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CVT/GPL PHASE II INTEGRATED TESTING

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April 5, 1974

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16. ABSTRACT

Five emperiments representing Earth Observations, Space Physics, and Material Sciences disciplines were installed in the General Purpose Laboratory (GPL). The experimenters were asked to provide engineering data and an outline of the experiment protocol and to simultaneously perform their experiments to their protocol for 8 hours per day during 4.5 days of integrated testing. A description of the experiments and the GPL is provided. Assessments of the experiment interfaces with the GPL and GPL support systems are presented. Four of the five experiments planned were completed to the satisfaction of the experimenters. During checkout, prior to initiation of testing, a vacuum-induced failure within the liquid helium dewar used in the Superfluid Helium Experiment resulted in loss of capability to carry out this experiment as planned. Overall, experiment interfaces with the GPL were satisfactory, Improvements can be made to provide more satisfactory utilization of the drainage and high vacuum systems of the GPL support facilities, more effective design of workstation layouts and equipment arrangements, more efficient experiment operation within experiment location volume constraints, a more reliable time code signal capability, and an environment conducive to more beneficial crew interaction and greater mission productivity. GPL systems operations were generally satisfactory. Improvements can be made to provide for better lighting and noise control, more effective communications, and less intrusion on experiment activities for documentary purposes.

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CVT/GPL PHASE II INTEGRATED TESTING

SUMMARY

This report presents the results of the Phase II Concept Verification Testing/General Purpose Laboratory (CVT/GPL) integrated test. Assessments of experiment and GPL subsystem integration are included. Significant experiment/GPL interface and GPL experiment support system problems are identified and suggestions for improvements are given.

The test incorporated GPL design changes that were recommended as a result of Phase I testing and demonstrated the integration feasibility for a multidiscipline experiment payload for Spacelab missions. Experiment interfaces with the GPL were generally satisfactory and most experiment objectives were met. An experiment equipment failure during pretest checkout resulted in greatly reducing the scope of one experiment. GPL systems operations were generally satisfactory. Recommendations for more effective communications and less intrusion on experiment activities, for documentary purposes, were made. Measurements of environmental parameters indicated that improvements can be made to provide better lighting and noise control. Information collected will support Spacelab requirements development and will aid in refining GPL test methods.

INTRODUCTION

As the Shuttle becomes a more predominant factor in NASA activity, the payloads for Shuttle missions present a significant integration and support challenge. Spacelab experiment accommodations and support must be flexible enough to accept various disciplines on successive flights and on the same flight at low cost and with rapid recycling of experiment complements on the ground. Low cost and rapid recycling are considered to be inconsistent requirements in reviewing Skylab and Lunar Landing Programs. It is clear that Shuttle payload carriers (i.e., Spacelab) require a new approach by NASA. A significant endeavor to define this new approach is the Concept Verification Testing Project.

CVT is a central NASA payload integration activity involving electrical, mechanical, and experiment breadboards, a general purpose laboratory and a pallet assembly. The GPL and pallet (Fig. 1) provide the hardware for investigating experiment integration concepts for Spacelab. This test involved five experiments: Cloub Physics, Ionospheric Distrubances, Material Sciences, High Energy Astronomy, and Superfluid Helium. These can be summarized as follows:

1. Cloud Physics — Principal Investigator, Mr. Otha H. Vaughan, Jr. Study fog formation and dissipation, using various chemicals as seeds, and photograph results. Obtain data for refinement of experiment apparatus and operating procedures.

2. Ionospheric Disturbance — Principal Investigator, Mr. George West. Study ionospheric density, depth, and distrubance periods by transmitting at 4.0125, 4.759, and 5.735 MHz, from three sites [162 km (90 mi.) from MSFC] and receiving the reflected signals in the GPL.

3. Material Sciences — Principal Investigator, Dr. Mary Helen Johnston. Obtain ground-based information on sintering and undercooling processes while performing tests of processing facilities and developing operational techniques.

4. High Energy Astronomy — Principal Investigators, Dr. Tom R. Parnell and Dr. Tom A. Rygg. Investigate experimenter functions and training requirements for operation of cosmic ray detection apparatus while demonstrating use of equipment in CVT/GPL-pallet configuration. Evaluate interface and acquire data from sea level cosmic rays (mu mesons) applicable to refinement of system.

5. Superfluid Helium — Principal Investigator, Dr. Eugene W. Urban. Test techniques for generating Helium-II droplets and obtaining photographs of droplet behavior. Perform operational checkout of equipment and procedures.

The experimenters were requested to provide the Test Team with the physical requirements for the experiment/GPL interface, to cooperate with the Test Team to develop detailed procedures for their experiments, and to check out the experiment in the GPL. With these minimum constraints, the experimenters were then free to conduct their experiments as they deemed necessary, within safety limits. Observations by the Test Team were limited to the adequacy of the GPL to meet experiment and experimenter needs and the interaction of experiments.

An assessment of experiment interfaces with the GPL and an evaluation of GPL systems integration was conducted during the test. The purpose of this report is to present observations concerning GPL/experiment interfaces, results of the GPL systems integration evaluation and a general description of the experiment results; scientific reports are the responsibility of individual principal investigators.

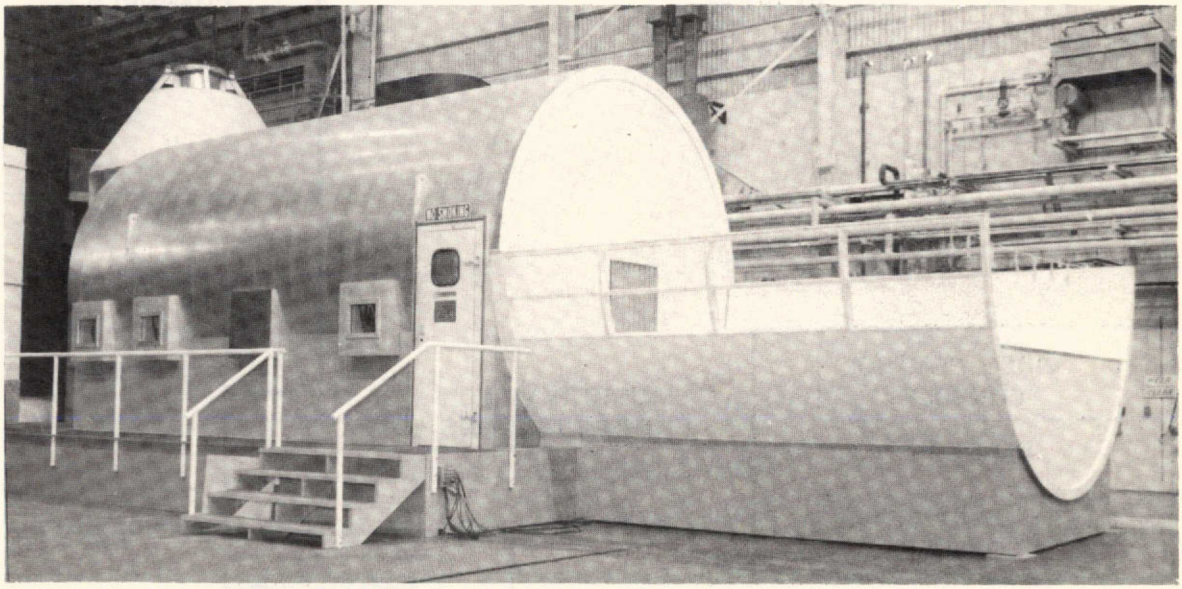


Figure 1. General Purpose Laboratory and pallet assembly.

APPROACH

Test Facility

The test facility consisted of the GPL/pallet aseembly and external facilities for test control, data handling and utilities (Fig. 2). As a result of Phase I testing, GPL experiment interface facilities were modified and standard laboratory support equipment was removed. Equipment which was removed included a sterilizer, fume hood, refrigerator, laboratory glass washer, and distilled water center. Experiment interface changes included the addition of electrical power and fluids interface panels and rerouting of cables to facilitate experiment hookup.

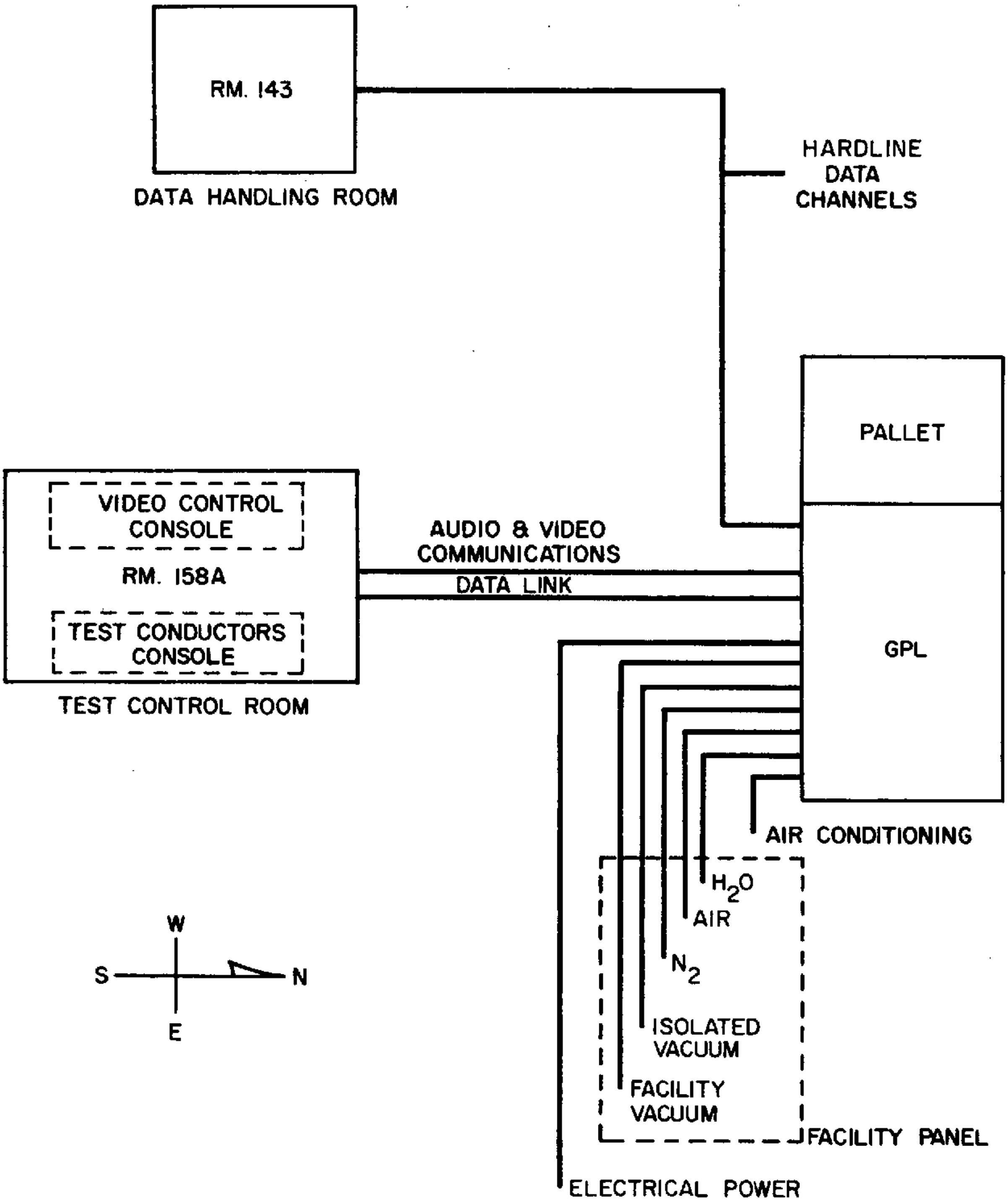
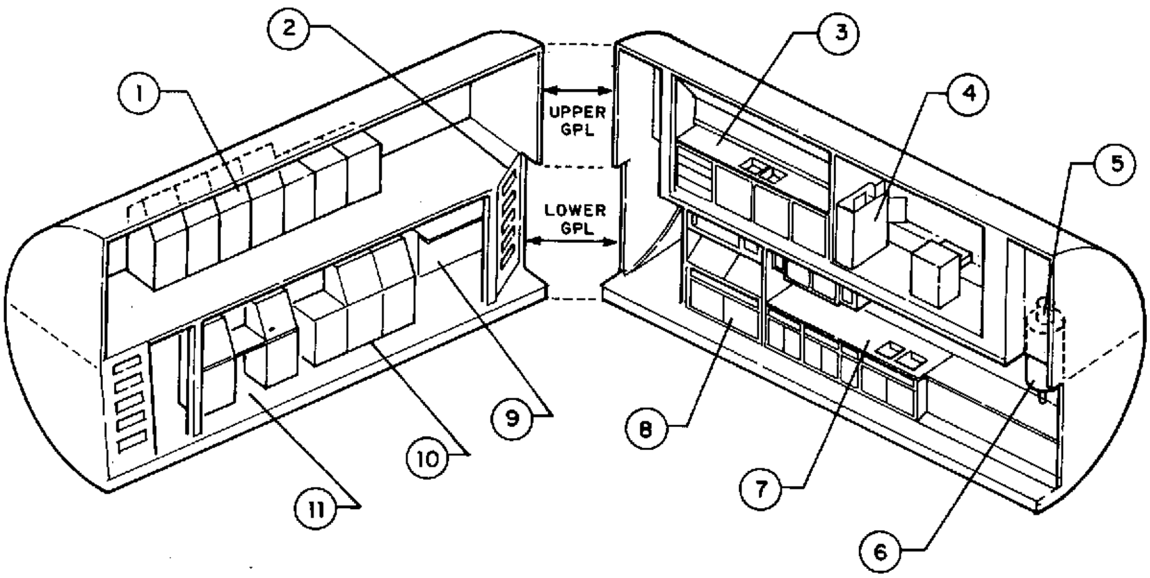


Figure 2. Test facility layout in Building 4619.

GPL/Pallet Assembly. The GPL provided a test enclosure representative of Spacelab's internal diameter. The GPL has a 4.3-m (14-ft) external diameter, a 4.1-m (13.5-ft) internal diameter, and a length of 7.3 m (24 ft). It contains two levels, designated lower GPL and upper GPL, as illustrated in Figure 3. The GPL floor is an offset configuration (Fig. 4), which improves ground access (1-g operations) and maximizes volume utilized for experiment hardware and crew workstations. The GPL floors are designed to withstand 45.4 kg/m^2 (100 lb/ft^2).

