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SPACELAB SIMULATION USING A LEAR JET AIRCRAFT – MISSION NO. 4 (ASSESS PROGRAM)

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16. Abstract

The fourth ASSESS Spacelab simulation mission utilizing a Lear Jet aircraft featured trained experiment operators (EOs) in place of the participating scientists, to simulate the role and functions of payload specialists in Spacelab who may conduct experiments developed by other scientists. The experiment was a broadband infrared photometer coupled to a 30-cm, open port, IR telescope. No compromises in equipment design or target selection were made to simplify operator tasks; the science goals of the mission were selected to advance the mainline research program of the principle investigator (PI).

Training of the EOs was the responsibility of the PI team and consisted of laboratory sessions, on-site training during experiment integration, and integrated mission training using the aircraft as a high-fidelity simulator. EO premission experience in these several disciplines proved adequate for normal experiment operations, but marginal for the identification and remedy of equipment malfunctions. During the mission, the PI utilized a TV communication system to assist the EOs to overcome equipment difficulties; both science and operations were successfully implemented.

This report is a final summation of the Lear 4 mission, supplementing the preliminary results published earlier in NASA TM X-62,408.

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TABLE OF CONTENTS

SPACELAB SIMULATION USING A LEAR JET AIRCRAFT — MISSION NO. 4

(ASSESS PROGRAM)

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

Ames Research Center

SUMMARY

The fourth ASSESS* Spacelab simulation mission utilizing a Lear Jet aircraft was conducted by the Airborne Science Office (ASO) at the NASA-Ames Research Center during the week of September 30, 1974. This mission continued the study of scientific experiment operation in the constrained environment of Spacelab, which was simulated by locating operations at a semi-isolated site, by confining the experiment flight crew to a defined work area, and by restricting outside communications.

The most significant feature of ASSESS Lear 4 was the use of two experiment operators (EOs) to operate the experimental equipment instead of the principal investigator (PI) and his assistant. In actual Spacelab operation, crewmen may be expected to conduct experiments for which they are not the principal investigators. All activities, including data collection, data reduction, equipment maintenance and repair, and eating and sleeping took place in a limited area approximating Shuttle constraints. Contact between the EOs and others was permitted only through specified communication links. A closed-circuit TV link provided two-way communications between the simulated Spacelab and the ground (Mission Center).

The experiment flown on this mission was a broadband infrared photometer operating in the region between 40 and 200 μm. The scientific objective was to measure infrared radiation from astronomical sources, some discrete, some correlated with visible sources, and some distributed sources visible only in the infrared and longer wavelengths. No compromises were made in experiment design or target selection for the benefit of the EOs.

Training of the EOs was the responsibility of the PI team and consisted of (1) observation and laboratory sessions at the PI's observatory and Ames, and (2) integrated mission simulation using the aircraft as a high-fidelity simulator. During the constrained period, the EOs obtained high-quality, original scientific data on difficult astronomical targets, and with the assistance of the PI, they were able to overcome equipment difficulties that arose. Their training, which was documented and analyzed in detail, proved adequate for nominal conditions; however, the EOs themselves noted some shortcomings, especially in their ability to identify equipment malfunctions and their remedies.

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*ASSESS: Airborne Science/Spacelab Experiments System Simulation.

INTRODUCTION

Since 1965, the Airborne Science Office (ASO) of the Ames Research Center has operated several flying laboratories in support of research programs in several scientific disciplines. The management and operations concepts employed by the ASO have received ever-widening acceptance by the international scientific community. These concepts emphasize informality, involve the investigators directly in the operation of their own equipment, and minimize documentation requirements. To make this experience more readily available for Spacelab planning, a two-phase program termed ASSESS (Airborne Science/Shuttle Experiments System Simulation) was started to observe and document the experience of the ASO in conducting scientific missions with aircraft. Phase A of the study covers normal airborne missions (refs. 1-3). Phase B includes missions modified to simulate the constraints of Shuttle/Spacelab missions. Three such simulation missions have been performed with a Lear Jet, and one with a CV-990. Results from these missions are reported in references 4 through 7.

The fourth simulated Spacelab mission utilizing a Lear Jet was conducted by the ASO at the Ames Research Center during the week of September 30, 1974; preliminary results were published in reference 8. The most significant feature of this mission was the use of experiment operators (EOs) to operate the experimental equipment instead of the principal investigator (PI) and his assistant as in the earlier missions. The utilization of the EOs simulates another possible mode of Spacelab operation where payload and mission specialists may be expected to operate several experiments not of their own devising.

As in the previous Lear Jet Spacelab simulation missions, a trailer complex, consisting of a work trailer and a living/sleeping trailer was used in conjunction with the aircraft to simulate the Shuttle/Spacelab accommodations. An added feature during this mission was a closed-circuit TV/voice link between the work area and the Mission Center. This TV link and a telephone simulated two-way communications between the Spacelab and the ground.

MISSION MANAGEMENT

The scientific research for this mission was managed by ASO in essentially the same manner as regular Lear Jet missions (refs. 1-3). The original scientific concept was approved and funded by NASA Headquarters, and the funds were then administered by the ASO for the development, construction, and operation of the experiment. A brief chronology of mission activities directed or monitored by ASO management is given in table 1.

Personnel

The two individuals with primary management responsibility were the ASSESS Program Manager and the ASO Mission Manager. The ASSESS Program

TABLE 1.- CHRONOLOGY OF MANAGEMENT ACTIVITIES

Date, 1974	Activities
February 12	Initial mission planning meeting (ASO)
March 4	Selection of experiment and PI notification
March 18	Preliminary mission schedule and EO selection; start of training
April 25	Planning meeting (ASO/PI)
May 15	Planning meeting (ASO); Program Plan with mission schedule
May 29-31	Initial ground training at Ames
June 11	Confirming letter to senior PI
July 12	Planning meeting (ASO)
July 15	Planning meeting (ASO/PI)
July 23	Planning meeting (ASO/PI)
July 23, 24	EO observes operation of experiment on C-141 airborne observatory
July 26	Planning meeting (ASO)
August 1-13	PI team on normal Lear Jet mission; preparation of training material
August 28-30	EO training at the PI's observatory
September 5-10	EO ground training
September 11	Flight readiness review for equipment
September 11-20	EO flight training (7 flights)
September 20	Flight readiness review for EOs
September 23-29	No activity (contingency week)
September 27	Flight safety review
September 30- October 6	Simulation mission week (9 flights)
October 6	Final debriefing

Manager developed the program and mission operations plans, including simulation study parameters and mission guidelines. He monitored implementation of the EO training plan developed by the PI, and was also responsible for most of the special procedures, material requirements, and logistics arrangements relating to the simulation aspects of the mission.

The ASO Mission Manager coordinated aircraft preparations and operations planning, was responsible for readiness of the Ames telescope, and monitored the assembly, testing, and calibration of the experimental equipment, which was accomplished by the PI. The Mission Manager conducted separate flight readiness reviews (FRRs) of the experiment, the telescope and associated GFE, and the EOs. The preflight installation was performed by the PI team with the assistance of the EOs.

During the simulation period, the Mission Manager served as director of activities and provided coordination between the EO/PI group and other flight and ground support personnel.

The Mission Center, housed in a trailer adjacent to the simulation site, was manned on a 24-hr-per-day basis by representatives of the Mission Manager and the ASSESS Program Manager. The PI was either at the center or on call at all times. An ASSESS observer was stationed in a separate room in the work trailer at the simulation complex.

Mission Plans and Guidelines

Program and mission operation plans- In May 1974, the ASO issued a Program Plan for the ASSESS Lear 4 mission, which provided a concise summary of the program, indicated special study parameters, and proposed a schedule to permit planning by those concerned with mission operations. The mission was divided into two main phases: preparation and confined simulation.

A Mission Operations Plan (MOP), much more detailed than the Program Plan, was issued by the ASO prior to the mission in September. The MOP covers all aspects of the operation of the mission and the support necessary for its successful fulfillment. The MOP is given in appendix A.

The original mission schedule and two subsequent revisions are presented in table 2. Compared to the original schedule, the first revision called for advancing the time of EO training flights by one week, but delaying the mission flights by one week. In the final schedule given in the MOP, the start of the training flights was delayed by two days.

Mission guidelines- The following mission guidelines were established to aid preparation and training as well as to facilitate the gathering of scientific data and simulate the constraints of the Shuttle/Spacelab environment.

1. Inflight experiment operations would be performed by experiment operators (EOs) acting in lieu of the PI team.

2. The EOs would make original scientific measurements in support of the PI's ongoing research program.

3. The PI would have prime responsibility for training the EOs and for most aspects of the experiment preparation and integration.

4. The EOs would be confined to the airplane/trailer complex for the five-day mission.

5. A goal of two flights per night was established to maximize the experiment operation time.

6. Prior to the FRR, the PI could modify his existing equipment to ensure more effective and reliable operation for the five-day mission.

7. The PI could place on board (within the aircraft or work trailer) any spare subassemblies or components considered necessary to ensure the

TABLE 2.- SUMMARY OF PROGRAM SCHEDULES FOR ASSESS LEAR 4 MISSION

Event dates	Program plan May 1974	Revised schedule August 1974	Mission operations plan - Sept. 1974
May 29-31	EO familiarization at Ames, ground and flight		
June to August (optional)	EO preliminary training at observatory		
August 28-30	EO training at observatory	EO training at observatory	
August 30	Expmt. FRR at observatory	Ship expt. to Ames	
Sept. 2	Ship expmt. to Ames	↓	
Sept. 3	↓	Install and checkout	
Sept. 4	↓	EO ground training	
Sept. 5	↓	PI flight	Install and checkout, EO ground training
Sept. 6	↓	↓	↓
Sept. 7-8	Open	Open	Open
Sept. 9	Telescope FRR	Expmt. & teles. FRR	EO ground training
Sept. 9	Install and checkout, EO ground training	EO flights begin	PI flight
Sept. 10	↓	↓	↓
Sept. 11	↓	↓	Expmt. & teles. FRR, EO flights begin
Sept. 12	↓	↓	↓
Sept. 13	↓	↓	↓
Sept. 14-15	Open	Open	Open
Sept. 16-19	EO flight training	EO flight training	EO flight training
Sept. 20	FRR for EOs, EO flight training	FRR for EOs	FRR for EOs
Sept. 21-22	Open	Open	Open
Sept. 23-27	Mission No. 4	↓	↓
Sept. 28	Debriefing	↓	↓
Sept. 29	Open	↓	↓
Sept. 30 to Oct. 5	Contingency week	Mission No. 4	Mission No. 4
Oct. 5		Debriefing	Debriefing
Oct. 6		Open	Open
Oct. 7-11		Contingency week	Contingency week

success of the mission; however, test equipment and tools would be limited to those that could be justified.

8. Every attempt would be made to complete the mission with only the equipment placed on board initially. However, if other equipment were required to avoid aborting the mission, it would be supplied and documented.

9. No direct personal contact with the EOs from people outside the ASSESS management and observation groups would be permitted during the mission. All outside communications would be limited to telephone and closed-circuit TV.

10. A mission manager would be selected to direct the mission. The Mission Manager and the PI would be located in a mission center.

ASSESS Study parameters- The study parameters established in the ASSESS program plan were as follows:

1. EO background and selection criteria

2. Subject material covered in training

3. Amount of theory required for experiment operation, maintenance, and repairs

4. Amount of hands-on training required for experiment operation

5. Ability of EO to track bright and dim targets

6. Ability of EO to process and evaluate data during the confined phase

7. Ability of the EO to maintain the experiment

8. Requirements for PI support

9. Usefulness of data obtained by EOs

In addition, experiment operator performance on the following specific tasks was monitored during the confined phase of the mission:

1. System testing

2. Removal and installation of experiment components

3. Alignment of telescope and focusing on targets

4. Equipment operation

5. Equipment maintenance and repair

6. Data processing and preliminary analysis

Documentation

Documentation for the ASSESS Lear 4 mission was deliberately held to a minimum. In addition to the basic program/mission plans outlined earlier in this section, the following documents were used:

1. Lear Jet Investigators' Handbook (ref. 9)

2. Implementation documents

    a. Experiment procedures and checklists

    b. Approvals by the Airworthiness and Flight Safety Review Board

    c. Flight plans

    d. Various Ames internal documents (e.g., shop orders, safety inspection records, and installation drawings)

EXPERIMENT DEVELOPMENT AND INTEGRATION

History of Experiment

The experiment flown on the ASSESS Lear 4 mission was the pioneering airborne infrared astronomy experiment. In October 1968, it was the first such experiment to be flown on the Lear Jet, under the auspices of the ASO. The experiment has been gradually modified by improvements in the electronic circuitry and dewar design. The senior PI on ASSESS Lear 4 had been associated with the original PI on the first Lear Jet flights as a graduate student and flew with this experiment on the ASSESS Lear 1 mission in October 1972 (ref. 4). For the Lear flight series of May 1974, new electronic circuitry and an onboard computer were used for the first time. The equipment was then flown in the same form on the Ames C-141 Airborne IR Observatory and again on the Lear Jet in August 1974.

Principal Investigators

The senior PI is an assistant professor of Astronomy at the sponsoring University. He has flown many missions on the Lear Jet, including ASSESS Lear 1 and is now flying this same experiment on the C-141 airborne observatory. For the ASSESS Lear 4, the senior PI delegated primary experiment responsibility to the PI and was not present until the last day of the mission. The senior PI did participate in some EO training sessions at the observatory, however, and was in frequent telephone contact with the PI throughout the mission.

The PI is a postdoctoral fellow in astronomy. He has flown several Lear missions and is now considered the primary PI when the experiment is flown on this aircraft. He participated heavily in the EO training program both at the Observatory and Ames and was the on-site PI during the confined portion of the mission. The PI's assistant, a graduate student, has flown several missions on the Lear with the PI. He participated in the training and premission checkout, but did not remain on site for the confined portion of the mission.

Scientific Objectives and Planning

Experiment objectives- The scientific objective was to measure infrared radiation from various astronomical objects, both discrete and distributed. The measurements were expected to (1) lead to a more complete understanding of nebular dust clouds and regions with a concentration of ionized hydrogen (HII regions); and (2) in some cases, relate infrared radiation to known sources of radio signals.

Science planning- The most significant feature of observational planning for this mission was that the astronomical objects were selected by the PI team to meet the needs of their research and were in no way compromised by the relative inexperience of the EOs. In general, the objects chosen were small areas of the sky of special interest, rather than discrete objects. Some of the chosen targets were optically invisible, necessitating offset tracking on preselected guide stars.

Planning for the scientific content of the mission was a dynamic process that extended well into the simulation period. The first recorded schedule of observations was defined late in August at the time of EO training at the Observatory, as a continuation of the senior PI's ongoing research effort with the ASO. Attention was focused on two cosmically young objects in which star formation could still be in progress, with interspersed calibration checks on the planet Jupiter. Initial science planning assumed the primary instrument was to be a filter-wheel photometer.

Between August 30 and the September 11 FRR at Ames, the senior PI selected his alternate, single-filter photometer as the primary detector, and began revisions to the observation schedule for effective use of its greater sensitivity. The final premission schedule of September 27 reflects this change, as well as the impact of exploratory measurements from the training flights. Three new targets were added, and more time allotted to the study of gas/dust excitation and radio/IR comparisons, at the expense of reference measurements on Jupiter.

Problems with aircraft and experiment forced schedule changes early in the mission and again at the midpoint. Minor operational problems on the first data flight (flight 2) also affected the PI's plans. As a result, it was necessary to spend more time than expected to verify the Jupiter calibration and to solidify M8 results. The PI therefore decided to forego two of the planned targets and to concentrate on those already observed. M17 and NGC 1333 were dropped from the schedule; both had priority attention in premission plans. W51 and OMC-2 were observed once, presumably to complement data taken during training flights.

Just half of the observations originally planned for the mission were completed (9 of 18), 9 were deleted, and 7 were added. In the end, primary emphasis was on the molecular sources and the structure of the IR source in M8.

Table 3 lists those objects initially selected for the mission. More detailed information on each object is given in appendix B. Table 4 shows the initial flight schedule established during the training period at the PI's home laboratory (August 28-30).

TABLE 3.- OBJECTS FOR OBSERVATION

W51	Optically invisible H II region approximately 3/4 degree square
M8	Optically bright H II region; roughly circular of 20 arc minutes diameter
NGC 2264	High-density gas cloud, about 4 arc minutes diameter
NGC 1333	Dust cloud, young objects, 10 arc minutes square
M78	Area of apparent new star formation, a few arc minutes on a side
Jupiter	To be used as a calibration object

TABLE 4.- ASSESS MISSION FLIGHT PLAN, 8/30/74

Nominal date		Telescope operator	Electronics operator	Object
Checkout				
Sept. 5		PI	Assistant	Jupiter, M8
Integrated Mission Simulation				
Sept. 11		Henize	PI/Asst.	Jupiter, M8
Sept. 12		Henize	PI/Asst.	Jupiter, M8
Sept. 16		PI/Asst.	Weaver	M78, Jupiter
Sept. 17		PI/Asst.	Weaver	M78, Jupiter
Sept. 18		Henize	PI/Asst.*	W51
Sept. 19		Henize	PI/Asst.*	W51
Confined Phase				
Sept. 30	early	Henize	Weaver	Jupiter, M8
	late	Henize	Weaver	W51
Oct. 1	early	Henize	Weaver	NGC 1333
	late	Henize	Weaver	Jupiter, NGC 2264
Oct. 2	early	Henize	Weaver	NGC 1333
	late	Henize	Weaver	Jupiter, NGC 2264
Oct. 3	early	Henize	Weaver	NGC 1333
	late	Henize	Weaver	Jupiter, NGC 2264

*Subsequently changed so both EOs could train together.

Experimental Equipment

The experimental equipment installation on the aircraft is shown in figure 1. A brief description of the major items follows, together with a summary of preparatory measures to ready the experiment for the Lear 4 flight series.

Item	Supplier
Telescope	GFE*
Finder telescope	Experimenter
Telescope stabilization & control	GFE
Secondary mirror control	Experimenter
Photometer with dewar	Experimenter
Vacuum pump	GFE
A/C inverters	GFE
Signal processing & recording electronics	Experimenter

*Government-furnished equipment

Government-furnished equipment

Description: The telescope used on the Lear 4 mission was the Ames 30-cm Cassegrain instrument, which was mounted through the port cabin window of the aircraft (fig. 2). A detailed description is given in the Lear Jet Telescope Operation Manual (ref. 10). For this experiment, a dichroic mirror was fitted in the focal plane to permit reflex viewing by the telescope operator while passing the IR signal to the photometer. A coaxial finder telescope was provided to assist initial target location. Gyrostabilization was provided to overcome the effects of slight aircraft motions. A joystick control permitted the telescope operator to aim and control the telescope. The same pair of torque motors handled both control and stabilization inputs to the telescope mount.

A pair of inverters, operated from the aircraft 28-Vdc supply, provided 60-Hz power to the experiment electronics. The telescope stabilization and control system operated directly from the 28-V supply. The two 60-Hz inverters (28 Vdc to 120 Vac), the vacuum pump, and the telescope stabilization electronics are all installed in the baggage compartment of the aircraft, behind the passenger seat (fig. 3).

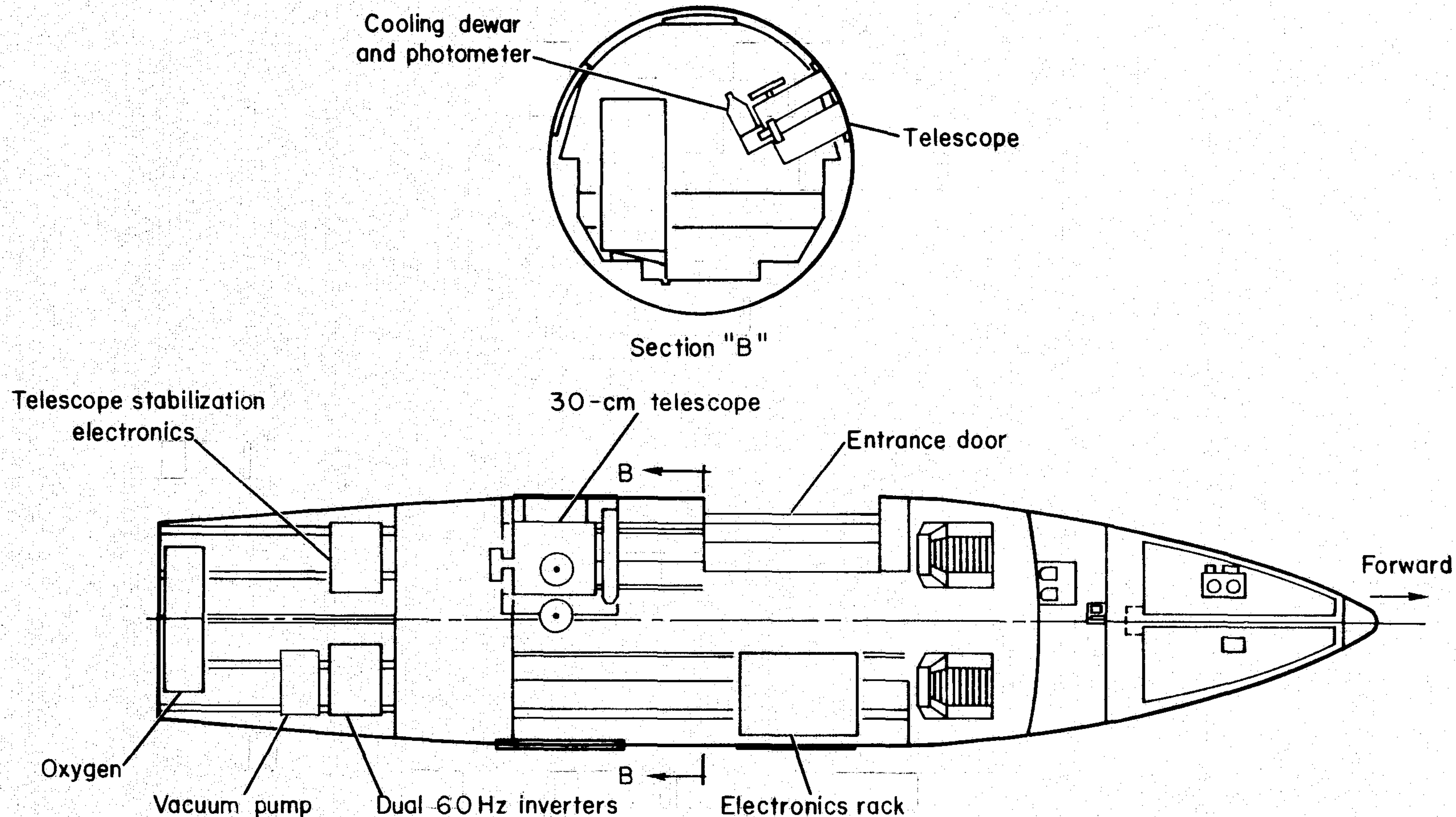


Figure 1.- Arrangement of experiment equipment in Lear Jet.

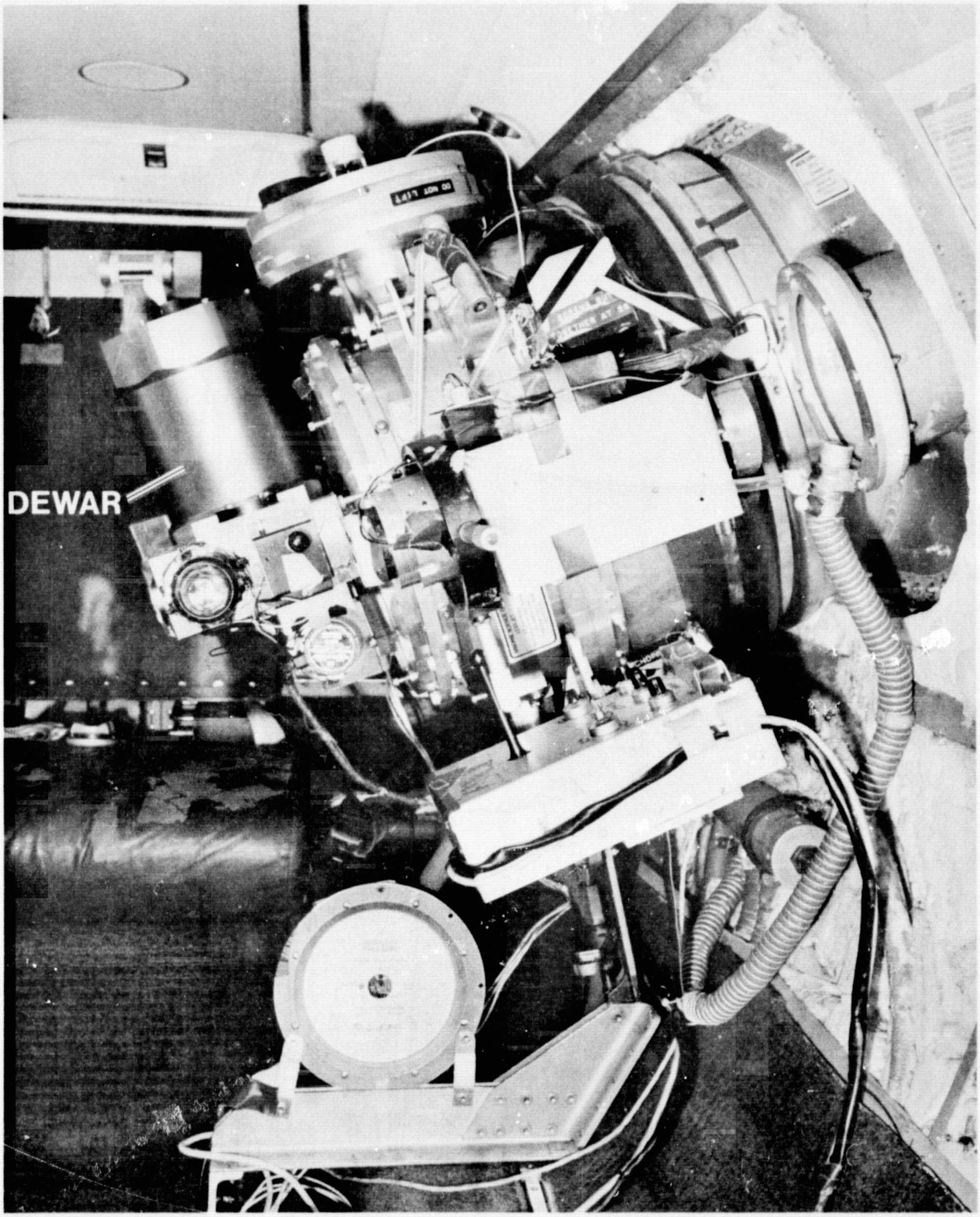


Figure 2.- Telescope and photometer in aircraft.

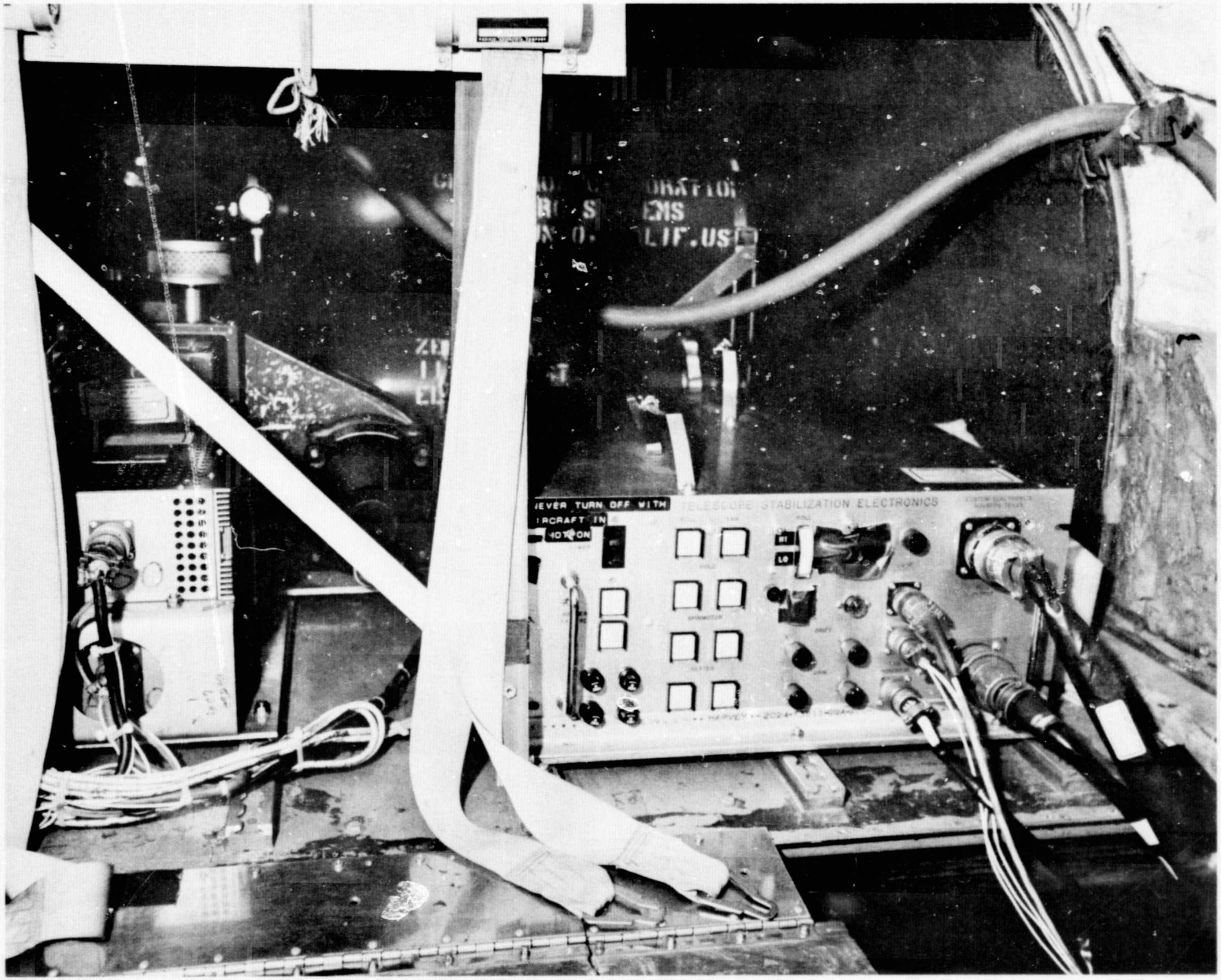


Figure 3.- Inverters, vacuum pump, and stabilization electronics.

Lear 4 preparations: Prior to the Lear 4 mission, responsibility for the Lear 30-cm telescope was transferred from another Ames research group to the ASO. Various small tasks of refurbishment and checking were performed on the telescope and the associated controls. The FRR on the telescope, held September 11, is discussed in a later section.

Experimenter equipment

Description: The Ames telescope was provided with an oscillating secondary mirror so that the target plus background sky was viewed alternately with the sky background alone to allow for subtraction of background noise level from the target signal (fig. 4). The experimenter provided the secondary mirror control, which supplied the square-wave voltage to the "chopper" electromagnets at a frequency of 20, 40, or 80 Hz, as well as the phase reference to the signal processing electronics.

The photometer, which was attached to the bottom of the cryogenically cooled dewar, was bolted to the rear of the telescope (figs. 2 and 5). The dewar was cooled by liquid helium and had a liquid nitrogen jacket between the helium and the outer vacuum jacket. The desired temperature of 1.8 K at the detector was achieved and maintained by means of an onboard mechanical vacuum pump.

Figure 6 is a block diagram of the signal-processing and -recording equipment, which also indicates the relationship of the secondary mirror control. This diagram was prepared by the PI for use in EO training. Figures 7 and 8 are photographs of the equipment installed in the aircraft. As part of the training material, the PI provided a sketch (fig. 9) identifying the various components of the equipment shown in figure 8. Detailed dimensional information on the experimental equipment is given in appendix C.

Incident radiation is focused on a tiny germanium crystal, the bolometer, whose resistance changes as a function of temperature. The output of the bolometer is a time-varying voltage of very low magnitude, about 10 μV. Initial amplification is performed by a preamplifier mounted on the dewar. The signal is then further amplified by the phase-lock amplifier (PLA), which takes its reference voltage from the chopper drive circuitry. The 5-Vdc signal output from the PLA circuitry drives a voltage-controlled oscillator (VCO, integral with the PLA package) and is recorded on the strip chart recorder. The dc signal may also be examined on the oscilloscope if desired. The ac signal from the VCO is recorded on one channel of the tape recorder as an audio signal. It is also available to the experimenter as an audio signal through an earphone, labeled "squealer" in figure 6.

The ac signal from the VCO also is fed to a counter, which integrates the signal over a specified time period (variable between 1 and 16 sec). The counter is triggered externally by the clock controller, and the digital information from the counter is fed into the HP-9810 computer. The computer

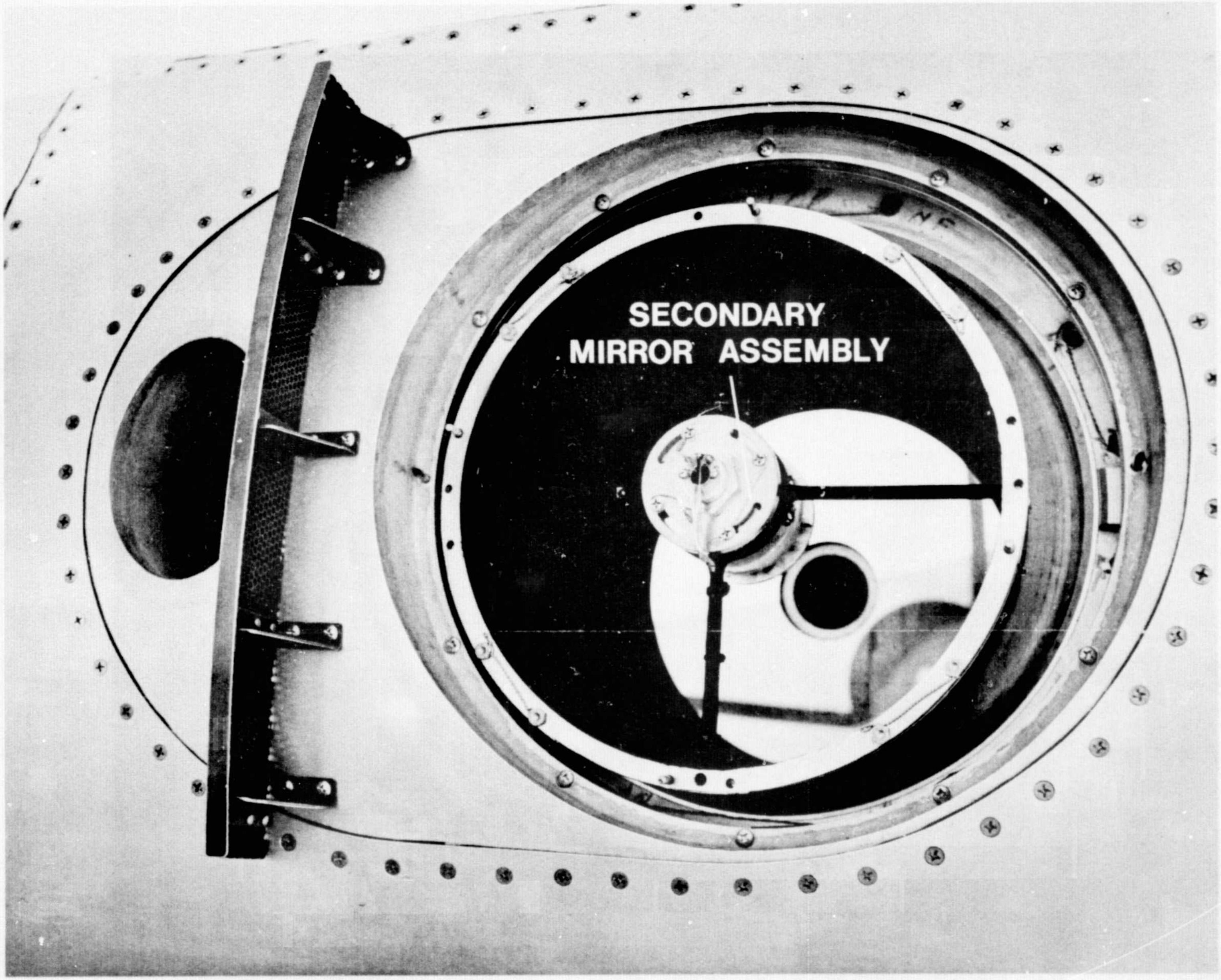


Figure 4.- Telescope secondary mirror.

