out of field of view	Installed right side up	Used by pilots to position aircraft; minor delay
Backup Dewar optics	x			4/9 M. 2	Data acquisition difficult	Realined optics after flight	Noted on flight M.1 also

TABLE E-1.- PROBLEM DESCRIPTIONS - Concluded

Problem	Origin			When detected	Symptom	How fixed	Comments
	Expmtr. equip.	GFE	Other				
Experimenters' intercom		x		4/9 M. 1 and M. 2	Aircraft communication override	Principal investigator switched out of "hot-mike" loop	Ground crew cannot solve
Signal electronics	x		x	4/10 M. 3	Source too weak to identify on VCO audio	Increase gain of system after flight	Air turbulence made scope guiding difficult
Dewar seal	x			4/11 M. 4	No signal from target; "whistle" from air leak	Temporary fix with tape	Possible condensation on telescope optics
Telescope stabilization system		x		4/11 M. 6	Slippage in yaw control, "jerking"	No fix, guide around	Fault coupled to aircraft roll
Sighting telescope		x		4/11 M. 6	Difficult to acquire target	No fix	Need improved sighting device
Tape recorder	x			4/12 M. 7	Tape jammed during ascent	Replace cartridge	Recorder operation varies with brand of tape
Telescope stabilization system		x		4/12 M. 7	Same as M. 6	Realined gyro and replaced power cable after flight*	Worse than on flight M. 6
System performance			x	4/12 M. 7	Low signal-to-noise from target	No fix	Air turbulence made scope guiding difficult

*Unsoldered electrical connection discovered, during next Lear Jet mission, in telescope stabilization control system.

P.M. = Premission checkout flight.

M. = Mission flight.

TABLE E-2.- EXPERIMENT MAINTENANCE ACTIVITIES

Definition - Work done by experimenters in response to a malfunction of the experiment.

Date	Time	Task
		Start of integration and checkout period
4/2	P. M.	Recompute equations of secondary-mirror motion needed for spectrometer alinement. Incorrect information provided.
4/3	1030-1530	Replace spacer rings in telescope barrel for proper focus; install secondary mirror; remove external baffle ring. ARC support not available.
4/4		Make internal adjustments to digital computer to fix data decoding malfunction.
	2000	Modified tape-recorder plug to eliminate interference with intercom.
	1 hr	Isolated and repaired VCO switch problem.
4/5	A. M.	Build and install low-pass filters,to eliminate 400-Hz pickup in signal electronics.
	A. M.	Build 10/1 signal attenuator to avoid saturating amplifiers with signal from Moon.
	2100	Check tape recorder for failure to switch channels in flight. Operation satisfactory.
4/6	A. M.	Change input impedence of tape recorder to match intercom system.
	A. M.	Fabricate extension to own LHe transfer tube. GFE not satisfactory.
	1500	Check primary Dewar with helium leak detector (Ames). No leak found. Test for leakage when cooled with LN_2; no leak found. Refill with LHe in normal manner.
4/7	0800-1600	Primary and backup detector systems disassembled, inspected, and tested for response. New system had at least 10 times more noise than in previous similar tests. Noise source in detector units. Signal gains checked as normal in both systems. Assembled backup system and readied for flight.
4/9	0915	Experimenter requests tilt-mirror collimator (GFE) to refocus telescope to backup Dewar. Task completed at about 1700.
	A. M.	Buy parts, build, and install reticle illuminator for guide telescope.
		Start of simulation period
4/9	1400-1630	Installation of new grating position indicator in progress at 1500; cutoff time set for 1630. Task not completed before flight.