Upper GPL. Workstations located on the upper level included those for the Cloud Physics and Ionospheric Disturbance experiments, part of the Superfluid Helium experiment, and a general purpose station including a sink and work surface area. Stowage provisions consisted of drawer and cabinet space in the sink unit, and a row of cabinets above the experiment area on the high section of floor. Experiment hardware and accessories, where feasible, were mounted in EMCOR modules.



1. Ionospheric Disturbance Experiment
2. Ladder Between Upper and Lower GPL
3. General Purpose Workstation
4. Cloud Physics Experiment
5. Superfluid Helium Experiment (Upper GPL)
6. Superfluid Helium Experiment (Lower GPL)
7. General Purpose Workstation
8. Engineer Station
9. Engineer Station
10. High Energy Astronomy Experiment
11. Material Sciences Experiment

Figure 3. Workstation arrangement in CVT/GPL.

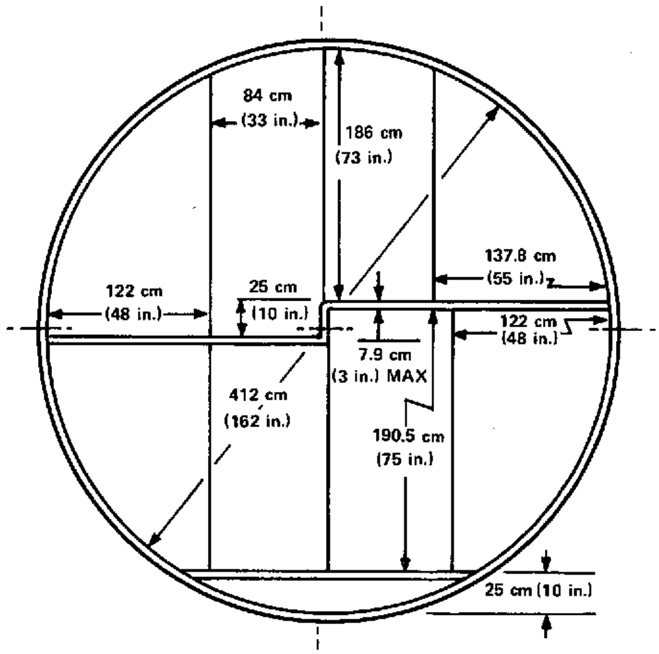
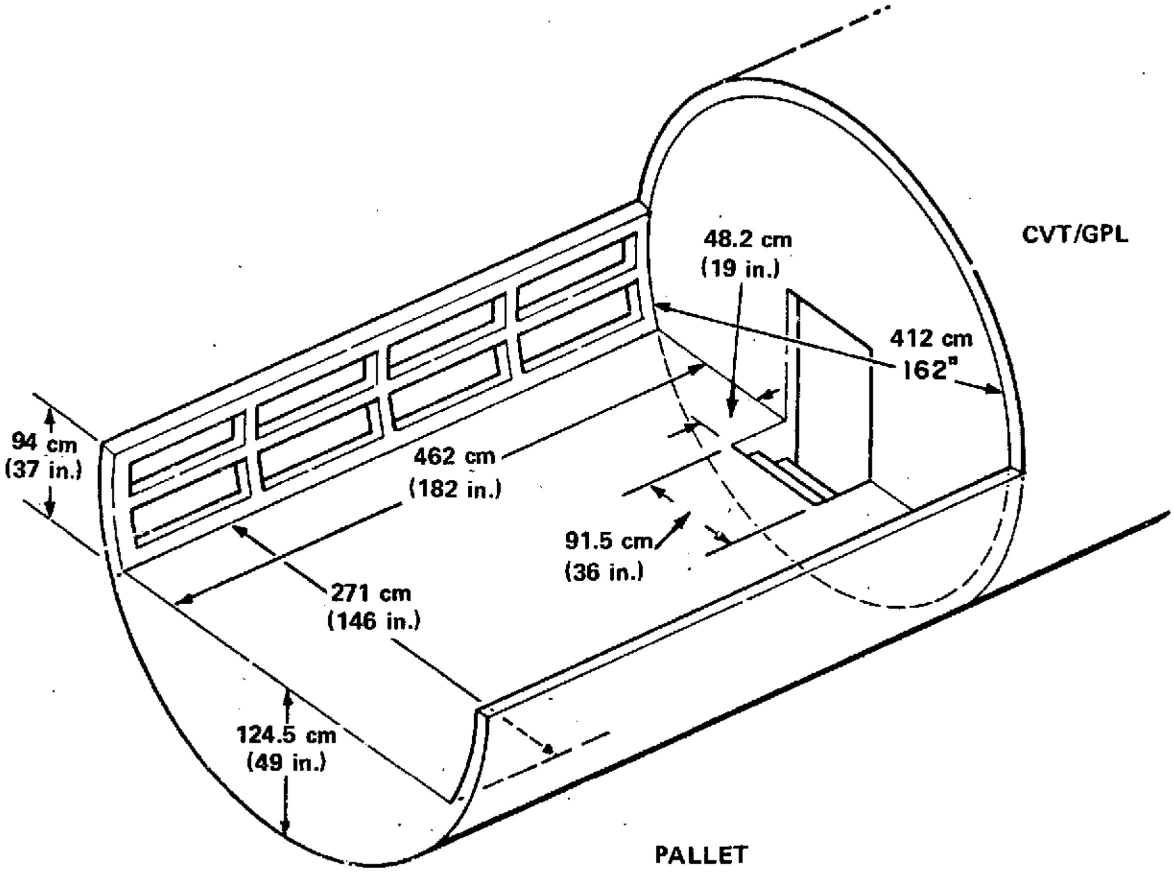


Figure 4. GPL offset floor configuration.

Lower GPL. The lower level included the High Energy Astronomy and Material Sciences experiment stations, part of the Superfluid Helium experiment station, the engineer's stations, and a general purpose workstation. As on the upper level, stowage provisions consisted of drawer and cabinet space in the sink unit and a row of cabinets above the experiment area. Where feasible, experiment hardware and accessories were mounted in EMCOR modules.

Access. Personnel access to the GPL is gained through a 96.5 by 207.2 cm (38 by 82 in.) airlock doorway on the east end of the GPL. A 71 by 207.2 cm (28 by 82 in.) emergency doorway is located on the north side of the GPL (quick-release for emergency egress). A ladder is located at each end of the GPL for access to the upper deck. This provides approximately a 101.8 by 81.2 cm (40 by 32 in.) opening for hardware transfer between decks.

Pallet. The pallet is a cylindrical half-section, 3.7 m (12 ft) wide and 4.9 m (16 ft) long. It was attached to the west end of the CVT/GPL and was accessible from the CVT/GPL through a hatch, as illustrated in Figure 5. The cosmic ray detection apparatus for the High Energy Astronomy Experiment was mounted on the pallet.



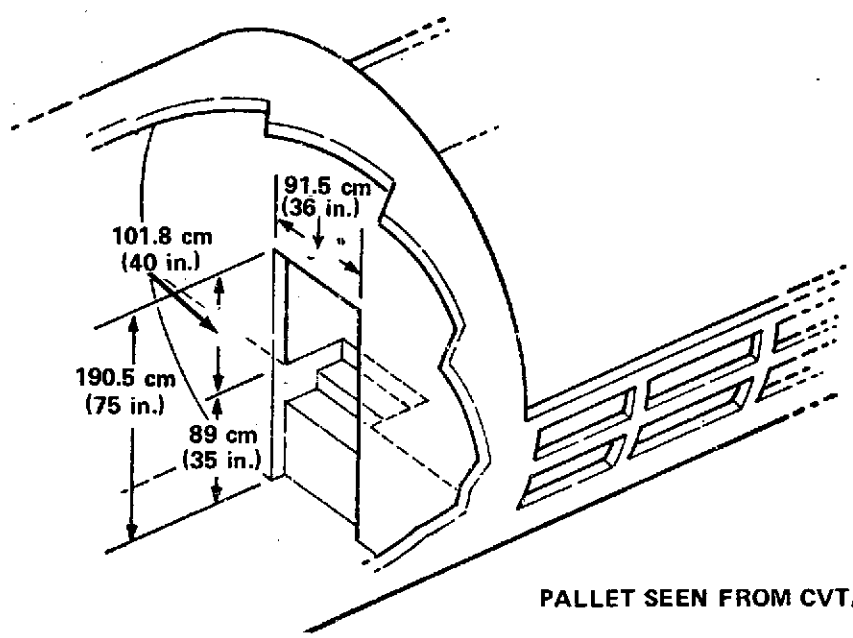


Figure 5. Pallet assembly.

Illumination. All GPL lighting is fluorescent and is permanently installed in the upper and lower decks. Master switches are located on both decks to control all the lights on the respective decks. In addition, some local light switches are provided. Additional illumination was available for installation upon request from an experimenter.

Temperature and Humidity Control. Temperature and humidity control was supplied by means of externally and internally cooled atmosphere and thermostatically-controlled duct heaters with distribution through fan/coil units located in the upper GPL. The conditioned air flowed through the GPL and was dumped overboard.

Support Facilities. The facilities utilized by the GPL included water, sewage, vacuum, GN_2, missile grade air pressurant, and electrical power. Additional support facilities included a test control room and a data handling room.

Test Control Room. The test control room, located near the GPL in room 158-A, was the center of external test operations. It included the video control console (Fig. 6) and the test conductor's console (Fig. 7).

Data Handling Room. The data handling room, located in the west end of Building 4619, room 143, was available for experiment and basic GPL system data collection. It contained magnetic tape and strip chart recorders which were connected to approximately 100 data channels leading to the GPL. This facility was not utilized for Phase II testing.

Experiment Facilities. The GPL was furnished with water, sewage, vacuum, GN_2, missile grade air pressurant, lighting, and hot and cold potable water. Waste water flowed into the sanitary sewerage. The vacuum was provided by MSFC facility system rated at 3 torr and a small vacuum pump rated at 0.1 toor. Internal fittings for access to the vacuum system were standard AN 1.3 cm (0.5 in.) bulkhead fittings. The pressurant gases were GN_2 and missile grade air at 6.89×10^5 N/m^2 (100 psi). [Gas fittings were standard 0.64 cm (0.25 in.) bulkhead fittings]. A typical fluids interface panel is shown in Figure 8. Three of these panels were located on the upper level and four were located on the lower level.

Figure 6. Video control console.

Figure 7. Test conductor's console.

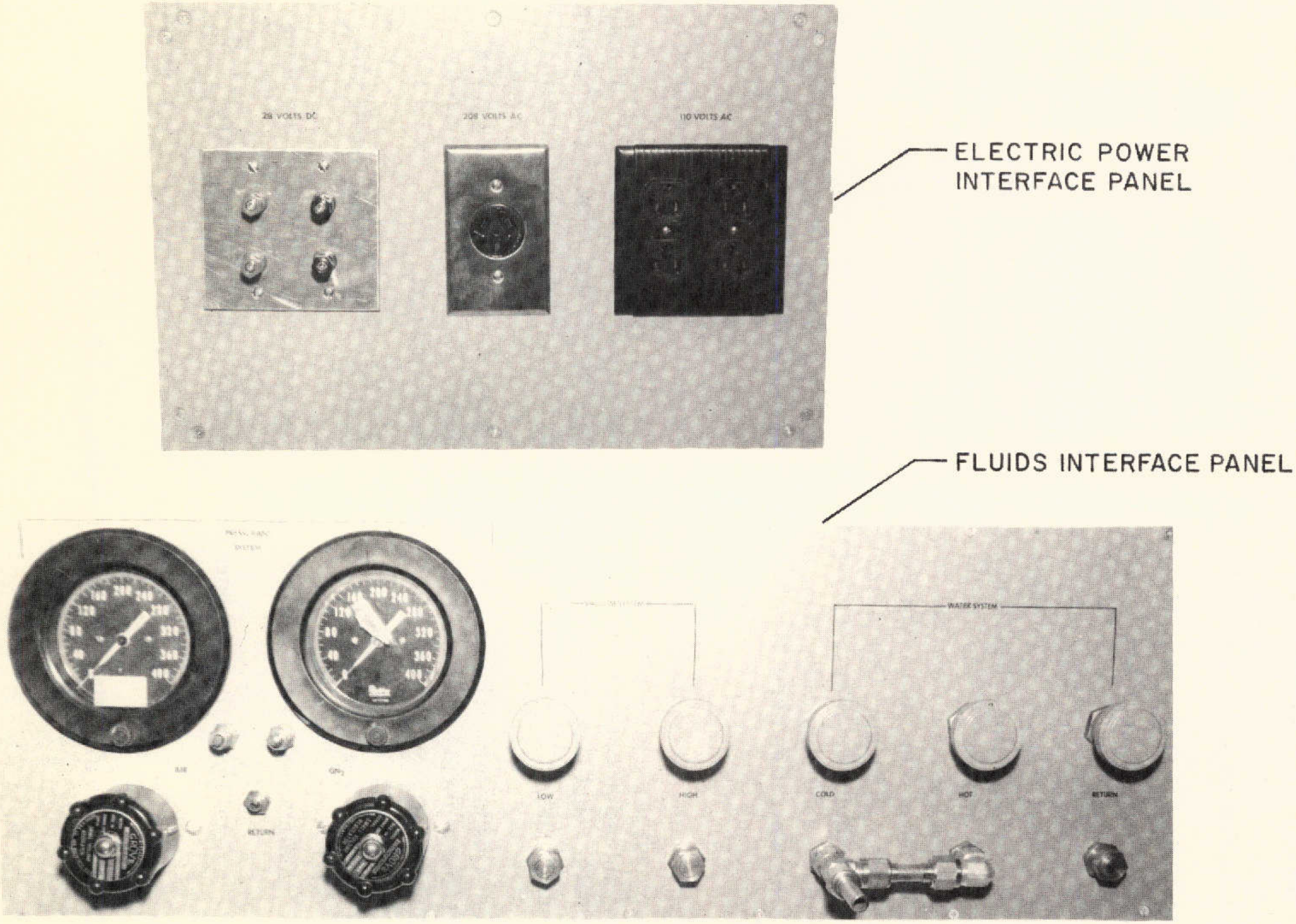


Figure 8. Typical electric power and fluids interface panels.