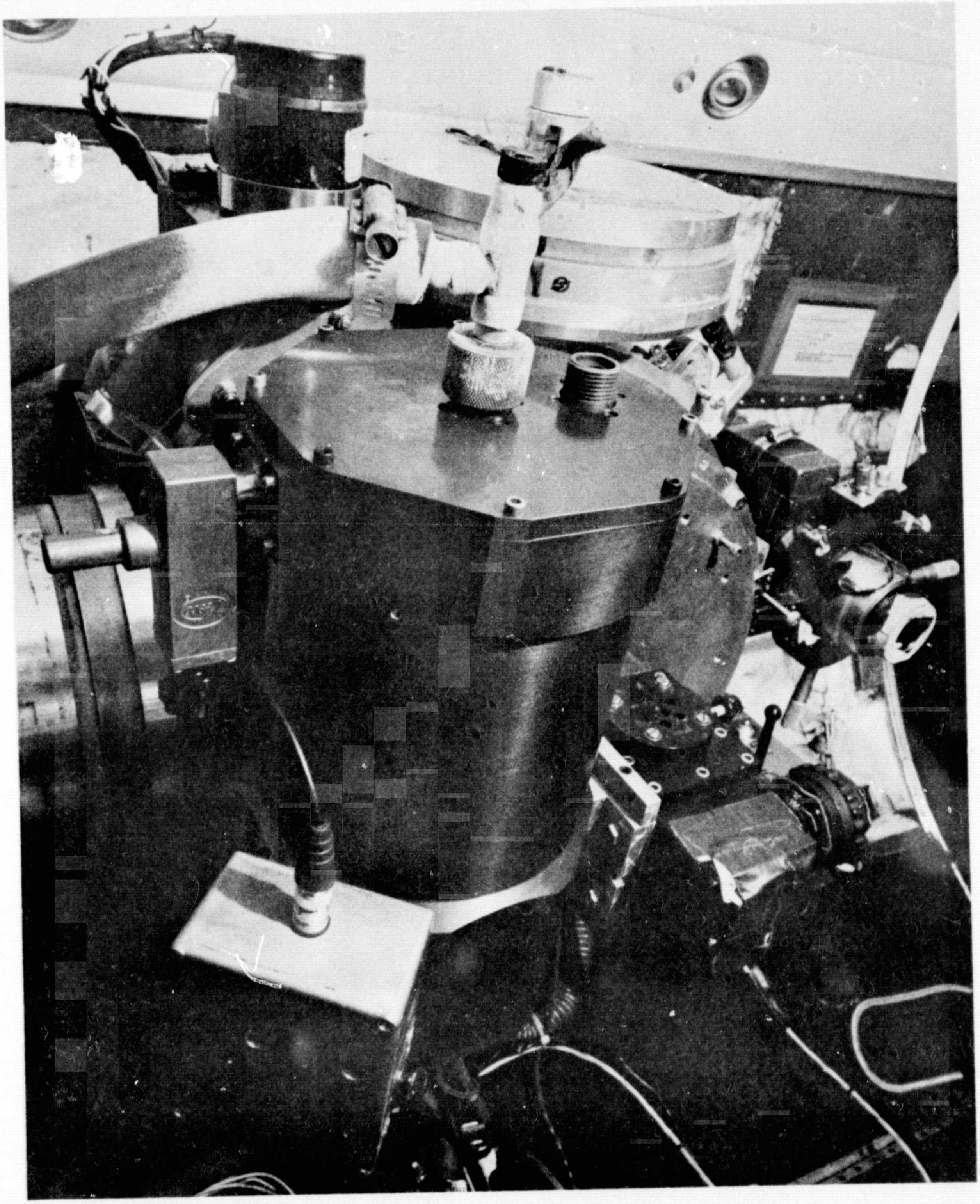


Figure 5.- Closeup of cooling dewar.

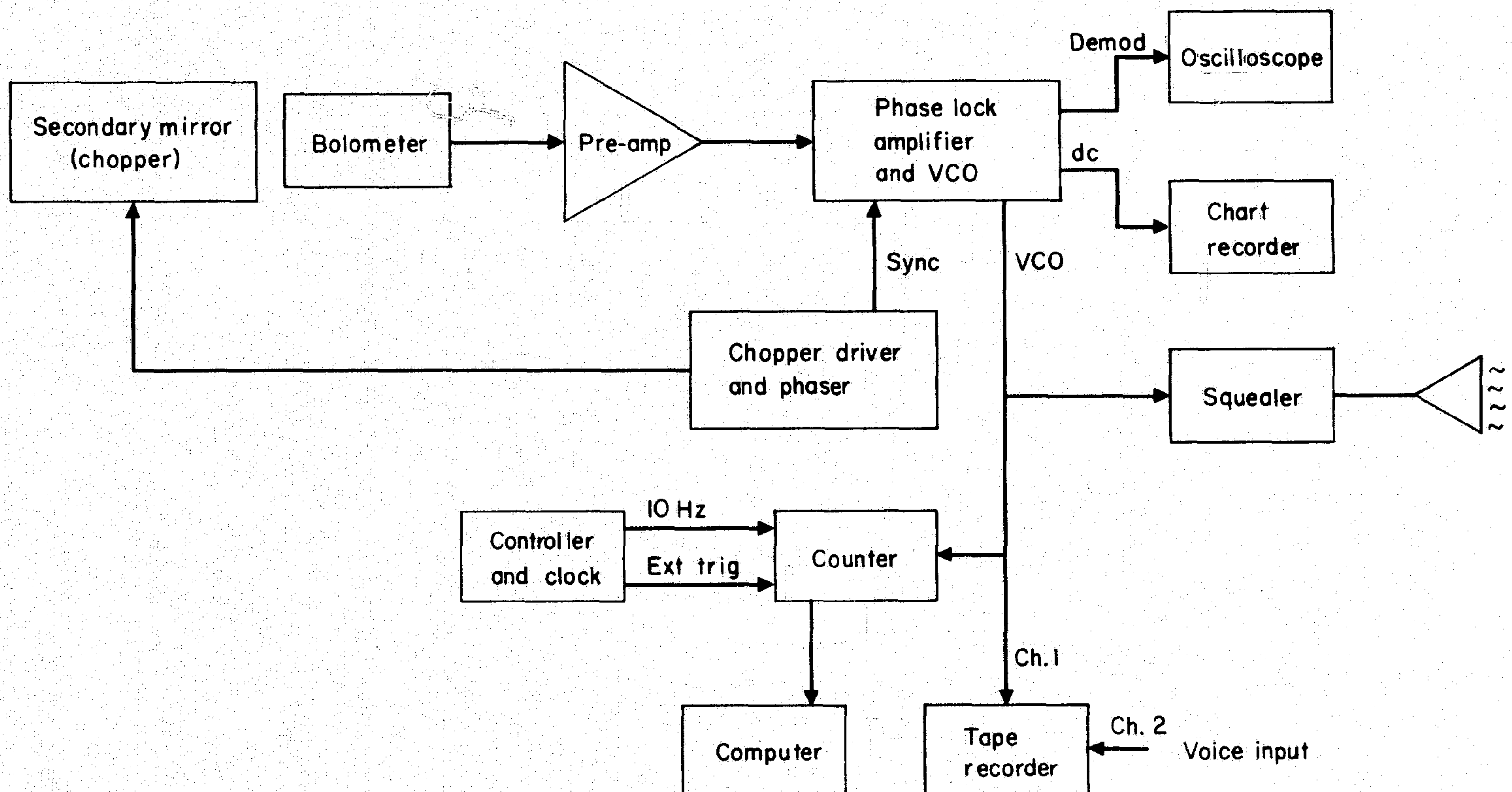


Figure 6.- Electronics block diagram.

Figure 7.- Location of electronics rack in aircraft.

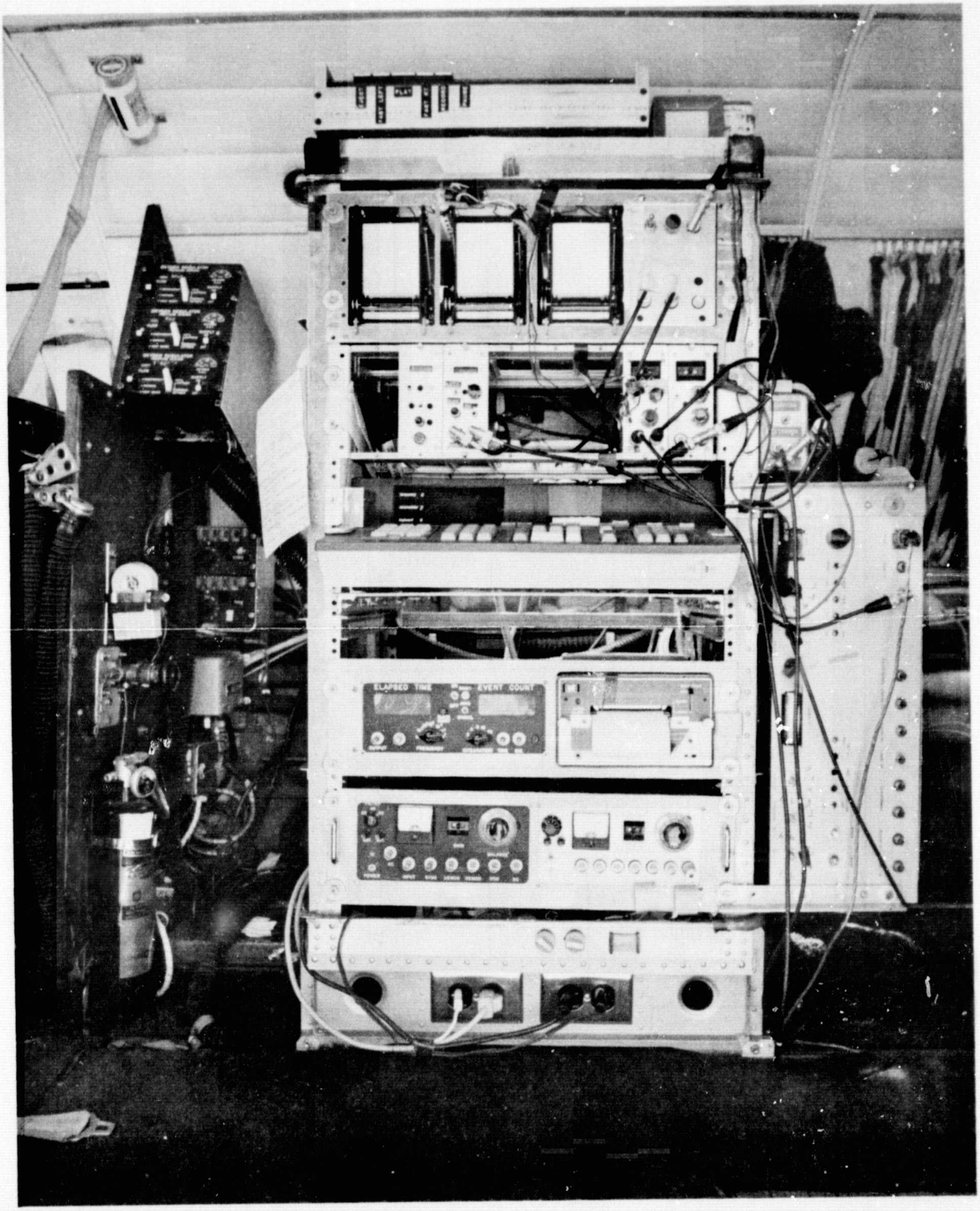


Figure 8.- Electronics rack installed in aircraft.

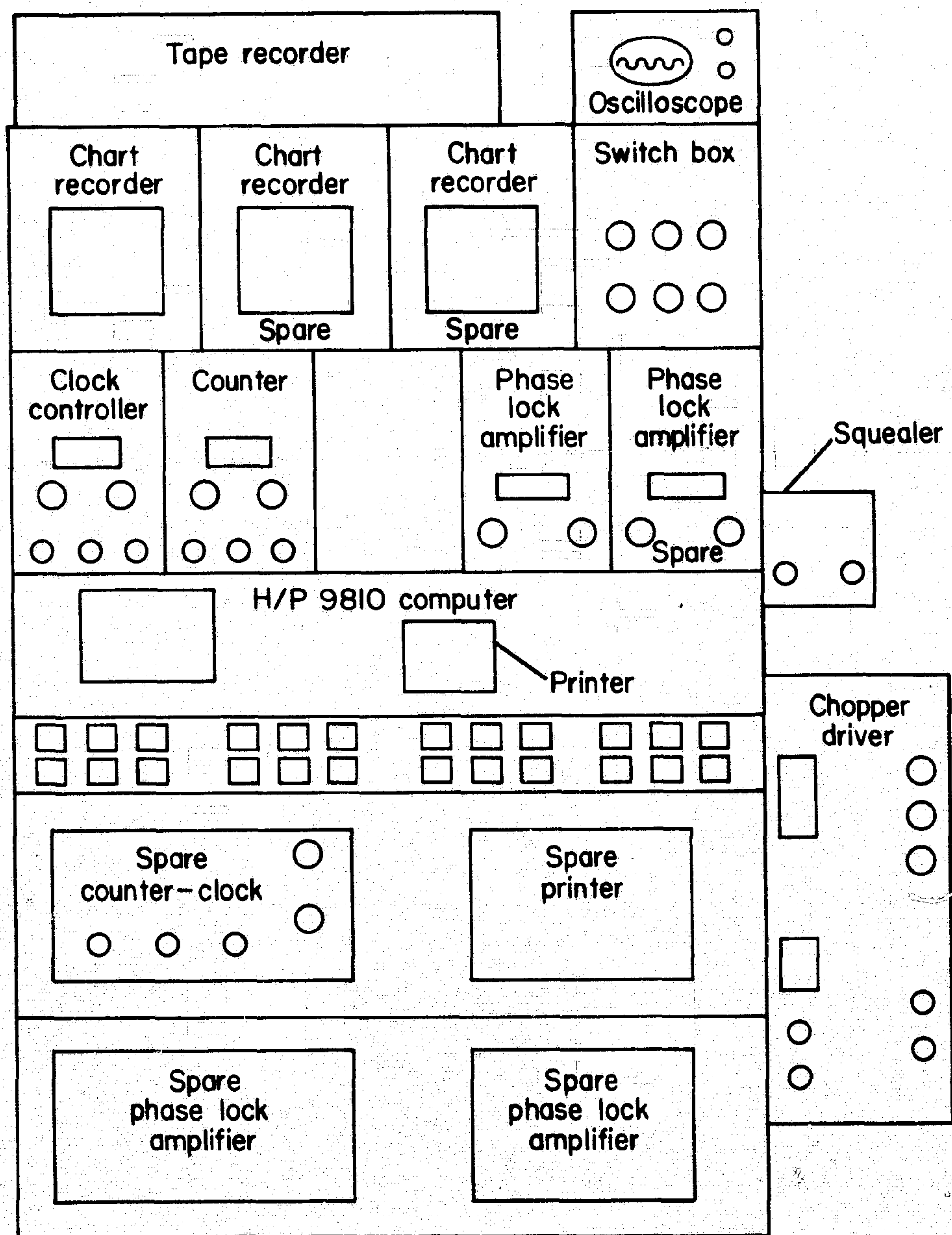


Figure 9.- Identification of electronics rack components.

performs averaging computations and prints out the raw digital data and a computation of the signal-to-noise (S/N) ratio. A more detailed discussion of the experiment electronics was prepared by the PI as part of EO training program and is included in appendix D.

The electronics rack contained selected spare equipment (fig. 9): a spare counter, three spare PLAs, two spare chart recorders, and a spare printer. If the prime PLA or chart recorder malfunctioned, a spare could be selected merely by changing the front panel connections. A failure in one of the other prime components (e.g., counter or printer) would require the use of the entire backup data system. Because the backup system did not include a computer, however, no real-time data reduction was possible when the backup system was used.

A backup preamplifier was carried aboard the aircraft and could be installed in flight. A spare photometer and dewar were also supplied, similar to that used as the prime equipment. The detector element of the backup photometer was of somewhat lower sensitivity, however. This unit remained on the ground but was cooled and prepared for flight in parallel with the primary system.

Lear 4 preparations: The PI was given the option of modifying his experiment to facilitate the operation by the EOs and to enhance the likelihood of obtaining quality data. In part because the experiment had been well proven in previous flights, the PI decided that only two such changes were necessary; both were relatively minor. The detector in the primary (single filter) photometer was replaced, and an improved filter wheel was installed in the backup photometer.

Most of the signal-processing equipment was stored at Ames after the August mission. The electronics rack therefore was not tested at the Observatory, and the FRR for this equipment, originally planned for the end of August, was held instead during the EO training period at Ames in September. The dewar and photometer units had been returned, however, and were used in the August EO training sessions and received normal tests during that time.

Table 5 is a summary of equipment tests normally performed by the PI prior to a flight series. As noted, the photometers were tested in the home laboratory; therefore, the special test equipment for this job was not shipped to Ames for this mission. Presumably, the specified tests on electronic equipment were performed at Ames prior to installation in the aircraft.

When the experiment was fully integrated into the aircraft, the final component tests listed in table 6 were performed. Both these and the previous equipment tests were valuable training exercises for the EOs.

Experiment cost- Since its inception, the infrared astronomy experiment flown on this mission has been sponsored by two different universities. Exact cost records are unavailable, and if they were, the use of graduate students for part of the labor would give an unrealistic basis of comparison with other experiments constructed by salaried personnel.

TABLE 5.- SUMMARY OF EQUIPMENT TESTS

Equipment	Test	Man-hours	
		Per unit	Incl. spares
Phase lock amp.	ac gain calibration	0.5	2
	dc gain calibration	0.25	1
	VCO-dc relation	0.25	1
	Measure time constant	0.25	1
	Freq. filter calibration	0.5	2
Chart recorders	Check linearity	0.25	0.75
	Check freq. response	0.25	0.75
Tape recorder	Check linearity	0.25	0.5
	Check reproducibility	0.5	0.5
Preamp	Gain calibration	0.25	0.75
	Check freq. response	0.25	0.75
Dewar-detector	Load curve Beam pattern Sensitivity Responsibility Freq. response	5	10
	TOTALS	8.75	21.0

A reasonable estimate of replacement cost has been developed from the actual procurement cost connected with each component and the number of man-hours estimated for the fabrication of the experimenter-built components. Labor has been estimated at $15 per hour. By this convention, the estimated replacement costs for the experimenter-supplied portions of the equipment (one complete system) comes to $12,000. (This figure does not include the GFE telescope and controls, and the onboard vacuum pump.) Similar costs for the spare or backup units totaled about $8,000.

Development costs have been estimated, with a lower degree of confidence, by tripling the labor costs for each component while holding the same procurement costs. According to this method, the development cost of one complete system was about $16,500. Estimated component costs are given in appendix C.

TABLE 6.- TESTS ON INTEGRATED EXPERIMENT

Equipment	Test	Remarks	OK criteria
Chopper driver	Checkout driver output	Run through all frequencies	Chopper should chop
	Check system output	Run through all frequencies	Output 5 Vp-p square wave
Phase lock amplifier (PLA)	Check dc output	(No signal necessary, vary bias)	Should vary from +12 to -12 V
	Check VCO output	(No signal necessary, vary bias)	Square wave should vary from 1000 Hz to 5000 Hz at 5 Vp-p
	Check ac output	Input mV level ac signal, run through gains	Should see normal amplification
Clock controller	Check clock	Reset and observe display	Correct timing
	Check trigger		Trigger lights should operate
	Check termination control		Light should change status after each press
	Check 10-Hz output		5 Vp-p square wave
Counter	Check counter display	Trigger with 2 Vp-p signal for all time intervals	Display should show appropriate number of counter
	Check BCD output	HP 9810 necessary to read data	HP display should agree with counter display
Chart recorders	Check zero	Ground input	Pen on zero
	Check full-scale deflector	Normalize to 5 V in	Pen at full scale
Tape recorder	Check record levels	Ch. 1 - data Ch. 2 - voice	Playback should be good representation of data (i.e., reproducible)

TABLE 6.- CONCLUDED

Equipment	Test	Remarks	OK criteria
H/P	Check program operation	Load program, use controller and counter for logic and data input	Correct arithmetical and logical operation
Preamp	Check noise level	Use either dummy load or cooled detector	10 mVp-p "grass" noise
	Check signal transmission	Use detector with signal input	Amplified signal out
Backup counter	Check counter display	Trigger with 2 Vp-p signal for all time intervals	Display should show appropriate number of counts
Backup printer	Check printer	Use backup counter BCD output	Printer output should agree with counter display

Experiment Operations

Experiment equipment operations may be broadly divided into three classes: preflight, inflight, and postflight. Preflight activity includes those actions necessary to prepare and check out the equipment for a given flight.

Appendix D includes checklists of preflight activities in dewar preparation and installation, and electronics checkout. Not all preflight activities were required before the second flight each evening.

Flight activity consists of the actual observations and the associated electronic equipment operation necessary to record data in an optimum manner. The experimental duties of each EO during flight are listed in table 7. Postflight activity consists of procedures to protect the equipment over a period of nonuse and preliminary data reduction. Following each night's second flight, the dewar was removed from its mounting and the cryogens emptied out. Data records were removed following each flight, reviewed for completeness by the EOs, and transmitted to the Mission Center for immediate review by the PI.

TABLE 7.- INFLIGHT DUTIES OF THE EXPERIMENT OPERATORS

Telescope Operator
- Locate desired target
- Guide telescope according to predetermined plan
- Monitor gyrostabilization operation
- Monitor He pump operation
- Communicate with rack operator concerning details of:
  - Guide star position or offset
  - Which beam on target — left or right
  - General comments on observations
  - Indicate start of integrations

Electronics Rack Operator
- Monitor all instrumentation
- Operate tape recorder and change cassettes
- Keep telescope operator aware of the status of data recording. Provide signal-to-noise readings from computer printout if available from mode of signal recording. Note deflections on strip chart when this mode of recording is used
- Relay information to telescope operator about details of the star field chart (no light available to telescope operator who must remain dark-accommodated)
- Relay information to telescope operators about details of the observing plan
- Initiate integrations upon request of telescope operator and inform when completed
- Keep log of information as recorded
- Mark strip charts, when use, with pertinent data
- Examine computer printout and inform telescope operator of measured S/N

EXPERIMENT OPERATOR SELECTION AND TRAINING

The ASSESS Lear 4 mission provided the first test of inflight experiment operation by proxy operators in support of the research program of a ground-based PI. Therefore, EO qualifications, effectiveness of the EO training program, and resulting inflight performance level were subjected to considerable study.

Operator Selection

The two EOs for this Lear mission were selected by ASO management on the basis of academic background, experience, and the nature of the experiment to be flown. The telescope operator was Karl G. Henize from JSC. He is a scientist astronaut and holds a PhD in astronomy. He is a jet pilot, and flew as copilot on two previous Lear Jet simulation missions; on one Lear mission he substituted for an ailing experimenter on several flights.

The electronic systems operator was Leon B. Weaver from the Spacelab Program Office at MSFC, who has been involved with Spacelab planning, particularly in the area of Mission and Payload Specialist selection and training. He has a degree in aeronautical engineering, and is experienced as a test subject for a wide variety of developmental simulations for previous manned spacecraft. He holds a commercial pilot's license, and has flight time in high-performance jet aircraft. He served as MSFC observer for all previous ASSESS missions and as the electronic systems operator on one check flight for a previous simulation mission on the Lear Jet.

Training Program Study Objectives

Study of the EO training program was directed toward the following objectives:

1. To determine how much training the PI considered necessary to enable qualified and motivated individuals to operate his experiment

2. To determine the optimum amount of theoretical versus practical training for satisfactory EO performance

3. To evaluate the EO response to the variety and depth of training

4. To measure the effectiveness of training in research operations

Role of the Principal Investigator

The EO training program was to be conceived and implemented largely by the senior PI. A tentative agreement to this effect was reached in early March. When ASO sent formal confirmation to the senior PI in June 1974 of his selection as a mission participant, the request was made for a milestone chart of his planned training activities. The Program Plan (appendix A), developed jointly by the senior PI, EOs, and ASO, was also furnished, which specified that intensive training was to begin the week of August 28 at the investigator's facility.

The major segments of the EO training program are listed below. The first four sessions emphasized observation, laboratory, and experiment integration training; the training flights constituted integrated simulation of the completely functioning vehicle/experiment system.

Location	Date	Training
Ames	May 29-31	Initial familiarization with equipment then being flown on a normal ASO Lear Jet mission.
Ames	July 23, 24	Participation of electronics operator in two flights on the C-141 airborne infrared observatory to observe operation of the experiment equipment.
Observatory	August 28-30	Hands-on training involving dewar and photometer. Lecture on bolometer theory. Observation of star fields through finder telescope on ground. Discussion of electronics equipment.
Ames	September 5-10	Experiment integrated into vehicle. Hands-on training on entire experiment. Preflight checks. Data interpretation.
Ames	September 11-20	Seven training flights. First five with one EO and one member of PI team. Last two with both EOs handling all functions.

Actual training had begun during May 29-31, when the PI's team was present at Ames for a Lear flight series, and both EOs had the opportunity to become briefly familiar with the operation of the investigator's equipment. During July, one of the EOs spent three days with the investigators at Ames and made two flights aboard the C-141 to observe the inflight operation of the experiment.

By August 1, neither the milestone chart nor any other communication had been received from the senior PI. Two members of the experimental team (the PI and a graduate student) who were present at Ames for a Lear Jet flight series in August agreed to provide written descriptions of their operating procedures as well as the activities involved in connecting the components of the electronics rack. They also prepared a one-page outline (table 8) of the training that would be conducted at the Observatory site later in August, although they had received no instructions or authorization from the senior PI. Appendix D contains the reference material prepared by the PI, describing in some detail observational procedures, telescope operations, details of the electronics circuitry, operation of the onboard computer, and dewar preparation.

TABLE 8.- PREFLIGHT GROUND TRAINING PLAN

1. Dewar Technique a. Design b. Calibration (load curves, sensitivity tests, beam patterns) c. Operating instructions
2. Electronics a. Block diagram b. Description of each component c. Basic design d. Operation e. Backup system f. Computer programs
3. Telescope a. Focusing b. Chopper tuning c. Stabilization d. Operation with joystick
4. Installation of Equipment onto Lear a. Optics b. Dewar c. Electronics
5. Integrated Operation of All Subsystems
6. Data Reduction Techniques

Observation, Laboratory, and Integration Training

Observation sessions at Ames- On May 29-31, the EOs visited Ames and were able to observe the ground testing and preflight activity associated with operation of the experiment on a regular Lear Jet mission. They were not able to fly at that time, nor were any particular efforts made by the PI team to provide specialized EO training. The EOs did feel that they obtained a worthwhile initial familiarity with the equipment from this exposure, however.

In July, the electronic systems operator made two flights on the C-141 airborne observatory, noting the operation of the equipment and listening to the intercom conversation between the PI's electronic systems operator and the senior PI at the telescope. No special efforts were made for EO instruction on the C-141 flights.

Laboratory training at the Observatory- The first intensive experiment operator training session began on August 28 at the PIs' home laboratory. Present were the senior PI, the PI and an assistant, the two experiment operators, and an ASSESS observer. Since the electronics rack had remained at Ames, the senior PI concentrated the teaching effort on the photometer and dewar, and the EOs principal activities at the PIs' laboratory were observing, and later performing three major tests on these units to determine their readiness for the mission.

Day 1: The first day of training began with an examination of the interior of a dewar that had been taken apart for repair. The photometer system in this unit utilized a filter wheel, and the senior PI demonstrated how the filters were mounted on the wheel and how the wheel was installed in the dewar to allow selected bands of radiation to reach the detector. The filter wheel had been redesigned for this mission to improve both the filter mountings and the shaft mechanism for rotating the wheel external to the dewar.

Later in the day, the senior PI gave a 2-hr lecture on bolometer theory from notes he had used in teaching a graduate course in radiation. This material, which turned out to be the only formal instruction on theory during the training program, was not particularly attuned to the meager electronics background of the EOs. Nevertheless, it did introduce them to the elements of far-IR measurement, as well as provide some background for the tests they were to perform the next day.

Following the lecture, the PI and the assistant began the evacuation of a dewar on a diffusion pump system, and the senior PI and the EOs spent an hour discussing general astronomical theory and some of the senior PI's experiences on the Lear Jet. When evacuation was completed, the EOs observed the cool-down procedures — first with liquid nitrogen and then with liquid helium. After the dewar was cooled down, the EOs were shown how to reattach it to the vacuum system in standby status.

The major portion of the evening (4 hr) was spent watching the assistant perform load curve and calibration tests on the photometer. These two tests, along with a beam profile, are run whenever any extensive alteration has been made to the photometer or dewar, or when the unit has not been tested for several months. The end product of the load curve test is a plot of current vs voltage across the bolometer, which is compared with previous tests to determine whether the shape and slope of the curve are within acceptable limits (within 15 percent).

The calibration test uses a standard black-body source to check the response of the detector. With the preamplifier attached to the detector and a mechanical chopper set at a given frequency, individual layers of black polyethylene are successively placed between the source and the detector to cut off more and more of the short-wave radiation from the source. The end product of the test is a measurement of the output voltage of the detector as a function of the layers of polethylene placed in front of the source while chopping at a given frequency. The test is then repeated for two more chopping frequencies.

Since it was a clear night, the EO responsible for telescope operation decided to use the opportunity to observe Jupiter through the PIs' finderscope following test completion. He also used the experimenters' start charts in an attempt to locate other targets. The first day's training ended at 1:30 a.m.

Day 2: The second training day began with a major problem. When the dewar was placed on the vacuum pump a sufficient state of evacuation could not be reached despite pumping for several hours. The EOs were exposed to live troubleshooting and were invited to try their hand at solving the problem. Despite the efforts of the PI, the assistants, and the EOs, the leak could not be found. Finally, several hours into the afternoon, it was found that the screws holding the dewar window in place were not tightened sufficiently to hold a vacuum. The EOs were then instructed in the use of the vacuum pump and left to evacuate the dewar on their own.

While the dewar was cooling, the PI distributed a block diagram (fig. 6) of the basic elements of the experiment and explained the function and operation of each. Since neither operator had an electronics background, the description was necessarily conducted at an elementary level, including an introduction to basic troubleshooting that could be logically deduced from the circuit diagram. Both operators expressed concern about their lack of electronics knowledge and their ability to repair any malfunctions that might occur.

The EOs finished cooling down the dewar and left it on the vacuum pump. Their next task was to repeat the load curve and calibration tests they had observed the day before. Then under the guidance of an assistant, the EOs completed the third major test of the dewar, a beam profile, which checks the response of the detector as the dewar is rotated both to the right and to the left of the peak signal point. A curve or beam profile is generated by first aligning the dewar with a peak signal radiated by the source (in this case LN_2) and then rotating the dewar in the horizontal plane 15° to the right and 10° to the left in increments of 0.5°. The beam profile is then compared to a previous curve from the same dewar. If there are no large asymmetries between right and left, and no gaps in the curve, the beam profile is acceptable.

After the three tests were completed, the senior PI pronounced the dewar fit for experimental use. He then took the preamplifier apart and showed the EOs how to check the battery voltages and where to look for possible short circuits; both agreed that this was a valuable demonstration. The training session ended after midnight with a discussion of the cutoff points of the four filters on the filter wheel and a general discussion of the block diagram in light of the knowledge gained during the testing experience. No direct experience was gained with the single-filter photometer/dewar unit that, at the time, was considered a backup component.

Day 3: The final day of the training session lasted only about 4 hr, during which the EOs reviewed their notes and asked questions on a variety of topics. The Observatory team was present throughout the session. Before leaving the Observatory, both EOs indicated that they felt ready and able to perform all dewar operations. As it turned out, however, the senior PI substituted the single-filter instrument for the filter-wheel unit in the primary experiment assembly shortly before the first training flight at Ames. Although the two are similar in many respects and require the same cooling processes, this change reduced the effectiveness of the EOs' initial training.

Integration training at Ames- The EO training program resumed September 5 at Ames. The senior PI remained at the Observatory and was represented at Ames by the PI and his assistant, who had both participated in the Observatory training.

Day 1: The first afternoon was mainly devoted to a discussion of the general properties of the components in the electronics rack, aided by the PIs block diagram and other reference material provided by Observatory personnel. The PI then demonstrated how each of the rack components was connected and the proper procedure for their installation.

The last portion of the day's training was conducted inside the Lear Jet. The PI and his assistant ran through the startup procedure for the telescope stabilization system and explained typical problems that might arise during its operation. The EOs examined the secondary mirror chopper and received a brief history of problems that had occurred with it on previous flights. They were then left alone and encouraged to get a feel for the stabilization system by operating the telescope.

Day 2: Early the next morning, the EOs pumped down and filled the dewar so that the Observatory personnel could mount it on the telescope and achieve a rough balance. Under the guidance of an assistant, the EOs spent the next several hours mounting and wiring the electronic components into the rack. Each component was checked to make sure it was operating properly. An hour was spent in discussions of the backup system (installed in the rack) and the procedure for connecting backup components to permit experiment operation if one or more prime components should fail in flight.

While the PI was repairing a phase-lock amplifier (PLA), he lectured on its theory and construction, and introduced the EOs to circuit-checking procedures using an oscilloscope. The operators then spent several hours in the Lear Jet learning how to place the lead weights to balance the telescope, and reviewed the techniques involved in scanning and integration of astronomical targets. That evening, the Lear was moved outside the hangar, and the assistant and one of EOs worked on boresighting and focusing the telescope.

Day 3: The following Monday the PI team and the EOs prepared the experiment for an early evening flight to ensure the proper operation of the equipment. This was the EOs' first involvement in the full sequence and timing of preflight activities. A calibration was made on Jupiter and data collected on M8. The PI team reported a smooth flight with all equipment functioning properly.

Day 4: This day had been planned as the last of EO preflight training. However, the participants agreed that more would be gained from flight experience and the schedule was changed accordingly.

Integrated Mission Simulation

In lieu of a high-fidelity ground-based simulation, actual training flights were made on the Lear permitting the EOs to work with a totally functioning system. Data were collected during these flights in the same manner as during the mission. The scientific output of this integrated mission simulation is summarized in table 9.

Preparation- On the morning of September 10, one of the EOs prepared the dewar for the first early evening training flight. Unfortunately, the flight was canceled by midmorning due to a landing gear problem. The rest of the morning was spent in an explanation and reconstruction of the previous night's flight using the strip chart and computer printouts. The afternoon was devoted to a preflight checkout at the aircraft to make sure the equipment was performing properly before takeoff.

A flight readiness review (FRR) was held the next day to review the status of the experimental equipment. (The mission FRRs are discussed in detail in the next section.) During this first FRR, however, it was revealed that some days earlier the senior PI, back at his laboratory, had decided to exchange primary and backup dewars; the filter-wheel dewar used for EO training was replaced by the single-filter dewar with 2 to 4 times higher sensitivity. Following the FRR, the newly designated primary dewar was pumped down and filled in preparation for the day's flight. By now, the EOs were routinely preparing the dewar without the assistance of the Observatory personnel.

Maintenance and calibration flights (1 and 2)- A maintenance flight was made early in the afternoon of September 11 to check the condition of the aircraft landing gear. One of the PI team members and the telescope operator participated in the flight for the purpose of familiarizing the EO with the telescope, oxygen system, and method of electronics operation. No attempt was made to collect scientific data. A second flight was made that evening with the same EO and the other PI team member to perform an instrument calibration on Jupiter and gather scientific data on M8. In both instances, the EO handled the telescope well, with no apparent problems.

EO/PI training data flights (3-5)- The following evening, the telescope operator and the PIs assistant made a data flight on M8. Despite an intermittent tremor, in the telescope caused by a malfunction in the stabilization system, the EO's performance was rated as equal to or superior to that of the PI. After this flight, the telescope operator felt that he had had sufficient flight training in the use of the telescope, and the assistant concurred.

Training resumed the next week with the electronic systems operator making two data flights with the PI. The EO's performance on the first flight was difficult to judge due to the failure of the electronic rack panel lights and the PI's difficulty in guiding the telescope correctly. Following the second flight, the PI stated that in his opinion, the operator was still too

TABLE 9.- INTEGRATED MISSION SIMULATION FLIGHTS

Flight	Date and time	Personnel - comments	Astronomical targets		
			Actual	9/12 plans	8/30 plans
1	9/11/74 1630-1805	Henize-Assistant Dewar blanked off-no target. Purpose-familiarization with oxygen system, controls, electronics operations, etc.	None	---	Not planned
2	9/11/74 2025-2235	Henize-PI Calibration on Jupiter; data on M8. Henize handled telescope well with no problems.	Jupiter (c) M8	---	Jupiter (c) M8
3	9/12/74 1945-2135	Henize-Assistant Data on M8. Tremor in telescope caused by problem with stabilization system occurred intermittently. Henize overcame this and acquired four data points on M8. Henize's performance rated equal to or superior to PI's.	M8	---	Jupiter (c) M8
4	9/17/74 0056-0301	Weaver-PI Acquired some data on W51, M78, OMC-2, M42. Weaver had some difficulty due to failure of rack panel lights. Telescope operator's trouble in guiding correctly made evaluation of Weaver's performance arbitrary.	W51 M78 OMC-2 M42 (c)	M78 W51	M78 Jupiter (c)
5	9/18/74 0052-0251	Weaver-PI Calibration on M42; data on W51. Weaver's unfamiliarity with rack causes telescope operator to have to remind him to call out computer readings. Failure to adjust gain properly causes difficulty in reading strip chart output. Telescope operator	W51 M42 (c)	M78 W51	M78 Jupiter (c)

TABLE 9.- Concluded

Flight	Date and time	Personnel - comments	Astronomical targets		
			Actual	9/12 plan	8/30 plan
		still not completely comfortable working with Weaver.			
6	9/19/74 0048-0253	Weaver-Henize Data on W51 and OMC-2. PI reports Weaver calling out computer readings and making proper gain settings. PI says that both Henize and Weaver doing better than he would have thought—ready to fly the mission now.	W51 OMC-2	M78 W51	W51
7	9/20/74 0045-0300	Weaver-Henize Data on W51 and OMC-2. Weaver could not get computer into scan mode—did left/right integrations instead. (Caused by error in computer operation instructions.) PI feels Weaver should write more on strip chart tape to reduce time spent in listening to voice tape when reducing data.	W51 OMC-2	M78 W51	W51

Flight Summary

	Number of observations		
	Actual	9/12 plan	8/30 plan
Calibration targets			
Jupiter	1	0	4
M42	2	0	0
Primary targets			
M8	2	4	2
M78	1	4	2
W51	4	0	2
OMC-2	3	0	0

unfamiliar with the electronics operation to provide the communication necessary to the telescope operator for proper guidance.

EO training data flights (6 and 7)- The EOs worked together on the last two data flights of the training series. The first of these flights went well, but the last was marred by the inability of the electronic systems operator to engage the computer in the scan mode. As a result, only integrations were performed on the targets. (The problem was later traced to a faulty checklist.) Both the PI and his assistant felt that the rack operator should provide more written commentary on the strip chart printout to reduce the time required in listening to the voice tape when the data is evaluated on the ground. On the other hand, the EOs felt that providing extensive written commentary inflight detracted from data recording and preferred to reconstruct comments postflight, referring to the tapes when necessary. At this point, the PI team felt that the operators were qualified to fly the experiment.

Science content of data flights- The integrated simulation period yielded a substantial quantity of scientific results. All of the planned targets were observed at least once and two additional objects were introduced, one (M42) for purposes of calibration. The actual numbers of observations made on specific targets were changed substantially from the planned schedule of two weeks earlier; four were deleted and seven added (table 9). This change is presumed to reflect the reliable operation of the equipment, the decision to switch primary and backup dewars, and the capability developed by the EOs.

Measurements made during the training flights are seen to consist entirely of left-right integrations on calibration and scientific targets (table 10). Sixty-four map points were observed; 7 percent of individual measurements were for calibration and 93 percent for scientific data. An average of just over 10 map points was measured per flight.