TABLE E-2.- EXPERIMENT MAINTENANCE ACTIVITIES - Concluded

		Start of simulation period (cont.)
4/9	1700-1730	Recheck focus of telescope with IR source.
	1730-1800	Primary tape recorder replaced with backup unit in aircraft.
	1930-2030	Grating control unit removed from aircraft, checked out on bench, and reinstalled.
	2045-2115	Final tuneup of backup experiment electronics in aircraft before flight.
4/10	1200-1530	Realine Dewar optics for optimum performance of backup system.
	2030-2200	Begin task of replacing damaged detectors in primary Dewar. Task not completed during mission.
4/11	0400	Temporary repair of Dewar seal in flight.
	0525-0615	Replacement of Dewar seal and test of system in aircraft and work trailer.
	1445-1550	Daytime checkout flight for adjustment of telescope alinement and guide scope sighting. Minor changes to increase gain of signal electronics.
4/12	0350	Inflight replacement of jammed tape cartridge and verification of recorder operation.
	A. M.	Consult with Ames personnel on repair of telescope stabilization electronics.

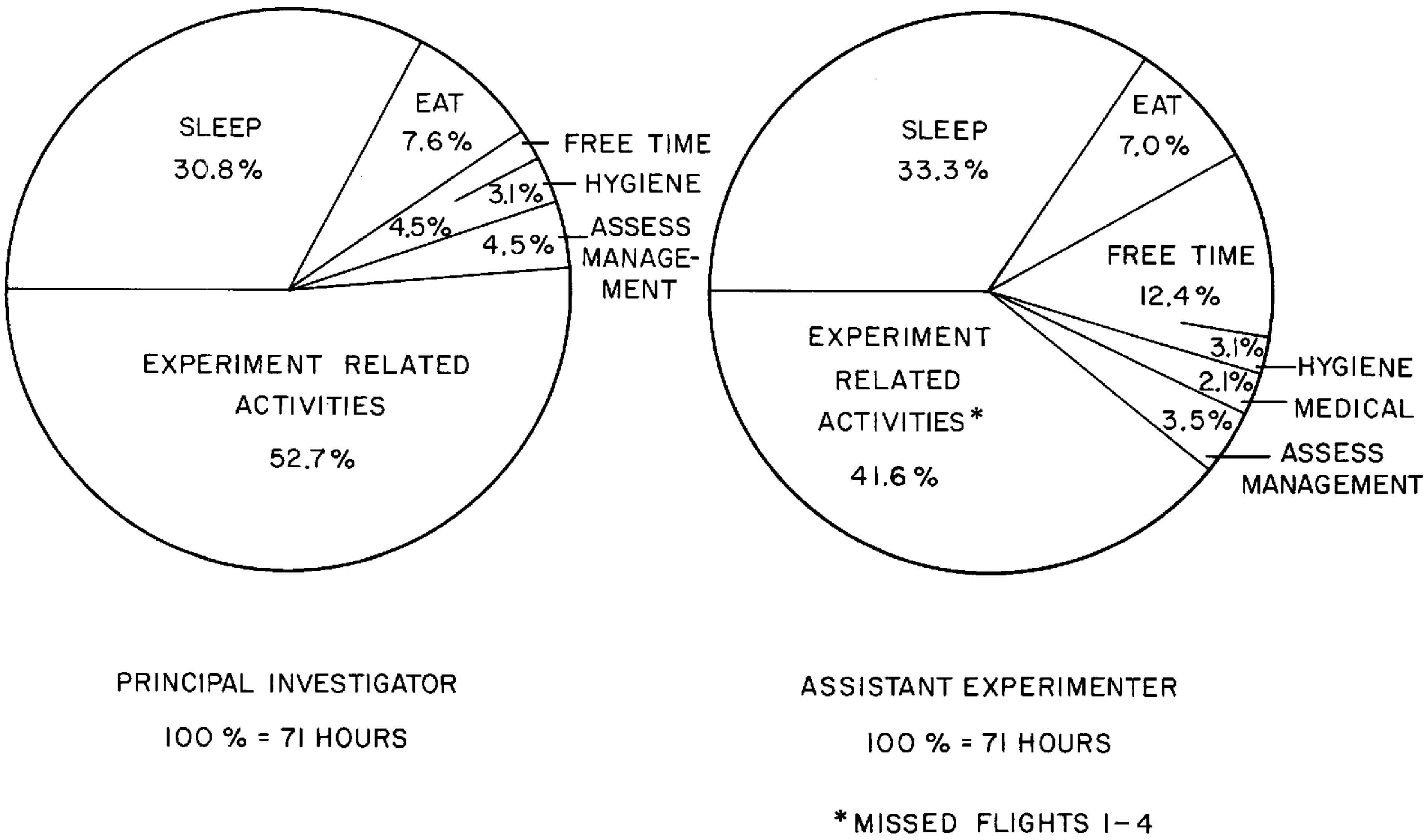


Figure E-1.- Experimenters' activity chart.