Power available for GPL experiments included 28 Vdc, 110 Vac, and 220 Vac (single phase, 60 Hz). Also available upon request by an experimenter were 120/208 Vac (3-phase, 400 Hz). A typical electrical power interface panel is shown in Figure 8. Two of these panels were located on the upper level and four were located on the lower level.

Instrumentation wiring in the GPL provided the capability for recording and monitoring experiments and GPL systems hardware. Approximately 100 channels were available.

Engineers Console. The engineer's console (Fig. 9) contained equipment for monitoring selected systems and managing other data. An intercommunications station included in this console provided an audio link to other areas of the GPL, as well as a link to the control room. A video link provided the capability to monitor and record audio on video tape. A caution and warning system was also included. Other items at this workstation included a library containing equipment drawings, schematics, operating procedures, maintenance logs, and other documentation; and a maintenance repair kit. A schematic of the GPL communications and data links is given in Figure 10.

Operations

Test Team. The operational test team dipicted in Figure 11 consisted of the test conductor, a support organization, and the simulator crew. The support organization consisted of an engineer with on-call assistance, an on-call medical doctor, and experimenters as required to assist the crew in performing experiments. The crew consisted of a mission manager and experimenters.

Test Conductor. The test conductor was responsible for the operation of the GPL for a period of 8-hours a day, or until relieved by an authorized test conductor. His responsibilities included the following:

1. Direct the performance of all external functions in support of GPL.

2. Maintain the required complement of support personnel at all times.

3. Select and train a support crew (engineer and experimenters).

4. Direct all communications with the crew.

5. Monitor all GPL caution and warning system parameters.

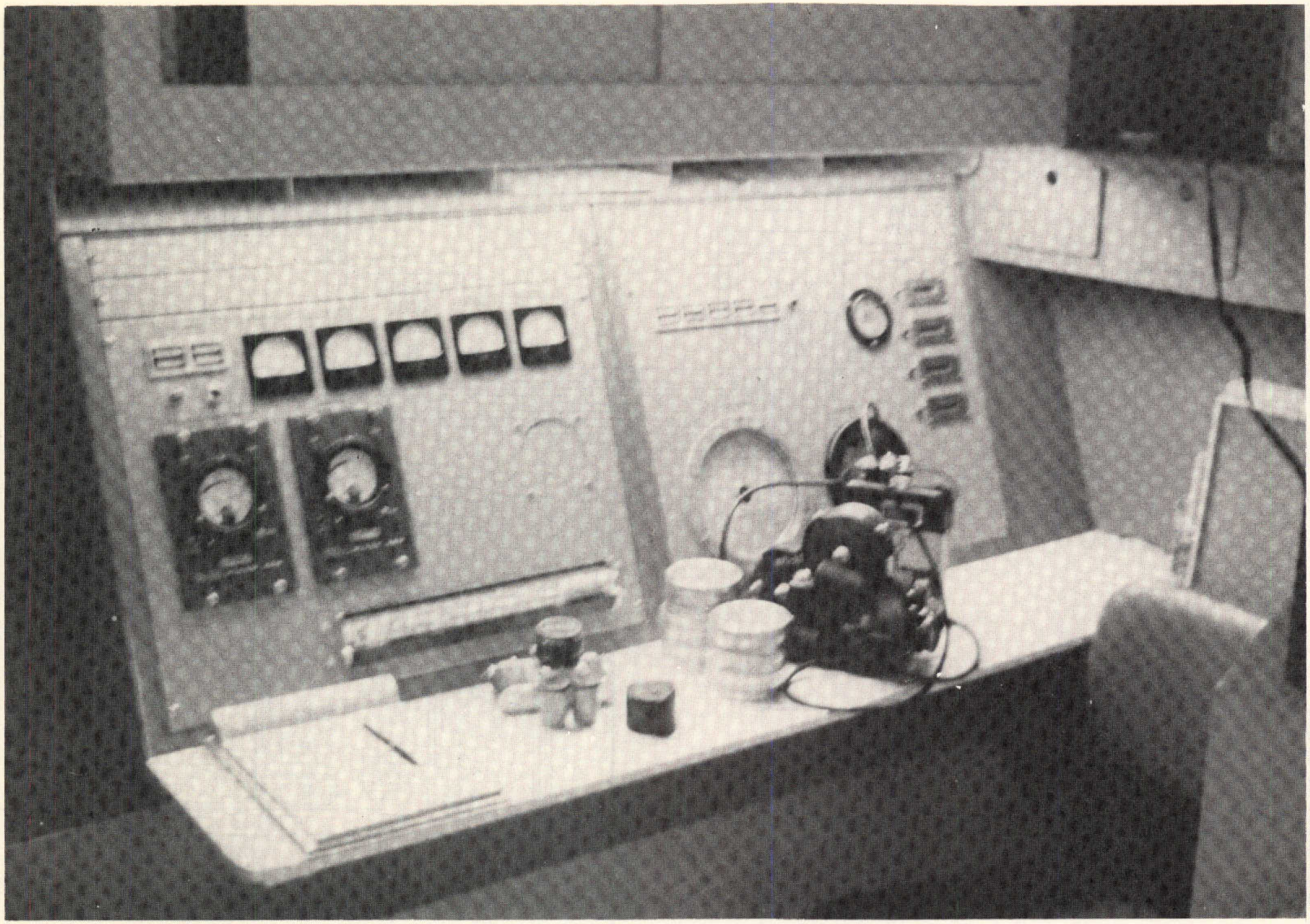


Figure 9. Engineer's console.

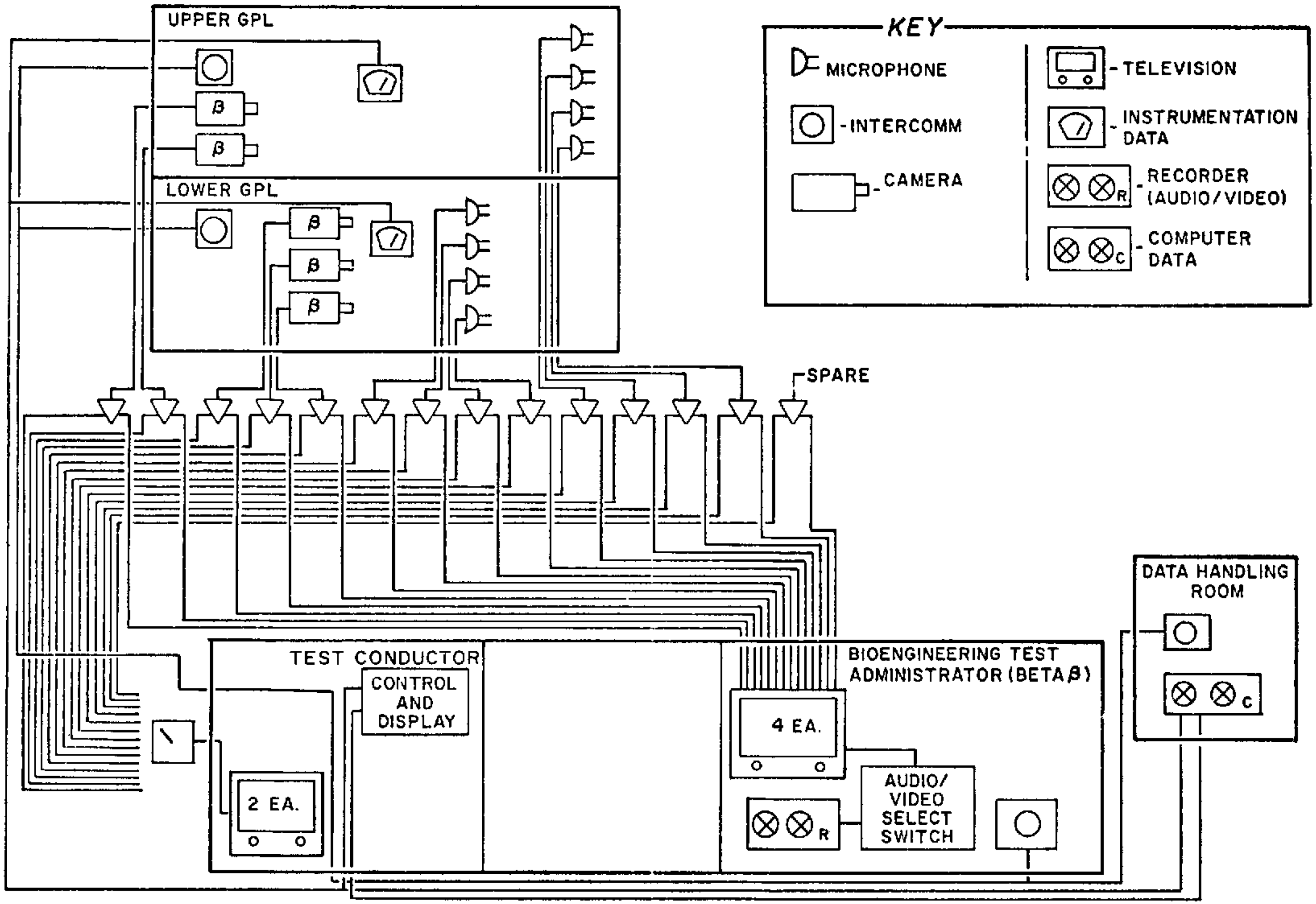


Figure 10. Communication and data handling schematic.

6. Declare any emergency conditions and implement emergency procedures.

7. Maintain equipment logs.

8. Maintain location of on-call medical doctor.

9. Prepare all test reports.

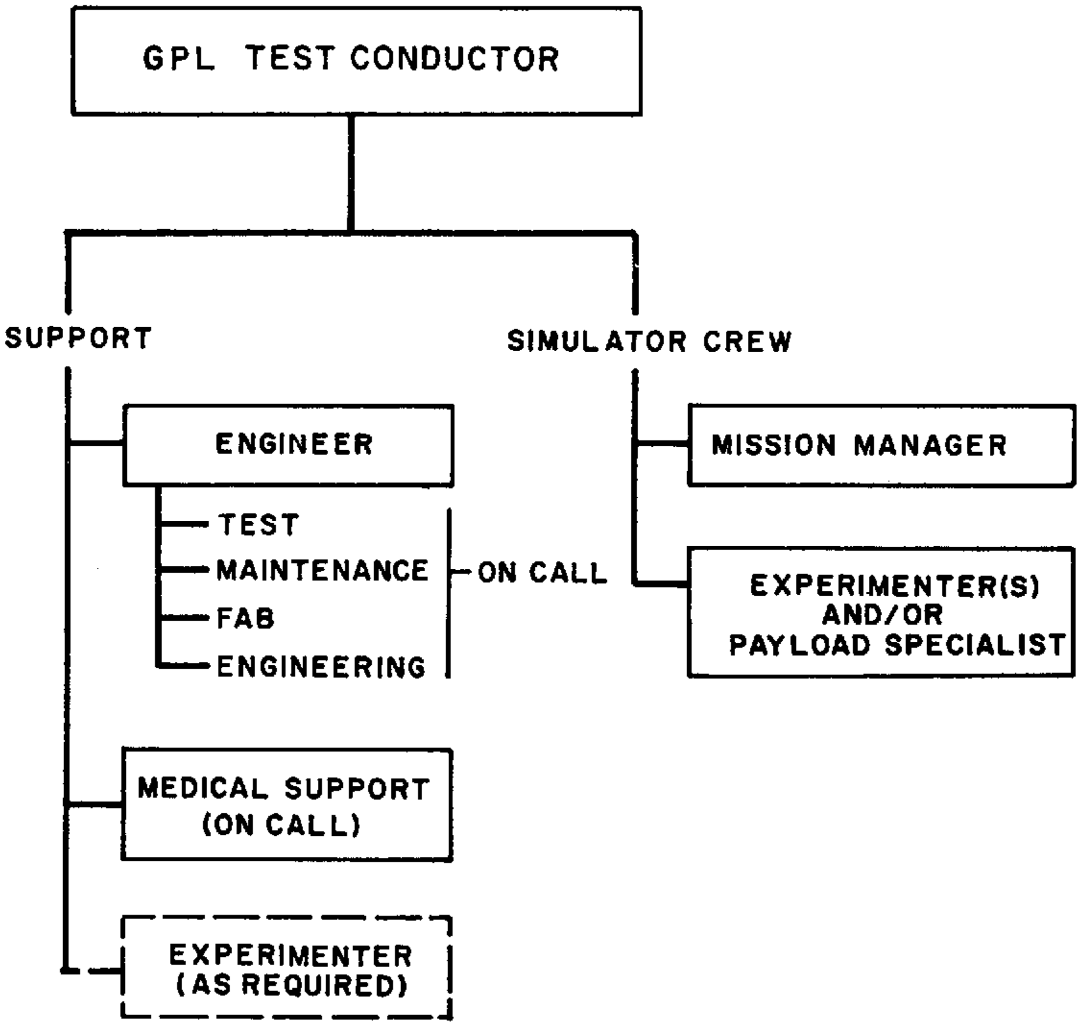


Figure 11. Operational test team.

Support Engineer. The support engineer was responsible for monitoring all test parameters and maintaining the GPL operational. The support engineer identified an on-call support staff and maintained the location of each person. The support engineer assisted the test conductor as directed in resolving operational problems.

Medical Support. The medical support personnel were responsible for providing medical services for the crew, as required, during the operation of the GPL. The medical support was a medical doctor licensed to practice medicine in the State of Alabama. Medical support was on-call during the test run.

Mission Manager. The Mission Manager was responsible for the following:

1. Preparation of daily work schedule.
2. Maintaining equipment log as required.
3. Compiling and transmitting requested reports.
4. Monitoring GPL operating parameters as required.
5. Providing documentary photography of test activities.
6. Reporting anomalies to the test conductor for disposition.

Payload Specialist. Individuals selected and/or trained by the experimenter to operate experiment equipment and obtain data were designated as payload specialists.

Crew. The crew was composed of a mission manager and the experimenters or their designated payload specialist.

