NASA CR-112332

EARTH ORBITAL EXPERIMENT PROGRAM
AND
REQUIREMENTS STUDY

VOLUME 8

APPENDIX F - DATA MANAGEMENT SYSTEMS MATRICES

APPENDIX G - INSTRUMENTATION MATRICES AND CONCEPTUAL CONFIGURATION DRAWINGS

APPENDIX H - RELATED BIOTECHNOLOGY LABORATORY EXPERIMENTS

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FOREWORD

The information presented in this report summarizes three major steps toward production of a reference manual for planners of manned earth-orbital research activity. The reference manual will serve as one of the principal tools of a systems approach to experiment and mission planning based on an integrated consideration of candidate research programs and their attendant vehicle, mission, and technology development requirements.

The first major step toward preparation of the manual was the development of long-range goals and objectives suitable for NASA's activities during the 1970-1980 time period. This work was completed by NASA Headquarters with active center support and was published in September 1969 as a portion of a report for the President's Space Task Group entitled, "America's Next Decade in Space."

The second major step was a contractual study effort undertaken in September 1969 by McDonnell Douglas Astronautics Company-West with the TRW Systems Group, the IBM Federal Systems Division, and the RPC Corporation. The purpose of the study was to structure the NASA-developed goals and objectives into an orderly, system-oriented set of implementation requirements. The contractor examined, in depth, the orbital experiment program required to achieve the scientific, technological, and application objectives, and determined in a general way the capabilities required in future manned orbital programs to accommodate the defined experiments. Thus, the basic task of the contractor was to aid NASA in studying the useful and proper roles of manned and automated spacecraft by examining the implementation alternatives for NASA experiments.

The third major step presented in this document is the result of an integrated consideration of NASA's long-range goals and objectives, the system and mission requirements, and the alternative implementation plans. It will serve as a source of detailed information and methodology for use by NASA planners in development and justification of future programs.

Management

Technical direction (fig. 1) of the contracted study effort is the responsibility of the Advanced Aerospace Studies Branch (AASB) of the Space Systems Division (SSD) at the Langley Research Center (LRC). Technical guidance is provided by the Earth Orbital Experiment Program Steering Group which reports through the Planning Steering Group (PSG) to the Associate Administrator. Technical coordination is also maintained with appropriate personnel at ARC, GSFC, MSC, and MSFC.

The membership of the Steering Group (fig. 2) comprises representatives of the working groups of the PSG under the chairmanship of Dr. R. G. Wilson, Director, Advanced Programs, OSSA. The NASA Study Management Team is headed by Mr. W. R. Hook of the AASB. Technical support is supplied by elements of the Langley Research Center as required.

The contractor's Study Team is headed by Dr. H. L. Wolbers, MDAC, and the Senior Management Review Council is chaired by Mr. C. J. Dorrenbacher, Vice President, Advanced Systems and Technology, MDAC.