Figure 10 summarizes the data by target and as a function of S/N. Targets toward the left of the plot had larger percentages of weak points (low S/N). M78 was very weak, while W51 was relatively strong and was the predominant choice (42 percent of all measured points) for these training flights. OMC-2 and M8 were of lesser strength and, presumably, were targets of somewhat greater difficulty. These latter three were scheduled for the early mission flights and accounted for nearly 90 percent of the points measured during training.

Training Activity Summary

A summary of time spent in all phases of training is given in table 11. Prior to flight training (integrated mission simulation) the telescope operator had accumulated 54 hours and the electronics operator 80. Nearly 70 percent of this experience was related to normal experiment operations and servicing, including data interpretation, while 20 percent was directed toward malfunctions and maintenance, and just over 10 percent toward background in theory and design philosophy.

TABLE 10.- SUMMARY OF MEASUREMENTS, EO TRAINING FLIGHTS

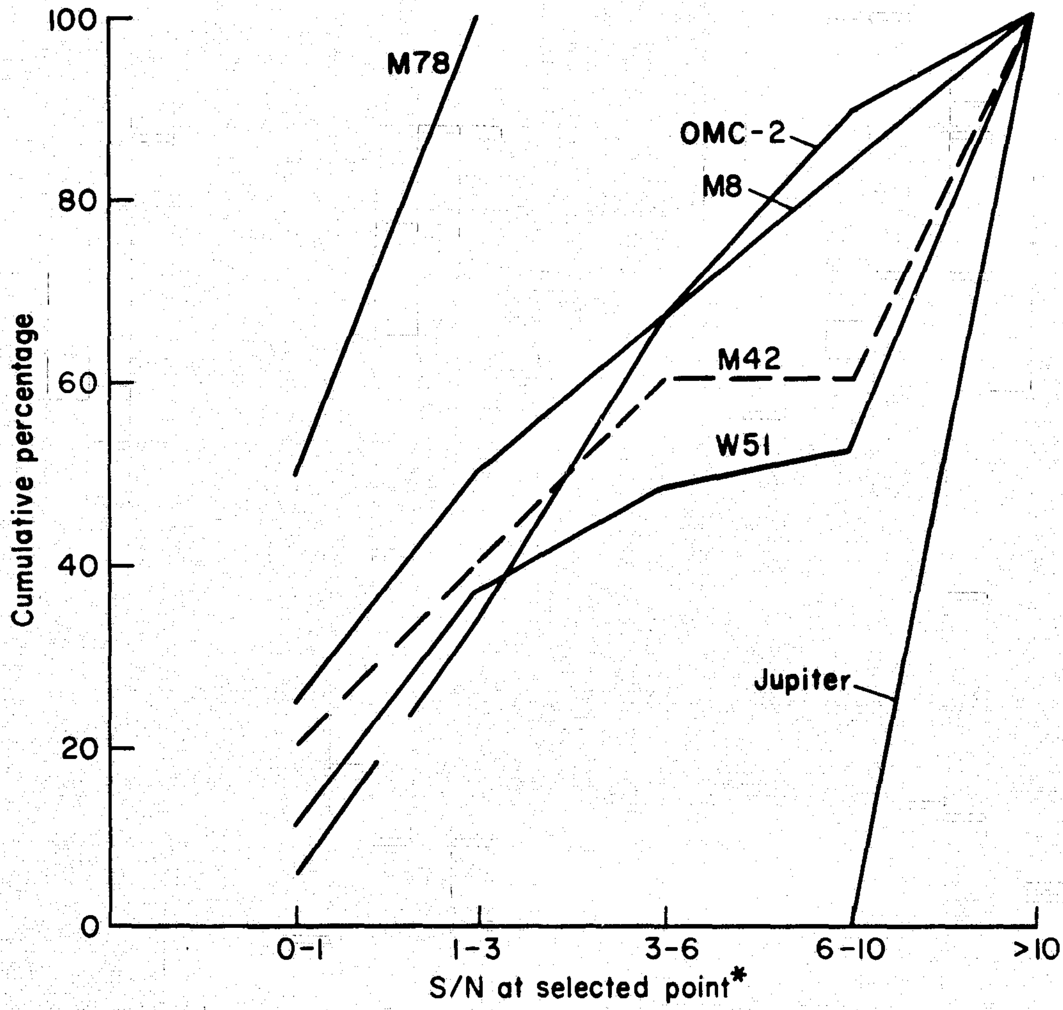
Flt.	Target	Purpose	Number of measurements			Map points
			Field scans	L/R	Integra. steps	
1 Teles. EO	none	Equipment checkout		none		none
2 Teles. EO	Jupiter M8	Calibrate data	none		5 140	--- 8
3 Teles. EO	M8	Data	none		83	4
4 Elect. EO	W51 M78 M42 OMC-2	Data Data Calibrate Data	none none none none		23 24 2 11	3 2 1 1
5 Elect. EO	W51 M42	Data Calibrate	none none		67 38	8 4
6 Both EOs	W51 OMC-2	Data Data	none none		53 142	4 8
7 Both EOs	W51 OMC-2	Data Data	none none		70 53	12 9
						64

Calibration measurements = 45 = 7%

Data Measurements = 624 = 93%

Target	Point measurements Number	% Total	Scans
W51	27	42	—
OMC-2	18	28	—
M8	12	18	—
M42	5	8	—
M78	2	3	—
Jupiter	1	1	0

$$\frac{\text{Map points}}{\text{No. flights}} = \frac{64}{6} = 10.7$$



*S/N a function of both signal strength and number of integration steps; operator decision terminates observation.

Figure 10.- Target evaluation for ASSESS training flights.

TABLE 11.- SUMMARY OF TRAINING ACTIVITIES

Date	Location	Hours per subject								Remarks	Training category
		Theory		Servicing		Operations		Mainten.			
		T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]		
3/18	---									Starting date	
5/29-5/31	Ames			12	12					On ground only	Observation
6/26	Ames						4			Train on computer, no instructor	Laboratory
Various	Home						8			Study star charts, no instructor	
7/23-7/24	Ames						20			On ground and in flight	Observation
8/28-8/30	Observatory	3-1/2	3-1/2	7-1/2	4-1/2	5-1/2	4	10-1/2	10-1/2	3 instructors	Laboratory
9/5-9/9	Ames	4-1/4	3-1/4	5-1/4	5-3/4	2-3/4	1-3/4	2-1/2	2-1/2	Installation and checkout	Integration
Subtotals hours	---	7-3/4	6-3/4	24-3/4	22-1/4	8-1/4	37-3/4	13	13	T.O. total = 53-3/4 hr E.O. total = 79-3/4 hr	All preflight training
%	---	11		35		34		20		Both operators	
9/10 to 9/20	Ames					10	10-1/2			In flight	Integrated mission simulation
		2	4	17-1/2	22-1/4	6-1/2	7	3-1/2	8	On ground	
Grand totals	---	9-3/4	10-3/4	42-1/4	44-1/2	24-3/4	55-1/4	16-1/2	21	T.O. Total = 93-1/4 hr E.O. Total = 131-1/2 hr	All training
%	---	9		39		35		17		Both operators	

[a]T.O. - Telescope operator
[b]E.O. - Electronics operator

Active training was slow to develop; none occurred in the first two months, and only observations in the next three. Over half of the preflight effort occurred in the last two weeks of the period. However, this was a first-time experience and the program had been only lightly structured, purposely, to allow maximum latitude for PI and EO initiative. Neither ASO management nor the participants recognized the potential impact of outside commitments at the start of this mission.

Integrated mission simulation (flight training) was less than a two week period, involving some 91 hours of training; again, normal operations and servicing was predominant, some 81 percent, with 12 percent of the time in maintenance and the remainder in theory. Forty hours were accumulated by the telescope operator and 51 by the other EO, for a total training experience of 93 and 132 hours, respectively.

An alternate breakdown of training effort into "classroom" and "hands-on" experience is given in table 12 for three distinct periods of preparation. The first period, from the start of training until completion of the Observatory sessions, was nearly 3/4 classroom-type hours, while the latter two on-site periods were almost as strongly weighted to hands-on time. Overall, the division of training between passive and active pursuits was nearly equal.

Training Evaluation

Although the training program could not be fully evaluated until the end of the mission, several deficiencies in program planning and content became apparent as training progressed toward the confined phase of the mission. Data on the adequacy of the training program were gathered through observation and participant questionnaires.

Observation- Following are general observations on the adequacy and progress of EO training during the preparation phase of the mission, including the integrated mission simulation period.

1. Owing to another mission assignment (C-141), the senior PI was not able to fully commit his time to the training program, either its planning or implementation. Except for the initial EO training sessions at the Observatory, which did not include any work with the electronics rack, the senior PI left his mission responsibilities to other members of his team, without giving them lead time to adequately prepare.

2. One half of the training time (225 man-hours) was devoted to "hands-on" operation of the experimental equipment, and the other half to "classroom" activities — instruction, observation and study. Relatively few hours were specifically devoted to theoretical aspects of the experiment. Basic theory did enter into EO/PI discussions in the context of equipment operation, however.

3. Because the electronics rack was not available for EO training at the Observatory, the EOs received initial instruction via a block diagram prepared

TABLE 12.- TRAINING EFFORT BREAKDOWN

Mission period	Classroom training man-hours				Hands-on training man-hours		Total man-hours	Days used
	Instruction		Observation and study					
	Normal activities	Malfunction response	Normal activities	Malfunction response	Normal activities	Malfunction response		
Experiment and operator preparation, 120 working days	7	0	62	8	15-1/2	13	105-1/2	12
Experiment integration, 3 working days	7-1/2	0	0	2-1/2	15-1/2	2-1/2	28	3
Flight training, 9 working days	6	10	7-1/2	1/2	60-1/4	7	91-1/4	8
Totals	20-1/2	10	69-1/2	11	91-1/4	22-1/2	224-3/4	
% effort	49				51		100	

Normal activities = 181-1/4 mh 81%

Malfunction response = 43-1/2 mh 19%

by the PI (fig. 6). The diagram was a poor substitute for the real thing; in addition, the short time devoted to it and the EO's lack of electronics knowledge combined to limit the potential usefulness of this part of the training.

4. The intensive training in dewar preparation and testing was not directly applied during training or confined flights, principally because of substitution of a different type of dewar. The experience gained during this activity was generally useful, however, in providing a good feel for the complexities of cryogenic systems.

5. Training was adequate for normal operation of a smoothly functioning experiment, but the attention given troubleshooting and repair was far from sufficient. This deficiency was intensified by the lack of electronics background for both EOs, and although recognized in the later stages of training, it could not be satisfactorily overcome.

6. The major deficiency of the training program was in malfunction location and repair. One important diagnostic technique, use of the oscilloscope and hand signals to check for proper system operation, was inadequately explained and demonstrated, particularly in the aircraft environment, and the EOs were unaware of its significance and failed to apply it satisfactorily until given additional explanation during the unstrained mission.

7. There was some confusion as to the details of EO responsibilities and division of effort, which reduced their efficiency and affected data return in some cases.

8. While the telescope operator achieved the desired proficiency very early in the training program, it became apparent during training flights that effective techniques for communication between the EO operating the electronics and the EO on the telescope could not be as readily acquired. Communication between the two is vital, because the telescope operator cannot monitor the data-recording process while guiding the telescope and must be continually advised of signal quality by the electronic systems operator. At the same time, however, the systems operator must monitor each integration measurement, adjust the proper gain settings, initiate and read strip chart and computer printouts, monitor and announce the time remaining on track, write the reticle positions on the strip chart as they are relayed by the telescope operator, monitor tape recorder operation, communicate with the pilots, and monitor the flow of oxygen to both EOs. These skills and effective rapport between the two EOs can only be achieved through experience under actual operating conditions.

Participant questionnaires- Before the integrated mission simulation period, the PI team members and each EO were given questionnaires on which to estimate how well their training had progressed in 41 different categories of instruction. The detailed results are in appendix D, and are summarized in table 13. Both operators were relatively more confident of their abilities than the PI and his assistant — the telescope operator more so (15 items to 6) than the electronics operator (12 items to 9). EO and PI ratings concurred in 20 of the 41 categories, however, indicating a common understanding between the two groups in at least these areas. On a more absolute basis, those

TABLE 13.- SUMMARY OF TRAINING PROGRESS SURVEY

Category of instruction	Telescope operator rating[a]				Electronics operator rating[a]				Rater	Status adequate or better	
	1	2	3	4	1	2	3	4		Telescope operator	Electronics operator
Overall experiment											
15 items	2	8	3	2	2	4	7	2	Self	10	6
(see table D-1)	2	6	2	5	0	5	4	6	PI & asst.	8	5
Components											
8 items—operations	5	3	0	0	0	6	2	0	Self	8	6
theory	3	4	1	0	1	6	1	0	PI & asst.	7	7
8 items—operations	1	5	2	0	1	6	1	0	Self	6	7
procedures	2	3	2	0	1	4	3	0	PI & asst.	5	5
8 items—maintenance	0	6	2	0	0	2	6	0	Self	6	2
	0	2	6	0	0	5	3	0	PI & asst.	2	5
Backup equipment											
1 item	0	1	0	0	0	1	0	0	Self	1	1
	0	0	1	0	0	0	1	0	PI & asst.	0	0
Test equipment											
1 item	0	1	0	0	0	0	1	0	Self	1	0
	0	0	1	0	0	0	1	0	PI & asst.	0	0
Comparison of ratings									Totals:		
									Self	32	22
									PI & asst.	22	22
EO & PI ratings concur	20				20						
EO rating higher	15				12						
PI rating higher	6				9						

[a]Rating scale: 1. Well prepared
2. Adequate
3. Need more
4. None yet

categories where training level was judged adequate or better are shown at the right of the table. Again the telescope operator indicated more confidence than either the electronics operator or the PI team; apparently, at this stage, his extensive background in related sciences was supplying information that was applicable to the task areas of primary interest.

The electronics operator and the PI team recognized that substantial training remained to be done; almost half of the listed categories needed attention. Some of course were unique to in-flight training and would be addressed there, but the majority were associated with potential equipment malfunctions and responses. It is notable that even before the full simulation experience the EOs were reasonably confident they understood and could operate the experiment to acquire valid scientific data.

MISSION REVIEWS

The flight readiness review (FRR) concept was introduced into the experimenter's schedule for the ASSESS Lear 3 mission (ref. 6) as a means of avoiding delays while last-minute changes or additions were made to the experimental equipment, as had occurred on Lear 1 and 2 (refs. 4 and 5). For Lear 4, three FRRs, chaired by the ASO Mission Manager, were planned: one at the Observatory where the PI would conduct an item-by-item review of his experimental equipment; and a second at Ames involving the GFE telescope and associated systems, as well as the PIs equipment, spares, testing procedures, and the like; and a third at Ames to review EO readiness shortly before the mission.

Review of Experiment Status

A FRR for the experiment was held at Ames on September 11, about 2-1/2 weeks before the start of the simulation period, and just prior to the EO training flights. This date marked the end of experiment integration and checkout by the PI team, including one flight to verify both experiment and GFE performance of the fully integrated systems. The reviewing group consisted of the ASO mission manager, as chairman, the ASSESS program manager, and two ASO representatives. The two PIs and the ASO telescope engineer represented the working groups, and the telescope EO was an interested observer.

The FRR served to assure that both the telescope and the PI's experiment, with spare parts and support equipment, would be ready for flight on schedule. If the reviewing group were not satisfied that the experiment (and telescope) was in final configuration, with only minor tasks or routine calibrations to be done, the mission could be delayed or cancelled.

Telescope review- Status of the GFE telescope was reviewed first, using a status report (table 14), lists of spare parts (table C-3), and a telescope guide manual (ref. 9) for reference. Preparations were essentially completed for the mission; tests were finished, and except for a spare secondary mirror

TABLE 14.- ASSESS LEAR 4 TELESCOPE STATUS

September 11, 1974

Task	Status	Remarks
A. Prepare telescope operations and maintenance manual	Completed on August 27	Six copies available. Includes troubleshooting guide and all wiring schematics.
B. Obtain spare gyros	1st order completed on August 19 2nd order due on September 16	1 spare delivered and tested. 6 additional units to be delivered.
C. Troubleshoot and repair spare gyro stabilization boards	Completed on August 29	Refer to spare board status sheet.
D. Fabricate spare cables for telescope system	Completed on August 23	2 spare gyro power cables 2 spare chopper cables
E. Procure spare secondary mirror	Delivery scheduled for September 15	Purchase order #A5795B
F. Fabricate spare secondary mirror backing plate	Completed on August 21	Spare chopper, back plate and mirror available.
G. Verify operation of pump and obtain spare filters	Completed on September 5	3 spare filters available.
H. Train experimenters to troubleshoot stabilization system	To be accomplished by September 13	Training by ASO telescope engineer

in transit, all replacement parts were on hand. Test equipment consisted of a gyro-control test box (GFE) and a laser (PI) for chopper adjustment.

Agreement was reached on the extent of EO response during the mission to telescope malfunctions — overall troubleshooting to isolate problems, optical alignment if required, electronics repairs to the level of replacing PC boards, and replacement of faulty gyroscopes. The ASO engineer would consult by telephone as requested, and assume repair responsibility at once if any complications developed. A date was set for instruction and hands-on training of the EOs to accomplish their assigned tasks. The telescope review concluded with a general expression of confidence that systems and procedures were in good shape.

Experiment review- Experiment status was reviewed by the PI, with selective elaboration by the senior PI. At the request of the reviewing group, a general description of major components and their functions was the lead topic. Preparations for the mission were summarized by task area — changes to the experiment, provision of spare or backup units, laboratory and field testing, failure-response options, and identification and repair of malfunctions. Emphasis was placed on the provision of redundant and backup components built into the flight experiment, so that equipment failures might be corrected quickly with little loss of observing time. The prime option in response to a component malfunction was to replace the entire unit.

Component tests and calibrations for this mission were outlined; for the most part they were relatively brief, mainly to verify conformance with earlier more extensive work. Since most components had flown recently and performed well, this was deemed adequate. Photometer systems, on the other hand, were thoroughly tested to assure known response of existing and newly installed parts (detector in one, filter wheel in the other). Full integrated system tests in flight were completed by the PI on September 9, using Jupiter as the calibration target; all systems were stated to be operational. No plans had been made to check out the backup computer (GFE) before the mission.

To complete his presentation, the PI summarized troubleshooting procedures developed (from experience) for the experiment as a whole, for subsystems, and for individual components. Likely problems were enumerated and repair actions indicated. At the time of the FRR, this information had not yet been reduced to written form for use by the EOs, nor had the final selection of support equipment (tools, spare parts, etc.) been made.

The remainder of the session was given over to a review of scientific objectives by the senior PI, who developed the rationale for this research mission in the Lear Jet, relative to existing knowledge of nebular H II regions, to his prior Lear Jet research and concurrent research in the C-141 aircraft, and to the capability of this particular instrument/telescope system.

It was the consensus of the reviewing group that the experiment was ready for flight in the constrained environment of the simulation period, with the understanding that final preparation of support equipment and procedural instructions would be promptly completed by the PI team.

Review and Evaluation of EO Status

A FRR was held for the experiment operators at the end of the integrated mission training period on September 20. Seven checkout/training flights had been completed, five by the telescope operator and four by the electronics operator. On the last two flights, the EOs ran the experiment without assistance. The ASO mission manager chaired the meeting, with the ASSESS program manager and two ASO representatives completing the reviewing group. (An ASO telescope engineer attended as a consultant.) The PI, his assistant, and the two EOs made up the experiment team.

The purpose of this review was to assure that operator capability had reached a level acceptable for sustained operations, both with equipment and with the science content of the program, during the simulation period. If the EOs were not adequately prepared, the option to delay the mission by one week could be exercised.

The principal element of the review was a subjective evaluation by the EOs of the training status. By mutual agreement, each had accepted certain responsibilities relative to the experiment, and had acquired specialized knowledge in those areas. Both, of course, had a working knowledge of the entire experiment and its operation, to facilitate cooperative tasks such as planning, observation, and troubleshooting. Against this background, the EOs were asked to state their confidence to handle both specific and general tasks. Replies are summarized as follows:

1. Preflight preparation of the experiment and operation in flight to acquire scientific data are established routines.

2. Telescope optics and electronics can be aligned and adjusted for peak performance by the operator, who is prepared to investigate any malfunction of stabilization electronics and replace circuit cards as indicated.

3. Photometer/dewar systems can be maintained in operating condition.

4. EOs can develop target observation plans from PI requirements, research the available reference material for background information, and make real-time decisions in flight in response to new or unusual findings.

5. Diagnosis and correction of equipment malfunctions in flight will be marginal to ineffective, because of very limited exposure during training period.

6. Experiment malfunctions (other than the photometer/dewar) will likely require PI assistance to resolve. Neither documentation nor hands-on training was adequate for such tasks.

7. Data evaluation and basic science planning will require strong PI participation, for two reasons. First, the operators' training was not in sufficient depth for major program decisions and, second, this preparation must occur early in the day when EOs would be sleeping.

The PI then explored the EOs' understanding of points of procedure and normal operation techniques that can facilitate data acquisition in flight. Real-time communication between EOs was his primary concern, as well as real-time decisions relative to the planned sequence of observations. The operators, in turn, proposed several changes to existing procedures to better utilize the time, such as more reference material to aid planning, an improved preflight checklist, and a visual display of the tabulated observation plan.

In conclusion, the PI stated his opinion that the operators were ready to fly the mission and could handle all normal experiment functions. A general concensus was reached to proceed on schedule, with the proviso that the PI be on site during the mission to support the operators in those functions where full training had not been realized.

Review of Safety and Airworthiness

A review of all preparations for the ASSESS mission was conducted on September 27 by the Airworthiness and Flight Safety Review Board (AFSRB), which constitutes the final approval authority for all airborne science missions on ASO aircraft. Following normal procedure, the ASO mission manager made the presentation of agenda items. Questions were fielded by him or referred to others at the meeting cognizant of details in special areas, such as the ASSESS program manager, chief pilot, or the Ames safety officer.

The review was brief, since the Board was familiar with the experiment, which had flown recently on the Lear Jet, and since arrangements at the simulation site and for aircraft movement followed closely the previous ASSESS Lear Jet missions. Several minor problems of aircraft logistics were resolved by assigning action items to the appropriate persons. Upon their completion, the board chairman stated he would approve the mission as presented.

THE SIMULATION MISSION

Mission Schedule

The confined phase of the ASSESS Lear 4 mission started at 1430, Monday afternoon, September 30, 1974. In all, nine flights were flown in the period from Monday through 2200 Saturday, October 5. The mission debriefing was held immediately afterwards, ending at 0300 Sunday morning. The detailed timeline of activity for the entire simulation mission is given in table 15.

The data-taking portion of the mission started a day late because of a problem with the aircraft landing gear indicator, which occurred immediately

TABLE 15.- MISSION TIMELINES

Event	Time (Start)
30 September	
Start mission-unpack	1430
Preflight checks dewar	1600
Preflight planning with PI	1710
Install dewar	1745
Free time	1850
Flight 1 (aborted)	1910
Free time & eat	2000
Fill dewar & preflight preparation	2245
Empty dewars	2315
Bed	2350
1 October	
Free time	(2350)
Bed	0230
Free time	1115
Preflight planning	1220
Eat	1235
Free time	1315
Preflight preparation-dewars	1535
Eat	1700
Install dewar in aircraft	1750
Flight 2	1840
Debriefing with PI	2139
Free time	2300
Preflight planning with PI	2310
Free time	2335

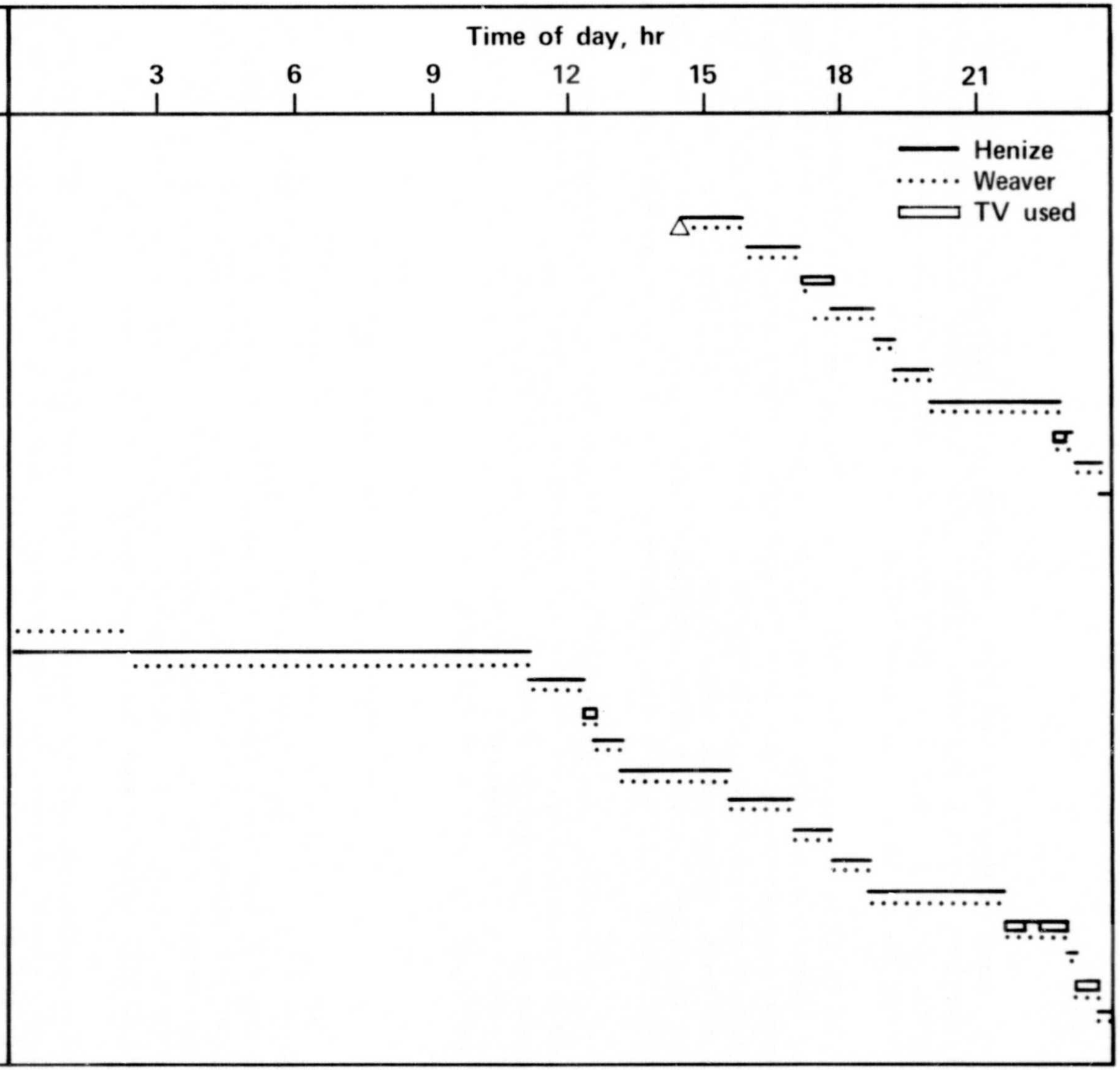


TABLE 15.- MISSION TIMELINES — CONTINUED

Event	Time (Start)
2 October	
Free time (continued)	(2335)
Install dewar in aircraft & preflight preparation	0015
Flight 3	0110
Empty dewar	0320
Review data	0352
Bed	0415
Eat (decision to extend mission)	1250
Free time	1325
Preflight planning with PI	1340
Preflight preparation	1405
Preflight planning with PI	1615
Preflight preparation	1625
Free time	1705
Preflight preparation	1720
Eat	1815
Flight 4	1850
Post flight debriefing with PI	2105
Inspect dewars	2145
3 October	
Inspect dewar (continued)	(2145)
Remove dewar from aircraft	0126
Bed	0210
Repair and align dewar	0400
Bed	0830
Eat	1450
Preflight dewars	1530
Install dewar in aircraft	1735
Preflight check	1810

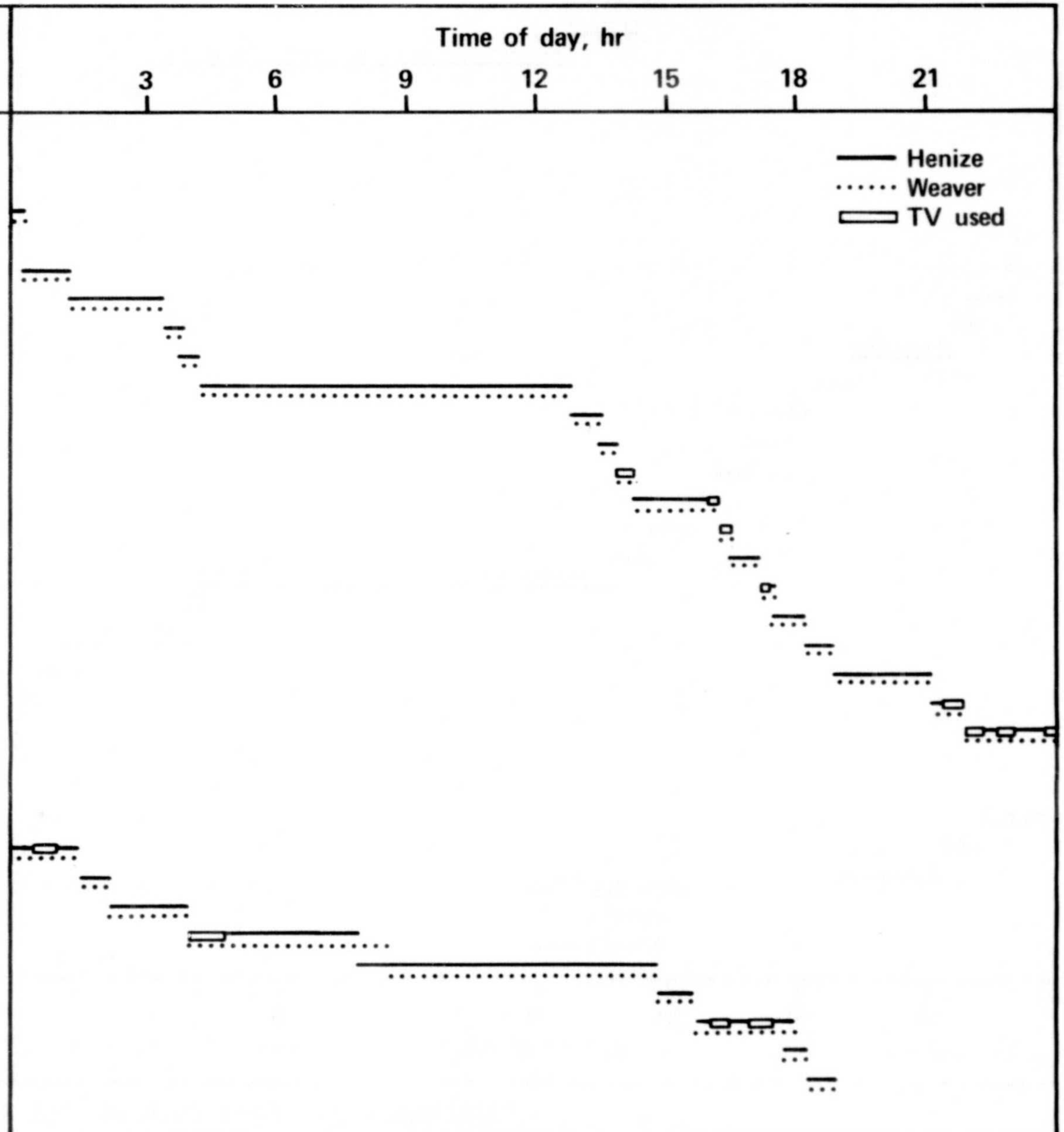


TABLE 15.- MISSION TIMELINES - CONTINUED

Event	Time (Start)
3 October (continued)	
Flight 5	1850
Post flight debriefing with PI	2125
Free time & eat	2215
4 October	
Preflight planning with PI	0005
Preflight check	0020
Flight 6	0100
Post flight debriefing with PI	0345
Bed	0400
Up-free time	1340
Preflight planning	1435
Preflight preparation dewars	1515
Free time & eat	1600
Dewar preparation and installation	1645
Review flight plan	1705
Preflight check	1805
Flight 7	1905
Post flight debriefing with PI	2130
Eat and free time	2150
Preflight discussion with PI	2245
Aircraft checkout and preflight tests	2255
5 October	
Flight 8	0000
Post flight debriefing with PI	0225
Bed	0300
Free time	1230
Preflight preparation dewars	1415

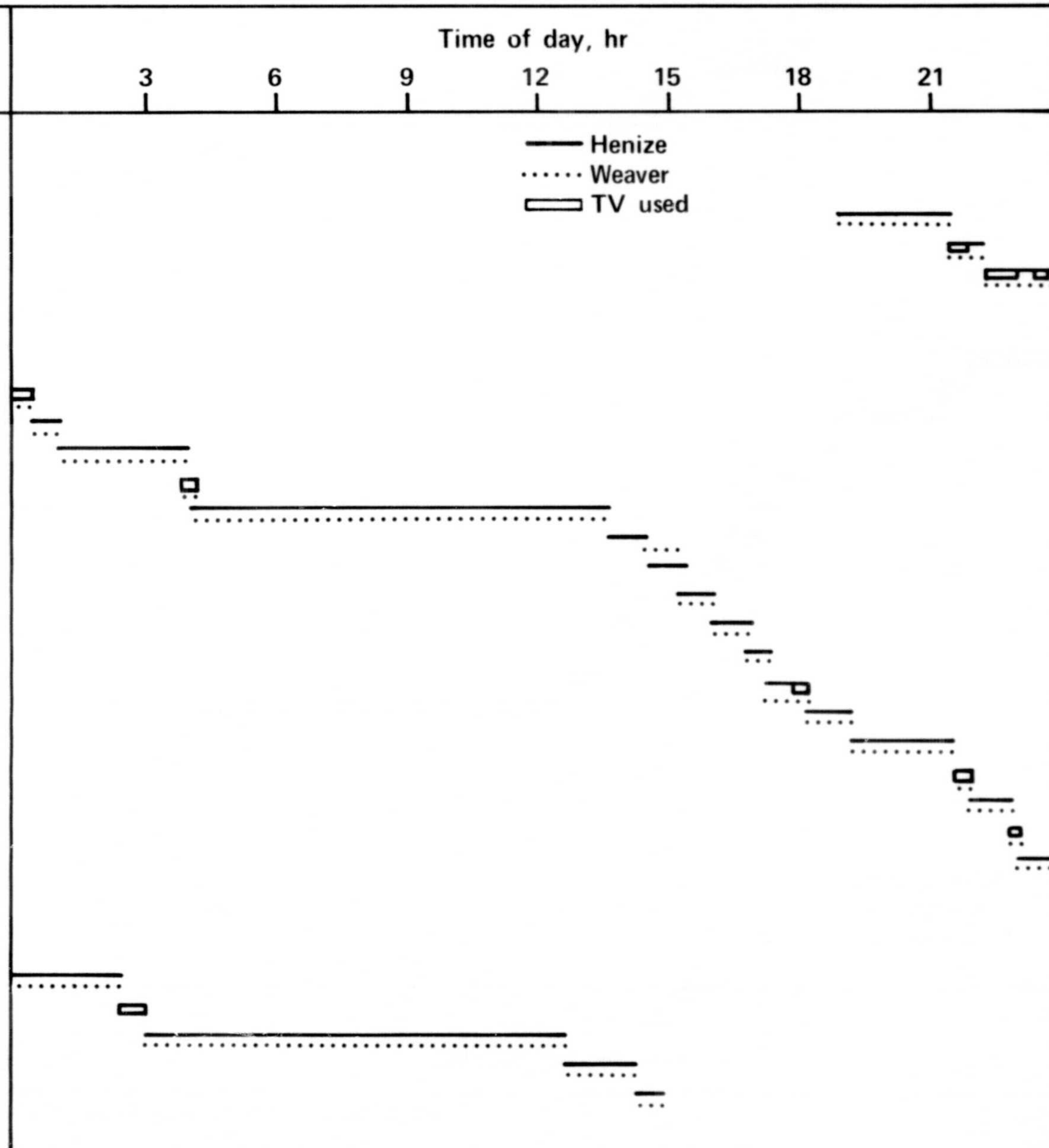
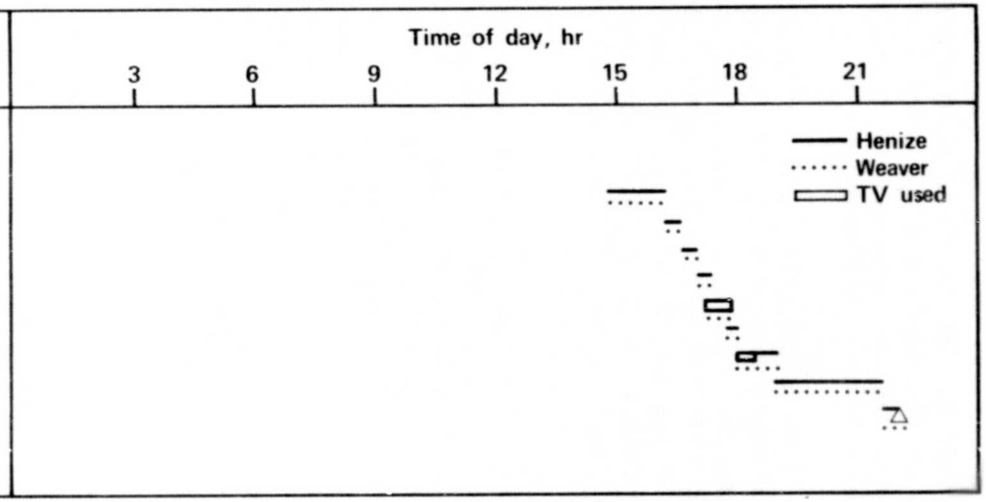


TABLE 15.- MISSION TIMELINES — CONCLUDED

Event	Time (Start)
5 October (continued)	
Eat	1445
Check aircraft intercom	1610
Preflight checks	1630
Free time	1700
Install dewar	1715
Free time	1750
Preflight briefing and checks	1800
Flight 9	1855
Post flight checks	2135
End mission	2200



after takeoff for the first flight and could not be resolved that night by the ground crew. One data flight was missed on the morning of October 3 while the EOs were repairing the photometer. The mission was extended to include Saturday, October 5 to permit one more data flight that evening.