Objectives

Experiment Integration. Experiment interfaces with the GPL were assessed with the objective of evaluating and/or determining methods, techniques and requirements for assuring experiment compatibility with the GPL and other experiments. The information collected for this assessment varied slightly from experiment to experiment but typical parameters usually included carrier support to experiments, relative layout of experiments, experiment volume requirements, and data requirements and experiment location with respect to GPL support equipment. Observations were made regarding the following:

1. GPL support facilities.

2. Workstation layout and equipment arrangement.

3. Equipment volume.

4. Data requirements with respect to GPL support equipment.

5. Crew interaction.

Systems Integration. A system integration evaluation was made to determine requirements for carrier support to Spacelab-type experiments. This involved an assessment of GPL support equipment and facilities, environmental requirements, CORE, and instrumentation and data management. Data were collected concerning the following:

1. Power usage.

2. Temperature.

3. Humidity.

4. Light levels.

5. Noise levels.

6. Photographic coverage.

7. Equipment usage time.

Test Procedure. A test procedure was released 2 weeks prior to the test. The procedure defined ground rules for experiment checkout, debriefing, communications and experimenter responsibilities. In accordance with the procedures, testing proceeded as follows:

1. Experiments were individually checked out prior to integrated testing.

2. During testing, a test team meeting was held the first morning at 7:30 a.m. and debriefings were held each afternoon at 3:30 p.m. On the last day of testing, the debriefing started at 1:00 p.m.

3. Constant audio and video communications were maintained between the GPL and the test control room.

4. The experimenters were free to leave the GPL at any time as long as their experiment was left in a safe mode. They were also free to bring any support equipment or tools into the GPL as long as the mission manager was advised.

RESULTS AND CONCLUSIONS

The test was completed during the week ending January 25, 1974. Testing was performed according to the CVT/GPL Phase II Test Plan (10M33226). The following describes general results of individual experiments and the experiment and systems integration assessments. Scientific results of the experiments will be addressed separately by the experimenters.

Experiments

Four of the five experiments planned were completed to the statisfaction of the experimenters. During checkout, prior to initiation of testing, a vacuum-induced failure within the liquid helium dewar used in the Superfluid Helium Experiment resulted in loss of capability to carry out this experiment as planned. A brief description of each experiment, experimental objectives, method, results, conclusions and recommendations is given below.

Cloud Physics. Fogs encumber the efficiency of shipping, aircraft, and ground operations for both Armed Forces operations and civilian transportation systems. Techniques used to dissipate warm fogs (ambient temperature greater than zero degrees Celsius) are still in the experimental stages. A study of warm fog formation and dissipation using chemicals as seeding materials was conducted during Phase II.

Objectives. The objectives of the experiment were to:

1. Obtain data concerning the definition of the experiment/GPL interface.

2. Conduct engineering and operational tests of the experiment equipment to obtain design criteria and operational technique data.

3. Obtain research procedure data.

4. Obtain time line data.

5. Obtain human factors interface data.

6. Obtain experimenter training data.

7. Obtain data concerning the effectiveness of chemical seeding materials.

Method. During the first portion of the week of testing, a number of fogs were generated and allowed to dissipate naturally. A typical dissipation rate curve for these fogs is shown in Figure 12. Subsequent experiment runs were conducted utilizing a mixture of 90 percent distilled water and 10 percent glycerin as the chemical seeding material. A typical experiment run is described below.

The test chamber, shown in Figure 13, was first purged by the GPL vacuum system, filled with filtered air, and a particle count of the unfogged chamber was obtained. The chamber was then filled with warm fog developed by a distilled water atomizer. When a dense fog had been established, glass slides were exposed inside the chamber. The slides were removed and photographed for later analysis. Various amounts of fog seeding material were then sprayed into the chamber. Again, slides were exposed to collect water particles which formed as dissipation occurred. The slides were then removed and photographed for later microscopic analysis to determine the number and size of particles formed.

The relative opacity of the fog was measured throughout the buildup, stabilization, and breakdown period by a laser transmissometer system which was built into the chamber. Transmissivity data were analyzed to determine the dissipation effects of the chemical seeding material.

The same experimenter operated the experiment daily during the entire Phase II test period.

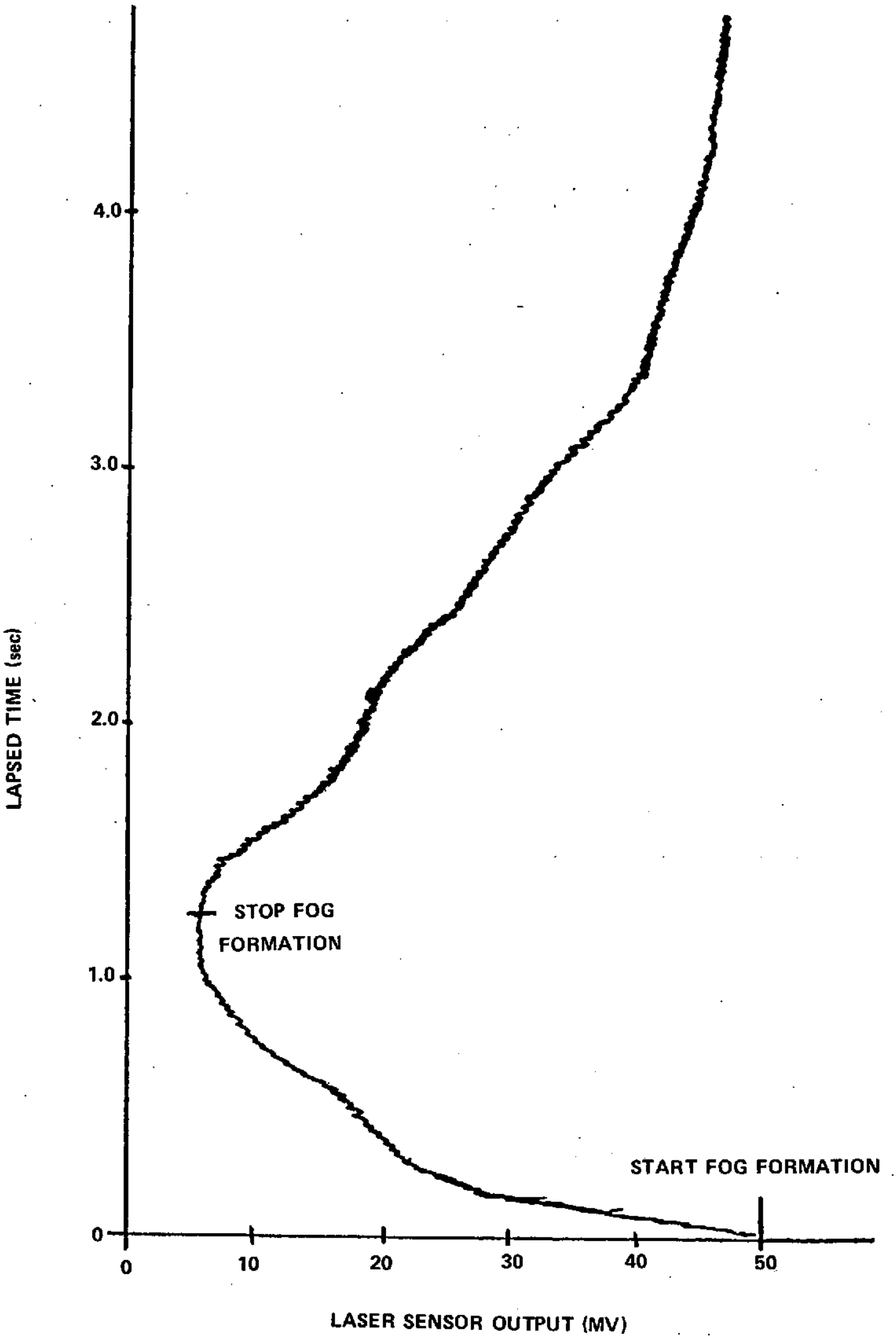


Figure 12. Natural decay curve for unseeded fog.

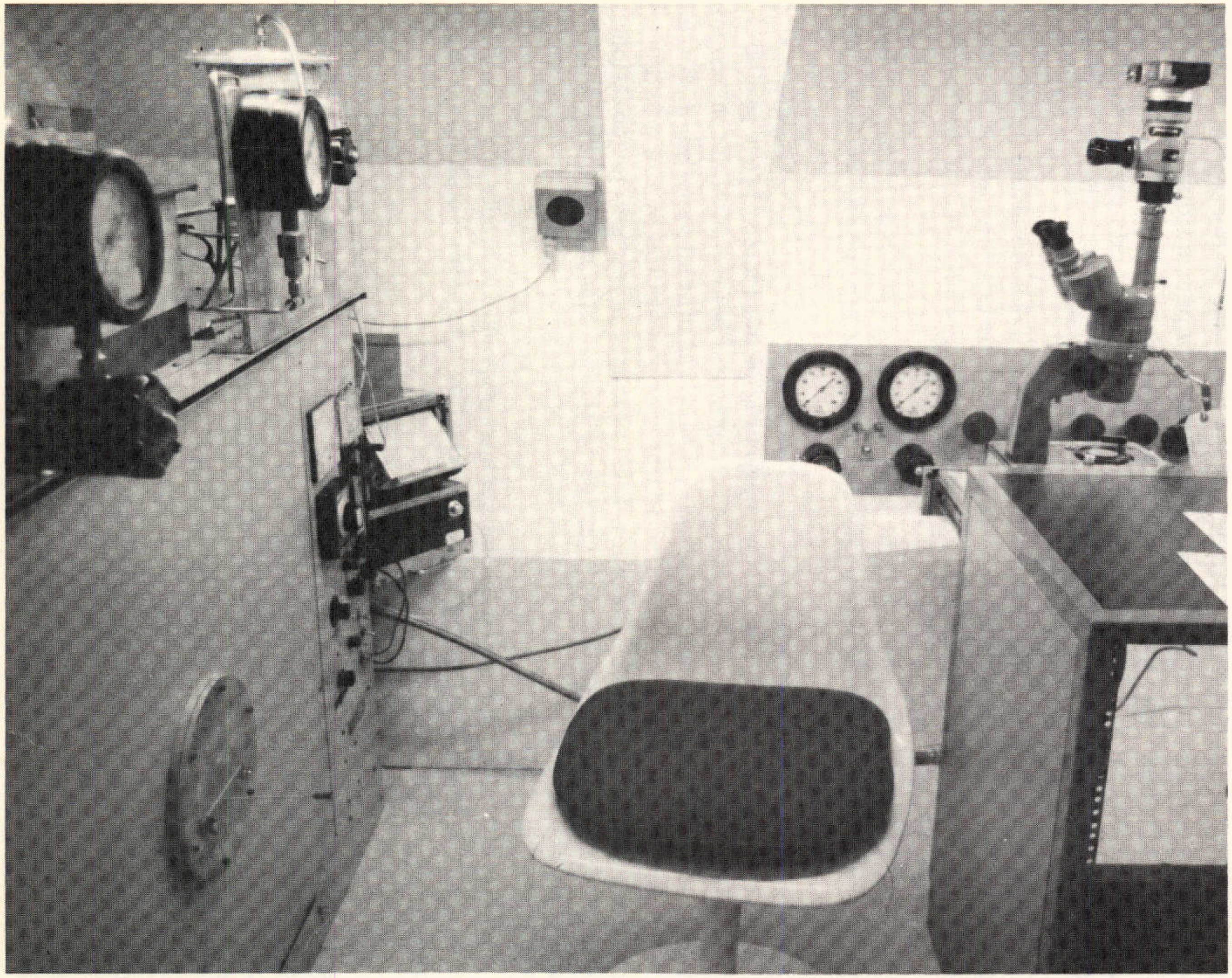


Figure 13. Cloud Physics experiment station.

Results and Discussion. The experiment operations were accomplished as expected and all equipment functioned satisfactorily during the Phase II test series. However, during the week of testing, a number of problems were noted.

The chemical spray mixture of 90 percent water and 10 percent glycerin appeared to have little dissipative effect. Because of the ineffectiveness of the chemical spray mixture used initially, a mixture of 70 percent distilled water and 30 percent glycerin was used in the last series of experiment runs. A typical dissipation rate curve of fogs seeded with the latter mixture is shown in Figure 14.

It was noted that the fog dissipated too quickly because of the kinetic effects of the chemical spray system. The kinetic effect of the chemical spray system resulted from the proximity of the spray nozzle to the top of the fog.

There was some leakage of fluid from the cloud chamber. This problem involved the absorbent padding on the floor of the chamber and the access tray near the chamber bottom.

Gelatin-coated slides used at the beginning of the Phase II test period were not effective because water particles evaporated before photographs could be made. As a solution, slides coated with a mineral oil and vaseline mixture were used and proved effective. Collection of water particles by the gelatin-coated slides was prevented by their low fall velocity. The rapid evaporation rate of collected water particles was caused by the microscope/camera unit internal light source.

The laser output received by the sensors was unexpectedly low following dispersion of the fog. This was probably caused by a moisture buildup on the sensor window.

The cleaning and refilling of the chemical spray system tank required excessive time because of a lack of easy accessibility. This was caused by an experiment design problem rather than by the experiment location in the GPL. Venting of the test chamber utilized the GPL vacuum system and was accomplished satisfactorily.