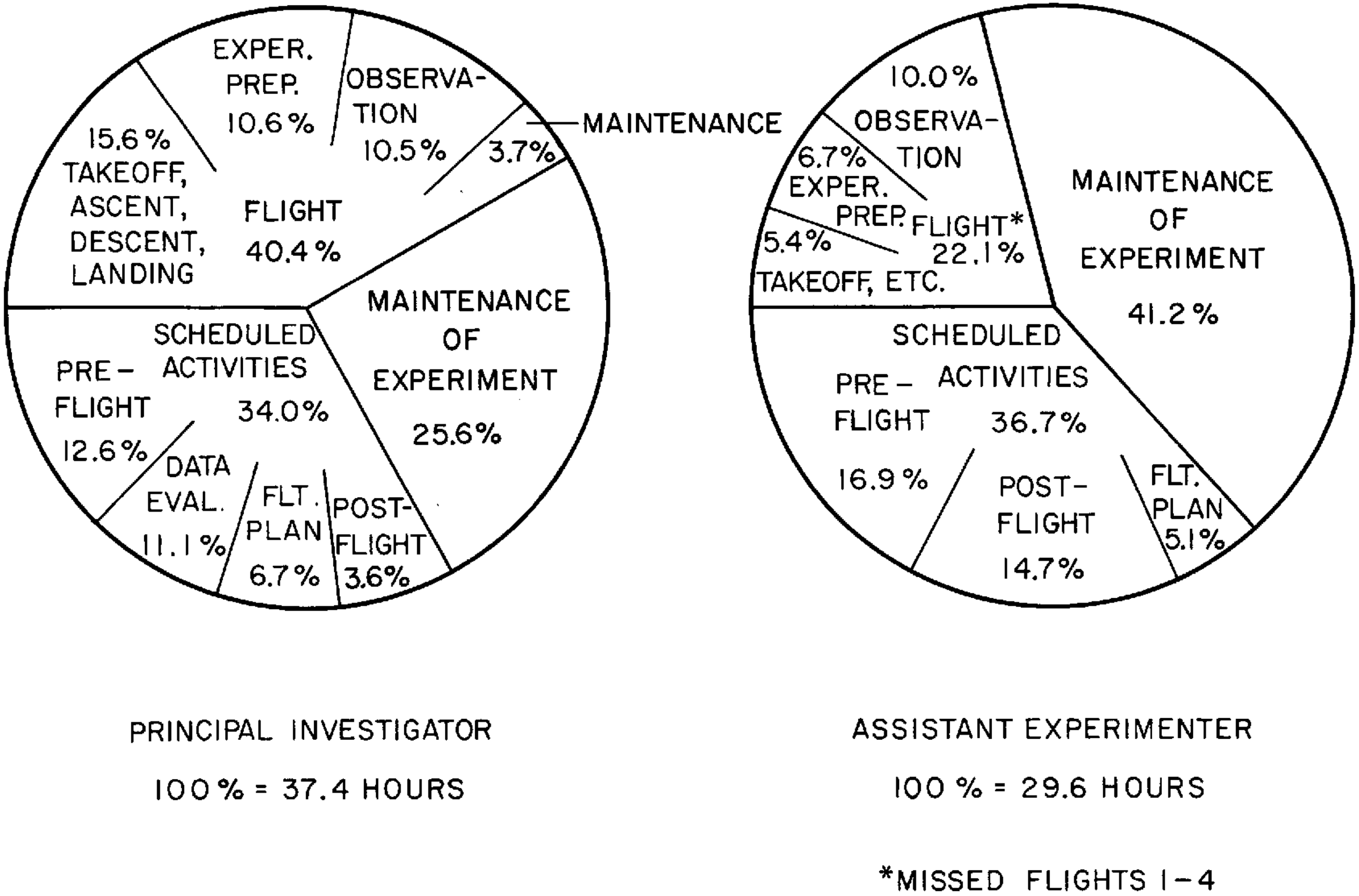