The schedule called for two flights each night, the first at about 1900 and second at about 0100. Preflight activity started about 4 hr in advance of the first flight with the loading of cryogenics. Detailed preflight checks of the electronic equipment were made during the last hour before each flight (fig. 11). No additional servicing of the cryogenics was required before the second flight of each night. After each flight, up to an hour was spent discussing the data results with the PI via the TV link. The EOs normally slept from about 0400 to about 1300 each day.

Table 16 compares actual flights during the confined phase with those scheduled. Table 17 indicates the changes in observational planning during the mission; several changes already had been made to the list of objects prepared during the training period (third column), and the actual requests for flight paths made to the ASO flight planner a few days before the start of the simulation week (fourth column). Three targets and 10 observations were added, and 4 observations were deleted. Such changes were the result of the PI's day-by-day assessment of the optimum use of remaining observing time. Revised flight plans were computed on the days of the flights. Only half of the 18 planned observations were actually completed; nine were deleted, and seven were added, while two of the planned targets were not attempted.

Science Results

Scientific return during the mission is summarized in table 18. Measurements were made on 68 map points; the calibration target Jupiter was scanned five times and measured at six individual points. Eighty-eight percent of the measurements were to obtain basic data, 12 percent were for system calibration. An average of nearly 10 points and scans was recorded per flight.

Figure 12 summarizes the observations by target and as a function of S/N. The astronomical object M8 was the predominant choice for observations, with over half of the total points measured. NGC 2264 was second in order of interest with 17 percent. Both objects were relatively weak, judging by the S/N of the selected points; fully two-thirds were S/N = 3 or less, as figure 12 shows. Both represented relatively new areas for astronomical research, M8 as an optically bright HII region that has received little attention and NGC 2264 as a young stellar object about which little is known. Thus, the EOs' major effort was directed toward unique scientific measurements on two relatively unknown and difficult targets in the mainline of the PI's research program.

The spatial arrangement of point measurements relative to telescope reticle coordinates for the principal targets observed during the mission is illustrated in figure 13. Similar points obtained during the integrated simulation (flight training) period are also shown to denote where

Figure 11.- EOs performing preflight hand check of photometer.

TABLE 16.- COMPARISON BETWEEN PLANS AND EVENTS DURING

SIMULATION FLIGHTS

Date, 1974 Planned events	Actual Events	Comments
Sept 30 p.m. Flight 1	Flight 1 (1925-2000)	Aborted—landing gear problem
Oct 1 a.m. Flight 2	Cancelled	
Oct 1 p.m. Flight 3	Flight 2 (1917-2120)	
Oct 2 a.m. Flight 4	Flight 3 (0110-0330)	
Oct 2 p.m. Flight 5	Flight 4 (1905-2105)	
Oct 3 a.m. Flight 6	Cancelled	Realign photometer
Oct 3 p.m. Flight 7	Flight 5 (1910-2115)	
Oct 4 a.m. Flight 8	Flight 6 (0100-0320)	
Oct 4 p.m. Flight 9	Flight 7 (1915-2115)	
Oct 5 a.m. Flight 10	Flight 8 (0000-0204)	
Oct 5 Day Debriefing		Mission extended one extra day
Oct 5 p.m.	Flight 9 (1900-2100)	
Oct 6 a.m.	Debriefing	

measurements were interspersed to complement earlier results, or repeated for verification or reference. Peripheral values of S/N indicate that the IR fields of M8 and NGC 2264 were roughly bounded by present observations, but that the other two objects have significant signals in areas beyond those surveyed. NGC 2264 is the smallest object, as expected, while W51 is so large that exploratory results were confined to two separate regions.

Problems and Reactions

A number of problems occurred during the mission of various complexity and result. Some were entirely beyond the control of the EOs, while others were caused by them. These problems are listed in chronological order and an attempt is made to establish the EOs' contribution to the creation of the problem and/or its solution.

TABLE 17.- LEAR ASSESS 4 MISSION, PLANNED AND ACTUAL TARGETS

Dates	Flight number	Planned 8/30/74	Planned 9/27/74	Actual
Monday, 9/30	1 (p.m.)	Jupiter M8	Jupiter M8	aborted
Tuesday, 10/1	- (a.m.)	W51	W51 OMC-2	cancelled
Tuesday, 10/1	2 (p.m.)	NGC1333	M8 NGC1333	Jupiter M8
Wednesday, 10/2	3 (a.m.)	Jupiter NGC2264	NGC2264 ON-4	NGC2264 ON-4 (not located)
Wednesday, 10/2	4 (p.m.)	NGC1333	M17 NGC1333	Jupiter M8
Thursday, 10/3	- (a.m.)	Jupiter NGC2264	W51 OMC-2	cancelled (realigned optics)
Thursday, 10/3	5 (p.m.)	NGC1333	M17 NGC1333	Jupiter M8
Friday, 10/4	6 (a.m.)	Jupiter NGC2264	NGC2264 ON-4	NGC2264 ON-4
Friday, 10/4	7 (p.m.)	open	M17 NGC1333	Jupiter M8
Saturday, 10/5	8 (a.m.)	open	open	W51 OMC-2
Saturday, 10/5	9 (p.m.)	not planned	not planned	Jupiter M8
Summary of observations				
	M8	1	2	5
	W51	1	2	1
	OMC-2	0	2	1
	NGC1333	3	4	0
	NGC2264	3	2	2
	ON-4	0	2	2
	M17	0	3	0
	Jupiter	4	1	5

TABLE 18.- SUMMARY OF MEASUREMENTS ON ASSESS LEAR 4

Flight	Target	Purpose	Number of measurements: Field scans	Number of measurements: L/R integra. steps	Map points
1	Jupiter M8	Calibrate Data	None—flight aborted		none
2	Jupiter M8	Calibrate Data	21 (2 scans) ---	--- 133	--- 8
3	NGC2264 ON-4	Data Data	--- ---	83 0	6 0
4	Jupiter M8	Calibrate Data	29 (1 scan) ---	5 (1 point) 30	--- 2
5	Jupiter M8	Calibrate Data	50 (2 scans) ---	3 (1 point) 164	--- 9
6	NGC2264 ON-4	Data Data	--- ---	132 40 (est.)	7 2
7	Jupiter M8	Calibrate Data	--- ---	6 (2 points) 173	--- 14
8	W51 OMC-2	Data Data	--- ---	45 71	5 7
9	Jupiter M8	Calibrate Data	--- ---	10 (2 points) 158	--- 8
				Total	68

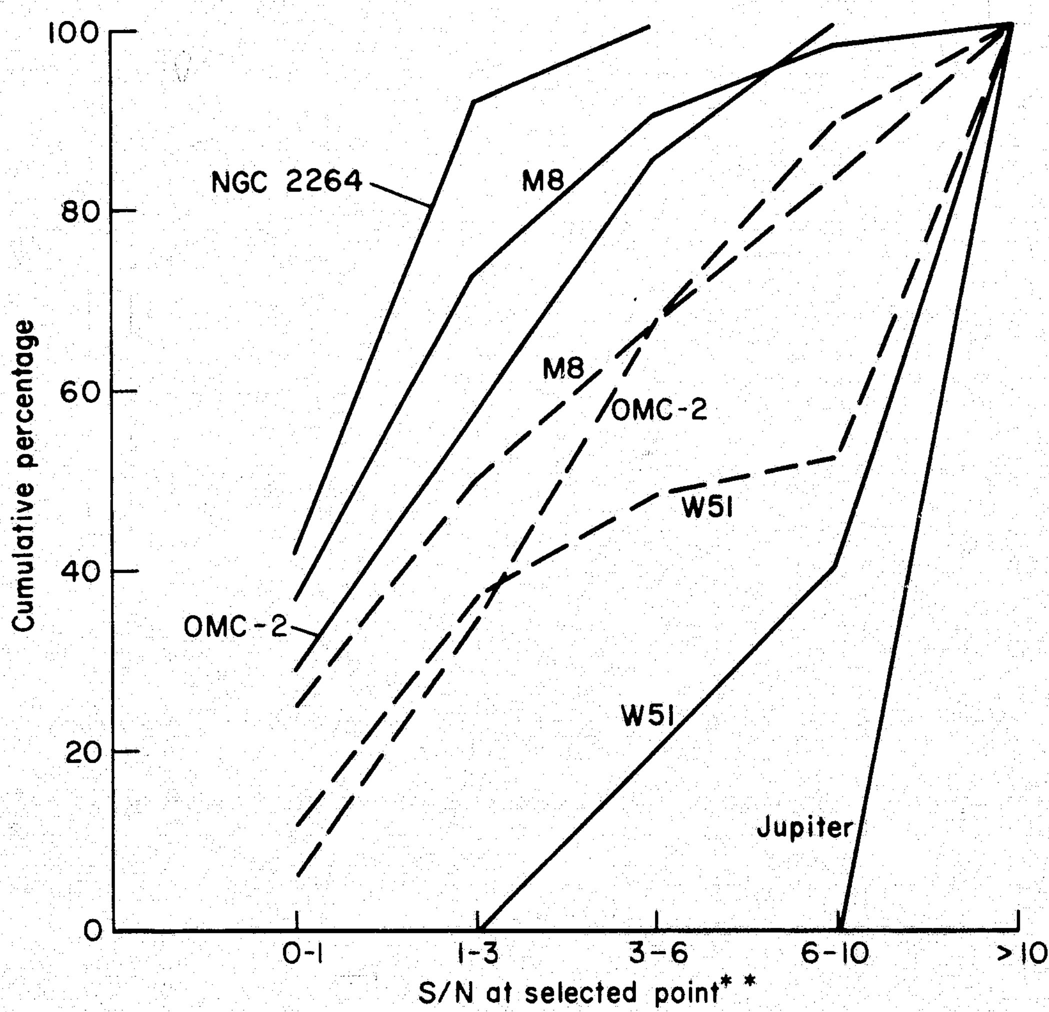
Calibration measurements = 124 = 12 percent.
Data measurements = 871 = 88 percent.

Aircraft landing gear (Sept. 30)- On the first flight of the mission, the landing gear status indicators malfunctioned during retraction, causing uncertainty about the condition of the landing gear. The first flight of the series was aborted and the second flight that night was canceled. The problem was corrected by replacement of a pressure switch in the landing gear actuation system.

Cassette recorder (Oct. 1)- The EO forgot to replace the cassette at start of data run. About 20 min of data were lost before the tape was changed.

Training flights	Target	Point measurements Number	Point measurements % Total	Scans
— — —	M8	41	55	—
	NGC 2264	13	17	—
— — —	OMC-2	7	10	—
	Jupiter	6	8	5
— — —	W51	5	7	—
	ON-4	2*	3	—

$$\frac{\text{Map points + calibration points + scans}}{\text{Flights}} = \frac{79}{8} = 9.9$$



*S/N not available

**S/N a function of signal strength and number of integrations; operator decision terminates observation

Figure 12.- Target evaluation for ASSESS Lear 4.

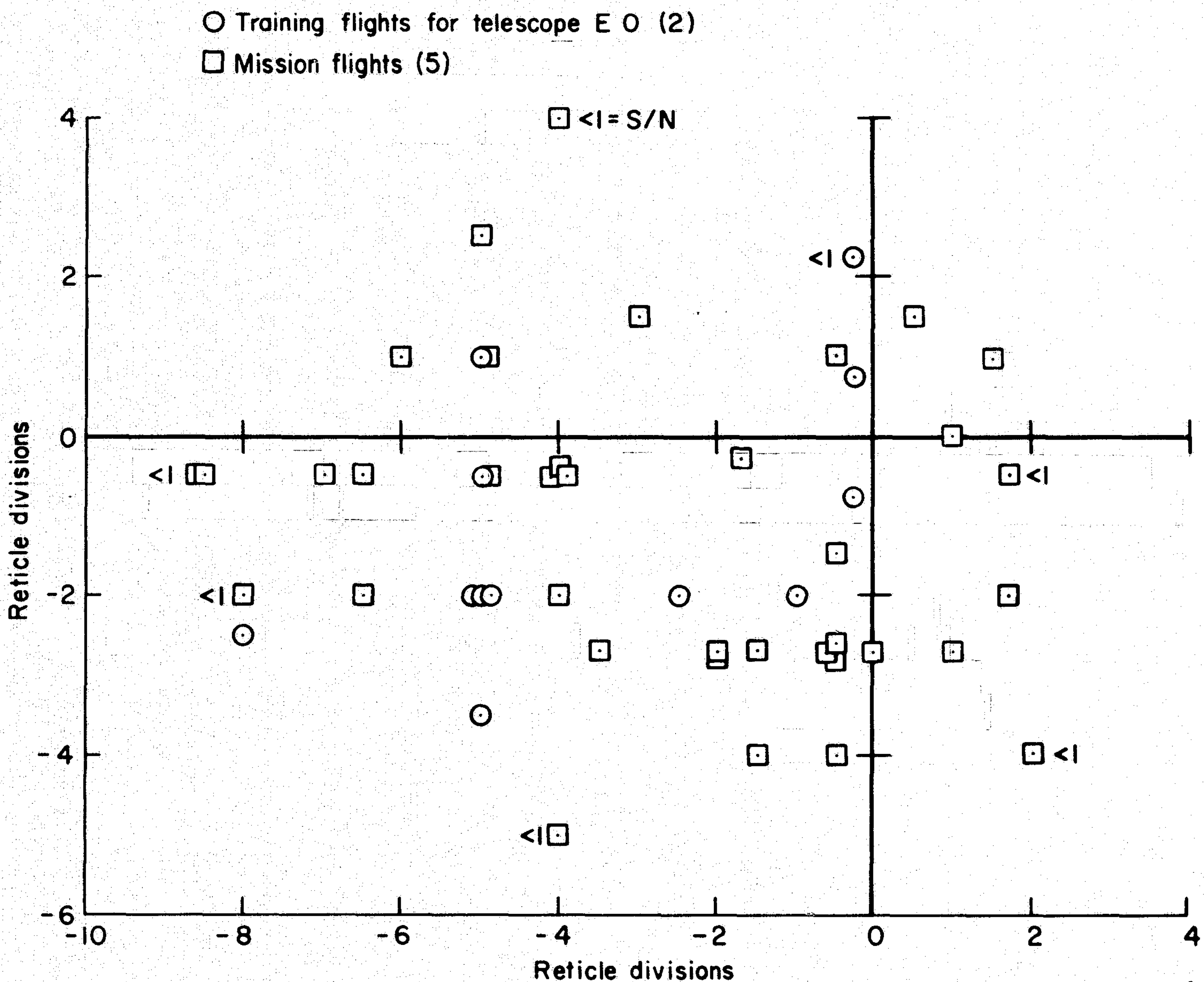
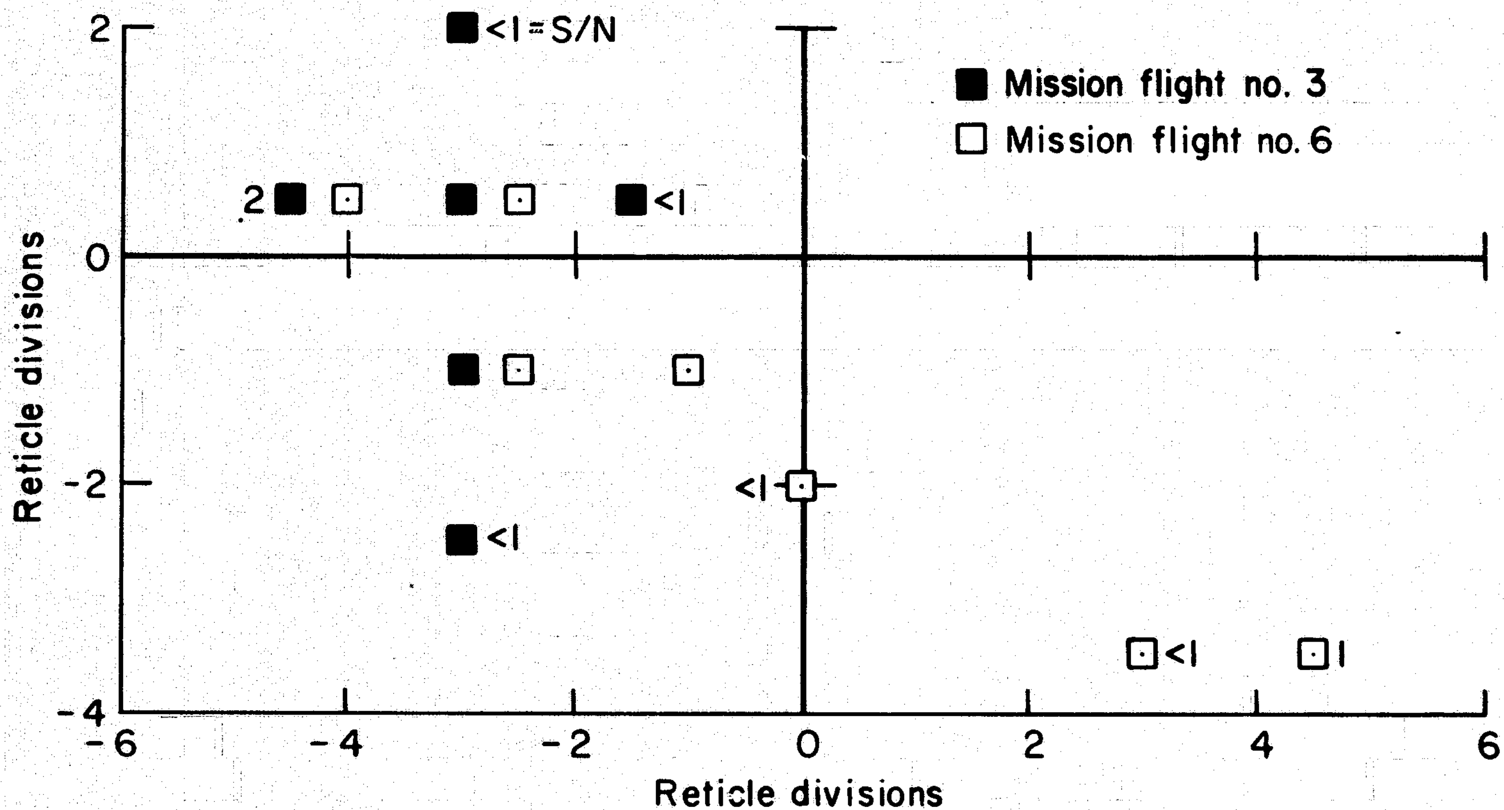
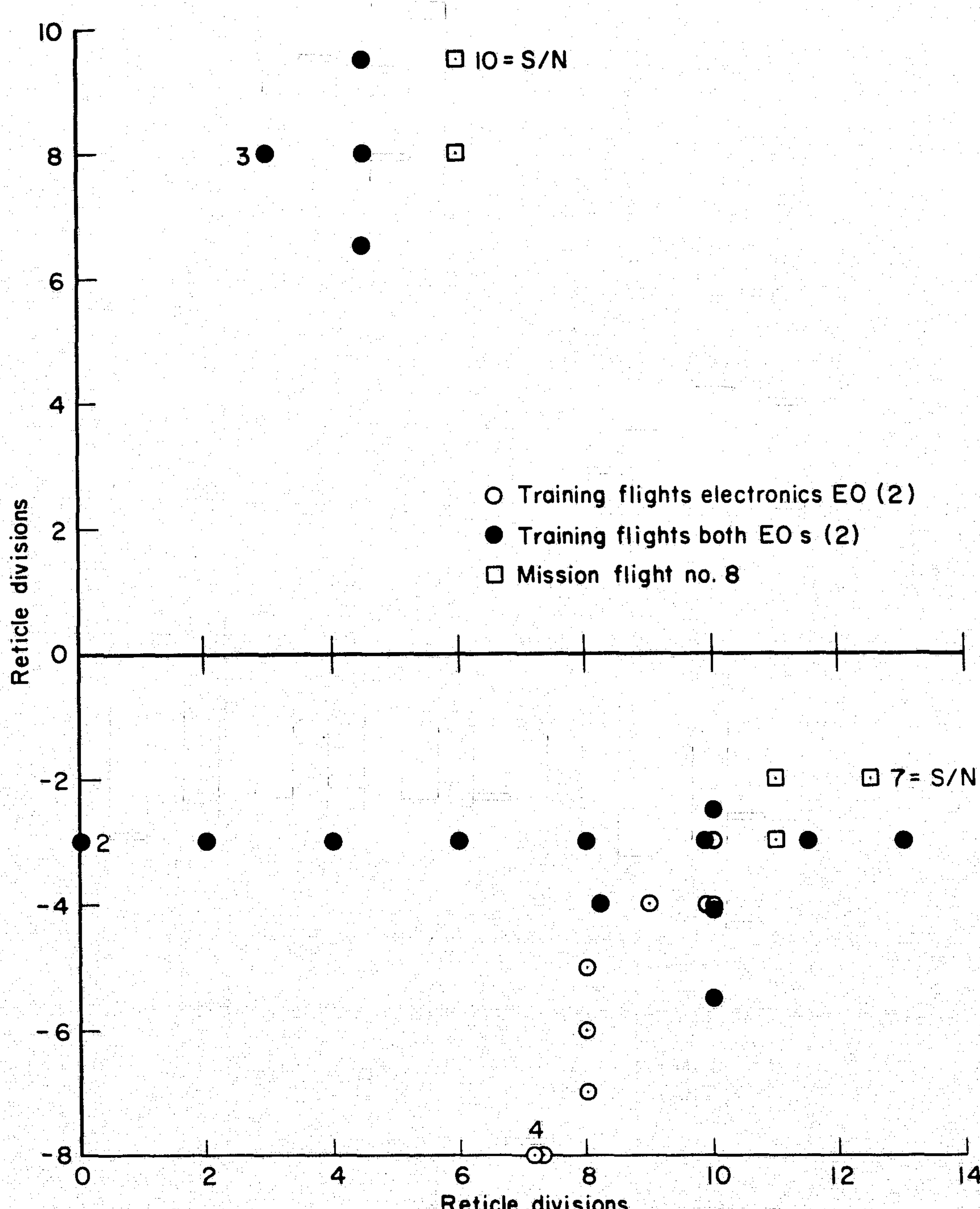


Figure 13.- Observation patterns on primary targets.



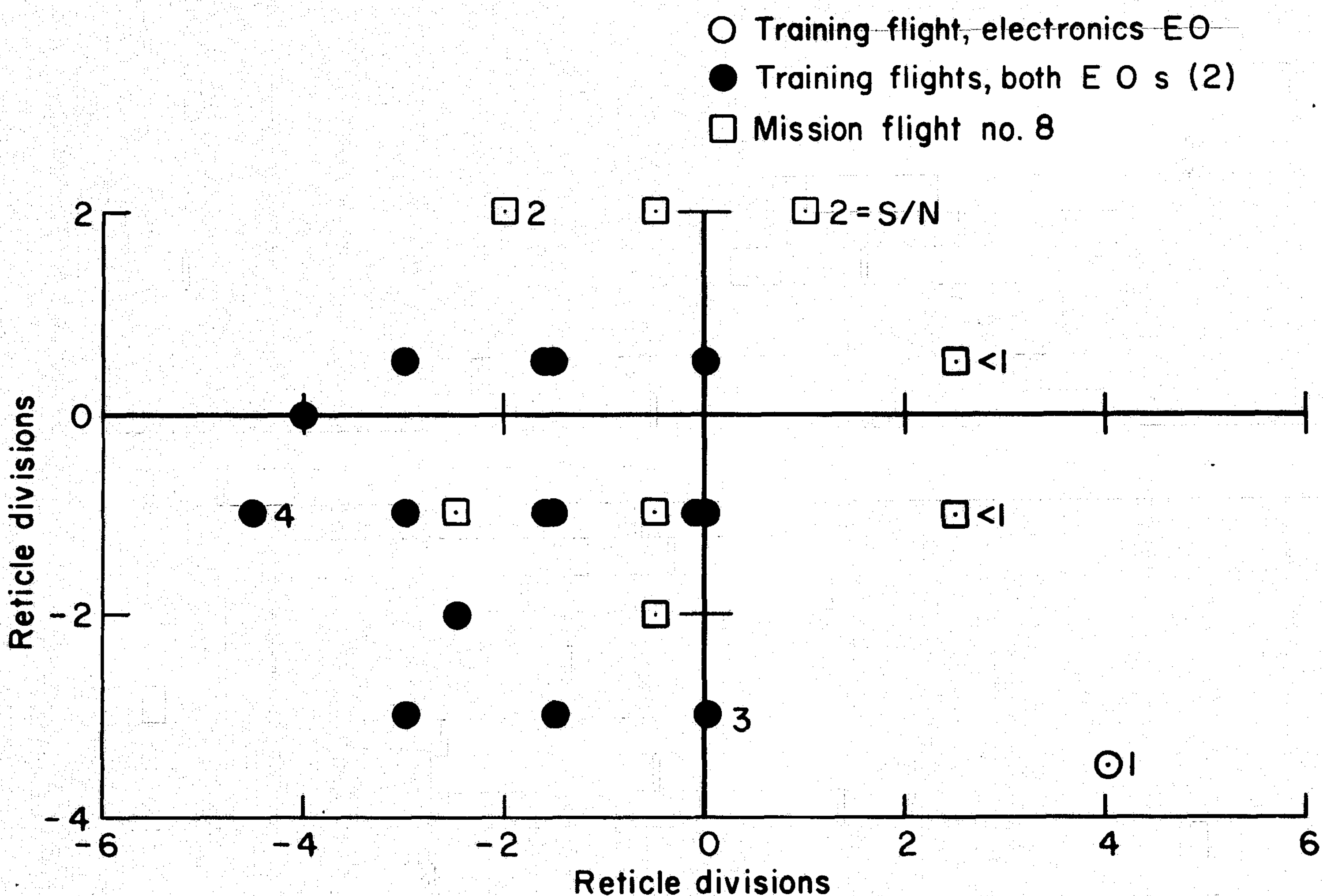
(b) Target NGC2264

Figure 13.- Continued.



(c) Target W51

Figure 13.- Continued.



(d) Target OMC-2

Figure 13.- Concluded.

Electronics phasing (Oct. 1)- Calibration was performed on Jupiter with the PLA slightly out of phase with the chopper. This operational mistake was noticed by the EOs, and the electronics were rephased, thereby introducing a significant error into the absolute measurements of M8.

Telescope travel limitation (Oct. 2)- On the early morning flight of October 2, the EO was unable to depress the telescope below 18° elevation to acquire a target at 14°. He reported a binding of the telescope sealing boot. The objective was achieved by flying the aircraft with the left wing low, and the EO was able to acquire his first target, NGC 2264, with no difficulty.

Upon consultation with telescope personnel after the flight, the EO learned that the problem was a procedural one: If the telescope is positioned down for the start of the flight it can be pointed up during the flight without binding; however, the reverse is not true. This point is not covered explicitly in the telescope operating manual (ref. 9), and it was not mentioned in training.

Target identification (Oct. 2)- A second problem occurred on the early morning flight of October 2 when the EO operating the telescope was unable to locate his second target, ON-4. The EO attributed the problem to his own failure to study the star charts sufficiently before the start of the flight. On subsequent flights, he was careful to properly prepare himself before takeoff and avoid future identification problems.

Unexpected computer printout (Oct. 2)- The electronic systems EO was baffled by some unexpected numbers that appeared on the computer printout before the first integration of the night. Although no loss of data or error resulted from this problem, the EO's confusion indicated a training deficiency. He subsequently learned from the PI that the printout was a normal occurrence resulting from a change in the integration time, and came to welcome it as a reminder.

Magnetic recorder (Oct. 2)- Neither voice nor data were recorded on the magnetic recorder for the early morning flight of October 2. After consultation with the PI, the electronic systems EO inspected control settings on the recorder using an inspection mirror. (The recorder is on top of the rack near the cabin ceiling and the settings cannot be seen directly.) It was decided to replace the faulty unit with a borrowed recorder (no spare had been supplied by the PI). Because the original recorder casing was specially built for compatibility with the aircraft, the borrowed recorder electronics were installed in the original casing.

The exchange was made without undue difficulty, and no attempt was made by the EOs to repair the faulty unit. (The repair could have been easily made, as the set screw was loose on the motor drive pulley.) Had no spare been available, it is highly possible that delays could have occurred without the intervention of the PI.

Low signal levels (Oct. 2)- Low signal levels occurred on the first flight of the evening on October 2. Neither inflight nor immediate postflight troubleshooting by the EOs isolated the problem. The alternate solution was to make the second flight with the backup dewar, although it had a lower sensitivity than the primary one and was less suited for the weak targets selected. However, the backup dewar was not ready for flight; it had not been pumped down and cooled. This was a procedural error by the EOs, resulting in part from operational difficulties with the vacuum pumping system. As a result, the second flight was canceled and the EOs returned to troubleshooting the primary dewar under the direction of the PI.

A thorough examination of the experiment and the data revealed that there was a 4:1 attenuation of the target signal but normal signal level for sky brightness. Thus, the problem was not a simple gain change in the electronics but a misalignment in photometer optics. After the dewar warmed up, it was disassembled by the EOs (fig. 14) with the PI observing and giving directions via the TV link. Two anomalies were found: a loose field mirror adjacent to the bolometer and some vacuum grease (or other substance), which partially obscured the dewar window. The field mirror was rebonded with low temperature epoxy cement and the window was cleaned. The photometer was realigned using a borrowed slide projector as a light source.

The signal level was restored as proven on the next flight, and the EOs were rightfully proud of their accomplishment. Although the EOs had been instructed on the theory and construction of the photometer and dewar, they had not participated in their disassembly or repair during training. The repair went smoothly but more slowly than if the PI had handled it.

After having repaired the unit, the EOs noted that better drawings and descriptive material would have aided in the isolation of the low-signal problem and would have permitted easier and more succinct communication to the PI via TV. In communicating with the PI, problems arose because drawings were not available to help the EOs understand how the equipment was assembled. Communication also was hampered because the EOs did not know the proper nomenclature for the various parts involved. As a result, impromptu sketches were made on paper and blackboard in an attempt to communicate with the PI.

On the following flight, it was necessary to measure the viewing angle (now somewhat larger) of the repaired system to provide a basis for correcting subsequent data. For this reason, the flight schedule was altered; a scan of Jupiter and several M8 map points provided the necessary measurements.

Aircraft vacuum pump (Oct. 3)- During postflight activities on October 2, the EOs were troubleshooting the dewar and preamplifier in the aircraft (fig. 15) when they noticed that the helium pressure was rising. The electronic systems EO turned on the aircraft vacuum pump, which began smoking and was turned off immediately. The problem was quickly diagnosed by the aircraft ground crew as a slipping belt on the pump. The pump was restarted and the aircraft vented. This problem was not related to EO operation of the equipment.

Ground-based vacuum pump (Oct. 3)- Recurring problems with the ground-based vacuum pump (fig. 16) were experienced the night of October 2 and early the next morning. Eventually, the diffusion pump was damaged in attempts to shut down the pumping system following a power failure at the simulation site

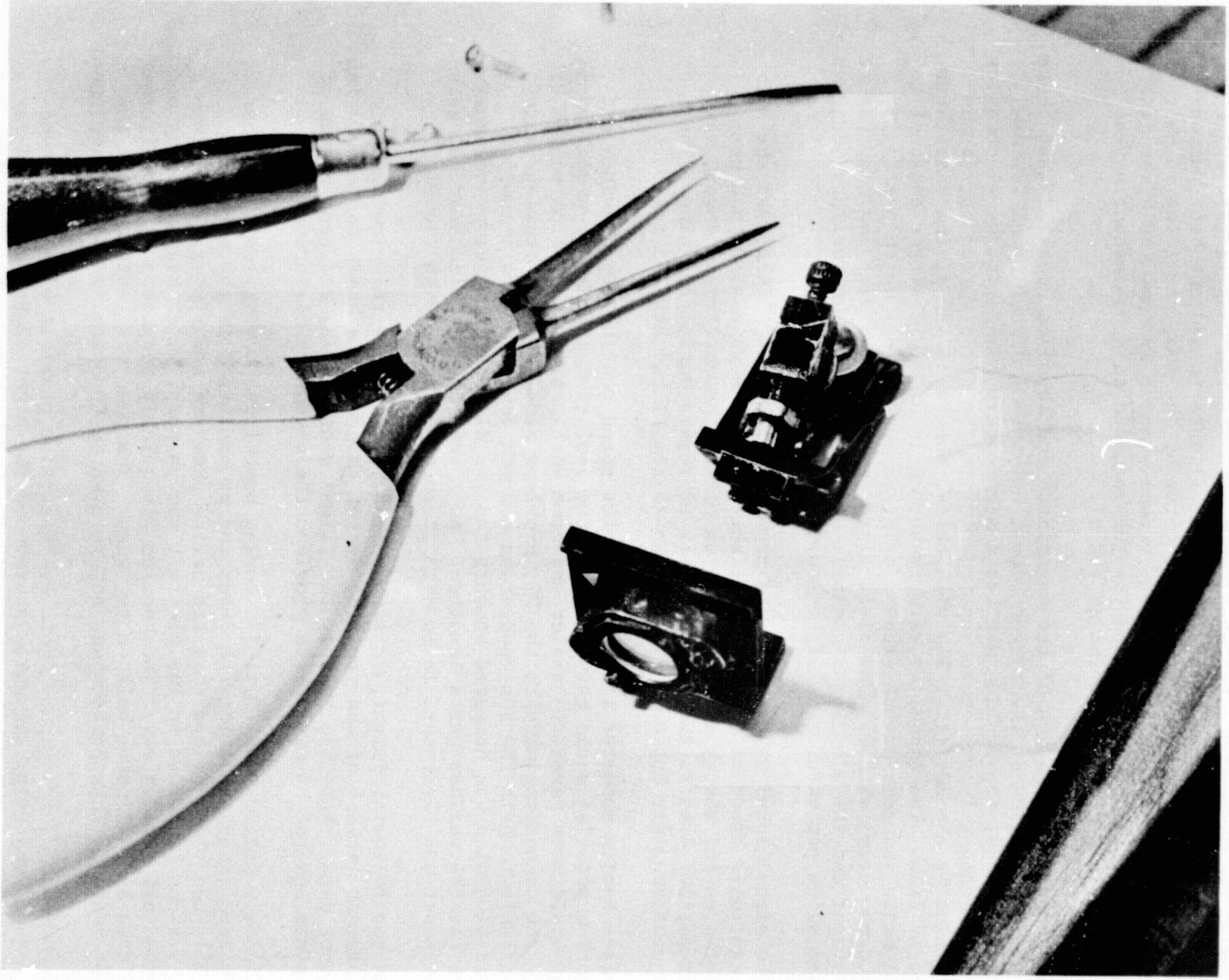


Figure 14.- Photometer components disassembled for repair.

Figure 15.- Electronics operator checking preamplifier circuits in the aircraft.

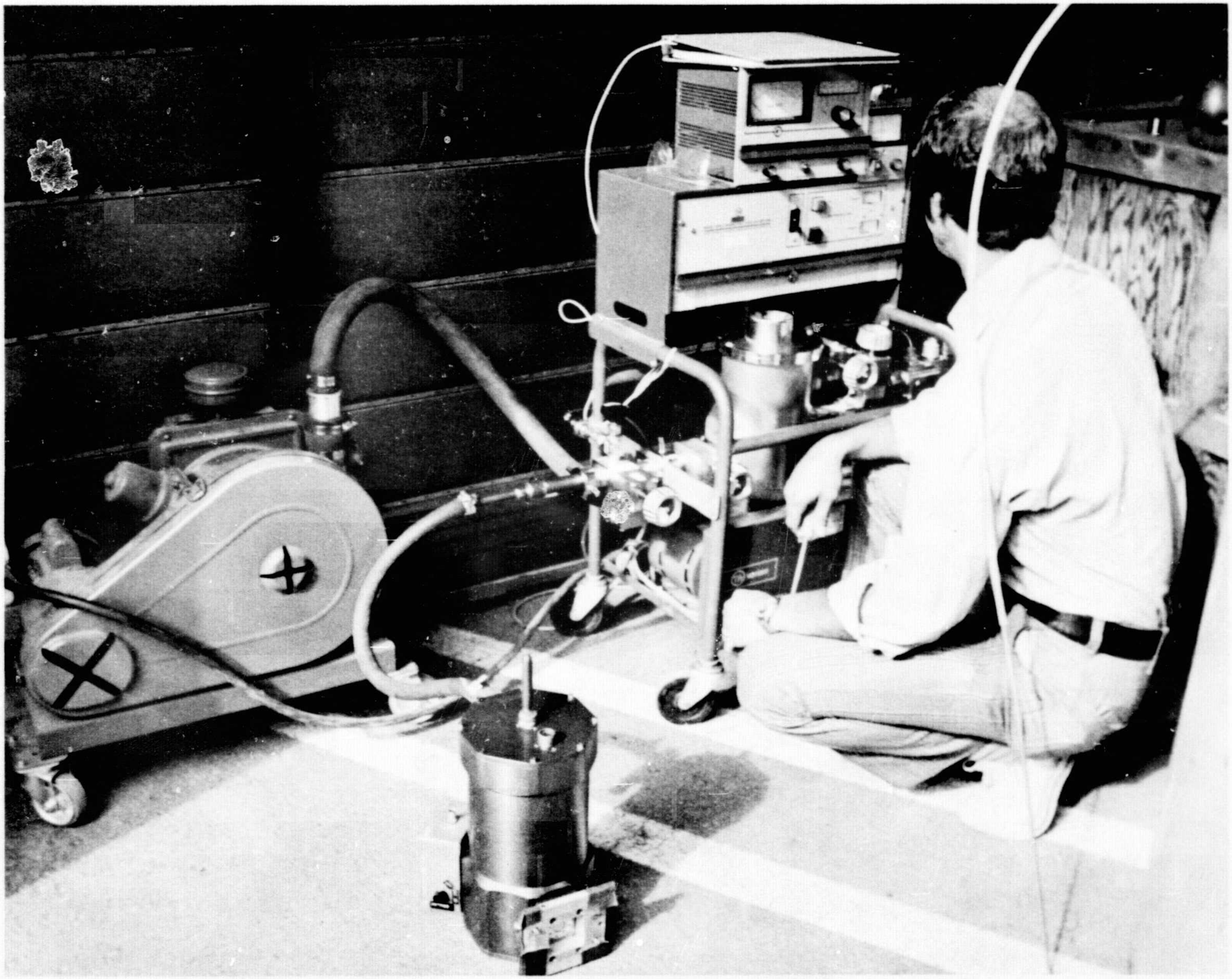


Figure 16.- Vacuum pumping system in cryogenics shed at simulation site.

and was replaced with another pump that performed satisfactorily. It is believed, although not confirmed, that these problems probably would not have occurred had the EOs been more thoroughly trained in the theory and operation of diffusion pumps.