Conclusions. Modification of the chemical spray system to a height of approximately 177.8 cm (70 in.) was proposed to prevent premature dissipation of seeded fogs. The impact of the cloud chamber leak could have been reduced by use of the chamber drain system. However, complete solution of this problem would require modification of the chamber internal design and its

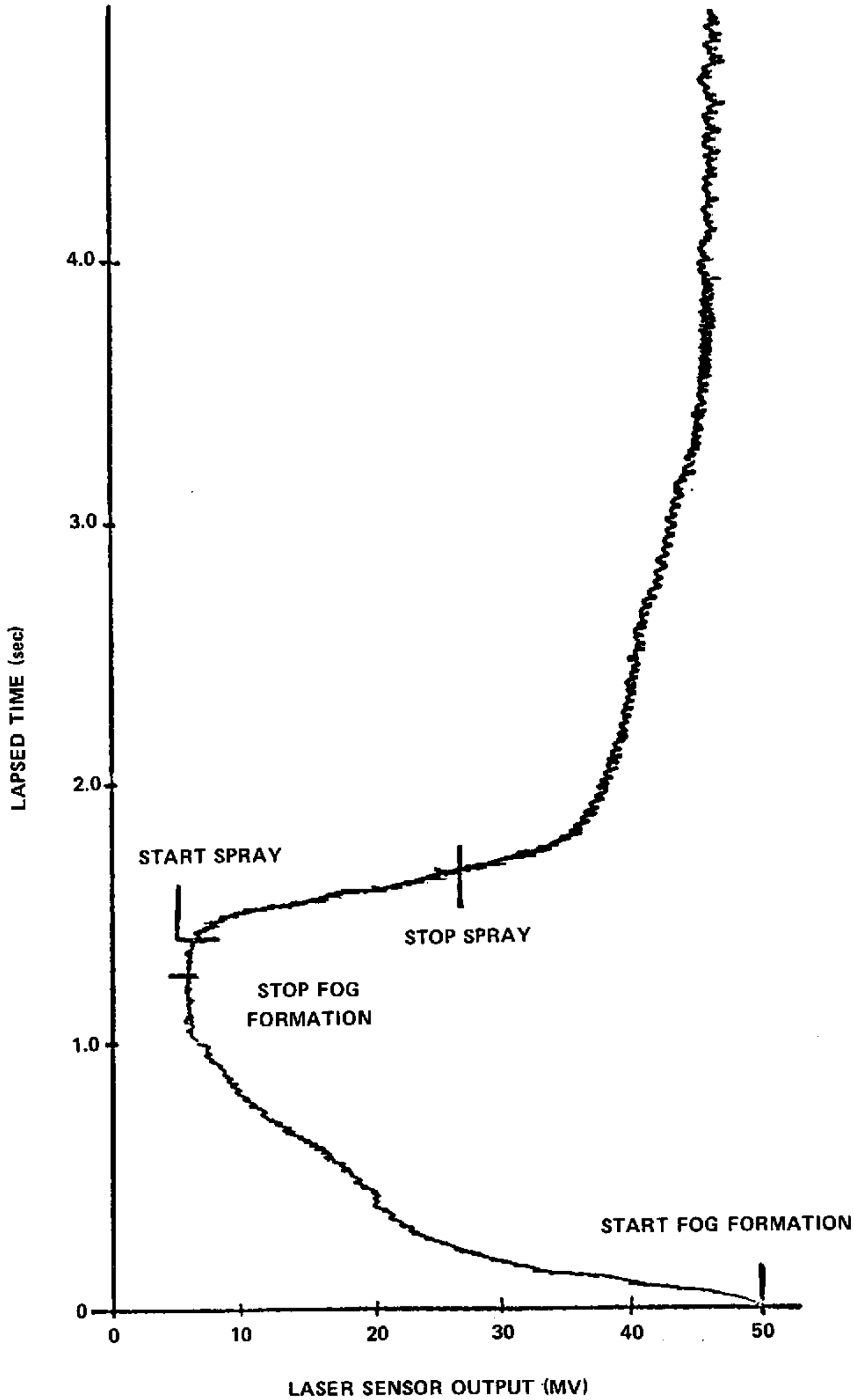


Figure 14. Decay curve for fog seeded with a mixture of 70 percent distilled water and 30 percent glycerin.

accessibility from the outside. Solution of the water particle evaporation problem could be accomplished by incorporating the microscope into the test chamber, prefocused on slides. This modification would reduce the time required to make photographs of exposed slides. Moisture buildup on the sensor window can be prevented by the installation of a sensor window heating element or by the use of antifogging materials. Redesign of the top of the chemical spray system to improve accessibility will eliminate the excessive time required to clean and refill the spray system tank. The excessive experimenter workload caused by manual recording of temperature readouts can be eliminated by use of a strip-chart recorder to collect this data. The maintenance required to render a strip-chart recorder operationally functional was satisfactorily provided. The storage space provided was satisfactory.

Ionospheric Disturbances. High frequency radio waves reflected from the earth's ionosphere experience Doppler shifts due to disturbances in the ionosphere. Therefore, by measuring the Doppler shift in radio waves transmitted between points on the ground via the ionosphere, a measurement of ionospheric disturbances is obtained. A Doppler system designed to detect disturbances in the F-region of the ionosphere was used in Phase II to continue testing initiated in Phase I of the CVT/GPL test series.

Objectives. The objectives of the experiment were to:

1. Obtain additional information concerning the physical characteristics and origins of ionospheric disturbances.

2. Provide pertinent integration and operational data, including data requirements for automatic versus manned modes of operation.

Method. Signals were transmitted from three sites located in a roughly triangular deployment relative to MSFC. Figure 15 illustrates the transmitter arrangement. Transmitting sites were located at Fort McClellan, Muscle Shoals TVA area, and TVA Nickajack Dam. Each site transmitted the same set of nominal frequencies, offset by a few cycles per second between sites so that the sources could be distinguished. The nominal frequencies were 4.0125, 4.759, and 5.734 MHz. Following reflection from the ionosphere, the signals were received by the experiment apparatus in the CVT/GPL, as shown in Figure 16, and recorded on magnetic tape. Reduction of data was accomplished during the test period by playing the tapes into an audio spectrum analyzer at a higher speed. The analyzer output, showing Doppler shifts as a function of time, was recorded with an electrolytic recorder which provided a permanent strip-chart for later analysis and interpretation.

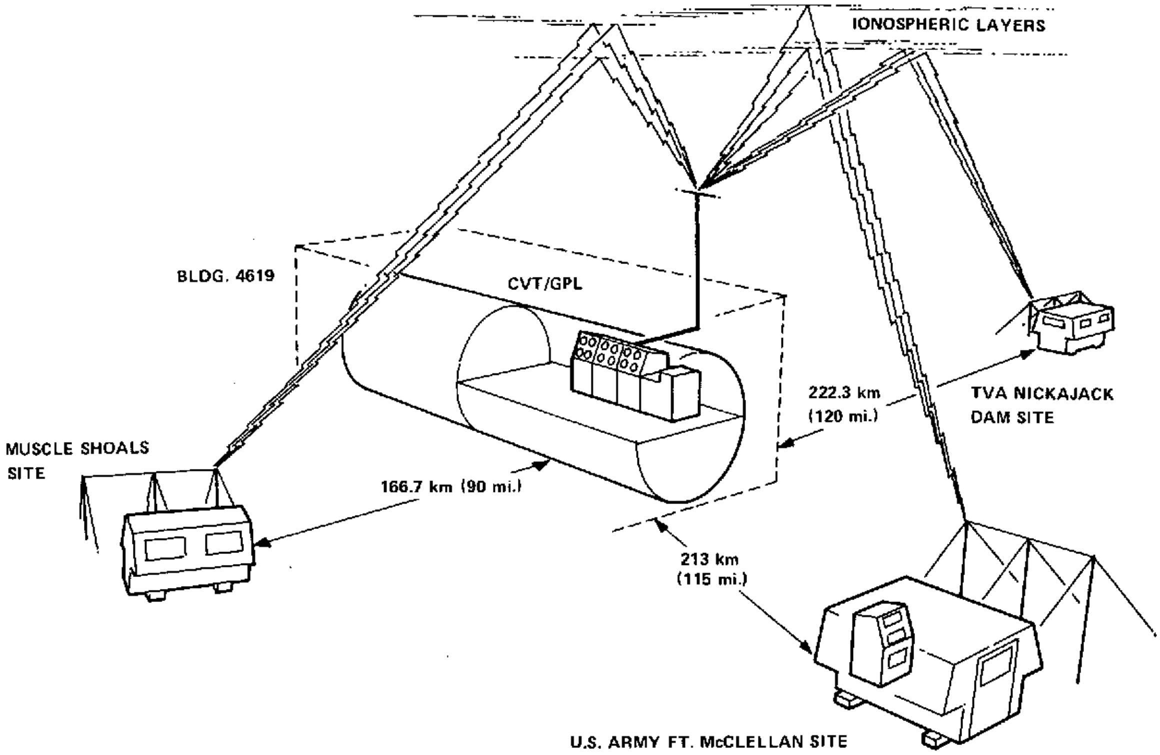


Figure 15. Doppler system transmitter-receiver arrangement.

Results and Discussion. Ionospheric disturbance data were collected as planned and the experiment was considered a success. However, two equipment malfunctions were noted during the test period. It was discovered on the first data reduction run that the midrange frequency transmitter at the Nickajack Dam site was not functioning and that another Nickajack Dam transmitter was weak. On the fourth day of testing, the audio spectrum analyzer circuit breaker malfunctioned and would not remain closed; the cause was not determined. The impact of the transmitter malfunction on the total data package was considered minor. Onboard maintenance capability could have provided quick turnaround of the malfunction. Fortunately, however, loss of the analyzer merely caused a delay in data reduction and did not result in loss of data. A backup analyzer was available for installation if continued data reduction during the test period had been necessary. Maintenance of the stripchart recorder and storage of experiment materials were accomplished satisfactorily.

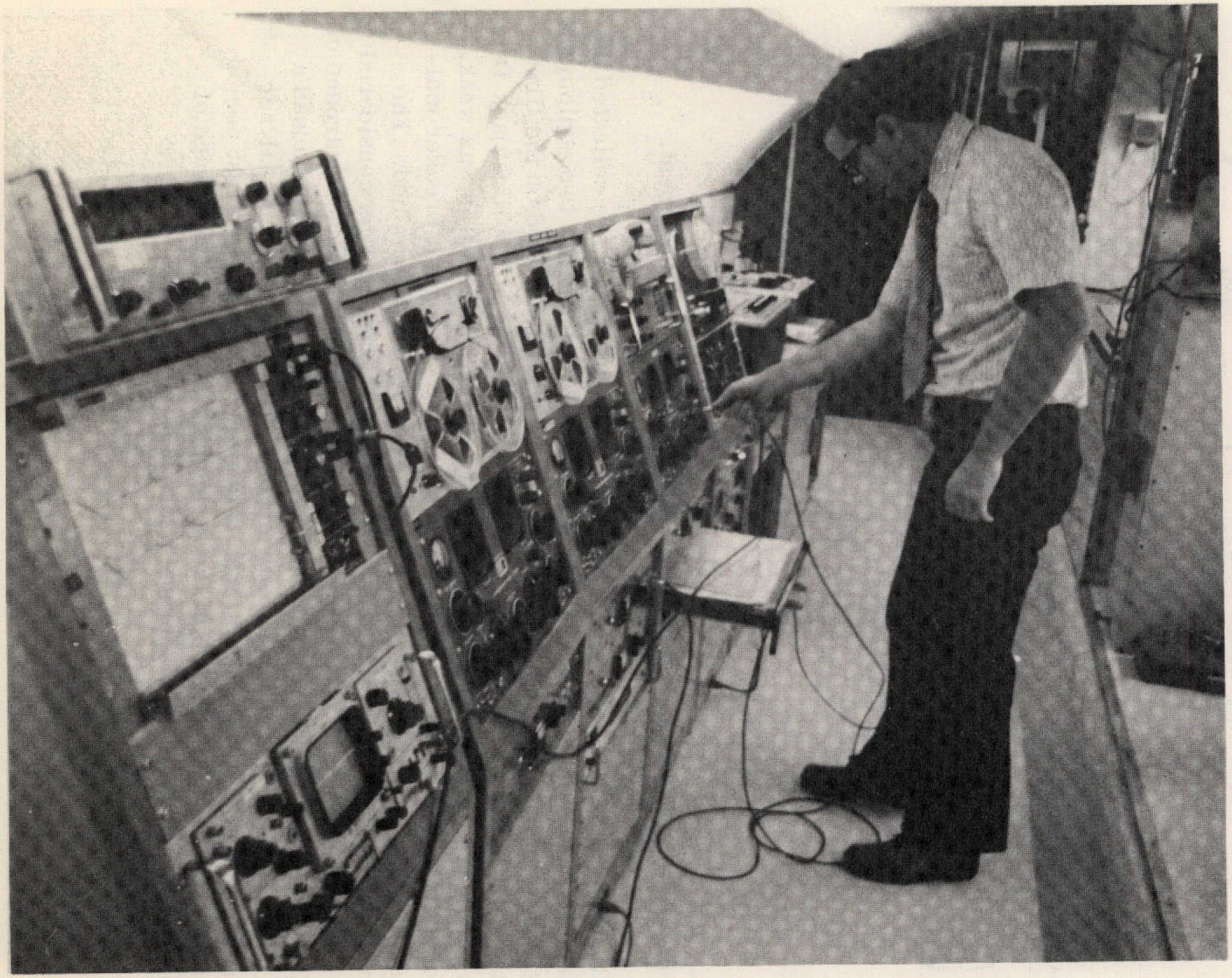


Figure 16. Ionospheric Disturbance experiment station.

Conclusions. All interfaces between the experiment equipment and the CVT/GPL were satisfactory.

All interfaces between the experiment equipment operation and other experiment apparatus operations were satisfactory.

The interaction of the experiment operator with other experiment activities was satisfactory.

The use of a payload specialist was successfully demonstrated for this experiment.

Material Sciences. The purpose of this experiment was to study the effect of gravity on the porosity and physical properties of metal powders and to increase our understanding of earth-based sintering and undercooling processes. Sintering of metal powders is a technique whereby materials are heat-bonded at a temperature well below the melting point of the constituents to produce precision components for power plants, filters, electrical contacts, and machine parts. The gravitational force is known to influence the process by consolidating the powders nonuniformly and possibly masking other sintering effects. The sintering portion of this experiment was designed to fully characterize the sintering process of selected materials in the 1-g environment to discern those properties which are directly influenced by the gravitational field.

Undercooling a material prior to solidification involves cooling below the solidification temperature while maintaining the molten state. When nucleation and growth does occur, it is very rapid and produces fine-grained homogeneous materials. The effect of gravity on the separation of metallic phases after undercooling eutectic alloys (alloys having the lowest possible melting point) is apparent when the density difference of the primary constituents is greater than 0.1 gm/cc. Therefore, the undercooling portion of this experiment was designed to characterize the gravitational separation of two eutectic compositions, one with a density difference of less than 0.1 gm/cc and one with a greater density variation. The first of two experimental investigations of sintering and undercooling planned for the CVT/GPL test series were conducted in Phase II.