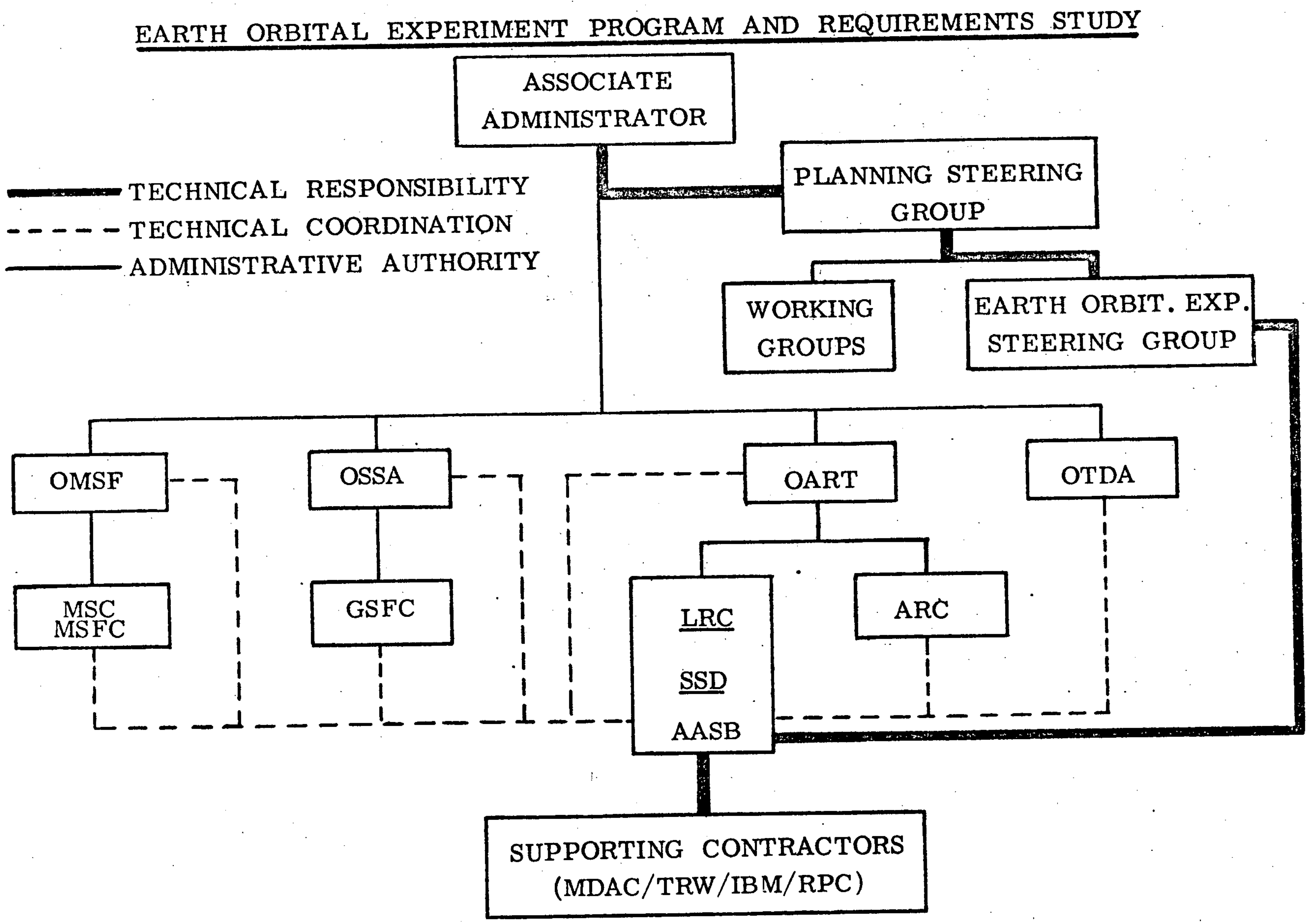


Figure 1. - Management Plan.