Telescope travel limitation (Oct. 4)- While observing the second target, ON-4, the EOs again were bothered by interference with the telescope sealing boot. Operations slowed while they worked around the problem, with the result that less than one-half of the planned measurements were made. The PI stated he probably would have had the same difficulty.

Aircraft turbulence and integration time (Oct. 4)- During the early morning flight of October 4, atmosphere turbulence was greater than on previous flights. The telescope operator stated that he had trouble keeping on target for the 4 sec period, and several integrations were taken without really improving the S/N. The PI felt that improved results could have been obtained if the integration period had been reduced from the planned 4 sec to 2 sec because of the unexpected turbulence. He felt that he would have obtained either better or equally good data the shorter period.

Aircraft intercom (Oct. 4)- A number of flights were plagued with intermittent connections on the aircraft intercom. The EOs isolated the problem in a Y-connection at the intercom-tape recorder interface, and twice repairs were made by an aircraft technician. However, before the early morning flight of October 5, the EOs discovered that they could not talk to each other over the intercom unless the Y connection was removed from the circuit. This was done and no magnetic recording was made for the ensuing flight. Following the flight the EOs repaired three broken wires.

Although the intercom is part of the aircraft system, the malfunction did affect the EOs and the data they obtained. The EOs detected the problem and were instrumental in the solution.

Stabilization system (Oct. 5)- On the early morning flight of October 5, the telescope stabilization system blew a fuse. The telescope operator replaced the fuse and proceeded without further incident.

Low signal levels (Oct. 5)- Signal levels were low again on the last flight of the mission. The problem was first detected during final checkout just before flight, but time was too short to switch to the backup dewar. While in flight, the EO switched to the backup PLA and recorder in effort to troubleshoot the system. No improvement was noted, and he switched to the backup preamplifier, again with no improvement. The mission ended without establishing the cause of the problem. Subsequent communication with the PI failed to establish any cause for this low signal level. The PI stated that a careful examination had been made of the photometer and nothing had been found amiss. He suggested the possibility of an undetermined telescope problem. Since the Lear 4 mission, however, several other experimenters have used the telescope without experiencing any transmission problems, so this possibility must be rejected. The cause remains unknown. The PI also suggested that earlier ground tests of the system might have allowed time for remedial action. As it was, no useful data were collected on this flight.

Data Handling

One of the study parameters of the Lear 4 mission was the EOs' ability to process data and perform preliminary analysis. The extent or end point of this evaluation was not defined in advance, but rather was a decision left to the PI team who would implement the training program accordingly. It was anticipated that training would equip the EOs to judge data quality, to make comparisons with other measured and referenced results, and to propose observation schedules for succeeding flights.

It was clearly the responsibility of the PI to select targets, to evaluate the scientific importance of the data, and to alter the selection if necessary in consultation with the EOs.

As it turned out the EOs did not perform much of the processing and analysis of data during the simulation period, and for two reasons; first, their hands-on training in this area was very limited and second, the lead time for aircraft flight planning necessitated target selection well before noon when the EOs were sleeping. Under these circumstances, the PI assumed an active and vital role in data evaluation. After a flight, the EOs first reviewed the printout records (fig. 17) for consistency and clarity, then initiated a TV consultation with the PI to discuss the results, and the occurrence and impact of any equipment problems. The records were then transmitted to the PI who analyzed the data, and, in phone consultation with the senior PI, selected the targets and prepared detailed observation plans and star plots for following flights. In turn, these were "up-linked" to the EOs who reviewed the plan, studied the available reference material (star plots, background literature), planned a working schedule of observations, and otherwise prepared for optimum utilization of flight time.

The EOs had been trained in the real-time interpretation of data in flight, which is necessary to optimize the science return. As the mission progressed, on-the-job training quickly improved their ability to evaluate data post-flight. In retrospect at the mission debriefing the EOs were of the opinion they could have handled the data satisfactorily if time schedules had permitted.

Communications

Telephone and television log sheets are provided in appendix F. Five of the 19 calls on the EO log were personal calls to the EOs' homes; two calls concerned return airline reservations; and 5 calls referred to nonmission EO business. Only 6 calls were logged to the Mission Center. One call, to the Ames telescope engineer, concerned the binding of the telescope sealing boot. The PI phone log records 11 calls to the home laboratory to discuss flight results and/or to consult on equipment problems. Three more were made, locally, between EO and PI.

Mission Center communications, mostly with the PI, were primarily via the TV link. Twenty-eight instances of use were recorded, varying in duration

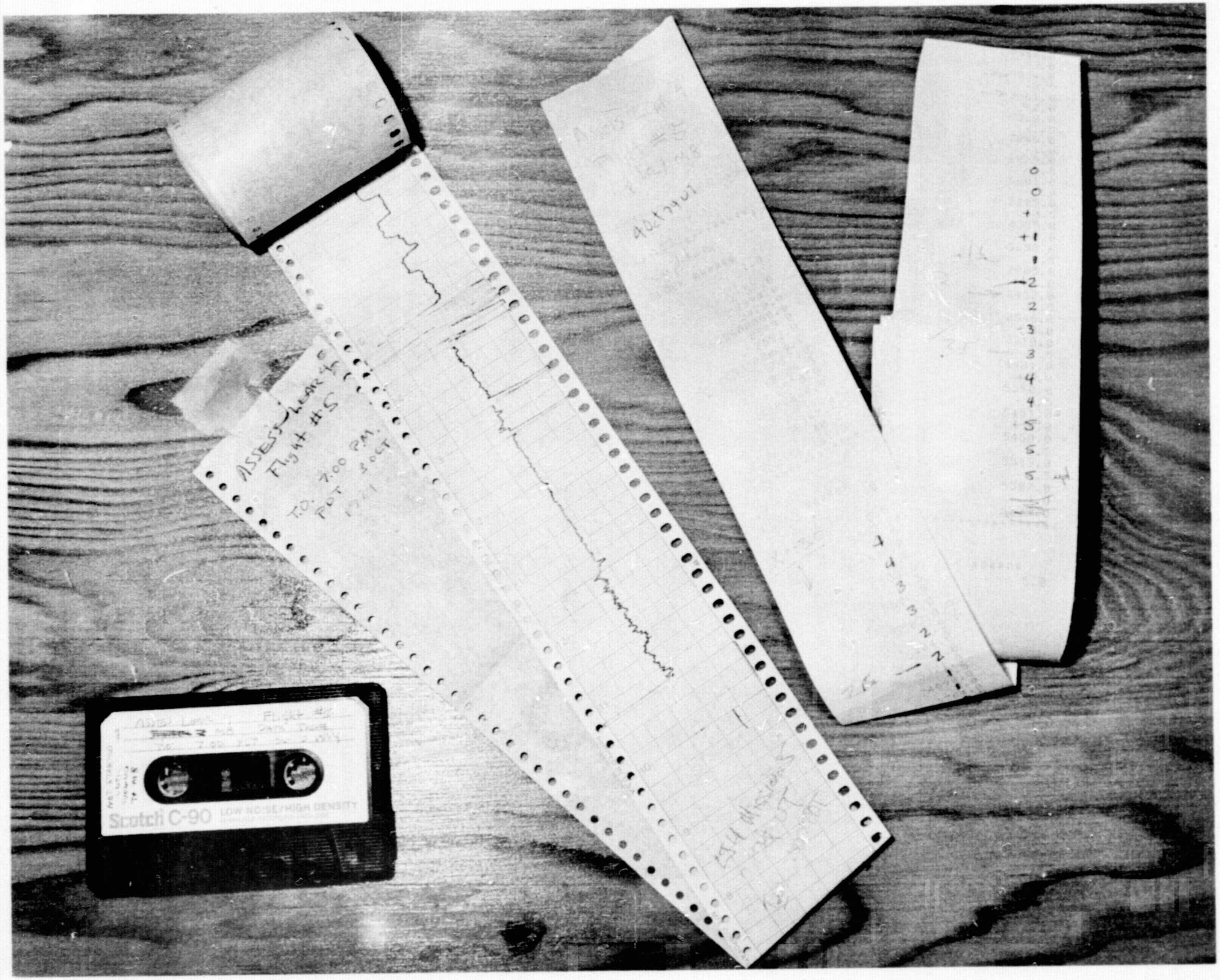


Figure 17.- Data output from experiment on one flight.

from 5 to 55 min. Total usage was just over 8 hr, of which half was spent in postflight review of results, over one-third in flight planning and equipment preparations, and the remainder in equipment troubleshooting and repair. The most concentrated use of the TV link occurred during photometer repairs between 2100 October 2 and 0500 October 3. The TV link equipment is described in the next section.

Support

Facilities- The basic facilities provided for the simulation missions (figs. 18 and 19) are described in references 5, 6, and 7. New for this mission was the Mission Center housed in a trailer 40 m from the simulation complex (fig. 20). The living quarters were not observed while occupied by the EOs. The work area end of the other trailer (fig. 21) was under continuous observation by the ASSESS observer team. Two specially limited areas were constructed to simulate space available in Spacelab; one area served as a workbench (figs. 22 and 23) and the other, of the same size, as a center for data handling. Cabinet storage space was also limited (fig. 24). An additional desk (fig. 25) was supplied for general-purpose activities (study, communications, etc.).

Following each flight, the aircraft was towed to the hangar area for refueling and servicing. It was returned to the simulation area in ample time for preflight checks.

TV link- The closed-circuit TV link was not originally planned for the Lear 4 mission, but the required equipment became available at the last moment and was installed in time for use at the start of the confined phase. This two-way link was used in preference to the telephone for communication between the EOs in the work area and the PI at Mission Center.

The TV equipment was designed for home recording of TV programs (fig. 26), and consisted of a small TV camera and a video recorder that accepted special cartridges. (The recorder was not packaged, being intended for installation with a TV receiver in a console.) The camera was a complete unit provided with a zoom lens and automatic gain control (AGC), which permitted operation from bright sunlight to the artificial light level of the work area. Display monitors were available from the ASO laboratory stock provided for the CV-990 and the C-141 aircraft. The monitors were small (13 cm) but provided good resolution. An additional large (35 cm) monitor was installed at the Mission Center.

Power supply- Figure 27 shows estimated energy for consumption for experiment servicing and repairs in the work area during the mission. The primary load during the first two days was the vacuum system shown in figure 16. It was normal practice to operate a small roughing pump (250 W) continuously to keep the associated diffusion pump in a ready status, and to use a larger mechanical pump (750 W) for initial evacuation of a dewar. Total energy consumption during this period averaged about 500 W per hour.

Figure 18.- Overview of simulation site.

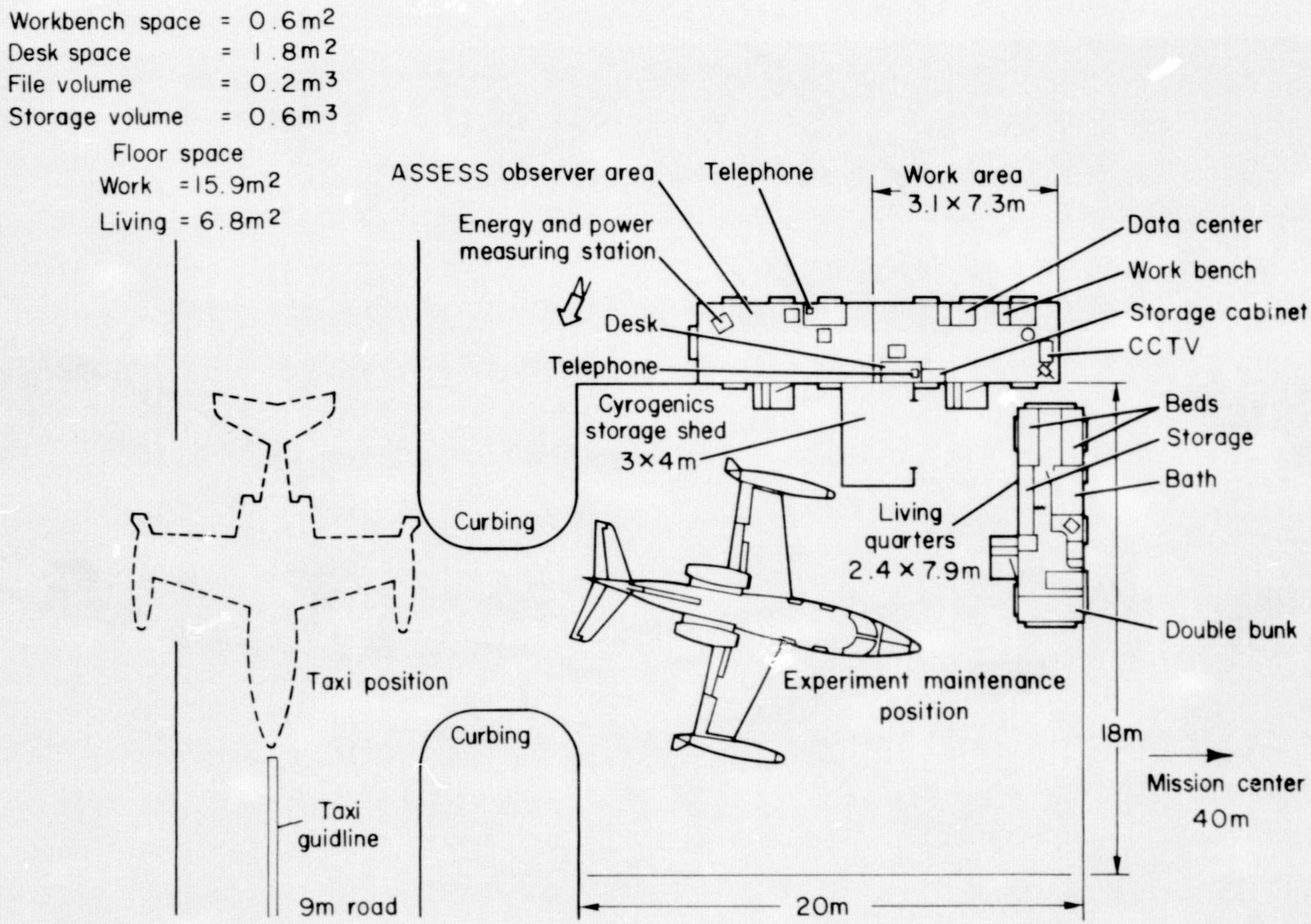


Figure 19.- Arrangement of the simulation complex.

Figure 20.- Mission Center.

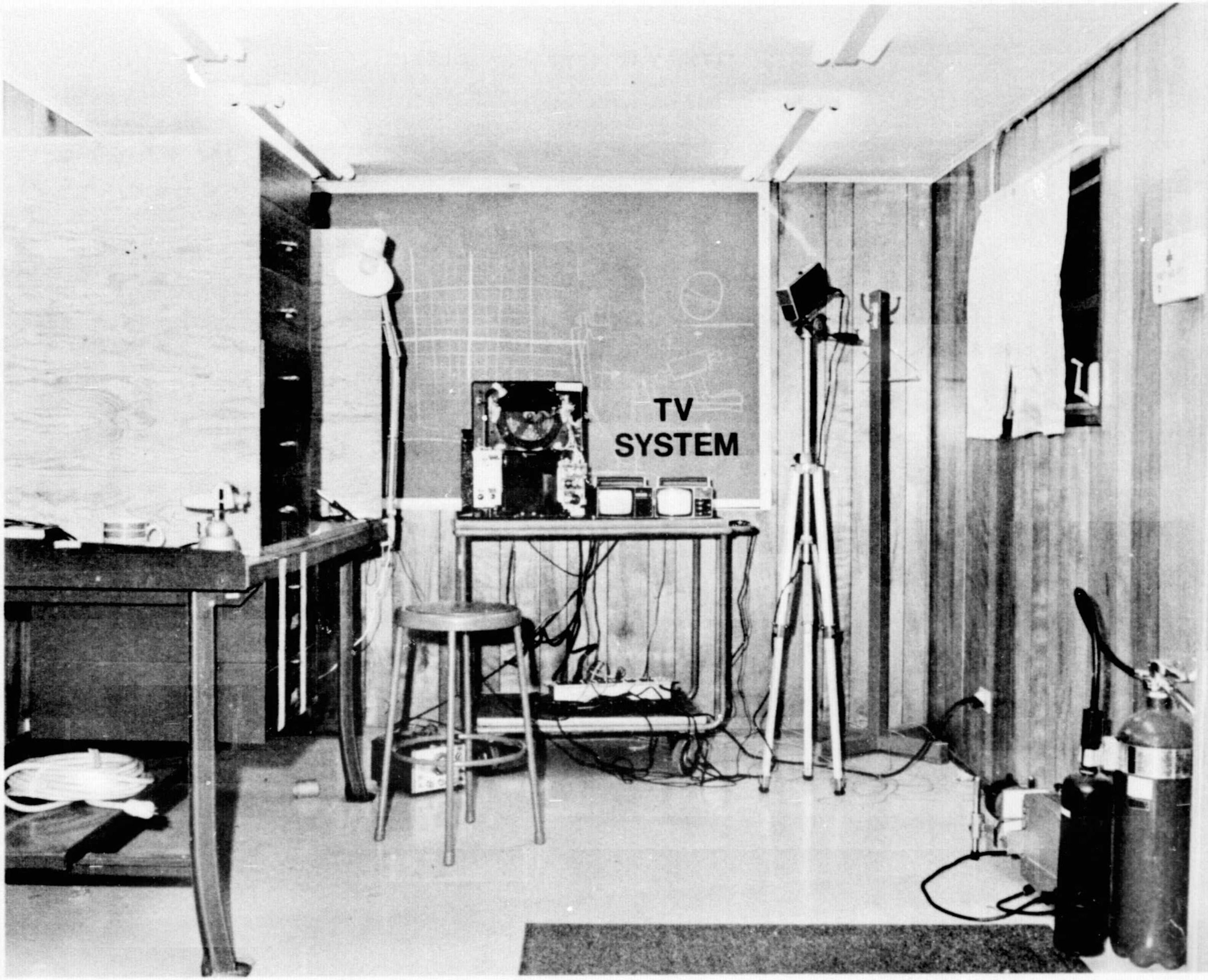


Figure 21.- General view of EOs work area.

Figure 22.- Simulated Spacelab workbench; surface area = 0.57 m^2, storage volume = 0.15 m^3.

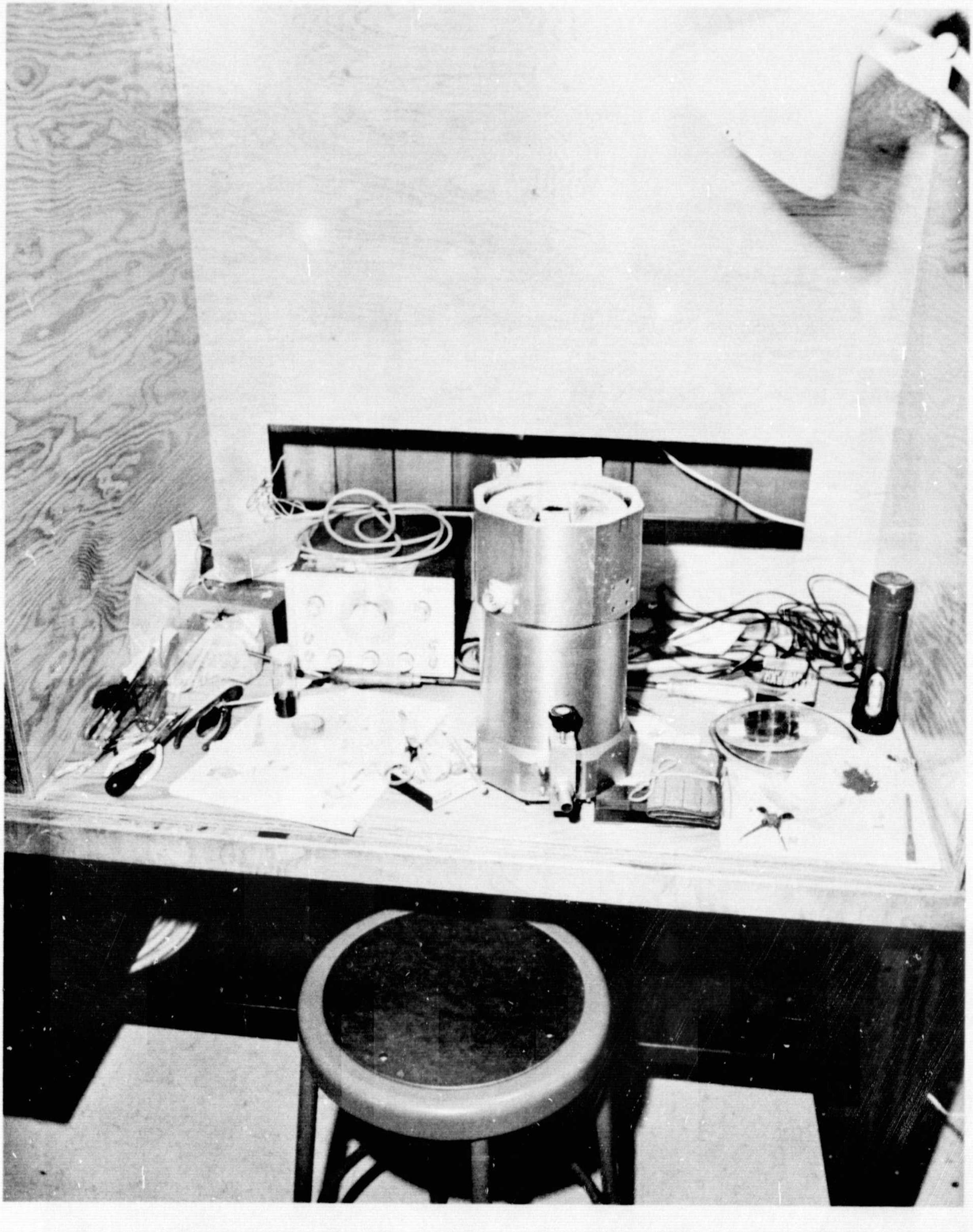


Figure 23.- Simulated workbench in use.

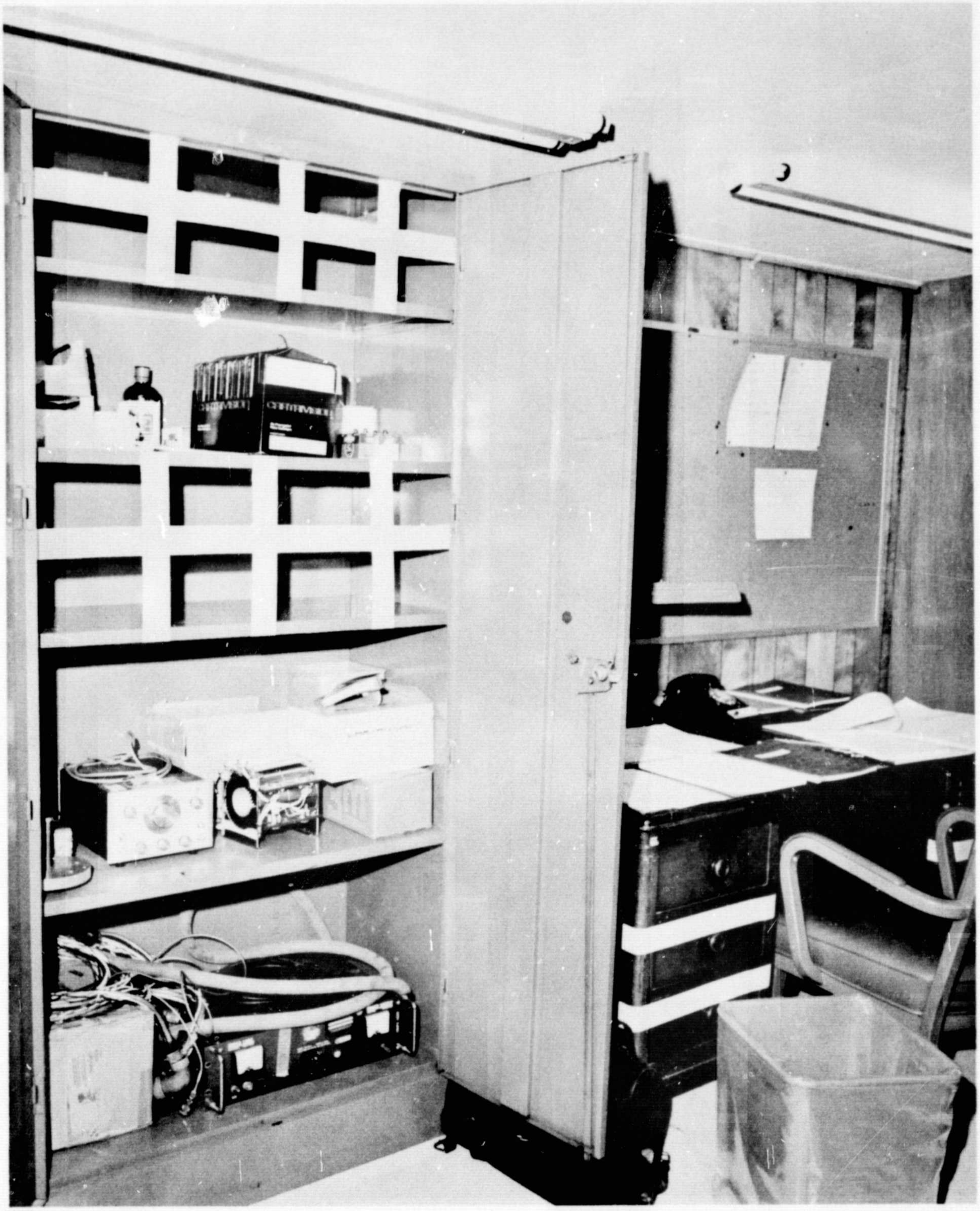


Figure 24.- Simulated storage area; shelf area = 1.2 m^2, volume = 0.48 m^3.

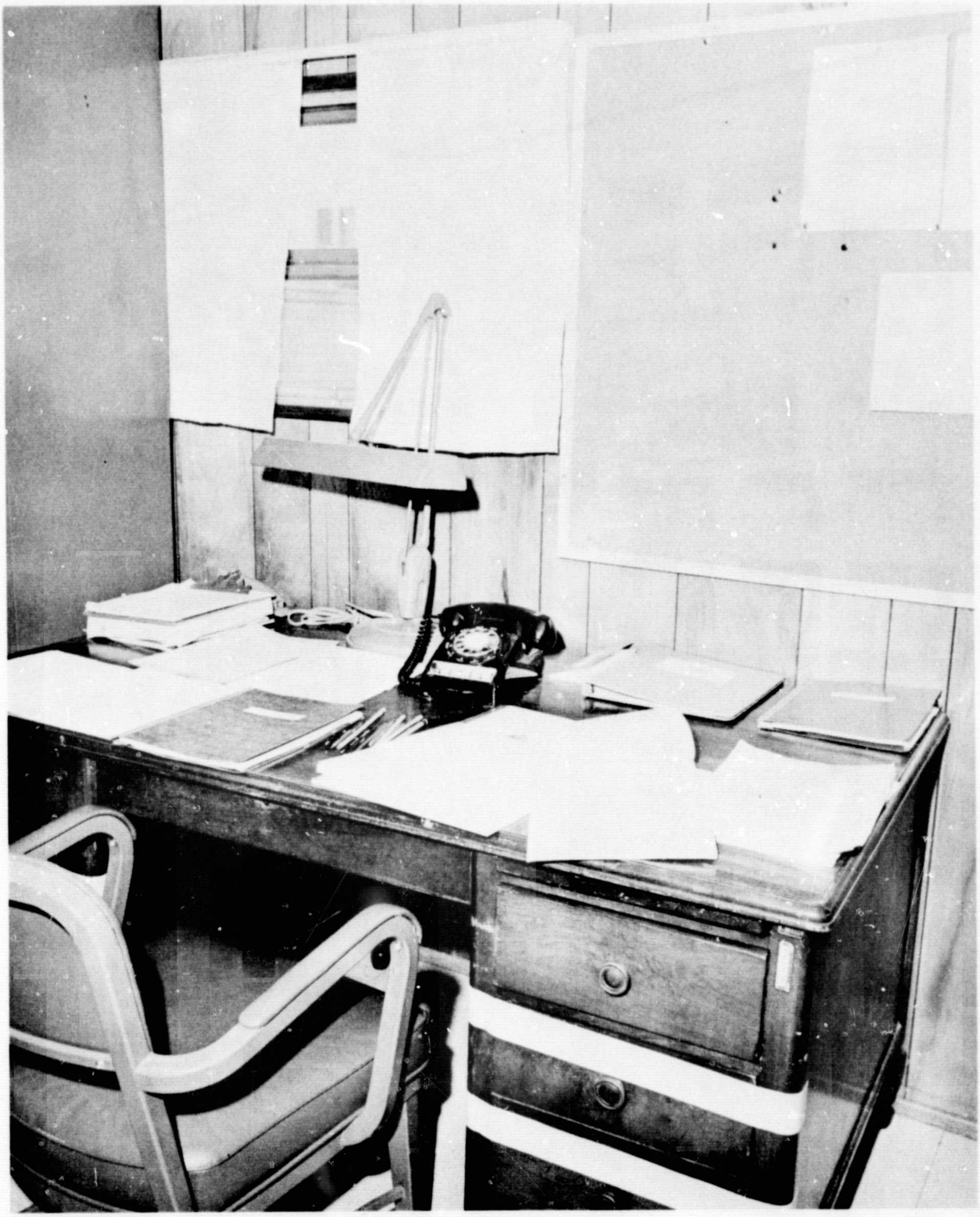


Figure 25.- Study and communications area; surface area = 1.26 m^2, file volume = 0.06 m^3.

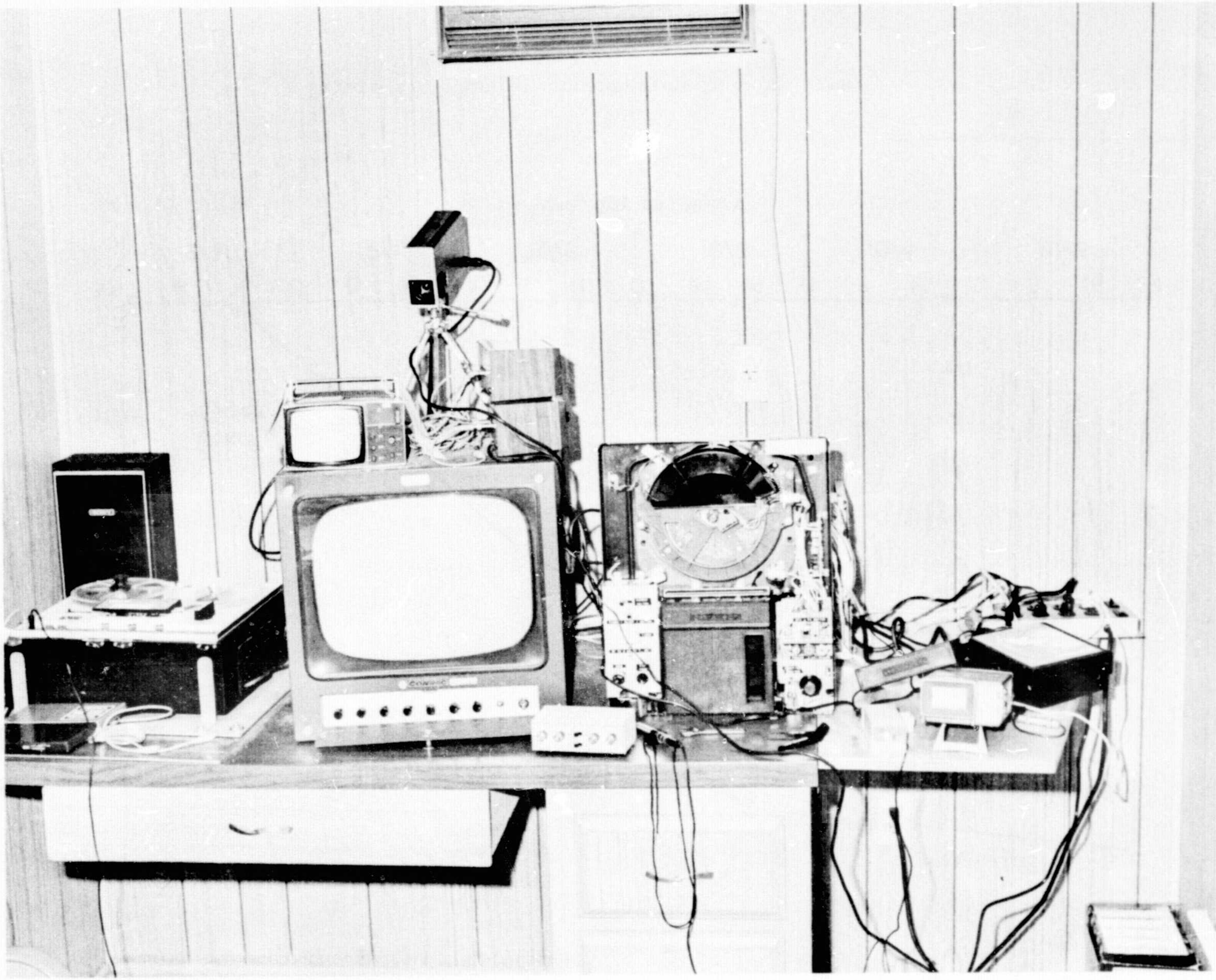


Figure 26.- TV equipment in Mission Center.

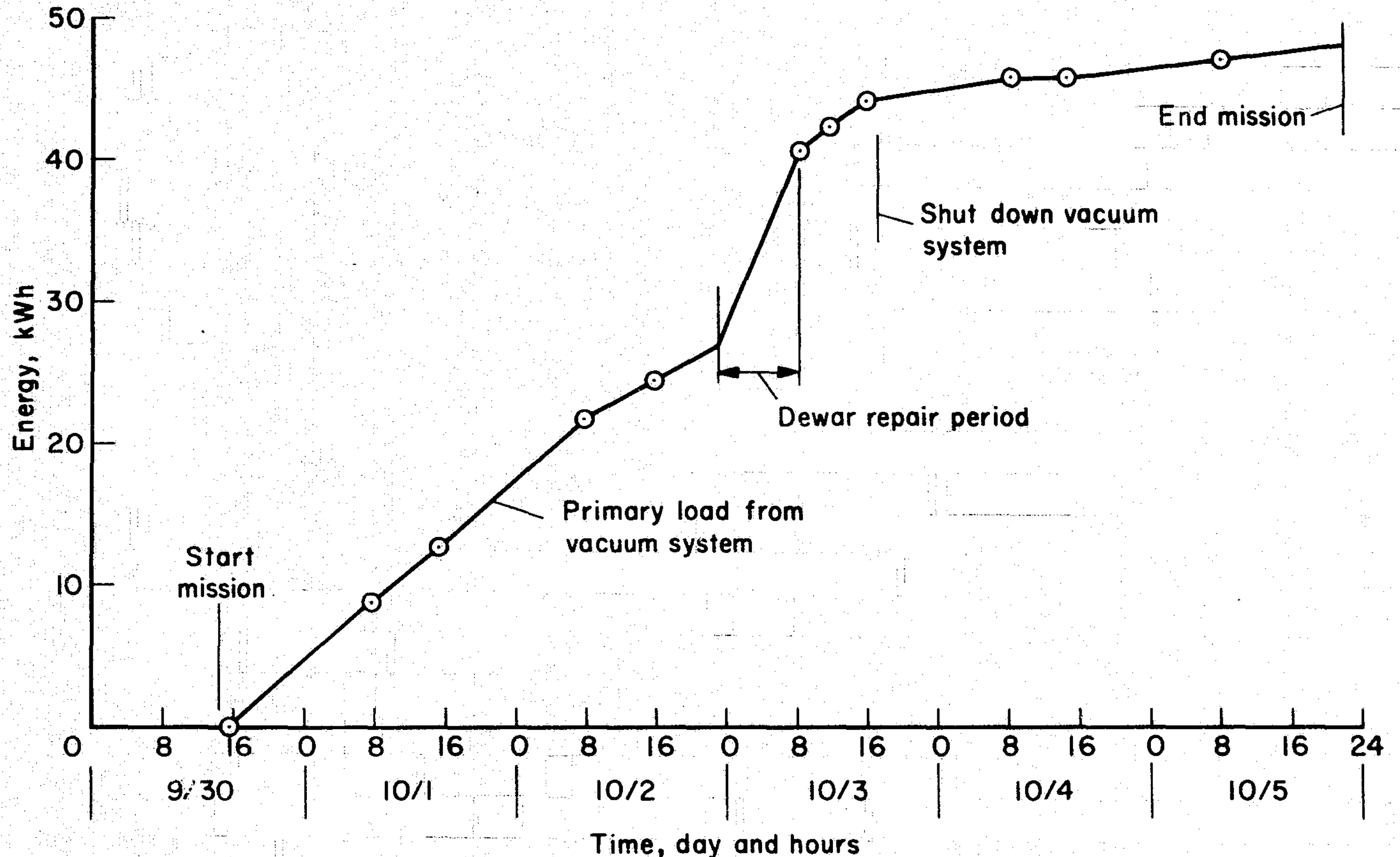


Figure 27.- Energy consumption in work area.

During the first 8 hr of October 3 while dewar repairs were underway, the energy use increased by a factor of three to about 1700 W. A good part of the load was a 750-W slide projector used to align photometer optics; the unit was larger than needed but the only one available. Later in the day the vacuum pumps were shut down and only a small load remained - an average of 75 W for the last two days. This represents normal servicing and minor repairs, including localized lighting for close work on small parts. General lighting for the work area was not connected to the metered circuit.

Use of electrical energy in the aircraft was not metered in the work area. Preflight checks using aircraft electrical systems were supplied by a standard 28 Vdc power cart. Conversion to 115 V, 60 Hz was by the onboard, solid-state inverters. The experiment itself required about 250 W; the telescope stabilization systems and chopper drive took about 330 W, and the vacuum pump about 340 W of 24 Vdc. Preflight checks in the aircraft required from 1 to 2 hr, indicating an energy consumption of 1 to 2 kWh for each preparation period.

Tools, test equipment, spares, and supplies- The PI prepared lists of the contents of the small repair kit carried on each flight, tools provided for general use, spare parts, test equipment, and consumables. Each EO reviewed the lists and noted which items were used; the details are in appendix E, table E-2.