Objectives. The objectives of the experiment were to:

1. Conduct engineering and operational tests of materials processing facilities that embody the design concepts for manufacturing-in-space experiments using off-the-shelf equipment.

2. Secure ground-based information concerning the effects of gravity on nucleation phenomena and powder segregation.

3. Obtain experiment integration data and develop operational techniques for installing and using equipment with high thermal requirements and constant thermal monitoring.

4. Demonstrate the modular concept of conducting complementary experiments in one timeline.

Method. The apparatus used to heat experiment materials and record temperature data was located in the lower level of the CVT/GPL (Fig. 17). As suggested following Phase I testing, a programmable temperature controller was utilized to automatically maintain the desired furnace temperatures.

The materials used in the sintering experiment were: (1) zinc oxide, (2) chromium coated cobalt, (3) nickel, and (4) nickel with 2 percent silver. Isostatic compaction pressures of the samples ranged from 8.27×10^6 to 1.65×10^7 N/m^2 (6 to 12 tons/in.^{2}). Two eutectic materials were used in the undercooling experiment. Lead-tin with a weight composition of 38.1 percent lead and 61.9 percent tin and a melting point of 183°C had a density difference of greater than 0.1 gm/cc. Indium-tin with a weight composition of 53.0 percent indium and 47.0 percent tin and a melting point of 115°C had a density difference of less than 0.1 gm/cc.

Sintering runs were performed throughout the Phase II test period. Samples were placed in the furnace and heated approximately 1 hour prior to removal and storage for later analysis. The peak operating temperature was 999°C.

Undercooling runs were performed daily during the week of testing. Peak operating temperatures for the indium-tin and lead-tin eutectics were 200 and 250°C, respectively. An experimental run consisted of heating a given sample through the melting point, undercooling until solidification occurred, and repeating this procedure until three melt-solidification cycles were completed. The sample was then removed from the furnace, cooled, and set aside for later analysis. The approximate duration of each undercooling run was 3 hours.

Coinvestigators conducted the sintering and undercooling runs during each day of the Phase II test period.

Figure 17. Material Sciences experiment station.

Results and Discussion. Analysis of the sintered samples revealed incompletion of the sintering process near the core of the Ni/Ag sample after 1 hour of sintering at 900° C in air. This result can be attributed to either uneven compaction or insufficient sintering time. Further analysis indicated uneven sintering of the chromium-coated cobalt after sintering at 900° C. This is too low to produce even sintering. Severe oxidation of the sintered samples also resulted because of exposure to the air.

Analysis of the undercooled samples indicated macrosegregation in all lead-tin samples. The indium-tin samples exhibited no such macrosegregation. Further analysis revealed that dendrite arm spacing decreased in the tin-rich portion of the lead-tin sample and did not change in the lead-rich portion.

Adaptation of the GPL power system to provide the experiment furnace 110 Vac at 30 A was accomplished satisfactorily. The high temperature furnace had minimal impact upon the GPL environment. The storage space provided was satisfactory.

Several problems were encountered during the testing. The experimenters were unable to complete sintering and undercooling runs according to their proposed schedule. This was caused by overheating of the GPL and slower furnace cool-down rates than encountered in the laboratory. As a result, online changes in procedures and adjustment of experiment apparatus were accomplished by the experimenters. Another problem encountered concerned excessive noise and vibration originating in the GPL upper level. This had a definite impact upon the experiment environment and can be particularly damaging to the undercooling experiments. In the opinion of the experimenters, the illumination of the experiment station was insufficient and requires improvement.

Conclusions. Complete sintering of the Ni/Ag sample can be accomplished by more uniform compaction or longer sintering time. Even sintering of the chromium-coated cobalt sample can be attained by use of a higher furnace temperature. Severe oxidation of all sintered samples can be prevented by the use of a reduced or inert atmosphere.

Results of the undercooling experiments included the development of macrosegregation in lead-tin samples; this indicates that the density difference between constituents is the motivating factor for the inhomogeneity. A decrease in the spacing of dendrite arms in the tin-rich portion of the lead-tin sample supports the hypothesis that the tin phase is the nucleation center for the eutectic structure.

The excessive time needed for completion of the originally proposed experiment schedule was caused primarily by a slower furnace cooling rate than was anticipated by the experimenters. The ability to make effective unscheduled changes in procedures and the adjustment of experiment apparatus was largely attributed to having the coinvestigators on board, directly involved in the experiment. As a result, the experiments yielded more data than was originally anticipated. Each segment of the experiment was successful.

A reduction of the noise and vibration levels originating in the upper GPL and an increase in illumination of the experiment station can improve the experiment environment.

High Energy Astronomy. This experiment was designed to demonstrate the feasibility of effectively performing cosmic ray investigations in a Spacelab-pallet configuration and to evaluate operational procedures and interfaces while obtaining data applicable to the refinement of experiment apparatus and the development of experiment operator training requirements. High Energy Cosmic Ray Experiment equipment, designed for high altitude balloon flight experiments, was installed in the CVT/GPL and on the pallet assembly to simulate the physical arrangement anticipated for future Spacelab missions. The mode of operation was intended to simulate a typical mission. The experiment operators represented payload specialists having relatively little premission experience with the apparatus and depending on ground-based experts for assistance when required to work through difficulties encountered in carrying out experiment procedures.

Objectives. The objectives of the experiment were to:

1. Determine which experiment equipment calibration and adjustment functions could best be performed by an onboard experiment operator and to help define the skills and training required for a crew member to carry out the experiment.

2. Obtain data, using sea level cosmic rays (mu mesons), for mapping the sensitivity of scintillation and Cerenkov cosmic ray detectors and for verifying the performance of a proportional counter hodoscope.

3. Demonstrate the feasibility of adapting equipment designed for balloon flight experimentation to the Spacelab-pallet configuration and evaluate CVT/GPL interfaces with the apparatus.

Method. The cosmic ray detection apparatus and associated electronics were mounted on the pallet assembly as shown in Figure 18. The detection equipment is designed to provide a measure of electronic charge and energy for particles passing through the system. These measures are generated by a Cerenkov counter and scintillators for particles with low charge and by ion chambers for particles with high charge. Particle position is determined by signals generated in a proportional counter hodoscope as charged particles pass through it.

The experiment control station was located on the lower level of the CVT/GPL as shown in Figure 19. The two equipment racks shown include a telemetry processing rack (left side) and a pulse height analyzer (PHA) rack (right side). A tape recorder, hidden from view beside the left-hand rack, was used to record data during the normal operating mode.

Nine volunteer test subjects were selected and trained prior to the test period to perform individually as experiment operators. The volunteer group included three with experience in operating part of the equipment, two with some familiarity but no operating experience, and four who had never seen the equipment. Test subjects were instructed about the equipment in a 4 hour ground school but were not given the opportunity to operate it. Subjects were given a procedures manual which included equipment descriptions and detailed procedures for test functions which they performed during the test period.

During the test, each subject performed an experiment run lasting approximately 3 hours. Subjects were required to perform an equipment calibration procedure, make a tape recording of data obtained in the normal operating mode, acquire calibration data on the proportional counter hodoscope, and perform a postrun calibration procedure. Each subject was asked to evaluate the training received after completing the experiment run.

Results and Discussion. All of the test objectives were accomplished. Every subject completed the calibration portion of the experiment. Three subjects did not have time to gather all of the hodoscope data. Operational problems were handled successfully via the intercom linking experimenters in the test conductor's room with experiment operators at the CVT/GPL experiment station.

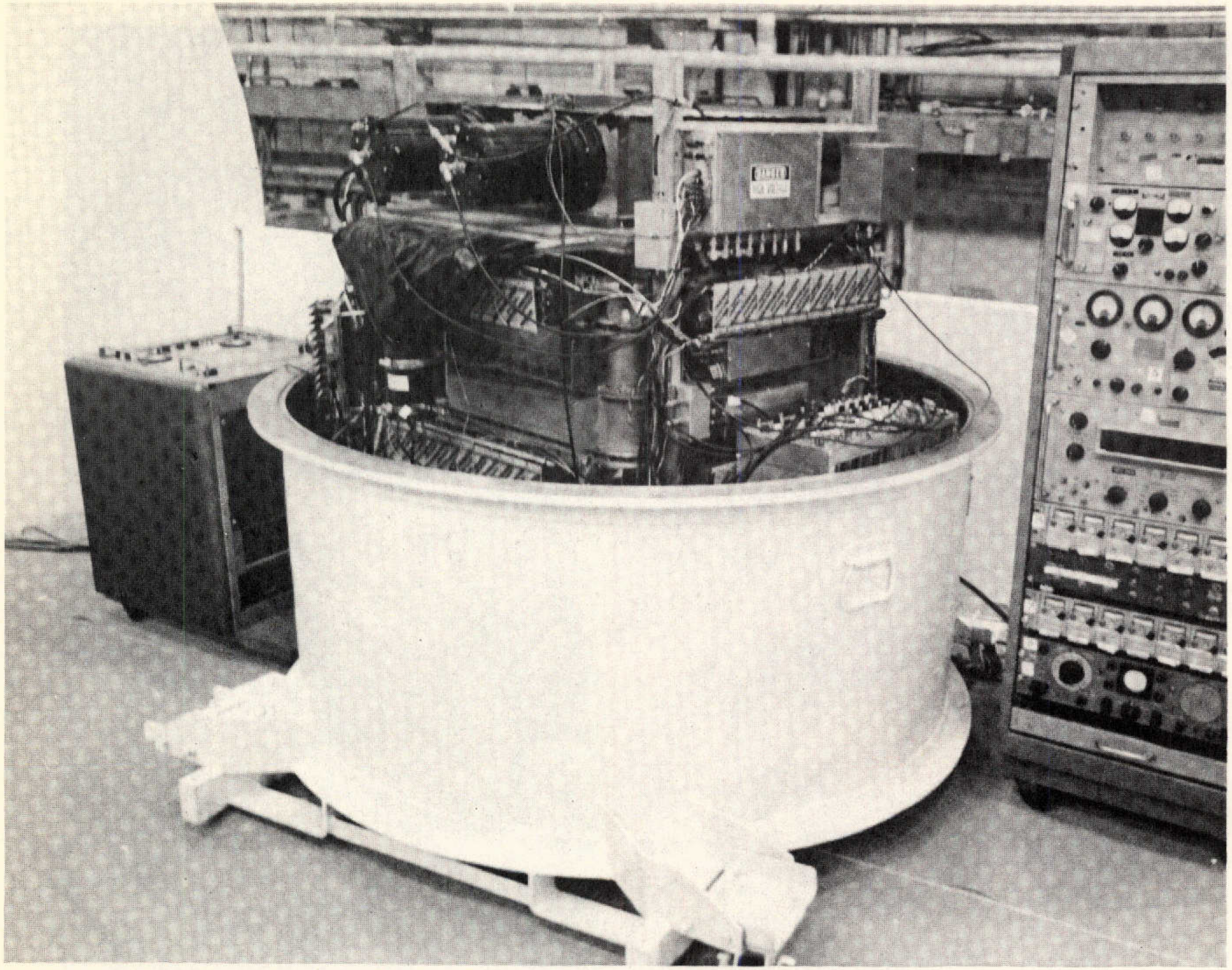


Figure 18. High Energy Astronomy cosmic ray detection apparatus.

Figure 19. High Energy Astronomy experiment station.

In the opinion of several subjects, there were man-systems interface and procedural instruction difficulties which will require attention to provide a smoother operation. Problems mentioned included equipment arrangement, lighting, seating, and difficulties in following experiment procedures. It was recognized by the experimenter that equipment layout problems existed by virtue of assembling various components according to availability and space constraints without the benefit of an integrated console design incorporating accepted human factors design principles.

The experiment equipment operated effectively throughout the test. However, two CVT/GPL interface problems were encountered. The CVT/GPL time code signal generator malfunctioned and it was necessary for the experimenter to bring in additional equipment to receive a time code signal from the Computation Laboratory. Also, ineffective control of water drainage on the upper level resulted in water dripping near the operator throughout the test. The interface between the apllet and pallet-mounted equipment was satisfactory, as was the storage space provided.

Conclusions. The ability of all the subjects to successfully complete the calibration procedures and, in most cases, obtain the required data demonstrated that, with minimum training, experimentally naive people could learn to perform the experiment effectively. Minor changes in the procedures manual were recommended. Also, a longer training period and the opportunity for each operator to work with the equipment prior to the test were recommended. The experiment equipment performed satisfactorily and interface problems were considered minor.

Data recorded by the test subjects will be used as planned in generating correction maps and verifying hodoscope performance.

Superfluid Helium. Helium-II, which exhibits unusual properties of considerable scientific interest, is formed when liquid helium is cooled to a temperature of less than 2.17°K. The purpose of the experiment was to examine the behavior of Helium-II in static and free-fall conditions. The experiment required photography of Helium-II droplets for postmission analysis. The experiment was designed to produce new scientific data and information useful in the design and operation of systems for cooling ultra-low temperature experiments and instruments.

Objective. The objectives of the experiment were to:

1. Collect useful scientific data concerning the behavior of the superfluid phase of helium.

2. Test techniques for generating, illuminating, and photographing Helium-II droplets.

3. Operationally check out experiment equipment and procedures.

Method. As originally planned, the experiment utilized a liquid helium dewar fitted with an optical tail assembly which provided the capability to generate, illuminate, and photograph both static and falling Helium-II droplets. Unfortunately, a pretest, vacuum induced, failure of the experiment dewar resulted in the loss of the capability to conduct the experiment as planned. Thus, a substitute dewar, as shown in Figure 20, was installed in the CVT/GPL. However, the substitute dewar lacked the optical access windows necessary for illumination and photographic purposes. Therefore, the generation of droplets was not attempted. The use of the substitute dewar limited the scope of experiment activity to the transfer of liquid nitrogen to the substitute dewar.

Results and Discussion. As a result of the limited capabilities of the substitute dewar, the only experiment activity attempted was the transfer of liquid nitrogen to the substitute dewar.

Conclusions. Liquid nitrogen was successfully transferred to the substitute dewar and no problems were encountered with the substitute system. Therefore, the abbreviated experiment was considered a success.