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

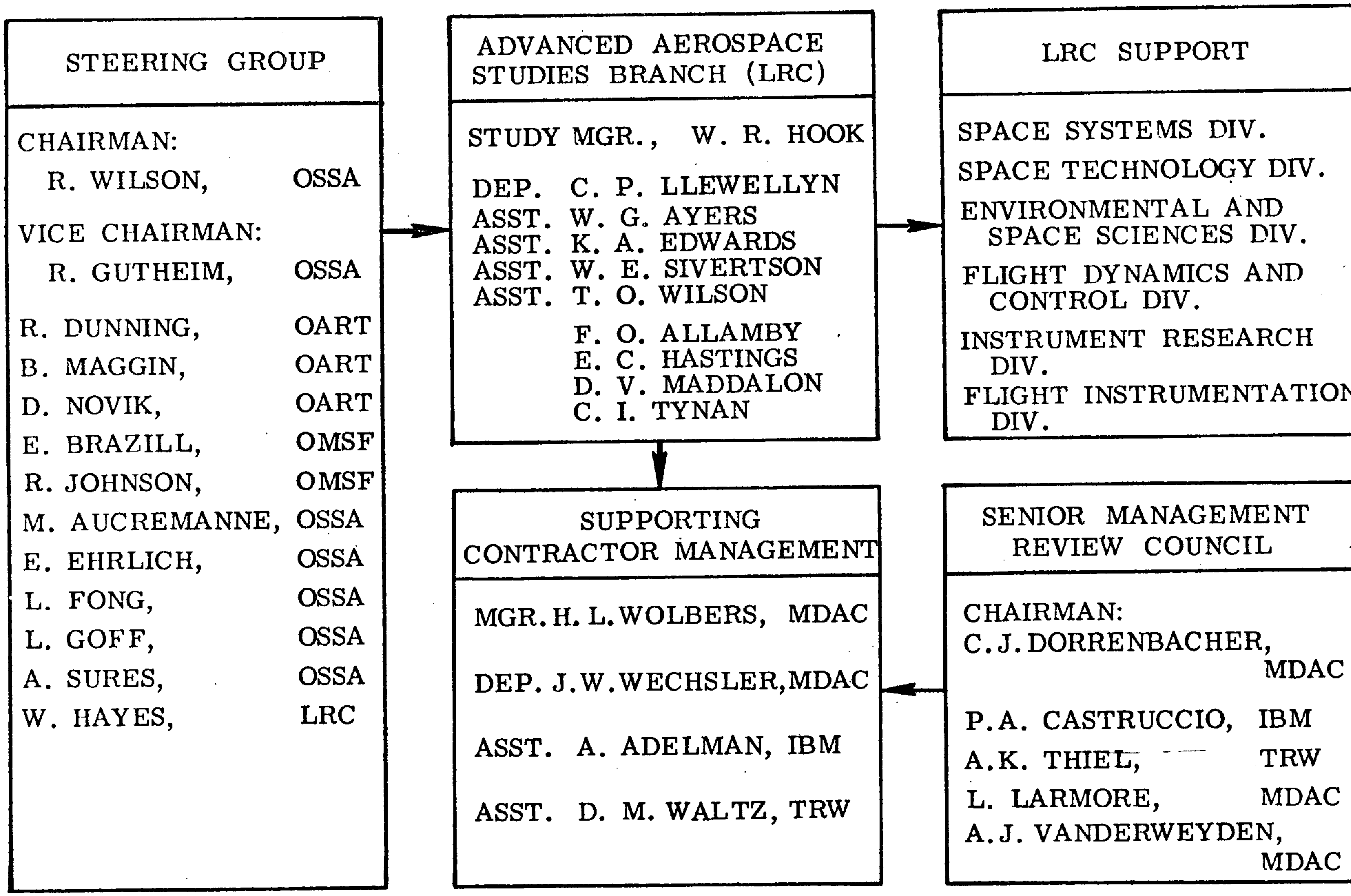


Figure 2. - Study Team.

APPENDIX F

DATA MANAGEMENT SYSTEM MATRICES

F-1

Appendix F

DATA MANAGEMENT SYSTEM MATRICES

This appendix contains (1) thirteen matrices which represent an example of eighteen selected research clusters analyzed for data-management implications and (2) discussion of the overall data management implication within major research areas. The discussion is found on Pages F-2 through F-14 and covers the research subjects of Biomedical Research, Behavioral Research, Engineering Experiments, Space Biology, Space Astronomy, Physics and Chemistry, Cosmic Ray Physics, Communication and Navigation, and Earth Observations. The eighteen matrices cover the research clusters listed below:

No.	Pages
1-BM-4	F-15, -16
1-BM-6	F-17, -18
1-BR-5	F-19, -20
1-EE-3-1	
2-PL-1,-2,-3	F-21, -22
3-OB	F-23, -24
3-XR	
3-OS	F-25, -26
3-OW	F-27, -28
4-P/C-8	F-29, -30
4-CR-1 through -10	F-31, -32
5-CS-1	F-33, -34
5-N-1	
5-N-2	
5-P-2	F-35, -36
6-A/F-1	F-37, -38
6-M-1	F-39, -40
6-M-2	

Selected Research Cluster Analysis

In order to present summary data, matrices representing 18 research clusters were completed. Each of these was selected to describe the most common data management support in each of the six scientific and technology disciplines. This sampling of research clusters provided a summary of the variety of data-handling options available to accommodate a wide assortment of sensors. Thus, the range of data requirements represents a cross section of the data management support necessary to proceed a synthesis at the system level. The variety found in the sample of research cluster descriptions is shown in the following listing:

Biomedical Research

Requirements in Biomedical experimentation are similar to the measurements, equipment, and services provided by intensive care units of modern hospitals, coupled with some clinical analysis and close supervision by medically trained personnel.

The most significant requirement caused by the program of activities outlined is the number of crew hours needed to perform the measurements and tests.

A technician is needed to administer the tests, and each of the crew members must participate as a subject. The options for easing this problem are:

A. Reducing the subject sample size.

B. Reducing the measurement requirement.

C. Stretching the measurement program over a longer period.

The potential requirement for onboard analysis of physiological data and a requirement for trend tracking establish both a functional need and a baseline for sizing the onboard computational facility and retrievable data storage.

It may be reasonably assumed that the Biomedical program will be one of the earliest to be implemented. It will require real- or near-real time data links to both the mission control center to assure the continued safety and welfare of the crew, and to the principal investigator (a medical doctor), whose consultation and evaluations will be necessary for experiment operation.