ASO had available spare parts and test equipment for the telescope systems, as shown in appendix B, table B-3. These consisted of printed circuit boards (PCBs) with brief remarks on troubleshooting, a gyroscope, cables, and various individual components.

It should be noted that the EOs had only introductory training in the maintenance of telescope systems, and were not expected to accomplish any involved repairs. Rather, it was planned they would conduct minor troubleshooting of malfunctions to the extent of replacing a PCB or gyroscope should the occasion arise. The ASO telescope engineer would handle any more complicated tasks.

RESULTS

The ASSESS Lear 4 mission has been evaluated from the several points of view represented by ASO mission management; the ASSESS observer team; the senior PI, PI, and assistants; the EOs; and ASSESS program management. Valuable insight into the relevance of mission results to the Spacelab program has also been provided by the EO associated with Spacelab planning at MSFC.

Experiment Management

The ASO concept of minimum administrative staff and documentation, and experimenter-centered experiment planning and integration again proved a viable and effective approach to airborne scientific research, in spite of the shift of primary experiment responsibility from the senior PI to PI near the beginning of the mission. However, the fact that the senior PI was unable to participate as expected suggests that experiment selection should consider prior PI commitments that could interfere with his performance on any additional assignments. In addition, the expected role of the PI — for example, in the development and implementation of the EO training program — was not adequately defined in the mission guidelines. The subject of PI responsibility and performance is treated in considerable detail in connection with EO training and mission performance; experience on the Lear 4 mission showed a close and important interrelationship between the two.

Previous mission commitments made it impractical to return the electronics rack to the Observatory for checkout and a FRR. Again, prior mission commitments should be a factor in experiment selection and/or mission scheduling.

Scientific Achievements

The PI considered the ASSESS Lear 4 mission very successful scientifically. High-quality original scientific data were recorded on difficult astronomical targets, both during the integrated mission simulation period and the confined phase of the mission.* The principal ingredients of a successful mission from the scientific standpoint, as indicated by ASSESS Lear 4 experience, are (1) appropriate EO qualifications and training, covered in subsequent sections; (2) use of a well-proven experiment; and (3) the on-site availability of the PI for certain functions during flight operations.

While satisfactory science return does indicate validity of the proxy operator concept, the primary object of study during this mission, it is also a reflection of the smoothly functioning, flight-proven experiment used. The importance of experiment readiness to mission success should not be underestimated.

A particularly significant finding of this mission — one that first became apparent during the FRR devoted to EO preparation and readiness for data flights — is that a tradeoff exists between amount of EO training and depth of real-time support by the PI during the confined phase. It was clearly shown here that adequate scientific return required the on-site presence of the PI for two principal functions: (1) postflight data analysis as a basis for planning subsequent flights, and (2) assistance to the EOs in the area of troubleshooting, malfunction diagnosis, and repairs.

*Initial examination of the data from early flights suggested the possibility of a professional paper being published on the results from this mission. Low signal levels on the final flight unfortunately precluded gathering the remaining measurements required.

EO Qualifications and Training

This section presents general findings on the relationship of EO background to training effectiveness and mission performance, including the role of the PI in the training process, as well as a more detailed analysis of the maintenance and repair aspects of EO performance, which proved the least satisfactory of the performance measures studied.

EO qualifications- The scientific and technical backgrounds of the EOs for the Lear 4 mission were reasonably appropriate and for the most part served them and the PI well. The familiarity of both EOs with aircraft operations and with the Lear Jet in particular eliminated any requirement for training in high-altitude procedures, and minimized mistakes and inefficiencies due to unfamiliarity with communication systems, oxygen systems, etc., in comparison with investigators new to airborne research. In addition, the experience of the telescope operator with the operation of astronomical telescopes minimized training requirements and possible inefficiency in the identification of star fields and the tracking of targets. On the other hand, neither EO had extensive experience in laboratory electronics, and it was generally conceded that this was a major hindrance to their prompt diagnosis of equipment malfunctions. Mission crews should include at least one EO with experience in the troubleshooting and servicing of electronic equipment. It is essential for future missions that EO qualifications be carefully reviewed against experiment requirements to ensure the availability of all necessary skills. Further, the PI should be involved directly in this review.

Training parameters and the role of the PI- The development and content of the training program on this mission was left entirely to the senior PI for general outline and to the PI for most of the detailed training. The results were not entirely satisfactory. For example, the lecture on bolometer theory by the senior PI during the Observatory training period had little relevance to the physical operation of the experiment. Also, even though over 8 hr were spent at the Observatory in dewar testing, none of the tests for proper operating characteristics was made during the mission.

Training on a PI-to-EO basis without intermediate instructors can be both effective and efficient, but the ability of the PI to conceive and execute a viable training program is a primary prerequisite.

The 16-18 days of training were adequate to prepare the EOs to obtain good data under nominal operating conditions with a proven experiment. With a total of 225 manhours accumulated, half was "hands-on" experience devoted primarily (91 manhours) to normal experiment activities, and the remainder was "classroom" experience — instruction, observation, and study — which also concentrated (100 manhours) on normal activities. About 10 percent of the training (21 manhours) was specifically devoted to instruction in theory related to design of the experiment and interpretation of measurements.

The remaining time, some 45 manhours equally divided between "hands-on" and "classroom" training, was not sufficient to prepare EOs for troubleshooting and repair of the equipment without the detailed direction of the PI.

However, it was the opinion of the EOs that extensive training in equipment repair would not be sensible. The results of this mission indicate that reliance on replacement modules and on *detailed* help from the ground is a reasonably effective way to handle repairs in situations where the PI himself is not on board. In addition, the PI should provide equipment drawings to aid EO/PI communication on malfunctions and repairs.

Equipment maintenance training- EO training in the maintenance functions proved to be marginal to inadequate for this mission. Two factors that limited EO training in this area were: (1) the split in responsibility between PI and senior PI that was not anticipated at the start and remained ill-defined for most of the presimulation period, and (2) the delay in documentation and an organized framework for the training program until the very end of the allotted time. As a result of these factors, the brief session at the PIs facility and the subsequent installation period focused, of necessity, on normal operation and servicing activities, at the expense of problem definition and corrective actions.

The PIs' approach to maintenance training, however, appeared logical. Realizing that neither EO had an electronics background, they chose the route of electronic unit replacement in the event of failure, and spent most of the available time in the calibration and common malfunctions of cryogenic dewars and associated photometer systems. In addition, they prepared some written guides for checkout and adjustment of telescope mechanics and optics (appendix D). Implicit in this general approach was reliance on the PI for more than superficial troubleshooting and maintenance during the mission.

Midway in the experiment integration period at Ames it became obvious that additional training in the diagnosis and correction of malfunctions was imperative. In the short time available, this took the form of verbal exchange and some hands-on experience; however, no systematic written guides were developed. At the end of this period when training progress was surveyed (table 13), the EOs identified equipment maintenance as a general area of weakness, and the PI indicated the same concerns. The notable exception was the dewar/photometer system where both EOs rated the training as adequate, despite the switch of primary and backup units.

Although more emphasis was given to maintenance training on the ground during the integrated mission simulation period, both by instruction and hands-on experience, the deficiency could not be fully made up and EO confidence remained low. Little maintenance experience was gained during the seven training flight; no equipment malfunctions occurred, and primary emphasis was on experiment operation.

Training limitations and scientific return- Training limitations were perhaps most apparent in their impact on data acquisition. In two cases when the backup dewar might have been used it was not ready to go; in one instance, a malfunctioning photometer was not detected before takeoff due to inadequate procedures training; and three observation periods were shortened by the troubleshooting of relatively unfamiliar equipment in flight. Taken individually, none of these events was a serious fault; together, however, they had a substantial impact on scientific return from the mission - an impact that might have been notably lessened by a more systematic training approach spaced over the available time period.

EO Mission Performance

Data collection- Table 19 summarizes inflight performance of the EOs as data-gathering scientists during the confined phase, while figure 28 relates the difficulty of their assigned task as related to training experience during the integrated mission simulation. The figure shows that mission assignments were generally more difficult; nearly one-half of the observed map points yielded $S/N < 2$, whereas in training the median was above 4. On the whole, more integration steps and pointing accuracy were necessary to achieve results during the confined phase. The EOs' response to this assignment — a natural result of their training — was to conserve time on strong signals and use it to achieve better definition in weak signal areas. Thus, in general, fewer steps were used in measuring a given S/N, and what earlier had been a rather random pattern developed into an obvious trend of inverse S/N with number of integration steps during the mission.

Table 19 also provides a comparison of PI plans with EO results. System calibrations on Jupiter were scheduled on five flights and were obtained. Planned map points varied in number from 9 to 24 per flight, with a trend toward heavier schedules as the EOs became more proficient. When not distracted by experiment or telescope problems, the EOs completed or exceeded their flight assignment. The one exception was flight 3 where a difficult target in an unfamiliar star field could not be located. Inflight problems with equipment cut heavily into observation time on four or five flights where the data return dropped to one-half or less of the planned amount. Despite these limitations, the EOs made measurements during the mission on about two-thirds of the map points scheduled by the PI.

The PI's evaluation of data quality by flight (table 19) indicates six with good data, one with questionable results, and two with no useful data. On a point basis, 50 of the total 69, or almost three-fourths, were of good quality. In the PIs opinion, there was only one flight (no. 2) on which more experienced observers could have obtained significantly better data; on perhaps three others, a larger data return could have been realized.

The limited experience of the EOs was evident in the early mission flights when equipment and target location problems occurred; later on, when less familiar targets were observed; and again when various electronic devices failed to function properly. These new experiences did not stop observations, but rather slowed them down noticeably as the EOs made appropriate responses.

EO performance in the data-acquisition function nevertheless developed rapidly during the mission and approached the level of the PI on familiar targets. Thus, the premission training ultimately achieved its primary objective: competent operation of a functioning experiment. This continuing improvement also demonstrated, however, that a certain amount of inflight

TABLE 19.- EO PERFORMANCE EVALUATION

Flight no.	Calibration on Jupiter	Map points PI plan	Map points EOs obtain	Percent data return	PI evaluation of data
1	Aircraft problem — flight aborted				
2	Yes	12	9	75	Large offset in data probably can be corrected, EO error
3	No	14 (est)	6	43	1st target — good data, time lost on telescope problem 2nd target — no data, EO not familiar with star field
4	Yes	9	2	22	No good data on target, equipment problems
5	Yes	9	9	100	Good data
6	No	14	7	50	Good data, limited by telescope problem
7	Yes	13	15	115	Good data
8	No	24	13	54	Good data, time lost on recorder problem
9	Yes	14 8*	8	57	No useful data, equipment problems

*For contingency only, none measured.

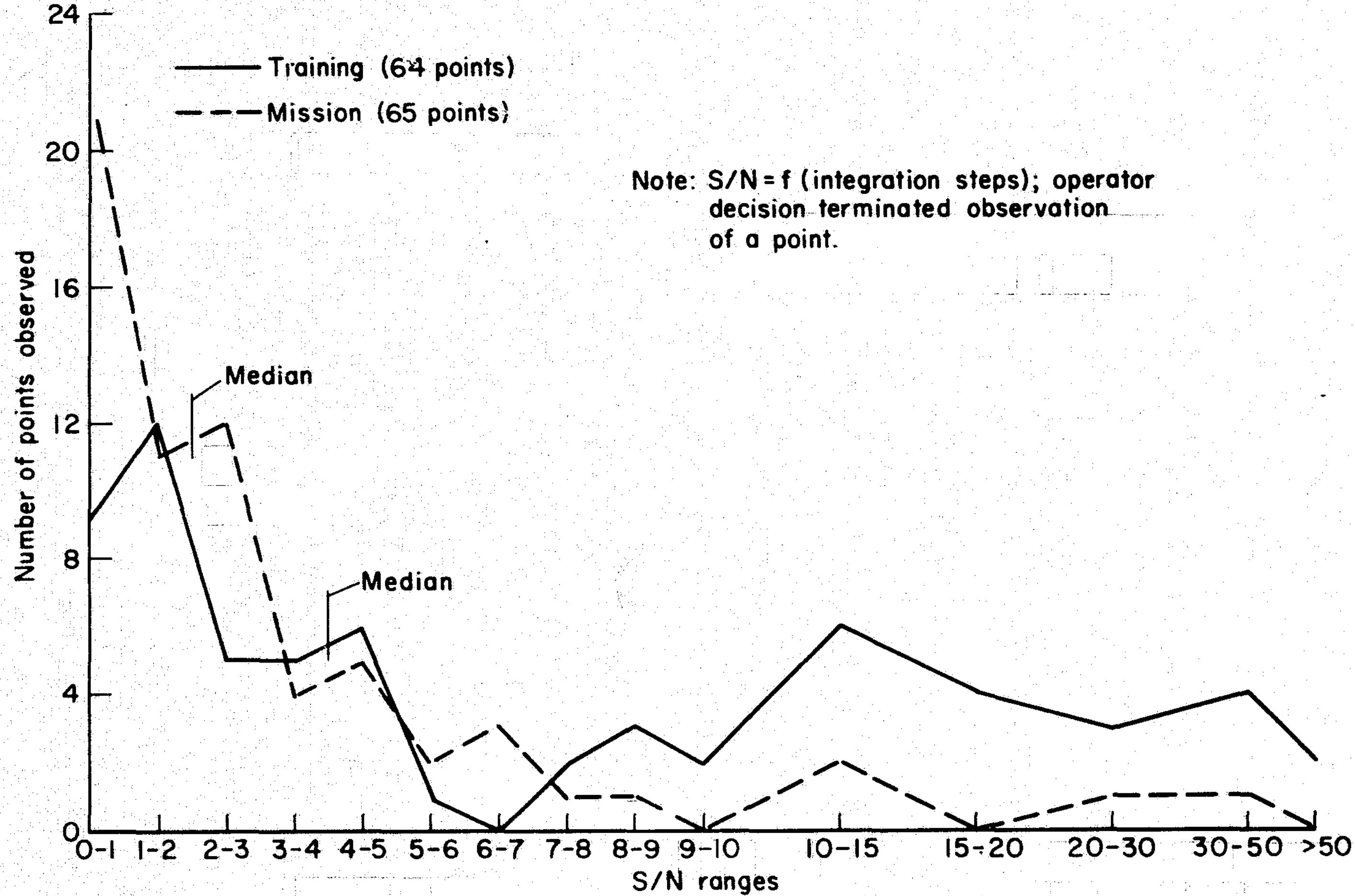


Figure 28.- Relative difficulty of mission observations.

adaptation time is required, particularly after the isolation factor has been introduced, for the EOs to attain maximum effectiveness. Depending on the experience of the EOs, and assuming normal equipment functioning, up to three or four inflight data-gathering periods appear sufficient. The requirement for Spacelab remains the same, and whether training is implemented through integrated mission simulation using an aircraft as a high-fidelity simulator, as in the ASSESS Lear 4 mission, or through high-fidelity ground-based simulation, there should be allowance for an acclimatization period at the beginning of a mission in space.

Experiment problems and solutions- Problems and responses observed during the Lear 4 mission are summarized in table 20. Some were the result of faulty operational procedures by the EOs and others were equipment malfunctions or failures. The former, with two exceptions, were easily corrected although their occurrence caused a degradation or loss of science data in six out of ten cases. Outside advice was sought for six of the problems and the PI provided answers to five.

Equipment problems were six in number, of which three resulted in data loss. Two were critical to experiment performance and without extensive PI support could have aborted the mission. Both were similar problems, a loss of signal strength from the experiment, and both times the indicated fix was to switch to the backup dewar. This action could not be taken either time; in the first instance the backup dewar was not ready for flight, and in the second the problem was not realized soon enough to make the switch. The PI attributed both situations to lapses in routine operational procedures that were part of the EO assignment.

In 12 of the 16 items in table 20, the EOs were able to identify the problem, and in 8 they took effective corrective action on their own. In the remainder they were adept at implementing repairs with PI support. When complicated equipment malfunctions occurred, the presence of the PI on-site was essential for detailed instruction and guidance.

Data handling and flight planning- A second area in which the PI proved indispensable was the analysis of data obtained by the EOs and guidance in planning the next flight. The PI's participation in this aspect of the mission was prompted, in part, by daily scheduling requirements: the EOs sleep period occurred at the only interval in the schedule when data analysis could be completed in time for the flight planners to define the next two flights. It is clear, however, that data analysis and flight planning were vital support functions of the PI, without which the scientific return from the mission would have been in jeopardy. Even with this support, the EOs were not sufficiently familiar with data patterns to communicate easily; they suggested that more attention to premission, in-depth study of similar measurements would have benefited both inflight data acquisition and postflight evaluation.

Workload

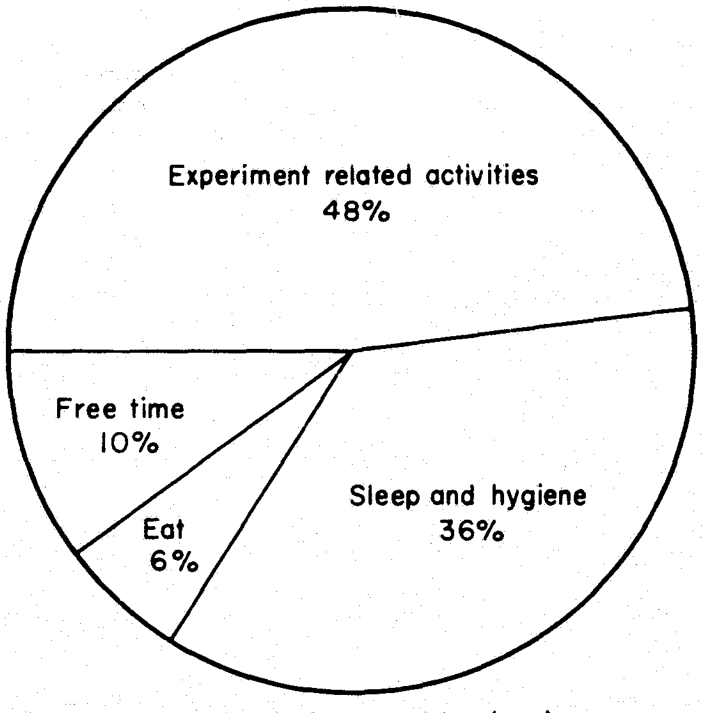
The timelines of table 15 are summarized in figure 29 as values averaged for both operators, since their schedules were nearly identical. The average

TABLE 20.- PROCEDURAL AND EQUIPMENT PROBLEMS AND THEIR DISPOSITION

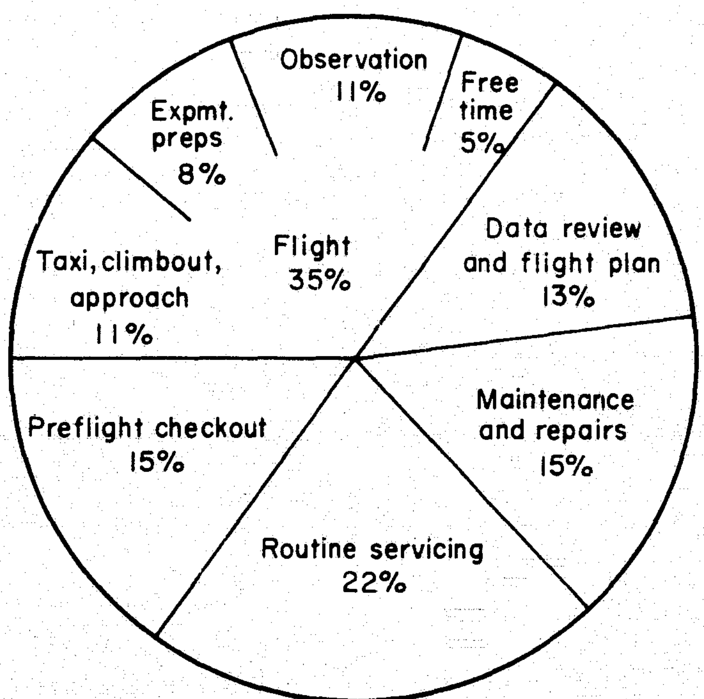
Class of problem	Where noted	Description	EO response	Science impact	PI support
Operational procedure	In flight	Limited telescope elevation	Ask pilots to fly aircraft at roll angle	None	None; instruction from Ames support personnel
	In flight	Same	Work around	Time lost caused some data loss	None
	In flight	Tape recorder stopped	Replace tape	None, redundant records	None
	In flight	PLA out of phase	Adjust	Data quality degraded	Advise correct procedure
	In flight	Target not located	Terminate observations	Data loss	None
	In flight	Unfamiliar print-out format	None	None	Review instructions
	On ground	Vacuum system performance limited	Work around	Data loss one flight, backup dewar not ready	Suggest corrective measures
	On ground	Diffusion pump damage	Switch to backup vacuum system	None	None
	In flight	Air turbulence hampers data acquisition	None	Data quality degraded	Advise correct response
	On ground	Preflight checkout delayed	Troubleshoot for low signal levels, too late to fix	No useful data on one flight	Advise compromise actions

TABLE 20.- CONCLUDED

Class of problem	Where noted	Description	EO response	Science impact	PI support
Equipment malfunction	In flight	Low signal levels from photometer	Troubleshoot in flight, repair on ground	Poor data quality on flight; next flight cancelled	Extensive and vital to success of repair
	On ground	Onboard vacuum pump failure (GFE)	Request ground crew support	None	None
	In flight	"Open" in intercom to recorder cable	Repair cable on ground	Some data loss on one flight	None
	In flight	Fuse out in telescope system	Troubleshoot and replace in flight	None	None
	On ground	Low signal levels from photometer	Troubleshoot in flight, no fix	No useful data on one flight	Advise inflight corrective measures
	In flight	Tape recorder failure	Replace after flight	None, redundant records	Consult and advise



Overall mission activities (avg)
total = 127.5 hours



Experiment related activities (avg)
total = 61 hours

Figure 29.- Experiment operators activity charts.

day consisted of 12 hr of work, 8 to 9 hr of sleep, and 3 to 4 hr of free time, meals, hygiene, and so forth. The work period was divided roughly into 4 hr of flight, 4 to 5 hr of routine servicing and preflight checkout, 1 to 2 hr for equipment maintenance, and the remainder for data review and flight planning.

As in the three previous Lear Jet simulation missions, daily activities were not timelined in advance, but were left to the discretion of the EOs. The resultant distribution of time was closely similar to the earlier missions in which PIs were directly involved, as shown in the following data summary:

	Percent of total time	
Activity	Lear Jet 1, 2, 3*	Lear Jet 4
Planning, acquisition & evaluation of data	11	12
Equipment upkeep	28	29
Life support functions	40	42
Free time	15	10
Flight time not utilized	6	7

*The figures given are the averages over the three missions.

Compared to the previous Lear missions, less flight time was realized per day because of aircraft problems early in the mission. Much of this available time was absorbed in experiment servicing activities as the EOs developed proficiency in handling the equipment. Even so, they had less than the average amount of free time, and little opportunity for in-depth data evaluation and observation planning. Figure 30 shows the division of effort in this latter area by EOs and the PI. Note that the PI, with his much higher level of experience, in frequent consultation with the senior PI by telephone, spent over 3 times as many hours with the data as the EOs spent in actually making the measurements (almost 7 hours, fig. 29). About one-third of this time (8 hr) was spent in conference with the EOs, reviewing data, and planning observations. (For the more closely spaced acquisition periods available in Spacelab, a more effective plan for data evaluation and planning is obviously required.)

Experiment Design

No modifications of the experiment, either in equipment or operating procedures, were made specifically to facilitate operation by the EOs. They were expected to operate the equipment in the same way as the PI and his assistant. Neither were there any apparent concessions made to the EOs concerning target selection or viewing difficulty; targets were assigned on the basis of scientific merit, as a continuation of the senior PI's normal research program.

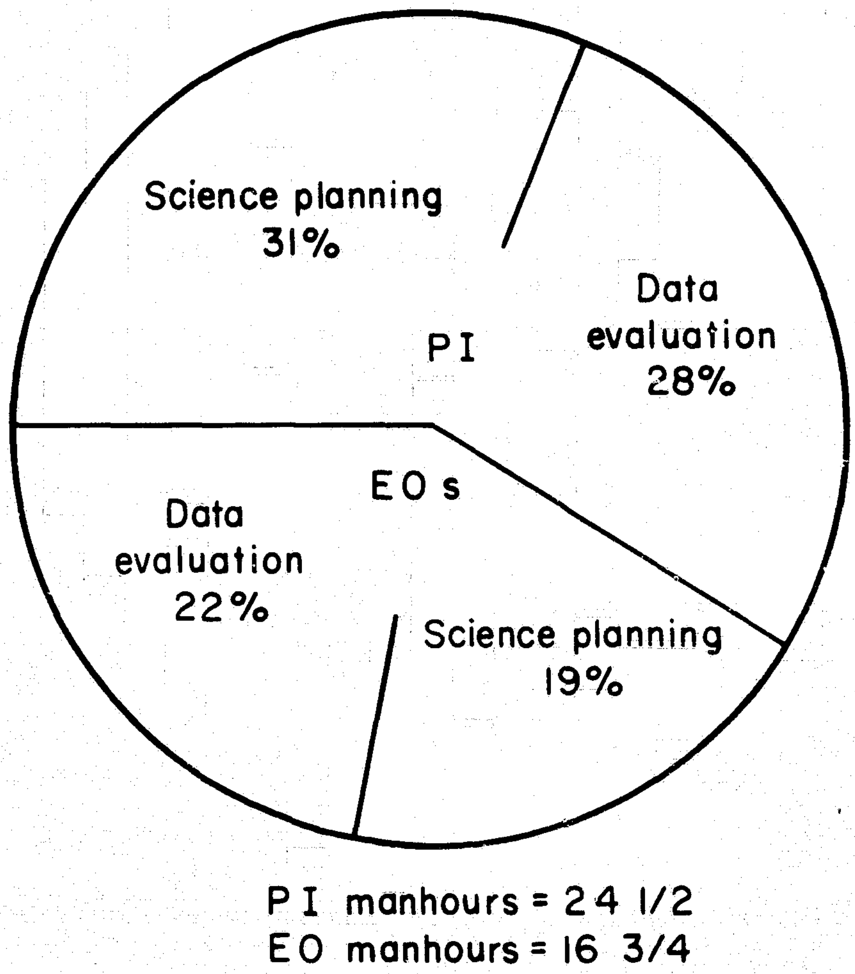


Figure 30.- Science planning and evaluation of results.

Except for the choice of primary photometer, the research equipment was the same as that flown on the C-141 airborne observatory in July and on the Lear Jet in August. A single-filter photometer was used for this mission, with the filter-wheel photometer of the August flight series retained as a backup unit.

Facilities

The EOs found the simulated workbench area generally satisfactory for both one and two-man equipment repair jobs. The space was not sufficient for optical realignment of the photometer because the available light source was physically too large.

The larger desk surface was used extensively for working with written materials. Lengthy strip charts and computer printouts were frequently spread on the floor for overall viewing. A smaller desk surface built to represent Spacelab restraints was not utilized as planned but would have been marginally adequate.

Work surfaces and equipment storage areas for EO use (figs. 22-25) were overly generous, judging from their utilization during the mission. Observations are summarized below.

Item	Quantity	Percent utilized
Workbench surface	0.6 m^2	30 100 for dewar repair (fig. 23)
Desk surfaces	1.8 m^2	50 (fig. 25)
File volume	0.2 m^3	10
Equipment storage volume	0.6 m^3	25 (figs. 22, 24)

For the one major repair of the mission, full use was made of the workbench area. Otherwise, the available space was at least twice that needed.

Communications

Three two-way communication links — voice, video and hard-copy — were available between the ground site and the outside world; none was available for EO use in flight. Use was unrestricted, with TV and hard-copy transmission between the EO work area and Mission Center, and with extended telephone service at both locations.

C-2

The TV link with its real-time visual impact was the preferred channel for communication between the EOs and the PI at Mission Center (28 uses compared to 6 for the telephone). It was particularly useful to the PI in appraising the EOs' equipment problems and assisting in repairs during the mission. However, the resolution was inadequate for identification of small parts, easy reading of equipment diagrams, or transmittal of written material. (This deficiency could be overcome through the use of supplemental lenses.) The largest use of TV was for preflight discussion of the observation plan and for postflight debriefing; nearly 3/4 of the total time of 8 hr was for these purposes (see appendix F). TV coverage in and around the aircraft would have helped in the diagnosis of signal level problems by bringing the PI directly into the activity.

The PI and EOs agreed the TV downlink capability was more important to mission operations than the TV uplink capability. Both were strongly augmented by the hard-copy link, which was used extensively to transmit observation plans, printouts, magnetic tapes, and the like; in part this use was forced by the limited resolution of the TV system.

A significant finding was that real-time communication with the PI during observations in flight was neither necessary nor desirable when the equipment was operating normally. The PI and EOs agreed that any interruptions of observations would have strongly degraded the rate of data acquisition. It was also clear, however, that a real-time PI/EO communications capability should be available for use in solving equipment problems.

Support Equipment Usage

Equipment and supplies to operate and maintain the experiment were selected by the PI, based on his experience in several flight series in the Lear Jet. His flight repair kit consisted of 31 items (table E-1) in a small canvas bag — tools, a soldering iron, cables and connectors, a digital voltmeter, fuses, etc., that would enable troubleshooting and minor repairs to electronic components. The EOs used about one-third of the items in flight, and about two-thirds for routine servicing and repairs on the ground. In general, the tools, test equipment, and supplies furnished by the PI were adequate for normal operations and servicing of the equipment. The only missing consumable was aluminum foil, needed for dewar repair. However, for the optical realignment of the photometer, it was necessary to obtain a light source from outside of the normal mission supplies. Likewise, a backup vacuum pumping system was brought in since none had been provided.

Table 21 compares utilization of support equipment for ASSESS Lear 4 with previous Lear missions. The PI was somewhat more selective of tools, test equipment, and consumable supplies, but more generous with spare parts. Percent utilization increased in three out of four categories from roughly 50 to 65 percent, and dropped by half where test equipment was concerned from 68 to 36 percent. These changes for the present mission reflect the EOs active concern with this aspect of the Spacelab simulation, and they worked to reduce

TABLE 21.- SUMMARY OF SUPPORT EQUIPMENT UTILIZATION

Category	Average Lear 2 & 3*		Lear 4	
	No. items supplied	Percent used	No. items supplied	Percent used
Tools	46	50	40	60
Test equipment	25	68	14	36
Spare parts	10	40	20	65
Consumables	57	58	28	79

*Table entries from references 5 and 6 recast into present format for comparison.

the equipment inventory to a realistic minimum. Except for test equipment, in which EO training was inadequate, the two-thirds use factor was a positive result.

Some 13 spare or backup components are listed in the table C-1; only three of these were used during the mission. A PLA, a chart recorder, and a preamplifier were used for troubleshooting during the last flight; only the preamplifier was used for signal measurements.

Only one experiment-specific tool was provided to service the PIs equipment, and only three items of special test equipment were on hand — a dummy source used to check out preamplifiers, a dewar pumping fixture, and a zoom-converter for the finderscope.

RECOMMENDATIONS FOR SPACELAB

The ASSESS Lear 4 mission afforded the first opportunity to observe and document an application of the proxy operator concept contemplated for Spacelab. Following are brief comments on the major areas in which Lear 4 experience appears particularly relevant to Spacelab planning. These should be considered in the context of the preceding discussion of mission results.

Mission Management

1. Experimenter-centered responsibility for science planning, experiment development, and equipment integration is a viable and effective approach to scientific research in sponsored, multi-use facilities.

2. Selection of experiments is not a direct function of mission management; their role is to coordinate, consult, and advise in the selection

process to assure a feasible payload. Selection of experiment operators is a function of mission management, subject to policy guidelines that encourage participation of the general scientific community.

3. Experimenter responsibility must be balanced by effective monitoring of progress on the part of mission management, through the use of milestone schedules and with the authority to defer participation to a later mission.

4. Adherence to the FRR concept, including its timing, should be encouraged to avoid last-minute equipment changes and subsequent delays.

Principal Investigator Selection

1. The PI and his team should be selected not only for their scientific qualifications and objectives, but also for their ability to develop and implement an effective EO training program, and to effectively manage available resources during all mission phases.

2. The PI should have a well-proven base experiment and a clearly defined procedure for developing it into a flight-ready experiment.

3. The nature and extent of his commitment to the mission should be clearly defined and understood at the outset.

4. The PI should provide broad definitions of the EO qualifications required for operation of his experiment, and develop guidelines for an effective EO training program, including its scope, content, depth, and implementation.

5. Research experience at a location remote from his home laboratory, preferably with the same or a prototype experiment, constrains the PI to develop time-effective, reliable methods of operation and maintenance that will benefit his planning for Spacelab.

6. The PI should be expected to work closely with the EO from the inception of the program, both in the human engineering aspects of experiment design and in adapting the training program for maximum effectiveness.

Experiment Operator Selection

1. EO qualifications should be evaluated in terms of the specific experiment involved; PI recommendations should be a factor in selection.

2. An important objective should be the development of a crew possessing collectively the skills required for experiment operation and equipment maintenance.

3. The nature and extent of basic EO obligation to the mission should be clearly defined at the outset. Beyond this, there should be latitude for

deeper involvement in an experiment where his scientific expertise would be of significant mutual benefit.

Training Program

1. The PI's training program should be based on the scientific requirements of his experiment, the nature of the experimental equipment, and a careful inventory of available EO skills.

2. Areas requiring special attention — for example, particularly complex steps in experiment operation or deficiencies in EO skills — should be identified and provision made to accommodate them accordingly in the training program.

3. The program should be well structured and designed to proceed in an orderly manner and in concert with other mission elements such as schedule, equipment availability, and staffing.

4. Management should monitor training program development, implementation, and progress at specified checkpoints during the preparation phase of the mission.

5. Malfunction training should proceed in steps from individual components to the full experiment, in relation to the EOs grasp of normal functions and operations. Until he has experienced normal operation of the entire experiment he is not fully prepared for training to respond to abnormal behavior of interrelated experiment systems.

6. Malfunction training should be emphasized to the point of having the PI create "dummy" problems in the laboratory for the trainees to solve.

7. Questionnaires should be used throughout the training period to monitor whether the PIs and EOs estimates of performance coincide. The results should be used by those responsible for training to guide the remainder of the program.

8. In the interest of developing greatest efficiency in the training activity, many crew duties can be divided into prime responsibilities of one operator and secondary responsibilities of the other(s). However, it is important that all science crew members attain a basic operational proficiency in all tasks they may be required to perform without assistance.

9. Every effort should be made to make sure the operators understand how the physical operation of the sensors and signal processors relates to the objective of the experiment. This will help the operators compensate for inflight anomalies that could otherwise result in degradation or loss of data.

10. Integrated mission simulation — to the level that allows each operator to practice all aspects of his in-flight duties under realistic operating conditions and pressures — appears to be a highly necessary part of the overall training process.

Inflight Performance and Science Return

1. Proxy operators can be trained in a few weeks for difficult research assignments using complex equipment, if preparation for normal experimental activities is the primary objective.

2. Selectively trained proxy operators can obtain good quality scientific data under the following conditions:

   a. The experiment must be thoroughly flight proven, although no concessions in design or objectives appear necessary to facilitate EO operations.

   b. A cutoff date for equipment and procedural modifications by the PI must be established and adhered to (the FRR can serve this purpose well).

   c. The PI must be available to provide support in the areas of data analysis, observation planning, and real-time guidance in equipment anomalies and repair. He should also provide the EOs with equipment drawings in support of the latter function.

3. Competent operators, relying on detailed guidance from the PI and on replacement modules, can isolate and resolve equipment malfunctions to keep an experiment operating for the duration of a mission.

4. Prompt identification and response to experiment problems during preflight and inflight periods depends on adequate training. In an operation with fixed and limited observing periods, failure to respond quickly can notably impact the acquisition of scientific data.

5. EO inflight performance improves markedly with hands-on experience, demonstrating that some sort of acclimatization period should be provided through actual experiment operation in a high-fidelity ground-based simulator or during a specified period at the beginning of the mission itself. The extent of the adaptation period will depend on operator skills and experience, as well as the degree of operator interaction required by the experimental objectives and procedures.

6. Allowance should be made for the various pressures and constraints of the actual operating environment, including the isolation factor, which will inevitably limit operator performance at the beginning of the mission, regardless of the nature of premission preparation.

Communications

1. TV communications (downlink especially) are of particular value for EO/PI consultation on equipment maintenance and repair.

2. An uplink facsimile facility was used extensively on Lear 4 and appears highly useful for Spacelab.

Facilities

The EOs' work area, which simulated Spacelab constraints, was more than adequate except for desk-top space, which must accommodate strip chart recordings and other large-size papers. Either more surface area should be provided or some other means provided for handling and storing recorded data.

Workload

Normal activities associated with two observing periods per day occupied about 12 hr, leaving insufficient time for postflight data reduction and detailed planning for successive flights. The performance of these functions by the PI was a workable compromise. It was evident that crew time can be a very limiting resource, and that mission productivity can be maximized by providing ground based support for functions which need not be accomplished onboard.

APPENDIX A

LEAR 4 MISSION OPERATIONS PLAN
September 1974

Introduction

The purpose of Lear ASSESS Mission #4 is to obtain data on the effectiveness with which two scientists can be trained to operate a flight experiment in place of the Principal Investigator (PI) and his assistant. These data will provide preliminary information on the requirements for experiment design and experiment operator training for Spacelab payload management.

The Lear ASSESS Mission #4 will be divided into the Mission Preparation Phase and the Confined Mission Phase. In the Mission Preparation Phase, the PI will establish a training program which he believes will provide the two scientists, who will serve as Experiment Operators (EO) with sufficient knowledge, documentation, and hands-on operation capability to perform the Confined Mission Phase. In the Confined Mission Phase, the EOs will operate an IR astronomical experiment in the Lear Jet to obtain meaningful scientific data. The EOs will perform, to the best of their abilities, all of the tasks such as might be performed in Spacelab and will receive only such assistance from the PI as would be available in Spacelab. Their ability to perform these tasks will be evaluated to provide data on the feasibility of the concept of one scientist operating another's experiment and to quantify the amount of training that may be necessary to establish proficiency in performing the required tasks. Prior to start of the Confined Phase, a Flight Readiness Review will be held to verify the proficiency of the EOs.