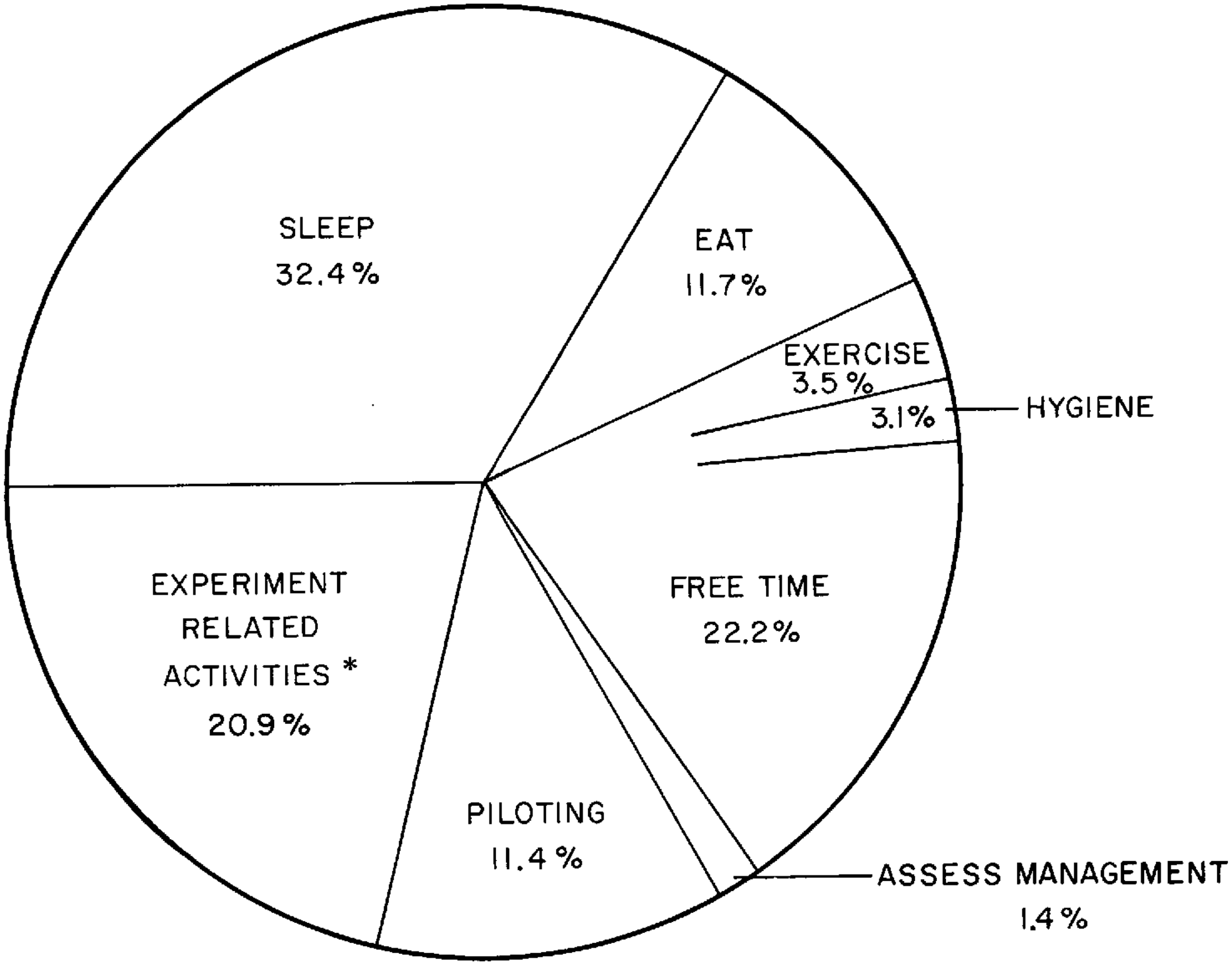