Experiment Integration Assessment

The assessment information that was collected varied among experiments. Therefore, certain general categories of experiment/GPL interaction have been delineated to provide a framework by which assessment information can be organized and evaluated. These categories of experiment/GPL interaction include GPL support facilities, workstation layout and equipment arrangement, experiment volume requirements, experiment data requirements with respect to GPL support equipment, and crew interaction requirements. A number of interface problems were noted during the Phase II test.

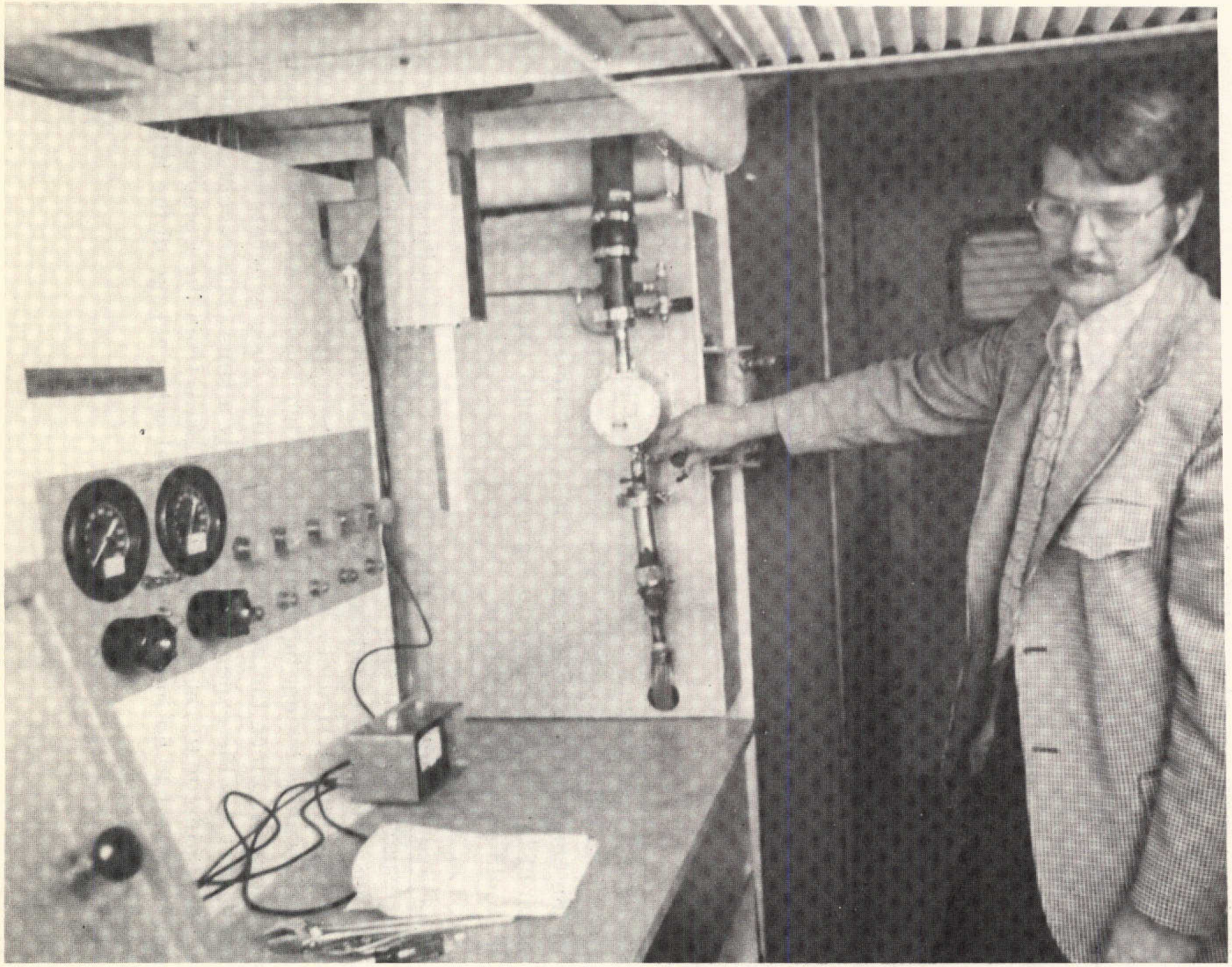


Figure 20. Superfluid Helium experiment station.

GPL Support Facilities. Facilities utilized by experiments in the GPL included water, drainage, high and low vacuums, missile grade air pressurant, and electrical power. The Cloud Physics experiment utilized both the GPL low vacuum and air supply systems and encountered no interface problems. However, the cloud chamber did develop a fluid leak, the impact of which could have been reduced through use of the GPL drainage system. Fluid from this leak dripped into the lower GPL where it created a distracting nuisance for the High Energy Astronomy experiment operators. The other four experiments successfully used the GPL power supply with no interface problems. The Superfluid Helium experiment utilized the GPL high vacuum [rated at 13.3 N/m^2 (0.1 torr)] but a vacuum-induced failure within the Superfluid Helium experimental dewar resulted in loss of capability to complete the experiment as originally planned.

Workstation Layout and Equipment Arrangement. The workstation layout and equipment arrangement were satisfactory in four of the five experiments. Neither layout nor arrangement was satisfactory in the High Energy Astronomy experiment. The experimenter blocked the lower level aisle when operating the experiment equipment in a sitting position and also had difficulties in reaching all equipment controls. This can be attributed to the fact that the equipment was assembled on an availability basis without the use of integrated console design principles.

Experiment Volume. Four of the five experiments operated satifactorily within the experiment volume constraints. The Cloud Physics experiment encountered premature dissipation of seeded fogs as the result of the kinetic effects of the chemical spray system. The experimenter anticipates that a modification of the spray system to a greater height [approximately 177.8 cm (70 in.)] would solve this problem.

Data Requirements with Respect to GPL Support Equipment. Interfaces concerning experiment data requirements and GPL support equipment included using GPL power to operate data recording equipment, using video cameras to record experiment activities, and superimposing time code signals on data tapes. All interfaces except the latter in the High Energy Astronomy experiment were satisfactory. Since the recording room time code generator malfunctioned, it was necessary for the experimenter to supply a time code receiver and subcarrier discriminator to receive time code signals from the Computation Laboratory. This had no impact upon the total data package of the High Energy Astronomy experiment.

Crew Interaction. It was the general opinion of the experimenters that the working environment and, therefore, the entire operation would benefit from more freedom to mingle and the establishment of closer personal relationships between crew members. Also, it was felt that a greater understanding of other experiment activities and the use of more premission briefings and informal training sessions could provide the basis for a more relaxed atmosphere during the testing.

Conclusions Concerning Experiment Integration. Overall, experiment interfaces with the GPL were satisfactory. The leakage of the Cloud Physics experiment chamber had a small impact upon the High Energy Astronomy experiment. This impact could have been reduced by use of the GPL drainage system. The vacuum-induced failure within the Superfluid Helium experimental dewar resulted in the adoption of an abbreviated experiment plan. The exact cause of the vacuum-induced failure is uncertain. The aisle blockage and equipment control inaccessibility problems of the High Energy Astronomy experiment can be eliminated through the use of integrated console design principles. Proper dissipation of seeded fogs in the cloud chamber can be accomplished by movement of the chamber to a location permitting an increase in chamber height. Although the malfunction of the recording room time code generator resulted in no data acquisition problems for the High Energy Astronomy experiment, the presence of a backup generator would have made the use of an external transmitting source unnecessary. The general opinion expressed by experimenters was that a more productive, relaxed atmosphere within the GPL would have resulted from more premission briefings, informal training sessions, and more freedom to mingle during testing.

Systems Integration Assessment

The systems integration evaluation revealed some problems with GPL systems and some deficiencies with respect to Spacelab requirements. The measurements of lighting, acoustics, temperature, and humidity levels were analyzed and compared with Spacelab requirements and improvements are indicated in these areas. Spacelab Requirements used in comparisions with GPL data were obtained from the second draft of "Spacelab System Requirements," ESTEC Ref. No. SLP/2100, dated January 25, 1974.

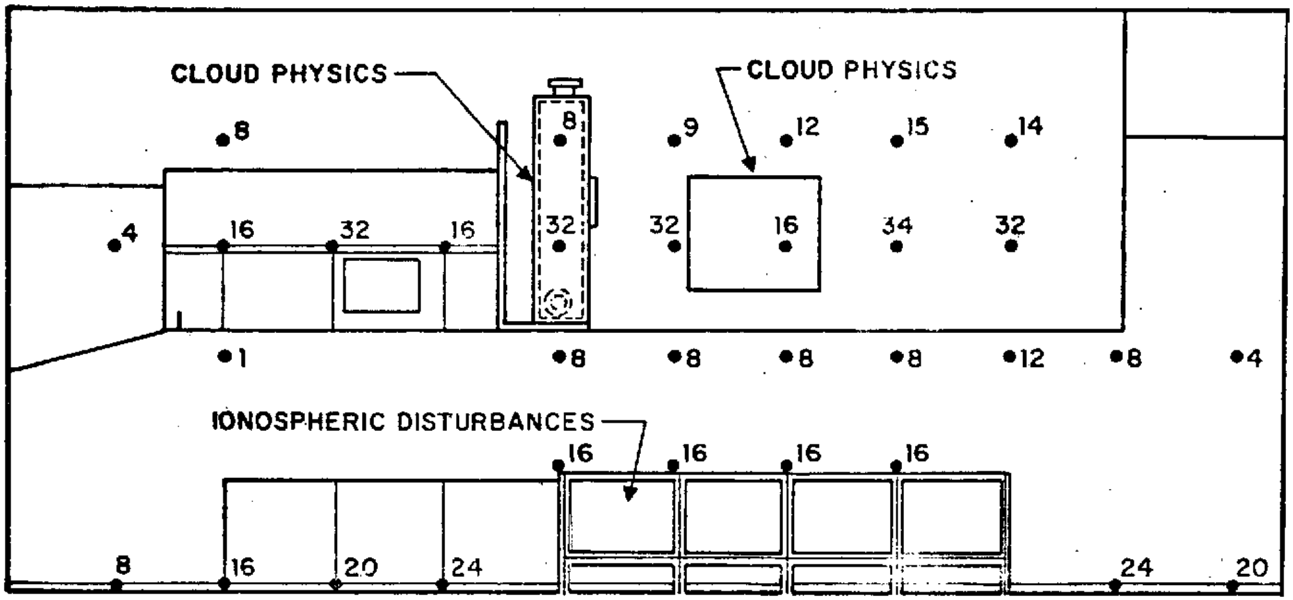
Light Levels. Light levels in the GPL were generally too low and in some cases light sources were not located for effective utilization. The lighting for the High Energy Astronomy experiment was directed into the experiment operator's eyes and modifications were considered necessary. Lighting for the Materials Sciences station was inadequate. The experimenters had difficulty seeing the equipment, expecially inside the furnace.

Light levels, measured at a height of approximately 1.45 m (5 ft) above the floor, were recorded at 87 points throughout the GPL, as illustrated in Figure 21. The number beside each dot in the illustration indicates the light level in foot-candles measured at that point. Average light levels determined for the various GPL workstations from these data points are compared with Spacelab requirements in Table 1. In general, the light levels measured are below the lower limit of the range required in Spacelab. The overall level in the upper GPL was 168 lumens/m^2 and the Spacelab requirement is 200 to 300 lumens/m^2. The lower level overall average was 176 lumens/m^2, also below the Spacelab requirement. The average levels of lighting at experiment stations and general purpose workbench areas were far below Spacelab requirements. The upper level average was approximately 200 lumens/m^2 which is half the minimum requirement for Spacelab. On the lower level, the average was approximately 116 lumens/m^2, about 29 percent of the minimum Spacelab requirement for these areas. The Materials Sciences area was exceptionally low, averaging approximately 50 lumens/m^2. This deficiency was obvious to the experimenters, as noted above. The engineers substation on the north side of the lower level was exceptionally bright at 1400 lumens/m^2, over twice the maximum Spacelab requirement.

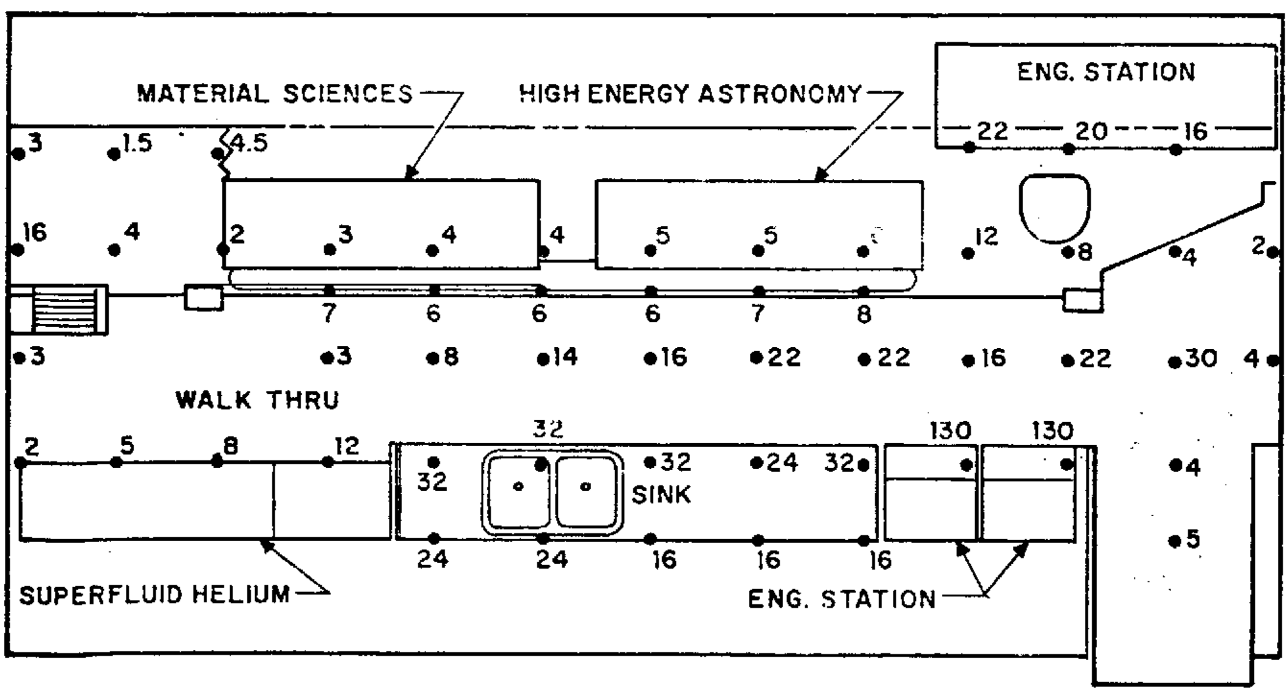
Acoustics. Noise levels in the GPL were generally too high and in some cases distracted the experiment operators. Noise generated by chairs moving across the upper level deck distracted experimenters on the lower deck. Noise generated by the camera covering the High Energy Astronomy station was noticed by one of the operators. In general, noise levels generated by equipment installations and intermittent activities drew the attention of the experimenters. It was felt that better control of noise should be practiced and that a method be developed for contacting all concerned prior to a heavy noise period.