The simulation will be performed with a Lear Jet to be used as the flying laboratory and a working/living trailer combination to simulate the constrained environment. Two experiment operators will be restricted from direct contact with other personnel for a five-day period. During the flights, authentic scientific data will be taken. During periods on the ground, the experiment operators will be confined to a contiguous complex at a relatively remote location. The experiment-operator activities and accomplishments, along with the hardware, management, and operational interface aspects of the scientific effort will be studied.

Study Parameters

To meet the objectives of the ASSESS program, the following parameters will be studied.

- Background of the EO Trainees
- Subject Material to be Covered in Training

- Amount of Theory Needed for Operation
- Amount of Theory Needed for Repairs
- Amount of Hands-on Training Needed for Experiment Operation
- Ability of EO to Track Bright and Dim Targets
- Ability of EO to Process and Evaluate Data during the Confined Phase
- Ability of EO to Maintain Experiment
- Need for Support by the PI
- Usefulness of Data Obtained by the EOs

Guidelines

The Airborne Science Office has established guidelines for the mission that will both satisfy the requirements of existing programs and comply with the conditions of the Shuttle constraints. The guidelines for the Lear Mission #4 are as follows:

1. The experiment preparation, aircraft installation and flight program will be conducted in accordance with standard ASO operation, that is, the PI will have prime responsibility for most aspects of the experiment preparation and integration.

2. The EOs will make authentic scientific measurements.

3. A goal of two flights per night will be established with the purpose of concentrating as much experiment-operation time as possible during the mission.

4. The EOs will be confined to the airplane/trailer complex for the duration of the mission.

5. The PI can modify his existing experiment to operate more effectively and more reliably for the five-day mission.

6. The PI can place "on-board" any type of spare subassemblies or components considered necessary to ensure the success of the mission. Test equipment and tools will be limited to those that can be justified. Once the mission is started, Ames will supply and document any additional test equipment, tools, or parts that are required.

7. During the mission, no direct personal contact with the EOs from people outside the ASSESS management and observation groups will be permitted. All outside communications will be by telephone.

8. The mission manager, PI and observer will be housed in the Airborne Science Office. The mission manager will serve as mission coordinator between the "Shuttle crew," the PI, and Ames support personnel.

Organization

Management- The scientific research for this simulation mission will be managed, for the most part, in the manner normally followed in the Airborne Science Office (ASO) for the ongoing Lear astronomy program. The regular mission manager will act as coordinator the the PI and EOs in installation and check-out of the experimental apparatus. For the simulation period, a mission-control center will be set up in the Airborne Science Office. All contacts with the "Shuttle" crew will be handled by telephone through the ASO Mission Manager. The mission-control center will be manned 24 hr per day throughout the mission. With the exception of aircraft-maintenance personnel and food-service personnel, direct personal contact between the "Shuttle" crew and others will not be permitted.

Principal investigator and experiment operators- The PI was chosen from the ongoing infrared astronomy program on the Lear Jet airplane. The fourth mission will be flown with the same PI as participated in the first mission. The principal experiment operator will be a scientist/astronaut who has flown as co-pilot on previous Lear ASSESS missions, and thus is familiar with the Lear Jet aircraft and the ASSESS program. The assistant experiment operator will be from the Spacelab Office of Marshall Space Flight Center. He has had previous experience in aiding experiment operation on the Lear Jet.

Observers- During the Mission Preparation Phase, observations will be made of experiment preparation and all aspects of EO training. During the Confined Mission Phase, observations will be made at two locations. An observer will be stationed in the work trailer of the simulation complex 24 hr a day throughout the mission. His function will be to make direct observations of all experiment-operator work activities in the complex, and to record work/sleep timelines. An observer will also be stationed in the mission control center during daily debriefing periods.

Support personnel- Support for the mission will be provided by a number of groups at Ames Research Center. Installation of the GFE in the airplane will be done by aircraft support personnel. The work will be monitored by the Aircraft Inspection Branch and the Airworthiness Assurance Office. Supplies and equipment will be provided by ASO laboratory personnel. During the simulation flights, the ASO flight planners, the Flight Operations Branch, the aircraft maintenance contractor, and the Aircraft Inspection Branch will all provide support for the mission.

Schedule

The schedule for the mission beginning with training of the EOs at the laboratory of the PI and extending through the remainder of the mission is given in table A-1.

TABLE A-1.- SCHEDULE FOR LEAR ASSESS MISSION #4

Date, 1974		Schedule	Principal Invest. (PI)	Principal EO	Assistant EO
Aug.	28	EO training in theory and construction of experiment at PI laboratory	X	X	X
	30	EO training and ship experiment to Ames	X	X	X
	31	Experiment in transit to Ames			
Sept.	1				
	2				
	3				
	4				
	5	Installation and check-out of experiment. Ground training of EOs	X	X	X
	6	Ground training of EOs	X	X	X
	7	Saturday			
	8	Sunday			
	9	Ground training of EOs, night flight for PI	X	X	
	10	Ground training of EOs	X		X
	11	Daytime flight for EO Night flight for EO training FRR telescope and experiment	X	X	
	12	Ground training of EO Night flight for EO training	X	X	
	13	Contingency			
	14	Saturday			
	15	Sunday			
	16	Night flight for EO training	X		X
	17	Night flight for EO training	X		X
	18	Night flight for EO training		X	X
	19	Night flight for EO training		X	X
	20	FRR for EOs	X	X	X
	21	Saturday			

TABLE A-1.- CONCLUDED

Date, 1974		Schedule	Principal Invest. (PI)	Principal EO	Assistant EO
Sept.	22	Sunday			
	23				
	24				
	25	Open			
	26				
	27				
	28	Saturday			
	29	Sunday			
	30		X	X	X
Oct.	1		X	X	X
	2	Simulation mission (2 flights per night)	X	X	X
	3		X	X	X
	4		X	X	X
	5	Mission debriefing	X	X	X
	6	Sunday			
	7				
	8				
	9	Contingency week			
	10				
	11				

Operations Plan

Facilities- The simulation complex will consist of the Lear Jet aircraft and two trailers. The complex is located in a relatively isolated parking lot well removed from other flight operations activities. The site and adjacent roadways will be blocked off from casual traffic. From the site, the aircraft can either be towed to the hangar area for maintenance or taxied to the runway for flight. Refueling, preflight checks, and minor maintenance will be performed at this location, except when rain forces these operations to be done in the hangar area. Figure A-1 shows the arrangement of the complex. For experiment upkeep the aircraft can be parked alongside the trailers, indicated in the figure. The area will be illuminated with flood lights to permit aircraft servicing at night.

The aircraft intercom system will be modified to give the co-pilot a "hot-mike" loop with the experiment operators and to allow recording of all communication within and from outside the aircraft.

Accommodations for the experiment operators will consist of two separate units, the living quarters and the work area. The former is a standard 2.5 by 8 m air-conditioned vacation trailer with four separate beds and the usual facilities. Windows will be covered for daytime sleeping. The work area used by the operators is a 3 by 7 m space in a standard office trailer. A partition separates the work area from a separate room which will be used as a service area and for the ASSESS observer.

Logistics- The logistics plan for the mission deals primarily with "Shuttle" utilities, life-support systems, and aircraft operations. All supplies for maintenance of the experiment will be onboard at the start, as specified in the mission guidelines. "Shuttle" utilities are electrical power and cryogenics. Electrical power enters the simulation complex at the main distribution panel in the service area at 60 Hz and 220V. A portable power cart will be used to convert line power to 28 Vdc for input to the aircraft systems, or to the work area. Aircraft inverters will provide the AC power for the experiment in the aircraft. AC power will be provided in the work area by stepping down the 60 Hz line voltage to 115 V, and by a small 28 Vdc to 400 Hz converter placed in the service area.

LHe and LN_2 will be supplied in 50-liter quantities, along with high-pressure bottles of helium and nitrogen gas. Additional quantities of cryogenics will be supplied if needed. A protective structure has been provided to permit filling of the experimenters' dewar in the event of rain.

At the start of the mission, the living quarters will be stocked with linens and paper supplies, cleaning supplies, eating and cooking utensils, and supplemental food supplies. The plan is to deliver one hot meal a day and store frozen food onboard for the other two meals. Meals will be ordered by telephone, through mission control with the selection to be made from the cafeteria menu. A supply of airline-type meals will be stored in a central location for delivery once a day to the complex. The time schedule for eating will not be planned in advance, but will be left open for the simulation crew to decide.

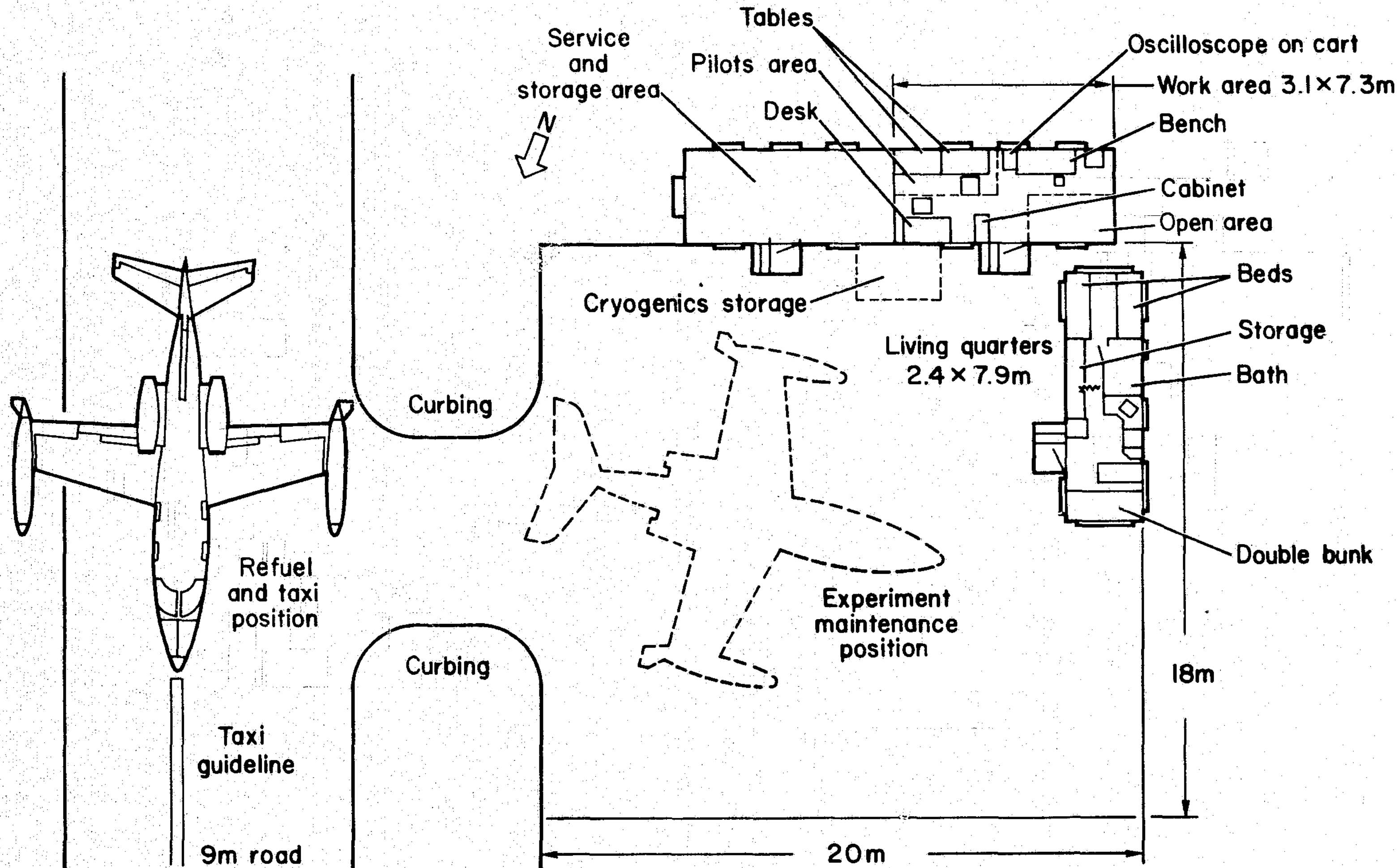


Figure A-1.- Arrangement of the simulation complex.

Weather permitting, all flights will be from the simulation complex. Thus, all supplies and equipment required for operation, inspection, and routine maintenance will be made available at the site. It is planned to deliver approximately 800 gal (3 m^3) of fuel for each flight. Breathing oxygen and other consumables will be on hand. If for any reason the aircraft is at the hangar prior to flight, the crew will be transported there by car when it is time for the preflight check-out, and returned to quarters at the completion of postflight experiment maintenance.

Mission operations

Mission preparation phase: The Mission Preparation Phase will consist of all events leading up to the start of the Confined Phase. Mission preparation will include all familiarization and training activities. The amount and type of training is to be established by the PI in conjunction with the EOs and the ASO Mission Manager. Training objectives are to provide sufficient skills and knowledge in the EOs to permit them to perform all necessary functions after start of the confined mission as would be required on Spacelab. A detailed training plan will be prepared by the PI. This plan will delineate material to be covered, facility or training aids to be utilized, and approximate schedule. During the training at the PI laboratory, the PI will instruct the EOs in the concept of the experiment and its objectives, design and construction, and maintenance and repair procedures. Interpretation and significance of results obtained and evaluation of data will also be covered. A Flight Readiness Review will be held to verify mission readiness of the telescope systems and the experiment.

At Ames, the PI will provide initial ground training and subsequent flight training of the EOs in all aspects of experiment operation, maintenance, repair, and preliminary data analysis.

Confined mission phase: The confined mission will be performed upon completion of the Mission Preparation Phase. During the Confined Phase, all experiment operation, maintenance, and repair will be performed by the EOs, in consultation by telephone with the PI, as required. It is expected that the EOs will be capable of performing the following tasks:

- Perform system tests
- Remove and install experiment components
- Align telescope and focus on targets
- Operate equipment
- Maintain and repair equipment
- Process data and perform preliminary analysis

Selection of observational targets will be the responsibility of the PI. Reevaluation of targets initially selected may be necessary as the confined mission progresses. This will be the responsibility of the PI in consultation with the EOs.

Real-time data evaluation will be performed by the EOs. After each Lear flight, the EO will initiate a telephone conference with the PI to review the data and general progress of the flight series. This conference will simulate anticipated Shuttle communications in orbit. If desired, copies of any data obtained during the Lear flight can be handed to the PI after each flight, simulating the transmittal of telemetered data from Spacelab. However, all verbal communication between PI and EO shall be by telephone through the Mission Control Office.

If problems arise during the confined mission of such severity that the above ground rules must be broken or the mission aborted, a reevaluation of the ground rules will be made by the Mission Manager. At such time the PI may be called upon to physically assist the EO in the repair or operation of the equipment.

The daily time schedule of mission operations will be at the discretion of the simulation crew in conjunction with the PI. Experiment maintenance, eating, sleeping, etc., will be scheduled daily as required to satisfy requirements of target observation times, experiment preparation, and aircraft preparation.

The plan for aircraft group operations is to refuel, perform minor maintenance tasks, and make safety inspections at the simulation site. Departure and recovery also will occur here. The aircraft will taxi under power between the simulation site and the airfield.

Support operations- Insofar as possible, the support-operations plan will follow the procedures normally used in the ongoing Lear research program. Overall coordination will be provided by the ASO Mission Manager. He will initiate 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 round-the-clock schedule will be planned in cooperation with the ASSESS Program Manager and representatives of the various support groups.

The aircraft maintenance contractor and the Ames Aircraft Inspection Branch will be requested to service and maintain the aircraft while it is based at the simulation complex, on a 24-hour-a-day basis. The aircraft maintenance crews will consist of two mechanics, one electrician, and one inspector; each crew to work a 12-hr shift, starting at 6 a.m. Ames' vehicles will be used for aircraft refueling and standby fire protection, as well as to accompany the aircraft along the taxi path from the simulation site to the airfield taxiway and return. Only in the event of a malfunction requiring special services, or adverse weather conditions, is it planned to bring the aircraft to the hangar.

Support activities of the Ames Flight Operations Branch will consist of their normal functions, adjusted to the time schedule of the simulation mission. The Aircraft Operations Office will normally be in radio contact with the aircraft while in flight and within radio range. The duty officer will monitor local weather conditions, will relay messages, will advise the ground crew of expected landing time, and will call to the office (for direct communication) any person requested by the flight crew. Aircraft commanders and back-up pilots will be assigned to research mission by the Flight Operations Branch, at the written request of the ASO Mission Manager. Normally, different individuals will serve as command pilot and co-pilot each night. The Aircraft Commander will participate actively in the operations planning, accepting responsibility for special taxiing arrangements relative to other local Flight Operations and for a detailed aircraft activities schedule and aircraft safety to be used before, during, and after flight. He also will monitor the physical condition of the experiment operators and judge their fitness for flight, as well as to verify that the aircraft life-support O_2 system is fully charged and operating.

The Ames Security Branch will support mission operations by arranging for the use of roads for aircraft towing and taxiing, and by planning traffic control measures, site isolation, and night security patrols. Security guards will be notified 30 min before takeoff or landing to allow time for road blockades along aircraft taxi paths.

Support for aircraft navigation and flight planning will be provided by the ASO, using normal procedures. The request for flight will originate with the PI who will submit his request to the ASO Mission Manager. When approved, it will be passed to the ASO Flight Planner for implementation. After checking with the FAA Center and others for clearance, the Flight Planner will return a completed flight plan to the Command Pilot. The plan will be approved by the pilots in consultation with the experiment operators and will be filed by telephone with local Flight Operations.

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

Safety- Flight safety is of prime importance, and normal precautions for the protection of personnel and equipment are well established. Safety requirements applicable to experiment design are given in the Lear Experimenters' Handbook.

The Aircraft Inspection Branch is charged with a specific responsibility for safety. They will inspect the experimental installation as well as the aircraft prior to every flight to ensure that all routine inspections and parts replacements are made on a timely basis and that any identifiable safety concern gets proper attention. They will have the authority to suspend operations if unsafe conditions are not corrected. Finally, the Airworthiness and Flight Safety Review Board (AFSRB) has a broad overall safety responsibility, and, utilizing the Airworthiness Assurance Office, will continually oversee all designs and operational plans as they progress toward actual installation and operation. They specifically will investigate, in depth, any unique new design, including the stress analysis.

A detailed review will be presented to the AFSRB prior to the ASSESS mission, covering thoroughly all new designs, operational plans, contingency considerations and any other facet associated with safety. The presentation will be made by the ASO Mission Manager; however, other key individuals may participate, such as the pilots, designers, ground operations personnel, and representatives of the Airworthiness Assurance Office. The Chairman of the AFSRB will issue approval of the aircraft mission before implementation.

In the case of the Lear Jet infrared experiment, the telescope installation has been basic to a number of missions by several teams of experimenters; thus, it has been reviewed deeply by the AFSRB well before the ASSESS Mission. Thus, the AFSRB review for this mission will concentrate on the unique features of the experimenters' sensing equipment and the mode of flight operation, as well as the considerations for personnel constraints and operations from the simulation site.

The experiment operators have participated in the required one-day high-altitude training course and altitude chamber at a military base and have attended a local training session on Lear life support systems and emergency procedures. Both men have satisfied the requirements for a current FAA Class II flight physical certificate, and a satisfactory condition of health. Both experiment operators will be given an examination by an Ames-approved physician immediately prior to the start of the mission.

A list of the significant operational safety rules which will apply to the ASSESS mission are as follows:

1. Aircraft will not depart the simulation site if weather forecast makes return to Moffett Field questionable.

2. Alternate recovery sites will be chosen before flight, to be used if adverse weather conditions or other emergencies develop.

3. All final approaches will be radar handoffs to Moffett GCA.

4. Flight Operations Branch radio operator will continuously monitor the aircraft communication frequency during flight.

5. Pilot not flying the aircraft will check and report on O_2 system every 5000 ft during climbout.

6. During periods of astronomical observation when the co-pilot is in the experiment operators' communication loop, the Command Pilot will monitor the O_2 life-support system.

7. The Command Pilot will be responsible for the operation of the aircraft O_2 life-support systems and will assure their proper maintenance.

8. The Command Pilot will be responsible for evaluating experiment operator physical condition and will cancel the upcoming flight if excessive fatigue becomes apparent.

9. A flight surgeon will be on call at all times and will receive a daily medical report from the ASSESS duty officer.

10. Security guards will provide traffic control and a safety vehicle will accompany the aircraft during taxi to or from the airfield taxi strip.

11. A guideline has been painted on the roadway to assist taxi operations; obstacles close to the roadway will be identified with flashing lights.

12. The aircraft taxi path will be inspected and all debris and loose gravel will be removed prior to start of operations.

13. Aircraft refueling will be done a safe distance from the living quarters and in the presence of a fire-protection vehicle.

14. Aircraft will be grounded to a 30 ft safety ground rod whenever located at the simulation site.

15. Crash and fire crews will be notified of aircraft parking locations, taxi and tow routes.

Contingency procedures- Procedures for handling contingency situations have been considered. Weather contingencies are of foremost concern, since the aircraft is to be parked outside at the simulation site for normal operation. Fatigue and/or illness of the crew is to be considered, since either could jeopardize mission performance. Provisions are to be made for landing at alternate airfields, which could interrupt the simulation aspects of the mission, and for major aircraft or experiment maintenance problems.

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

1. In the event of a major maintenance problem, or rain, the aircraft will be *stationed in* and *depart from* the hangar. The "Shuttle" crew will be taxied from the simulation site to the hangar by car for each flight.

2. If a problem with the experiment should require some part or item of test equipment that is not available "onboard," the necessary item will be supplied if the success of the mission is considered to be in jeopardy.

3. The Aircraft Commander can elect to:

   a. Recover to Ames hangar in case of bad weather or a safety problem.

   b. Cancel the upcoming flight in case of over-fatigue of pilots or experiment operators.

4. In the event of illness of either pilot, he will be replaced by the assigned back-up pilot. If either of the experiment operators becomes ill, the upcoming flight will be canceled and rescheduled.

5. Any decision to cancel the mission will be made by the ASO Mission Manager in conjunction with appropriate personnel.

6. In event of a telephone malfunction at the simulation complex, the ASSESS duty officer will be responsible for maintaining and reestablishing communication.

7. Alternate landing fields will be used in emergencies; if at a nearby airport, the ASSESS duty officer will retrieve the "Shuttle" crew, and other Ames pilots will recover the aircraft; if at a remote airport a decision will then be made as to the effect on the simulation mission and plans for subsequent operation.

Documentation- The same documentation procedures will be used for the ASSESS mission as are normally followed by the ASO. The aircraft work order calling for installation of the telescope and attendant electronic equipment will be issued by the ASO Mission Manager and will serve three functions. It will be used to notify the AFSRB for review and approval of the safety and airworthiness of the experiment. It will be used to authorize fabrication of the attachment hardware. It will serve to notify the Aircraft Inspection Branch for inspection and approval of the final installation.

Just prior to the flight period, the ASO Mission Manager will initiate a flight request for the entire flight series. This authorizing document will be circulated to those groups concerned with flight operations. All other coordination and decision-making activities will be accomplished by the ASO Mission Manager and the PI in informal discussions with representatives of the cognizant support groups.

The somewhat unique operations associated with the Shuttle simulation mission will require some documentation in addition to that normally used. A Mission Operations Plan is hereby formulated by the ASO Mission Manager and ASSESS Program Manager. This will be submitted to the Airworthiness Assurance Office for concurrence, will be approved by the Airworthiness and Flight Safety Review Board, and will serve as the guide for the detailed activities of the simulation mission.

Research Experiment

Basic instrument- The basic instrumentation for the mission will consist of the NASA/ARC 30 cm Cassegrain telescope in conjunction with a liquid-helium-cooled bolometer filter photometer. The signal-processing electronics for the experiment will require one forward/side mounting Lear Jet rack located in the forward starboard side of the Lear. The gyro stabilization system will be located on a pallet mounted on the port side in the baggage compartment. Power for the experiment will be furnished by a dual 60 Hz 110V solid-state inverter system also located in the baggage compartment. Figure A-2 depicts the aircraft layout.

Modifications- The experiment system will remain unchanged from that previously flown during the latest ongoing Lear astronomy program. The major

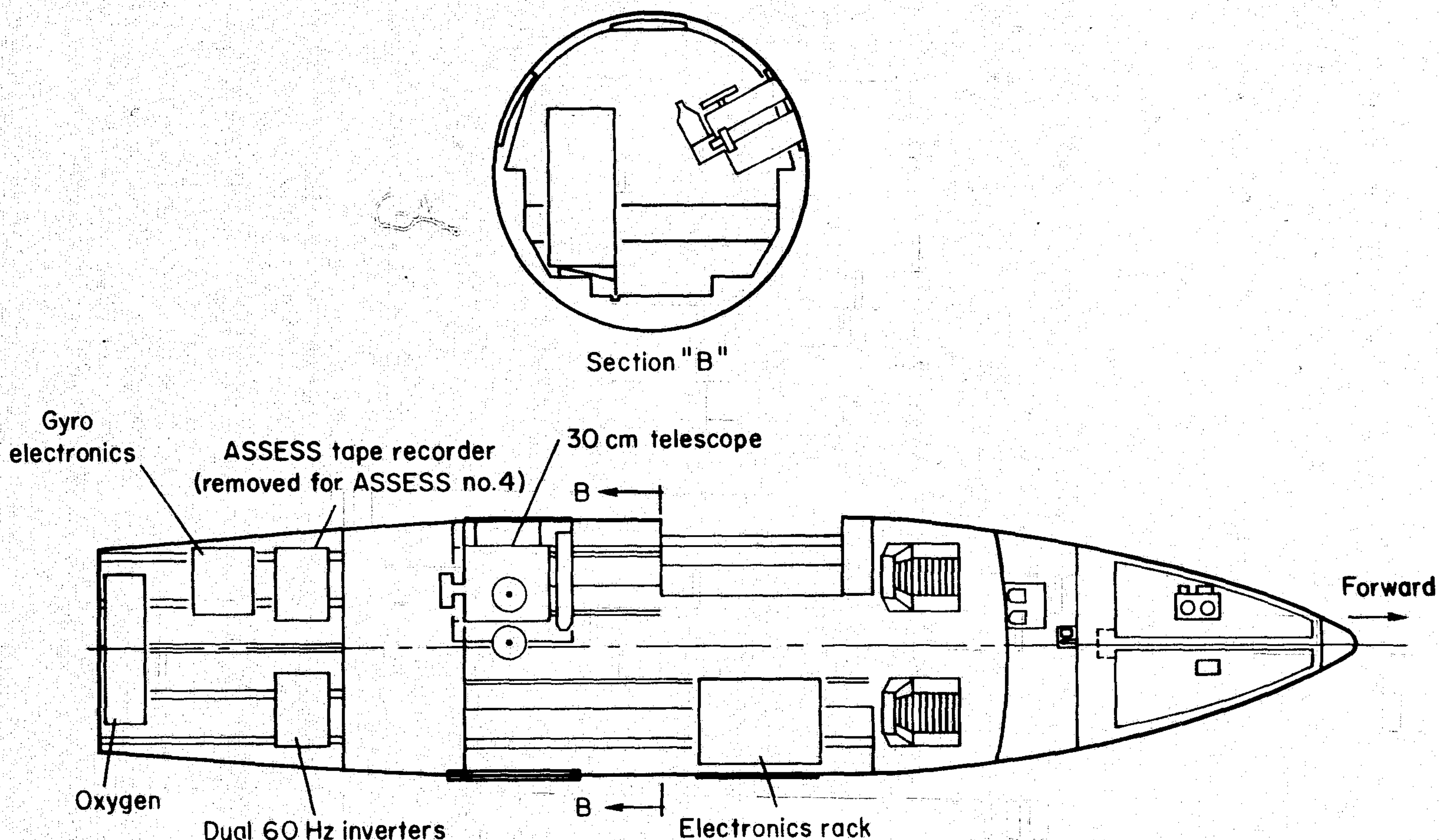


Figure A-2.- Arrangement of experiment equipment in Lear Jet.

emphasis is in the area of back-up equipment to enhance flight reliability. The primary item the PI will supply is a back-up dewar which includes optics, filters, windows, etc.

The telescope system including gyrostabilization electronics is the responsibility of ASO. The system has been modularized to facilitate rapid troubleshooting and replacement of PC boards with a minimum of background knowledge. Replacement parts are presently in-house, and the modular boards are on hand.

Installation- The experiment for the ASSESS mission is the same as for the last flight series with the Lear Jet aircraft. The electronics rack will be removed for a 600-hr inspection of the aircraft, which is to take place immediately before the start of ASSESS activities on the aircraft. The PI, together with the EOs, will reinstall the rack electronics units as part of the EO training plan. The telescope will not be removed for the inspection, and thus will remain in the aircraft from the last flight series. The entire installation has been approved for flight in the previous flight series by the Airworthiness Assurance Office.

Initial contacts between experimenters and ARC personnel will be handled through the ASO Lear Jet Manager. During installation of the equipment, however, the experimenters will work directly with the support groups, with the Mission Manager being advised of progress and resolving problem areas.

Experiment Support

A mission guideline has been established that the experiment operators can bring "on-board" any type of spare subassemblies or components considered necessary to ensure the success of the mission. Limitations have been placed on test equipment and tools, however, and will be limited to those that can be justified by the PI. Once the mission is started, the Airborne Science Office will supply and document any additional test equipment or parts that are found to be required.

Test equipment- Test equipment will consist primarily of general-purpose diagnostic devices for troubleshooting electronic circuits. These will be standard laboratory-type devices for use in the work area between flights and will be in sufficient quantity and diversity to enable the isolation of system/component faults. Circuit diagrams for experimenter-built equipment and service manuals for commercial units will be available, as well as reference documents on cryogenic and infrared technology.

Spare parts- Spare parts fall into three major groupings: Back-up major subassemblies (dewar, tape recorder, etc.), electronics components, and mechanical parts. The GFE telescope provided by ARC will have back-up modularized PC boards for the gyro electronics. Spares are available for the telescope gyros; however, spare torque motors will not be provided, and they are not considered to be field repairable.

Tools- The experimenters will furnish the majority of small hand tools, soldering irons, etc., that are required. A list will be compiled.

Supplies- The experimenter will furnish a variety of supplies, mostly in small quantities, to support the program. These will be supplemented by cryogenics and other supplies provided by the Airborne Science Office.

ASSESS OBSERVATION PROCEDURES

Observations of PI and EO activities will be made throughout the mission by trained ASSESS observers. Observations will be made of EO training at the PI laboratory and at Ames. Several techniques will be used for ASSESS data collection. The primary technique is by direct observation. This will be supplemented by voice recordings by the EOs at various stages in their training. During flight, voice recordings of conversations among the EOs and the co-pilot will be made on one channel of a two-channel recorder that is part of the experiment data-acquisition system.

During the confined phase of the mission, an observer will be stationed in the work trailer to observe activities of the EOs in experiment preparation, maintenance, and preliminary data reduction. Recordings will be made of communications between the EOs and the mission control center.

APPENDIX B

INFORMATION ON SELECTED ASTRONOMICAL TARGETS

Detailed information describing the selected astronomical targets was prepared by the PI for the benefit of the EOs. Note that many of the targets of interest were small areas of the sky rather than point sources such as individual stars. A review of these descriptions gives an idea of the difficulty of location and scanning this class of objects. The combinations of letters and numbers are the designators for the various objects according to standard astronomical references.

W51

This optically invisible, giant complex of H II has been rather extensively studied. Covering an area over 3/4 of a degree on a side, the half-dozen or so strong radio continuum sources are clustered into two major regions. Some of these components have been resolved into many smaller sources. In addition, the radio spectrum of W51 shows evidence of wide ranges of physical conditions within the object.

A number of molecules have been detected in this region: CS, CO, NH_3, H_2O, and OH. As usual, the association of a number of molecular sources with H II regions, such as W51, is definite, but not well understood. At the very least, the molecular data show regions of moderate to high density, as would be expected in such a complex.

W51 has been observed at a number of IR wavelengths, but either with beams so large that only the grossest features were observed, or with resolution so high that only a portion of the object could be observed in the available time. With the present Lear system, which has a resolution of about 3 arc minutes, a good percentage of the object could be observed in the time available.

A comparison of previous IR and radio observations shows W51 to be much like the smaller, better-known H II regions. It is a strong source, both at radio and IR wavelengths, and the maps in the radio and IR show much the same features, suggesting that both are powered by the same source: hot, massive young stars, obscured by intervening dust clouds.

The Lear observations should help define the relationship between the gas, dust and exciting stars within W51.

M8

This optically bright H II region, and associated cluster of bright, young massive stars, has been relatively ignored, probably because of its location: well into the southern hemisphere.

A moderately-bright radio source, observations at those wavelengths show a roughly circular region about 20 arc minutes across, with some evidence of smaller structure on a scale of the beam size of our instrument — about 3 arc minutes.

Recent radio molecular observations show emission in a region displaced somewhat from the peak IR emission. The molecular sources, as well as the main body of the IR source are to be investigated during this series of Lear flights.

NGC 2264

In most respects, this object shows characteristics standard to a young object: it is an association of T Tauri stars, as well as showing radio molecular and IR emission. In addition the optical observations show an extensive filamentary system of hot gas. However, the radio continuum is very weak, not at all what is usually found in a region of recent star formation such as this, and is evidence against the existence of the hot massive stars that commonly power the various excitation mechanisms in objects such as M8 and W51. Indeed, one might have in NGC 2264 an object with its most massive stars still contracting out of the clouds of gas and dust in which stars are born, and a type of object that has not yet been well studied.

A number of molecular species have been observed in this region: extended H_2CO and HCN, as well as lines of CS, and an OH maser. The molecular observations indicate a region of emission of about 5 arc minutes in diameter, with densities implying a surprisingly large 10^4 solar mass tied up in the NGC 2264 gas cloud.

Finally, an optically invisible 20 micron point source has been found in this region, as well as a number of sources at shorter IR wavelengths.

NGC 1333

Without much visible star clustering, this object has a number of indicators of extreme youth: 5 Herbig-Haro objects, 2 near-IR sources, and a T Tauri star, all divided between two distinct groupings. In addition, the object appears imbedded in a dust cloud, and shows extensive radio molecular emission.

A map of NGC 1333 with H_2CO and HCN shows a large — about 100 square arc minutes — plateau of emission upon which sits a pair of peaks coincident with the Herbig-Haro objects and IR stars. Emission from CS, NH_3, and CO are seen as well.

M78

A relatively unexplored region of apparently active star formation, M78 has, in an area of few arc minutes on a side, 5 Herbig-Haro objects, at least one molecular source, and an IR star.

An H_2CO map of the region shows a roughly circular region of emission about 8 ft across, in addition to CO and HCN observations that indicate an object both dense and extensive.

M78 is located in the Orion region, an area of most active star formation, and is, itself a highly obscured portion.

M17

This object, commonly known as the Omega or Horse-shoe nebula, is a gaseous emission nebula in the constellation Sagittarius. Its brightest portion, which is roughly rectangular in shape and about 22 arc min across, has been estimated to have a mass 800 times the Sun. The structure is very loose and irregular with about 35 embedded stars. M17 is also a radio source and is within 2° of the X-ray source Sgr XR-2. The former property is of interest here, to pursue the relationship of IR to radio emissions.

ON-4

In line with the general objectives of gaining understanding of nebular dust clouds and regions with concentrations of ionized hydrogen, ON-4 is an identified OH region about 4.5 arc min in size and close to a point source. The region is associated with early stages of star formation and is relatively unexplored. Overall photometric measurements are desired.

OMC-2

This object is a molecular cloud IR source in the region of M42 in the constellation Orion. It was discovered by ground-based observations at shorter wavelengths and remains relatively unexplored. Present measurements at 40 to 200 μ would be made to determine the shape of the nebulosity and correlate with the ground-based observations.

APPENDIX C

DIMENSIONAL AND COST INFORMATION ON EXPERIMENTAL EQUIPMENT

This appendix gives the physical parameters of each component of the experiment — the PI's equipment, the telescope systems, and the onboard support equipment. Primary and backup units are identified. Type of construction, dimensions, weight, power, and cost estimates are listed in table C-1. Cost estimates for developing the PI's equipment, and for replacing the existing components, are summarized in table C-2.

Table C-3 lists spare PC boards and other components that were available for GFE telescope systems, along with remarks to aid the EOs in their use.

TABLE C-1.- CHARACTERISTICS OF EXPERIMENT COMPONENTS

EXPERIMENT: Observatory IR Photometry

B = Backup

Component	Construction	Dimensions, cm			Power			Weight, kg	Cost* ($)	Comments
		Height	Width	Depth	V	A	W			
Sensor package and associated equipment										
• Sensor package (2) Single filter 40-200 μm	Experimenter built	Contained within cylindrical package 20 diam. × 30 high					none	9.1 each	---	Experiment uses one of two different dewars.
4 position filter (B) 30-50 μm 40-90 μm 30-200 μm 90-200 μm	Experimenter built						none		---	
Liquid nitrogen & Helium dewar (2); 1 backup unit	Custom commercial						none		1500 each	
Detector (2); 1 backup unit	Custom commercial								1200 each	Germanium bolometer
Low noise preamp & bias circuitry (2); 1 backup unit	Experimenter built						battery 9V		220 each	
Signal processing equipment								Weight of computer, signal & recording equipment in rack = 71		All signal processing equipment has been replicated; old components are backup units. Built-in power supply with 115V, 60 Hz input.
• Phase lock amplifier (2); 1 backup unit AC amplifier Narrow pass filter Phase sensitive demodulator DC amplifier Voltage to frequency converter	Experimenter built	14	5	18	±12Vdc		27 (est.)		560 each	
• Audio amplifier	Experimenter built				28V battery		1 (est.)		50	
• Phase lock amplifier (2 B) AC amplifier Narrow pass filter Phase sensitive demodulator DC amplifier Voltage to frequency converter	Experimenter built	13	23	25	±12Vdc		27 (est.)		560 each	Built-in power supply with 115V, 60 Hz input.