Figure E-2.- Experiment-related activity.



100 % = 71 HOURS

* EXPERIMENT OPERATOR ON FLIGHTS 1-4

Figure E-3.- Copilot/observer's activity chart.

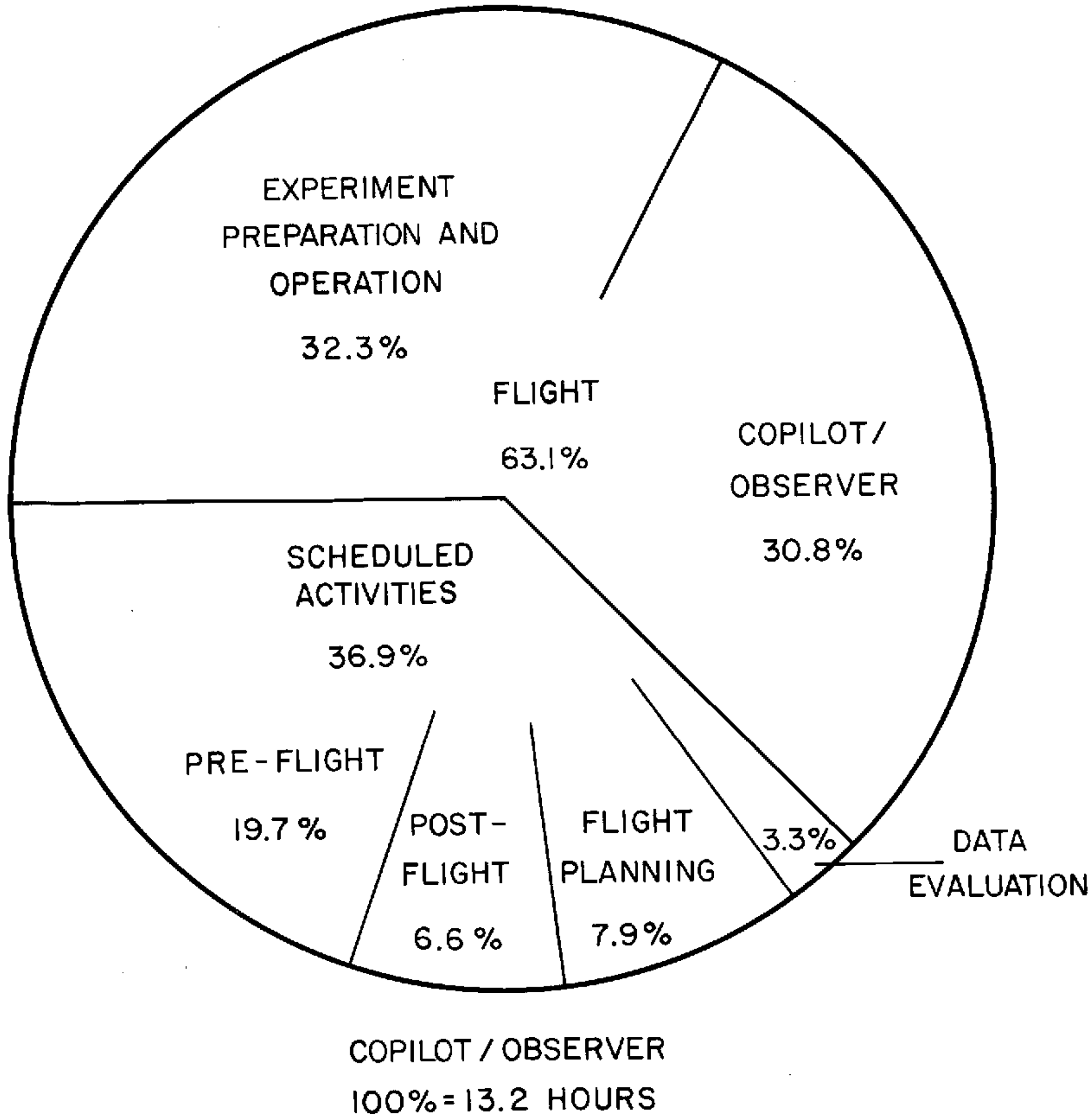


Figure E-4.- Experiment-related activity.