Table 2 lists 100 sound level measurements made during Phase II. The measurements were made with a Bruel and Kjoer Impulse Precision Sound Level Meter. Four scale weights, A, B, C and D, were used. Each reading is a measurement of total acoustic energy over the audio frequency range (approximately 20 Hz to 20 000 Hz).

The differences in values measured on scales A, B, and C indicate that most of the sound energy was concentrated in the frequencies below 600 Hz, which is outside the speech interference level. This conclusion follows from the fact that sound levels measured on the C scale were consistently higher than those on scales A and B.



UPPER GPL LIGHT LEVELS (footcandles)



LOWER GPL LIGHT LEVELS (footcandles)

Figure 21. GPL light level measurements.

TABLE 1. AVERAGE LEVEL OF ILLUMINATION, GPL VERSUS SPACELAB

Location In GPL	Measured in GPL		Spacelab Requirement	
	lumens/ft^2	lumens/m^2	lumens/ft^2	lumens/m^2
<u>Upper Level GPL</u>				
General Purpose Workbench	18.0	194	37.2 - 55.6	400-600
Cloud Physics Experiment Station	20.4	219	37.2 - 55.6	400-600
Ionospheric Disturbance Experiment Station	17.7	190	37.2 - 55.6	400-600
Aisle Areas	9.4	101	18.6 - 27.8	200-300
Overall GPL	15.6	168	18.6 - 27.8	200-300
<u>Lower Level GPL</u>				
Engineers Station				
North Side	130.0	1400	37.2 - 55.6	400-600
South Side	15.6	168	37.2 - 55.6	400-600
General Purpose Workbench	24.8	267	37.2 - 55.6	400-600
Superfluid Helium Experiment Station	6.8	73	37.2 - 55.6	400-600
Materials Sciences Experiment Station	4.6	50	37.2 - 55.6	400-600
High Energy Astronomy Experiment Station	6.2	67	37.2 - 55.6	400-600
Aisle Areas	10.2	112	18.6 - 27.8	200-300
Overall GPL	16.4	176	18.6 - 27.8	200-300

TABLE 2. GPL SOUND LEVEL MEASUREMENT

GPL Location	Scale Weight	Time and Magnitude of Measurement (dB)						Range
		1-21-74		1-22-74		1-24-74		
		a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	
Mission Manager Station	A	53, 64	63	—	—	62	62	53-64
	B	59, 70	68	—	—	68	66	59-70
	C	67, 72	70	69, 70	68, 69	71	71	67-72
	D	59, 70	66	—	—	67	66	59-70
High Energy Astronomy Experiment Station	A	54	59	—	—	60	51	51-60
	B	58	63		—	65	59	58-65
	C	65	69	67, 69	67, 68	69	60	60-69
	D	59	64	—	—	63	62	59-64
Materials Sciences Experiment Station	A	57	58	—	—	56	64	56-64
	B	63	65	—	—	62	59	59-65
	C	67	65	63, 64	64, 65	66	64	63-67
	D	64	68	—	—	62	69	62-69
Ionospheric Disturbances Experiment Station	A	66	56	—	—	56	—	56-66
	B	67	60	—	—	60	—	60-67
	C	69	68	70, 75	67, 68	67	—	67-75
	D	71	60	—	—	61	—	60-71
Cloud Physics Experiment Station	A	63	56	—	—	61	—	56-63
	B	64	60	—	—	65	—	60-65
	C	66	68	63, 64	67, 67	69	—	63-69
	D	67	62	—	—	64	—	62-67
Superfluid Helium Experiment Station	A	—	—	—	—	—	56	56
	B	—	—	—	—	—	62	62
	C	—	—	—	—	—	66	66
	D	—	—	—	—	—	62	62

In order to compare the GPL sound level measurements with Spacelab requirements, an approximation method* was used to reduce the raw data to rough estimates of decibel levels in low (20 to 150 Hz), middle (150 to 600 Hz), and high (600 to 8000 Hz) frequency bands. The median values (Table 3) for the GPL, upper GPL, lower GPL, and individual workstations throughout the GPL were anlyzed using the referenced approximation method. The Spacelab requirement for the same three frequency bands was estimated from the sound pressure level NC-50 (noise criteria 50) curve given in the Spacelab requirements document. Accordingly, the maximum decibel levels allowable for Spacelab in the three frequency bands are: low band, 67 dB; middle band, 56 dB; high band, 49 dB. A comparison between these values and the levels calculated for the GPL is presented in Table 4. Where the difference (D) between E and M is positive, the GPL sound level exceeds the maximum required for Spacelab. Where the difference (D) between E and M is negative, the GPL level is within the Spacelab requirement. This analysis shows that, in general, the noise level in the GPL was a little high with respect to the requirement currently specified for Spacelab.

Temperature and Relative Humidity. GPL temperature and relative humidity measurements are given in Table 5. Spacelab temperature and humidity requirements are: air temperature in crew area adjustable between 18°C and 26°C; relative humidity upper limit 70 percent, lower limit 30 percent. These requirements were exceeded on two occasions during the test period. During the first day of operation the outside air unit did not function properly and the temperature reached 37.8°C in the lower GPL. On the morning of the thrid day of testing the relative humidity in the upper GPL was 84 percent. One experiment operator reported being cold during a short interval but otherwise temperature and humidity were maintained at comfortable levels.

Audio Communications. The talk-a-phones provided at experiment stations and in the recording and test conductor's rooms were not considered adequate according to most of the participants. The main objections were lack of capability to address all stations simultaneously, difficulty in hearing, difficulty in gaining channel access, and the necessity of moving from a working position to a talking position. It was suggested that the system be provided with one button which the mission manager could use to talk to everyone at once. This was considered especially necessary for effective communication of messages concerning noise control/scheduling. Lightweight headphones were suggested as an inprovement which would permit movement about the experiment area while carrying on a conversation.

*Beranek, L. L. and Peterson, A. P. G.: Handbook of Noise Measurement. Chapter VI, General Radio Company, 1956, pp. 34-37.

TABLE 3. RANGE AND MEDIAN VALUE SOUND LEVEL (dB)

a. Overall GPL

Scale	Upper GPL		Lower GPL		Total GPL	
	R[a]	M[b]	R	M	R	M
A	56-66	58	51-64	59	51-66	59
B	60-67	62	58-70	63	58-70	63
C	63-75	68	60-72	67	60-75	67

b. Upper GPL

Scale	Ionospheric Disturbances Station		Cloud Physics Station	
	R	M	R	M
A	56-66	61	56-63	61
B	60-67	63	60-65	63
C	67-75	68	63-69	67

c. Lower GPL

Scale	Mission Manager Station		High Energy Astronomy Station		Material Sciences Station	
	R	M	R	M	R	M
A	53-64	62	51-60	56	56-64	58
B	59-70	68	58-65	61	59-65	62
C	67-72	70	60-69	68	63-67	64

a. R — Range of sound level measurement in decibels
b. M — Median value in decibels.

TABLE 4. GPL SOUND PRESSURE LEVELS (dB) ESTIMATED FROM FREQUENCY BAND ANALYSIS

a. Overall GPL

Frequency Band (Hz)	Upper GPL			Lower GPL			Total GPL		
	E[a]	M[c]	D[d]	E	M	D	E	M	D
20-150	67.5	67	+0.5	65	67	-2	65	67	-2
150-600	b	56	b	61	56	+5	61	56	+5
600-8000	57.5	49	+8.5	57	49	+8	57	49	+8

b. Upper GPL

Frequency Band (Hz)	Ionospheric Disturbance Station			Cloud Physics Station		
	E	M	D	E	M	D
20-150	67.5	67	+0.5	66	67	-1
150-600	b	56	b	55	56	-1
600-8000	61	49	+12	61	49	+12

c. Lower GPL

Frequency Band (Hz)	Mission Manager Station			High Energy Astronomy Station			Material Sciences Station		
	E	M	D	E	M	D	E	M	D
20-150	59.5	67	-7.5	b	67	b	57	67	-10
150-600	70	56	+14	b	56	b	62.5	56	+6.5
600-8000	50	49	+1	55.5	49	+6.5	54.5	49	+5.5

a. E — Estimated sound pressure level calculated from sound level measurement using approximation method.
b. Approximation method not applicable.
c. M — Maximum sound pressure level requirement for Spacelab.
d. D — Difference in decibels between GPL and Spacelab requirement (E - M).

The effectiveness of the experiment monitoring microphones was considered marginal. The microphone in the Superfluid Helium Experiment area was ineffective.

TABLE 5. GPL TEMPERATURE AND RELATIVE HUMIDITY

Time Measurement Taken		Temperature, °C		Percent Relative Humidity	
		Upper GPL	Lower GPL	Upper GPL	Lower GPL
1-21-74	10:05 a.m.	20	27.2	37	46
	1:00 p.m.	—	37.8	—	—
	3:00 p.m.	—	22.0	30	38
1-23-74	8:15 a.m.	17.5	19.1	84	66
1-24-74	11:00 a.m.	19.2	23.0	40	45
	1:15 p.m.	16.1	21.4	42	40

Video Camera Operations. Photographic coverage of experiment activities was provided by fixed position and pan-tilt-zoom video cameras operated from the control room and hand-held 16 mm (motion) and 35 mm (still) film cameras operated by the mission manager. Video cameras provided excellent documentary coverage of all experiment activities. However, obtaining this coverage required considerable intrusion on the experimenters. Illumination was also a frequent problem. Camera burns occurred from several sources including the light source for the Fog Modification microscope, the High Energy Astronomy Hodoscope display, a flashlight used in the Cloud Physics experiment, and white clothing worn by participants. The problem of brightspots could be reduced by increasing the general level of lighting and by making light sources more indirect. Since the video camera system is intended to be nonintrusive, future tests will require better camera locations, perhaps more cameras, and improved lighting. Otherwise, it may be necessary to forego some video documentation in order to preserve a nonintrusive working environment.

The 16 and 35 mm cameras were used to provide documentary coverage of experiment activities and to assess the storage space provided for photographic supplies and cameras. The storage space provided for photographic equipment was considered adequate and documentary coverage was satisfactory.

Equipment Usage and Maintenance. GPL and GPL support equipment was operated from 8:00 a.m. through 3:30 p.m. during the first 4 days and from 8:00 a.m. through 1:00 p.m. on the fifth day of testing.

Malfunctions occurred in the video recording system, the air conditioning system, and the intercom system. Two video tape recorders malfunctioned but three recorders were operational at all times and no data was lost because of the malfunctions. The air unit malfunction caused excessively high temperatures to develop in the GPL during the first day of testing.

Repair of the video tape recorders and of the mission manager's intercom required considerable time and it was suggested that future tests have a man on-call to provide quick turnaround repair time for malfunctioned equipment.

Electrical Power Usage. The electrical power sources provided in the GPL for experiment support and subsystem operation are essentially the same as those required for Spacelab. Peak loads measured during Phase II included the following: Lighting system, 800 watts; Cloud Physics experiment, 500 watts; Ionospheric Disturbances experiment, 1500 watts; Materials Sciences experiment, 3000 watts; High Energy Astronomy, 1724 watts; mission manager station, 300 watts. The total peak load for these systems was 7824 watts. These measurements are not sufficient to determine total power usage for a comparison with Spacelab requirements.

Conclusions Concerning Systems Integration. GPL systems operations were generally satisfactory. Improvements can be made to provide for better lighting and noise control, more effective communications, and less intrusion on experiment activities for documentary purposes.

Light levels throughout the GPL were generally below the levels required for Spacelab. Increased illumination, in accordance with Spacelab requirements and relocation of light sources to provide more indirect lighting will improve the GPL with respect to both crew operations and video monitoring/documentation functions.

Noise levels throughout the GPL were generally higher than those defined by Spacelab requirements and were occasionally a distraction to the crew. Most of the noise was in the lower frequencies (below 600 Hz). Scheduling of heavy noise periods by coordination between the mission manager and the experimenters will improve experiment operations.

Temperature and humidity levels were generally within the limits required for Spacelab. Exceptions occurred when the air unit malfunctioned and when equipment was inoperative overnight, allowing abnormal conditions to develop in the GPL.

The communications system between the control room, mission manager and experimenters would be more effective if it included the capability to address all experiment stations simultaneously and if headphones were provided, allowing experimenters to move about while communicating with other stations. The experiment monitoring microphones were marginally effective.

Obtaining complete video documentary coverage of all experiment activities required considerable intrusion on experimenters and lighting was a problem. Camera burns, which occurred because of bright spots, can be reduced by increasing the general level of lighting (to meet Spacelab requirements) and providing low-reflectance clothing for the crew. Camera locations and the number of cameras used are variables which will continue to require close attention in future tests to facilitate effective documentary coverage of crew activities. The storage space provided for photographic equipment at the mission manager's station was adequate.

Malfunction of GPL support equipment did not seriously affect the test. Experiments were carried out successfully and no data loss occurred as a result of malfunctions. Faster repair time can be achieved by providing a man on-call for future tests.

Electrical power measurements in future tests should include enough data to determine average loads, peak loads (magnitude and duration), and total power usage for both experiment equipment and GPL systems equipment.

APPROVAL

CVT/GPL PHASE II INTEGRATED TESTING

By Robert E. Shurney, George Maybee, and Stan Schmitt

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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