TABLE C-1.- CONTINUED

B = Backup

Component	Construction	Dimensions, cm			Power			Weight, kg	Cost* ($)	Comments
		Height	Width	Depth	V	A	W			
Computer	Off-the-shelf	14	46	58	115V 60 Hz		150VA	Weight of computer, signal & recording equipment in rack = 71	5000 each	Computer weight 20 kg. Backup unit from ASO.
Recording & display equipment										
• Strip chart recorder (3); 2 backup units	Off-the-shelf	8	13	18	115V 60 Hz		9	↓	300 each	
• Cassette recorder	Off-the-shelf	8	41	31	115V 60 Hz		22	↓	200	Backup unit from ASO during mission.
• Audio monitor (squealer)	Off-the-shelf	0.6 diam. × 1.3					battery	↓	70	Ear-plug speaker
• Digital printer system Controller and clock	Experimenter built	14	5	18	+5Vdc		20	↓	580	Controller, clock, and counter have been replicated; old components are backups.
Counter	Experimenter built	14	5	18				↓	1040	
• Printer (B)	Off-the-shelf	13	18	--			16	↓	900	
• Counter (B) (incl. controller, clock)	Experimenter built	13	18	23	+5Vdc		20	↓	520	Built-in power supply converts 115V, 60 Hz to +5Vdc.
• Oscilloscope	Off-the-shelf	8	15	25	115V 60 Hz or battery	0.2	20	↓	800	
			Total for primary experiment				~250	↓		
Secondary mirror drive system										
• Chopper drive and phase reference	Experimenter built	18	48	18	28Vdc	2	56	Included in above weight	440	
• Chopper	Custom by Ames	8 diam. × 10 long						---	---	GFE
• Secondary mirror	Custom by Ames	8 diam.								GFE

TABLE C-1.- CONCLUDED

B = Backup

Component	Construction	Dimensions, cm			Power			Weight, kg	Cost* ($)	Comments
		Height	Width	Depth	V	A	W			
<u>Telescope system</u>										
• ARC 30 cm telescope with gyros and torque motors	Custom by Ames	38 outside diam. × 51 long			28Vdc	7.5 min., 40 max.	206–1120	124	---	GFE
• Telescope stabilization electronics	Custom by Ames	22	48	51	28Vdc	3	84	24	---	GFE, installed behind seat.
• Joystick control	Custom by Ames	8	15	20	--Included above--			5.5	---	GFE
• Finder telescope	Modified	25	8	8			none	0.9	190	Supplied by experimenter 300 mm, f/4
<u>Accessories</u>										
• Vacuum pump & motor	Off-the-shelf				28Vdc	12	336	43	---	GFE
• Power distribution	Custom by Ames	11	48	8			none	---	---	GFE, installed on bottom shelf of electronics rack.
• Power supply	Experimenter built	23	48	10	---	---	---		200	Installed in rear of electronics rack.
• Inverters (2), 28Vdc to 115V, 60 Hz	Off-the-shelf	10	19	30	115V 60 Hz		250 max. each	7.3 each	760 each	GFE, installed behind seat.

*For cost summary see table B-2.

TABLE C-2.- COST ESTIMATES ON EXPERIMENT EQUIPMENT

Component	Replacement cost				Development cost		
	Labor hours	Labor cost at $15/hr	Purchased parts & assys $	Total $	3 × labor cost in $	Purchased parts $ assys in $	Total $
Operational experiment							
Phase lock amplifier	24	360	200	560	1080	200	1280
Oscilloscope (Tektronix 212)	--	---	800	800	---	800	800
Chart recorder (MFE-M12C)	--	---	300	300	---	300	300
Squealer	4	60	10	70	180	10	190
Recorder (Sony)	--	---	200	200	---	200	200
Computer	--	---	5000	5000	---	5000	5000
Counter	56	840	200	1040	2520	200	2720
Controller & clock	32	480	100	580	1440	100	1540
Preamp	8	120	100	220	360	100	460
Bolometer	--	---	1200	1200	---	1200	1200
Dewar container	--	---	1500	1500	---	1500	1500
Chopper drive	16	240	200	440	720	200	920
Finder telescope	4	60	130	190	180	130	310
Power supply	--	---	---	200	---	---	200
GFE components of experiment not listed	--	---	---	---	---	---	---
TOTALS				12300	6480	9940	16620
Backup components							
Phase lock amplifier (3)				1680			
Controller and clock				580			
Counter				1040			
Preamp				220			
Chart recorder (2)				600			
Bolometer				1200			
Dewar container				1500			
Printer				900			
TOTAL				7720			

TABLE C-3.- TELESCOPE GUIDANCE SYSTEM SPARES

I. Gyro boards

Location	Description	Spare board	Remarks
Board A	Roll power driver	Yes	Boards A and B are interchangeable.
Board B	Yaw power driver	Yes	Boards B and A are interchangeable.
Board C	Roll signal processing	Yes	Spare board can be used only with extender card.
Board D	Yaw signal processing	No	Board C can be modified to be used for board D.
Board E	Gyro control	Yes	- - - - - - - - - - - - -
Board F	Roll motor/heat	Yes	Spare board is inoperable at present time. Parts on order.
Board G	Yaw motor/heat	Yes	Spare board is inoperable at present time. Parts on order.
Board H	Signal processing power supply	Yes	Boards K, L, and M can also be used as spares only if extender card is used.
Board K	Roll gyro control/power driver power supply	Yes	Boards L and M can be used in place of board K.
Board L	Yaw gyro control/power driver power supply	Yes	Boards K and M can be used in place of board L.
Board M	Motor/heat power supply	Yes	Boards K and L can be used in place of board M.
Board N	Position indicator	No	If board fails, will not affect operation of system.
Board P	22-pin extender card	Yes	- - - - - - - - - - - - -
Board R	Limiter detector	No	If board fails, will not affect operations of system.
Chassis	Power amplifier assembly	Yes	Before using spare power amp., it must be checked in unit to see if it's operation is OK.

TABLE C-3.- CONCLUDED

II. Additional spare equipment

a) 1 - spare Gyro HIG-4 (C-9)

b) 2 - spare Gyro control cables

c) 2 - spare chopper cables

d) There are some spare components for the board and power amplifier assembly available.

e) There is also a Gyro control test box available to be used in case of failure of the system.

III. Spare components

a) 2N2222 - 5 ea

b) 1N914B - 5 ea

c) 2N5685 - 4 ea

d) 2N5191 - 3 ea

e) 2N5194 - 1 ea

APPENDIX D

STANDARD OPERATING PROCEDURES, CHECK LISTS, AND TRAINING QUESTIONNAIRE

Detailed standard operating procedures were prepared by the PI team as a basic reference for the EOs, describing all aspects of experiment operation. The procedures discuss the various modes of observation of an astronomical target, the physical details of the operation of the telescope, the various portions of the electronic equipment and their operation, and the operation of the onboard computer.

The procedures conclude with activity lists in which the PI gives the sequence of operations required to prepare and checkout the dewar and experiment electronics for flight. Next, in order, is a time-coded checklist developed by the EOs to assure completion of preflight activities and the presence onboard of operational and spare equipment at time of lift-off (L).

Table D-1 is a sample of the training-progress questionnaire used at the end of the ground training period. Individual responses are grouped together for ease of comparison.

STANDARD OPERATING PROCEDURES

Introduction

Observations may be performed in several different modes with the current detector/electronics system. The three primary factors determining which mode will be employed during a given observing sequence are the type of source (e.g., how strong an IR emitter, whether or not it is extended, and so on), the type of data that is desired (e.g., multi-band photometry of the peak of the source or, perhaps, a map of the region at a single wavelength), and, third, the requirements of a specific observing situation (e.g., the availability and positions of suitably bright guide stars in the region of interest). Naturally, if there should be difficulties with the telescope/detector/electronics system the observing program may need to be adjusted.

No matter which observing technique is chosen, there are a few procedures routinely followed by the telescope operator and electronics operator.

The telescope operator's job is to locate the object, guide the telescope in the manner decided upon, and monitor the telescope/detector system, or the portion he has at hand (e.g., the gyros, detector filters, He pump, etc.).

The electronics rack observer must keep an eye on the functions of about a half-dozen pieces of equipment (making sure the data is being recorded in as many as three places) communicate with the pilots, and keep the telescope observer up-to-date on the status of the data-taking and function of the equipment. In addition he must be adept at electronic troubleshooting and ready to deal with other problems that rise.

Good communication between the electronics and telescope operators is essential. Before the flight, both should be aware of the sequence of objects to be observed and the observation method for each object. During the actual observation run, the telescope operator will communicate to the electronics operator the filter that is being used, position of the guide stars (usually a running position as data is taken), the position of rotation and scale stars (see below), and other pertinent information.

In addition to *always* writing down what the telescope operator is saying, the electronics operator must keep the telescope operator informed on the status of the experiment (e.g., signal-to-noise ratios on integrations, deflections on the strip chart, etc.) and relay information from finding charts, the flight plan, or the observing plan.

Observing Procedures

In this section, we will describe several standard observing procedures. First, however, it should be pointed out that there is some leeway; there are no hard and fast rules. There is much overlap in the information deduced from the different observing techniques. Experience is, as always, the final arbiter.

Left-Right Integrations - this is a series of observations in which a source is placed first in one beam for a specified length of time, then the other beam, then the first beam, and so on. This method results in optimum cancellation of instrumental drifts and highest ultimate signal to noise ratio. It is the only suitable technique for sources too weak to show a deflection on the strip chart.

The telescope operator gives the position of the guide star, or of the object itself, if it is visible, then gives a running report of which beam is on the source, and when to begin the integration. The electronics operator writes down the telescope operator's information while simultaneously initiating the integration by throwing a toggle switch on the control box to the left or right — depending on which beam is one the source — and the electronics do the rest: taking the data for the chosen period of time (usually 2 sec, longer for weaker sources), printing it out, and after every "left-beam" displaying the signal-to-noise ratio and other data. Before the last integration is done, the "terminate" button is pushed, and the computer prints out the final signal-to-noise levels.

Before this technique of data-taking can be used, the position of the beam on the eyepiece grid must be known (or estimated while data taking is being done, but determined exactly later). In the case of optically invisible objects, the rotation/scale of the field and offset from the guide star must be known.

Scan - this is a series of observations evenly spaced along the x or y axis. This technique is usually reserved for mapping those sources that are bright enough to give a strip chart deflection. It is faster for exploring a region than the technique given above, but usually gives a lower signal-to-noise ratio.

In this case, the telescope operator calls out the co-ordinates of the object or guide star, gives the order to begin the integration at that point, and waits for the electronics operator to acknowledge that the integration is complete; he then goes on to the next position. The scans along one axis are usually repeated several times to improve the quality of the data. The telescope operator may rely on the electronics operator to tell him when the strip chart shows that he is off the source.

There is a subroutine in the computer to accept this type of data. Naturally no signal-to-noise ratio is calculated, and the program is little more than a "print-out" program. The keying is done from the control box, and, if desired, the position of the guide star can be automatically printed out as well.

Strip-chart output - the least used of the techniques for data taking, requires a strong source. This technique is used, for example, when there is time for only a few left-right deflections.

The telescope operator merely moves the object around in the field of view, looking for the peak signal and getting a running commentary on the magnitude of the signal from the electronics operator. A value for the source in the other beam should also be obtained (check for equality of "left" and "right" signals), as well as "no signal" or "sky" with the object well out of both beams. It is important to spend sufficient time on the "sky" position to establish a reliable baseline.

Telescope Operation

From experience, we find that the operations of the telescope should be checked twice, once about 4 hr preceding, and again, about an hour preceding the flight.

A. Gyro-stabilization check

1. Power on warm-up time before gyros come on is about 10-15 min, but can be as long as 20-25 min.

2. When gyro spin indicator lights are on, engage gyros with telescope off limits.

3. Torque motors should hold telescope rigidly in place in both axes.

4. Malfunction — most common is when stabilization is lost or bad in one axis.

a. Check that all cables are connected.

b. Check that gyros are oriented properly.

c. In the past, problems have occurred in the electronics, cables, and the gyros themselves. One can narrow down which of the three components has problems.

1) Interchange control/power cables at the two gyros, if the problem remains in the same axis then something is probably wrong with the gyro for that axis. If the problem, after the interchange, is now at the other axis, then the difficulty probably lies in the cables or electronics.

2) Interchange control/power cables at the electronics rack. If the same axis on the telescope is malfunctioning, then the problem lies in the cables or gyros. If the other axis malfunctions, then the problem probably lies in the electronics.

d. Once the problem has been located, the defective part must be repaired or replaced (usually the latter in the case of the gyros and electronics). Fuses, spare gyros, and space electronic component cards will be available.

B. Telescope focus and chopper

1. The focus and chopper throw can be checked with or without telescope stabilization.

a. The focus is changed by releasing the two large nuts that hold the bolt (upon which the chopper is mounted) in place and slide the unit in and out of the spider hole until satisfactory focus is achieved.

b. The throw of the chopper is set by adjusting the outer nuts on the chopper body.

c. "Tuning" the chopper is accomplished by adjusting the inner nuts on the chopper body.

2. Though the focus of the telescope rarely needs readjustment, the throw and "tuning" of the chopper can change, due to vibrations, and may need readjustment. This can be observed during a flight.

3. Chopper throw, and to a certain degree, focus and tuning, can be checked by use of a laser shining into the telescope, and (with the eyepiece removed) projected onto a sheet of paper.

4. The chopper driver will be discussed in the "electronics" section.

C. Fine tuning of telescope

1. Balance — though rough balancing of telescope is done on ground with lead weights, air flow around the telescope will change the balance, and a few lead disks should be carried to affix to telescope in flight.

2. Drift in the gyros may have to be cancelled out with a pair of dials on the joystick box. If possible, trim the gyros before acquisition of the first object. Additional adjustments may be required later in the flight.

D. Pressure differential

1. The "noise" (as read out on the strip chart recorder) may depend upon the difference between ambient and cabin pressures. This applies primarily to 12μ and 21μ observations.

2. The minimum noise seems to be around 5-1/4 psi differential pressure, but this should be checked every flight.

3. The procedure is to have the telescope operator hold the telescope off limits, and have the pilots change the differential pressure (in a range from about 4 psi to about 6 psi). Note the pressure that minimizes the noise, and use it.

Electronics

I. Overview

The signal electronics are shown in block diagram in figure D-1. The output of the bolometer is a time varying voltage (~10 μV). The preamp output is fed into a phase lock amplifier (PLA) which electronically switches between periods of left beam input and right beam input, giving a resultant dc voltage that is the difference between the two inputs. This dc voltage varies between 0-5V and drives both a chart recorder and a voltage-controlled oscillator. The VCO output is recorded on magnetic tape and also fed to a counter which integrates the signal over a specified time period (variable between 1 and 16 sec). The counter is triggered externally by the controller, and the digital information from counter is fed into the computer. There the raw digital data are printed and certain reduction computations are performed.

II. Individual components

Chopper driver:

The present chopper driver contains phase-shifting circuitry to provide a reference signal to the PLA. Three chopping frequencies are commonly used: 20 Hz, 40 Hz, and 80 Hz. The frequency to be used during the data taking is determined during the flight on the

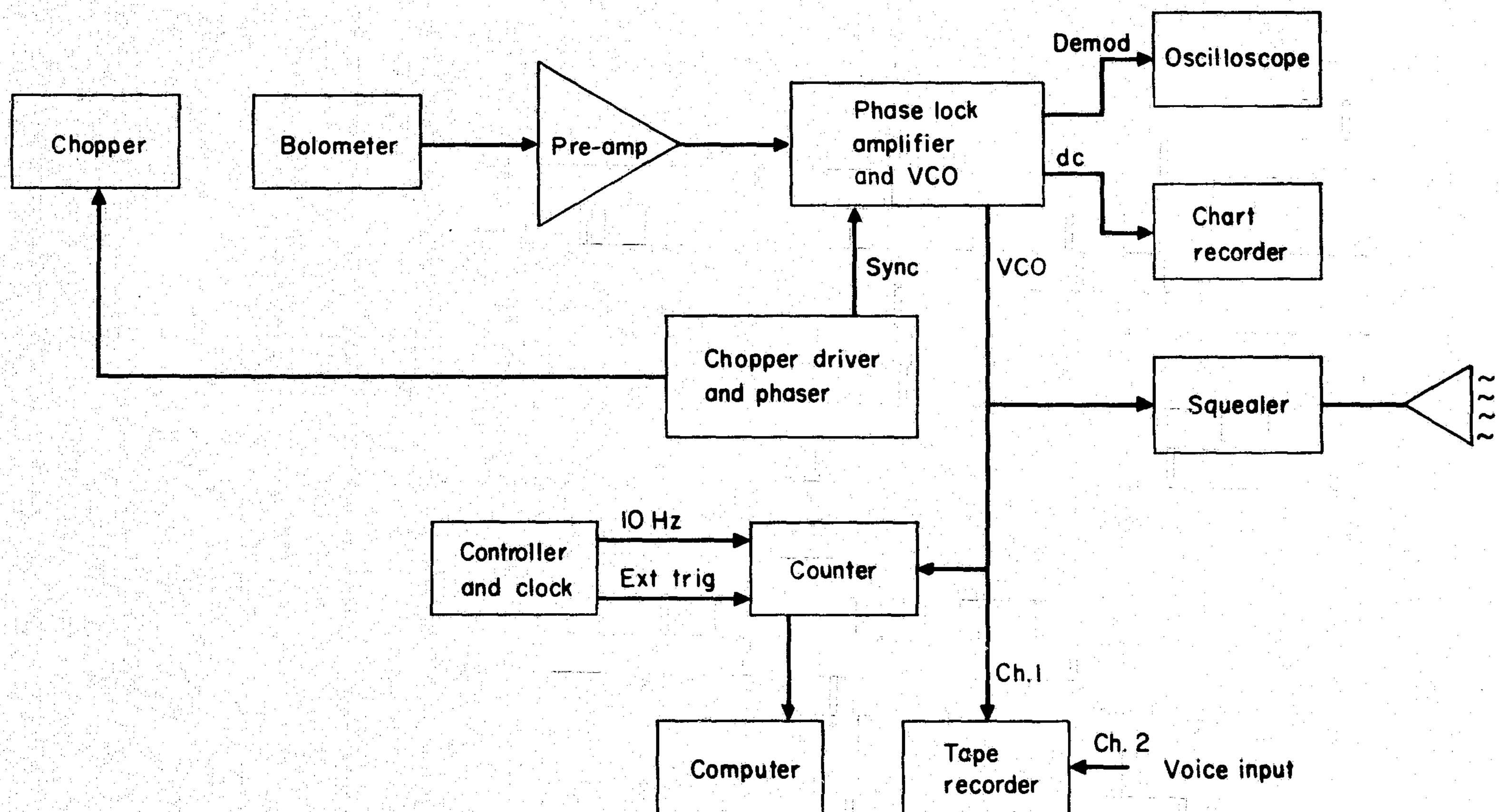


Figure D-1.- Lear electronics block diagram.

basis of the frequency which yields the highest signal-to-noise ratio.

Power requirements: +28V (2 amp)
Input : none
Output : chopper cable, sync cable [to PLA]

Phase lock amplifier:

Controls: dc bias level adjustment
chopping frequency filter selector
gain switch
÷ 1000 attenuator switch
Power: +12V, -12V, (30 ma) (total)
Input: preamp signal, sync [from chopper driver]
Output: demod (ac when no sync) [to osc]

Clock-controller:

Controls: left-right trigger
termination switch
clock reset
Input: none
Output: trigger [to counter]
logic info (L, R, term) [to counter]
10 Hz reference [to counter]
Power: +5V (~1 amp)

Counter:

Controls: auto-manual switch
trigger switch
integration time selector
Input: 10 Hz reference [from clock-controller]
signal in [from VCO]
ext trigger [from clock-controller]
logic info [from clock-controller]
Output: data and status info (BCD) [to H/P]
Power: +5V (~1 amp)

Peripheral:

Chart recorder:
Controls: input attenuator
Input: dc [0-200 mV from PLA]
Output: visual
Power: 110 ac

Squealer:
Controls: volume
Input: VCO [from PLA]

Output: earphone, tape input
Power: +28V (usually batteries)

Tape recorder:
Controls: standard tape rec.
Input: channel 1 - VCO [from PLA]
channel 2 - voice [from Y-connector]

III. Backup system

The onboard backup signal electronics consist of the following instruments:

1. phase lock amplifier
2. counter-clock
3. printer

A failure in the primary system can be associated with the phase lock amplifier, in which case all that is necessary to continue data-taking is to switch to one of the backup PLAs. However, if the failure occurs in either the controller, counter, or computer, the complete backup system must be used. In this configurations, no real-time data reduction is possible since the computer is by-passed; no left-right information is contained in the external trigger. The counter is simply triggered on command, and the output is automatically printed by the printer. This requires the rack operator to pay close attention to the left-right series called out by the telescope operator. If the same beam is repeated on consecutive triggers, this information must be written on the printer paper (or the strip-chart recorder) by the electronics operator.

Computer Operation

I. Operating modes

The Hewlett-Packard program consists of 3 operational modes.

A. "Left-right" or "integration" mode

This mode provides real time statistical analysis of the collected data. It is usually employed whenever low signal to noise ratios are expected. The observation method is described in Telescope Operation, and is simply the alternating measurement of the source from left beam to right beam. The arithmetic and statistical quantities of interest are described below:

The measurement of a source in this mode begins, by convention, with a "left" beam containing the source. Integrations are then alternated between right and left beam. We denote the counter output over the ith integration period by ℓ_i or r_i (depending on whether the data was taken with the left beam or the right beam, respectively). The quantity of interest, representing twice the signal is $N_i = (1/2)\ell_i - r_i + (1/2)\ell_{i+1}$ (note: the subscript i increments with each left-right pair). Thus a set of numbers $[N_i]$ is generated such that ℓ_{i+1} is common to each N_i, N_{i+1} pair. As the $[N_i]$ set is built up, the computer program displays after every left, these statistical quantities derived from $[N_i]$:

mean

$$\mu = \frac{1}{n} \sum_{i=1}^{n} N_i$$

standard deviation

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (N_i - \mu)^2}$$

standard deviation of the mean

$$\sigma_\mu = \frac{\sigma}{\sqrt{n}}$$

and the ratio

$$\eta = \frac{\mu}{\sigma_\mu}$$

It is this last value, the signal-to-noise ratio η that indicates how good the measurement is and whether more left-right integrations should be taken. If η is sufficiently large, the program mode may be terminated and another block of data may then be initiated.

B. "Scan" mode

When η is large, a one-beam incremental scan across the source is employed. This requires the telescope operator to define the direction of the scan, starting position, and increment of movement referenced to the eyepiece retical. The program prints each integration and the position of the telescope in the scan axis. The position is calculated from the starting position and the known scan increment.

C. "Automatic" mode

Whenever a string of data is to be collected (usually noise data), the computer can accept the auto output of the counter, printing out each integration and calculating μ and σ of the data string.

II. Loading the program

turn on computer

press (STOP) (END)

insert mag card containing "Main"

press (LOAD)

press (VARIABLE) (1) (STOP) (END)

ready to begin any of the three possible modes.

III. Operation

A. L-R integration mode

Press (STOP) (END) (CONT) New block is begun

left trigger:	prints counter output as positive number
right trigger:	prints counter output as negative number
left term trigger:	normal termination, statistics printed.
right term trigger:	for termination at any other time — prints the right value, but calculates statistics only through last left.
addendum:	if left term trigger has been performed, and one needs another left, press (CONT) , left (term) trigger.

B. Scan

Press (STOP) (GO TO) (LABEL) (1) new block is begun

enter starting position in scan axis

press (↑)

enter absolute value of scan increment

press (CONT)

left trigger: decrements scan position by scan increment right trigger: increments scan position by scan increment

right term trigger: no increment added (repeats last position).

left term trigger: immediately begins a new scan block (ready for new position and increment to be entered from keyboard).

C. Auto

Press (STOP) (GO TO) (1) (SET FLAG) (CONT)

set counter to auto and initiate with right trigger; to terminate, press term button.

CHECK LISTS PREPARED BY THE PI

Electronics Checkout Procedure

1. Turn on rack and all associated equipment.
2. Check dc output by varying bias and observing strip chart recorder output.
3. Calibrate chart recorder for full scale deflection at +5V dc in.
4. Check VCO output on oscilloscope (~5V p-p).
5. Observe clock for correct operation.
6. Trigger right and left and observe counter display (should be non-zero).
7. Check termination button (light should change status after each press).
8. Load "Main" program into computer.
9. Check all program modes by performing appropriate operations and using controller. (VCO output can be changed by varying bias control on PLA).
10. Check squealer output (using earphone).
11. Check chopper.
12. Check tape record levels (ch 1 - data; ch 2 - voice).

Noise Check

1. Turn on preamp (input to preamp can be either cooled detector or dummy load). Noise should be 10-20 mV peak to peak "grass" on the oscilloscope.
2. Turn on PLA, chopper, and chart recorder.
3. Check dc output on strip chart recorder (noise should be ~1-5 units at G9 on #1 PLA).

Dewar Preparation and Installation Checklist

Preparation:

1. Pump dewar vacuum jacket to ~5μ pressure.

2. Fill both containers with LN_2.

3. Allow to cool for > 15 min.

4. Close dewar vacuum jacket valve and remove from pump.

5. Pour LN_2 completely out of both containers.

6. Refill outer LN_2 jacket.

7. Transfer LHe into center container.

8. When transfer is complete, seal LHe container from atomosperic contamination by use of a balloon.

Installation:

1. Insure that dewar window is dry (by visual inspection). Diamond-coated windows may be dried by a fan or heat gun (use low heat only). Uncoated windows may be dried with a clean rag.

2. Check to see that mounting bolts all have electrically insulating washers and sleeves.

3. Position dewar onto guide pins on beam splitter.

4. Before tightening bolts down, rotate dewar clockwise to insure consistent positioning from installation to installation.

5. Tighten bolts to a few foot-pounds.

6. Insert hose tube assembly (making sure cork is seated).

7. Attach roughing pump hose.

8. Begin pump down of LHe slowly.

9. Gradually open manifold valve over 15 min. period.

10. When pressure < 35 mm Hg, λ point is passed and valve should be now be fully open.

Trouble: If cork pops off and gauge still shows low pressure, replace it and pinch pump hose closed for several seconds and release. Continue until cork stays sealed. If gauge shows atmospheric pressure, remove pumping fixture and clear ice plug from neck tube.

CHECKLISTS PREPARED BY EOs
L = Liftoff

L -4 hours

- Check vacuum pump status
- Mechanical pump on

L -3-1/2 hours

- Start pump down
- Fill diffusion pump with LN_2

L -3 hours

- Start chilling dewar
- Fill dewar with LN_2 and LHe

L -1-1/2 hours

- Install dewar
- Check continuity
- Start pump down
- Start gyro warm up
- Check telescope balance
- Load paper in strip charts
- Load tapes in recorder

L -45 minutes

- Check gyros on
- Check stabilization
- Check torque motors off
- Check dewar pressure $\leq$ 10 mm
- Turn on rack and all associated equipment
- Check dc by varying bias
- Check preamp output (10 mV peak to peak)
- Trigger L and R, observe lights and counter display
- Check termination button
- Check squealer
- Check chopper
- Check dc output on strip chart (noise ~1-5 units @ G9 on #1 PLA)
- Check phasing and signal with hand (best done outside of hangar)
- Check tape recorder levels
- Review equipment list:
    - Flight plan
    - Observing plan
    - Star charts
    - Karl's notebook
    - Lee's knee board
    - Flashlights

Pencils and pens
Watches
Tool kit
Spectacles
Magnetic tape
DVM
Spare preamp
Spare cables
Green tape
Wallets

Before strapping in:

Bungee cord on telescope
Tape recorder on
Chopper on
Computer off
Torque motors off
Dome lights off
Tool bag tied down

TABLE D-1.- STATEMENT OF PROGRESS IN TRAINING — SEPTEMBER 9, 1974

X = Self rating
O = PI rating

Category of instruction	Operator training status							
	Well prepared		Adequate		Need more		None yet	
	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]
<u>Overall experiment</u>								
Research objectives			XO	XO				
Experimental method	XO	X		O				
Program planning			X	X	O	O		
Astronomy and star fields	O				X	O		X
Assembly and installation			XO	XO				
Alignment of optics	X	X					O	O
Calibration of system			XO			XO		
Equipment servicing			XO			X		O
Preflight checkout						X	XO	O
Target acquisition and tracking							XO	XO
Electronics operation			XO	XO				
Overall experiment maintenance			XO	O		X		
Review of potential problems					XO	XO		
Data processing			X			X	O	O
Data evaluation					X	X	O	O
<u>Components</u>								
Telescope optics								
- operations theory (O.T.)	X		O	XO				
- operations procedure (O.P.)			X	X		O	O	
- maintenance (M.)			X	O	O	X		
Telescope stab. system								
- O.T.			XO	O		X		
- O.P.			XO	XO				
- M.				O	XO	X		
Chopper - O.T.	X		O	O		X		
- O.P.	X				O	XO		
- M.			X		O	XO		
Dewar - O.T.	XO			XO				
- O.P.		X	XO	O				
- M.			XO	XO				
Detector - O.T.	O		X	XO				
- O.P.			XO	XO				
- M.			X	XO	O			
Signal conditioning electronics								
- O.T.			XO	XO				
- O.P.	O		X	XO				
- M.					XO	XO		

[a]Telescope operator
[b]Electronics operator

TABLE D-1.- CONCLUDED

X = Self rating
O = PI rating

Category of instruction	Operator training status							
	Well prepared		Adequate		Need more		None yet	
	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]	T.O.[a]	E.O.[b]
Components - Cont.								
Tape and chart Rec. - O.T.	XO	O		X				
- O.P.	O	O		X	X			
- M.			XO	O		X		
Computer system - O.T.	X			X	O	O		
- O.P.				X	XO	O		
- M.			X		O	XO		
Back-up Equipment			X	X	O	O		
Test Equipment			X		O	XO		
Other Functions or Equipment								
1. Use of tools, spares, supplies						X		
2.								
3.								
4.								

[a]Telescope operator
[b]Electronics operator

APPENDIX E

INVENTORY OF TOOLS, TEST EQUIPMENT, SPARE PARTS, AND CONSUMABLES

Tables E-1 and E-2 list the contents of the EOs' flight tool bag and the support equipment in the work area, respectively. Spare or replacement electronic units have been noted earlier in appendix C. The tables show which of the items were used by the EOs, and those brought into confinement while the mission was in progress.

TABLE E-1.- CONTENTS OF FLIGHT TOOL BAG

Item	Utilization		
	Not used	Used in flight	Used on the ground
1 set small open end wrenches			X
1 small screwdriver		X	X
1 jeweler's screwdriver	X		
1 set small Allen wrenches			X
1 set large Allen wrenches	X		
1 pair pliers			X
3 needle nose pliers			X
3 7/16" box wrenches			X
1 wire stripper			X
1 wire cutter			X
1 gripper screwdriver			X
1 torque set screwdriver	X		
1 set torque set heads	X		
1 pair tweezers			X
1 roll electricians tape		X	X
1 set BNC T connectors			X
1 roll solder			X
1 battery-operated soldering iron			X
1 set spare dewar mounting hardware			X
1 set small lead weights (balance)	X		
Spare fuses - 2, 5, 10, 20 amps		X	
Electric wire			X
2 spare D cell batteries		X	
2 flashlights		X	
1 roll green tape		X	X
1 DVM (battery operated)		X	X
1 spare preamp		X	X
Mechanics mirror		X	X
Spare signal cable		X	X
Spare electronic cables		X	X
Spare stopper for dewar	X		
TOTALS 31	6	11	22

TABLE E-2.- EQUIPMENT IN EO WORK AREA

		Not Used	Used
(a) Tools			
1 hacksaw		X	
1 file			X
1 tap set		X	
1 set jewelers screwdrivers		X	
1 awl		X	
1 set counterpunches		X	
1 scribe		X	
Various screwdrivers, wrenches, needle-nose pliers (est. 10)			X
1 reamer		X	
1 pair pliers			X
1 torque set screwdriver		X	
1 Phillips screwdriver			X
2 Exacto knives			X
1 feeler gauge		X	
1 channel lock pliers			X
1 pair scissors			X
4 C clamps		X	
Tip for soldering iron		X	
1 heat gun			X
2 funnels			X
1 can opener		X	
1 measuring tape			X
1 safety glasses			X
Tools in flight bag (17 items)		4	13
TOTALS	40	16	24
(b) Test equipment			
Dummy source for preamp		X	
1:10 attenuator		X	
1:1000 attenuator		X	
Various load resistors		X	
Jumper cables			X
Signal generator		X	
Power supply (0-30 Vdc, 1 amp)		X	
H/P accessories (mag. cards, BCD interface, math ROM)		X	
Laser (used to check and adjust chopper)		X	
Slide projector (used to align optics)*			X
2X-3X zoom converter for guide scope		X	
Items in flight bag (1)			1
Vacuum pump systems (2) ASO; (1)*			2
TOTALS	14	9	5

*Supplied by ASO during the simulation mission.

TABLE E-2.- CONCLUDED

	Item	Not used	Used	Amount
	(c) Spare parts			
	Integrated circuits†	X		
	Assorted transistors†	X		
	Chopper cable		X	
	Vacuum hoses		X	
	Dewar windows (2)		1	
	Balance weights		X	
	Set O-rings	X		
	Dewar pumping fixture		X	
	Dewar stopper	X		
	Recorder pens (3)		X	
	Assorted bolts	X		
	Hose clamps		X	
	Spares in flight bag (7)	1	6	
	TOTALS 20	6	13	
	(d) Consumables			
	Chart recorder paper		X	9 rolls
	H/P printer paper		X	~18 m
	Digital printer paper (roll)		X	30 cm
	Magnetic tapes (cassette)		X	18
	Balloons		X	10
	Tablet paper		X	~20 sheets
	Batteries; 1.3 to 22.5V (20)		X	
	Miniature lamps	X		
	Heat shrink tubing	X		
	Aluminum foil*		X	
	Emery paper		X	
	Rope	X		
	Varnish		X	
	RTV cement	X		
	Cotton swabs		X	
	Kel-F rod	X		
	Teflon sheets (0.8 & 1.6 mm)		X	
	Silicone grease		X	
	Epoxy cement		X	
	Adhesive tape (1 roll)		X	
	Loctite	X		
	Items in flight bag (4)		4	
ASO	Helium gas (215 SCF @ 2500 psi)		X	50 SCF
ASO	Liquid helium (60 ℓ)		X	54 ℓ
ASO	Liquid nitrogen (320 ℓ)		X	210 ℓ
	TOTALS 28	6	22	

†Complete replacement set for primary clock/controller and counter.
*Supplied by ASO during mission.

APPENDIX F

TELEPHONE AND TELEVISION LOGS

Tables F-1 and F-2 are records of telephone use by the EOs in the work area and the PI in the Mission Center, including the destination and purpose of the call. Table F-3 lists uses of the two-way TV link between the same two areas, with elapsed time for each contact, and a summary of total utilization for different task areas.

TABLE F-1.- OPERATORS' PHONE LOG

Date	Time	From	To	Purpose
30 Sept.	1830	Henize	Home	Crew morale
2 Oct.	1530	MMC	Henize	S019 Skylab photos
	1600	Ames	Henize	Discussion of telescope boot binding
	1615	Henize	PI	Discuss flight plan
	1640	Weaver	PI	Operation of backup tape recorder
	1700	Henize	Home	Crew morale
	1730	Henize	Mission Center	To report water heater malfunction
3 Oct.	0920	Weaver	NASA/MSFC	Ames/ASO visit to MSFC
	1500	Henize	Mission Center	Report that experiment systems up and ready to go
	1730	Henize	Home	Crew morale
4 Oct.	1330	Henize	NASA Base Operations	Plans for next week
	1340	Henize	NASA/JSC	Trip arrangements
	1450	Henize	NASA/JSC	Check in at Office
	1500	Weaver	ASO	Airline reservations
	1640	Weaver	Mission Center	Looking for MSFC representative
	1700	Henize	Home	Crew morale
	2200	Weaver	Home	Crew morale
	2230	Weaver	Mission Center (PI)	Tape recorder problem
5 Oct.	1600	Henize	Commercial Airline	Reservations
Total	19			

TABLE F-2.- PI PHONE LOG

Date	Time	From	To	Purpose
30 Sept.	1625	Senior PI (home lab)	PI	Status of mission
1 Oct.	1215	PI	Asst. scientist at home lab	General information
	2355	PI	Senior PI at home lab	Discuss results of first flight
2 Oct.	2306	Senior PI (home lab)	PI	Review problems and equipment status
3 Oct.	0030	PI	Senior PI at home lab	Discuss dewar problem and plan action
	0345	PI	EOs	Resume dewar repair
	0430	PI	Asst. scientist at home lab	Diagnosis of dewar problems
	Between 0430 & 0600	PI	Technician at home lab	Photometer optics repair
	0615	PI	Technician at home lab	Discuss dewar alignment procedures
	2340	PI	Senior PI at home lab	Flight results after repairs completed
4 Oct.	0230	PI	Senior PI at home lab	Discuss progress of mission
	0400	PI	Asst. scientist at home lab	Results from flight with repaired dewar
	2230	EO	PI	Discuss cabling and gain settings on tape recorder
5 Oct.	1830	EO	Senior PI at Ames	Discuss telescope problem
Total	14			

TABLE F-3.- TELEVISION LOG

Date	Time on	Minutes	Purpose
30 Sept.	1710-1745	35	Flight planning
	2245-2300	15	Preflight preps
1 Oct.	1220-1235	15	Flight planning
	2139-2145	6	Flight results
	2225-2300	35	Flight results
	2310-2335	25	Flight planning
2 Oct.	1340-1350	10	Flight planning
	1355-1405	10	Flight planning
	1605-1625	20	Flight planning
	1642-1645	3	Preflight preps
	2115-2155	40	Flight results
	2235-2250	15	Equipment repair
	2315-2320	5	Equipment repair
3 Oct.	0057-0103	6	Equipment repair
	0400-0455	55	Equipment repair
	1605-1610	5	Preflight preps
	1620-1625	5	Preflight preps
	2125-2140	15	Flight results
	2215-2255	40	Flight results
	2330-2335	5	Flight results
4 Oct.	0005-0020	15	Flight planning
	0345-0400	15	Flight results
	1745-1755	10	Flight planning
	2130-2150	20	Flight results
	2245-2250	5	Preflight preps
5 Oct.	0225-0305	40	Flight results
	1730-1735	5	Preflight preps
	1800-1815	15	Preflight preps
	Total	490 min in 28 consultations	

Division of time for TV usage

Flight planning (8)	140 min = 28%
Flight preparations (7)	53 min = 11%
Flight results (9)	216 min = 44%
Equipment repair (4)	81 min = 17%

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