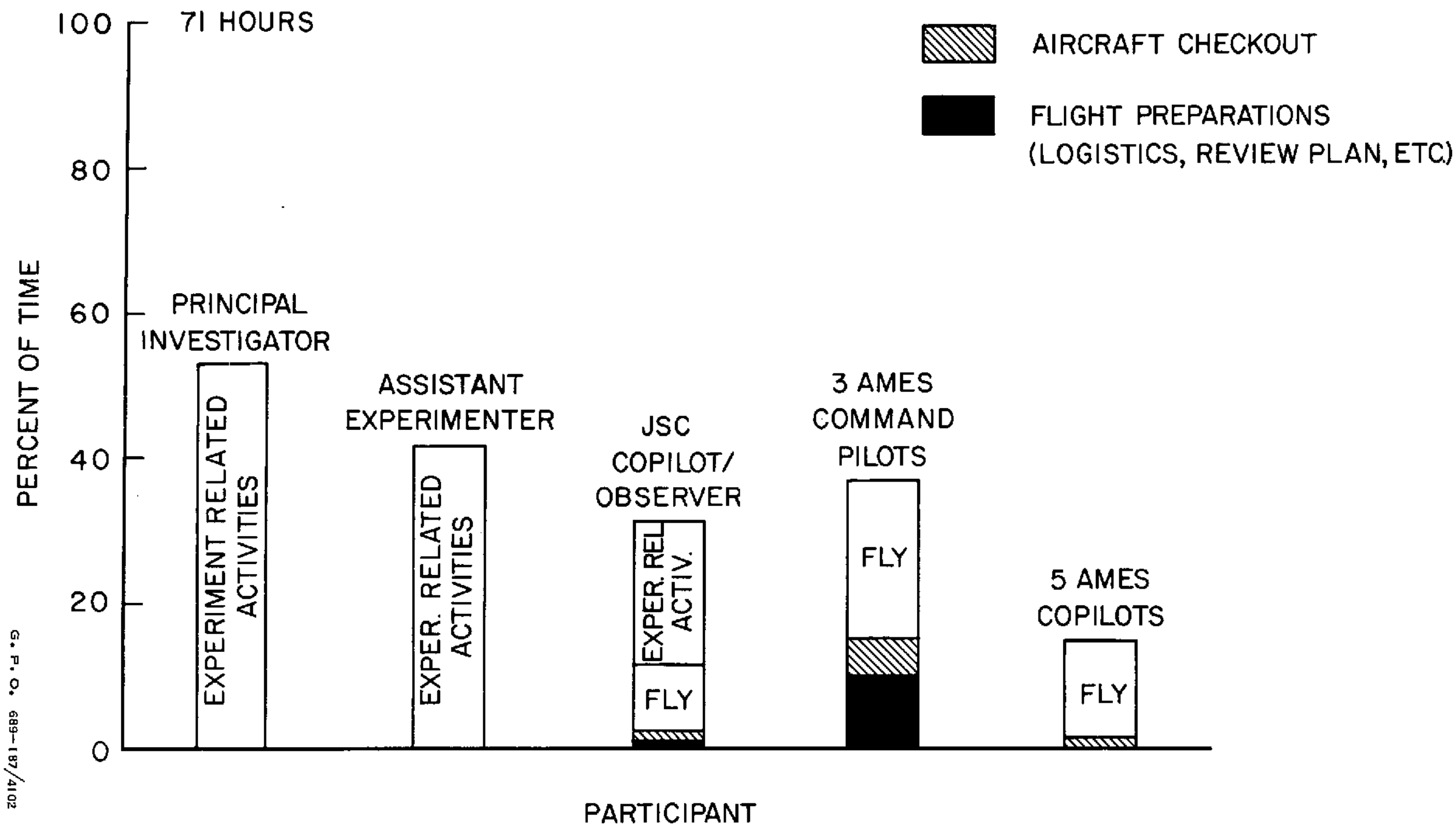


Figure E-5.- Pilot participation in ASSESS program.

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