There are requirements for radiation to be used in two of the experiments (1-BM-4 for heart x-rays and 1-BM-5 for controlled animal exposure). This will be considered a potential source of hazard to the crew, equipment, and other experiments in accommodation, integration, and sensitivity analysis.

Data from the experiments are expected to be:

A. Written observations (amount not known).

B. Daily voice reporting (estimated at 1 hr).

C. Video images (TV) (estimated at 2 hr daily).

D. Digital data: 2 kbits, 10 kbits/sec continuously.

Behavioral Research

In the Behavioral research, like the Biomedical activities, testing will draw heavily on crew time. No significant onboard data requirements exist outside of the needs for real-time and non-real-time video and voice reporting. A large part of the data for Behavioral evaluation can be drawn from data collected in support of mission operations and other experiments. The expected data characteristics are:

A. Digital: Low-rate, low-duty-cycle only.

B. Video or film: images in slow motion for motor response evaluation.

C. Voice: high-fidelity (20-kHz bandwidth) voice samples for crew stress evaluation.

The Man-Machine Interface research clusters assess the interaction of man with the space environment, spacecraft conditions, and task tools. The results will be drawn from measured variables, images of the operations, and subjective comments made by the subject and observer. There is a significant requirement that all the activities being evaluated be recorded in both real time and time lapse. Recording media can be either film or video tape.

Tasks and equipment defined for the man-machine evaluation tasks are highly integrated with normal operational activity and equipment. Therefore, they present very little additional resource demand. Data from this experiment will consist of:

A. Crewman evaluations (written).

B. Verbal comments during tasks (recorded or transmitted).

C. Task image recording: film or video (if video, the images may be obtained from crew station video coverage).

D. Low-rate digital data

1. EEG made during sleep.

2. Performance efficiency (time and error).

3. Energy expenditure.

4. Force (acceleration) applied.

5. Crewman condition.

Engineering Experiments

Life Support and Protective Systems experiments provide for two different investigative areas: evaluation of mechanisms in zero gravity and evaluation of crew protective systems. Because of this difference, examples are presented separately.

The boiling heat transfer and condensation experiment equipment, consisting of tanks, tubes, heaters, lights, and measurement sensors, will be manually set up and adjusted, and measurement instrumentation (mostly image recording) will be triggered. Data resulting from the observations will consist of:

A. 16 mm motion pictures recorded at 40, 400, 1,000 and 4,000 frames per sec.

B. Video images recorded at 30 frames per sec with a resolution of 800 TV lines.

C. Low-rate digital data containing equipment condition and status information.

Requirements for processing the photographic film are stated for the purposes of a review of information collected to determine when or whether the proper phenomenon was recorded. Processing can be by the dry BIMAT process.

In the evaluation of crew protective systems, the reactions of the crew to real or simulated emergencies are to be investigated by measuring derivations from the control baseline during ground training. Data for this purpose can be obtained from crew station monitors, crewman observers, and the subjects themselves. The volume of data from these evaluations will be minimal from approximately 30 test periods (five emergency situations and six tests per situation). Each "emergency" is expected to last for 2 hr.

The most important equipment in this research will be the highly integrated detection center, or console, that will monitor 17 parameters and notify the crew when there is a real or simulated emergency in any one of five danger categories: fire, meteoroid penetration, excessive radiation, atmospheric contamination, and microbiological contamination. Because of the critical nature of the parameters sensed as well as the action to be taken when an alarm is given, continuous validation of the approximately 25 sensor channels will be necessary to ensure proper operation. Sensor outputs will be sampled frequently, and their reasonableness will be checked. Very little data will be recorded or transmitted. The system will respond to checkout stimuli by generating condition statement 2 to 4 times per hr.

Engineering Experiments address the evaluation of hardware systems, man-machine interactions, and technology. These research clusters are expected to place no significant requirements on data management or any mission resource. Engineer-scientists will typically want results instead of raw data. Therefore, much of the data collected will be reduced by simple methods such as limit checking (bounding the measurement and reporting only exceptions), redundancy removal, smoothing, etc. A minimum of controls and displays will be needed by this set of experiments.

Operations Experiments will address equipment, methods, and procedures tested before use on orbit. Space stress factors may invalidate part of the original design concepts. The research activities are directed toward evaluation of operations and the acquisition of new mechanical design specifications by in-space measurements.

Data collected during operations must be evaluated prior to the next occurrence of the operation so that any indicated ineffectiveness can be corrected. Data collected can be either processed onboard for evaluation (as would be the case with photographic film) or transmitted to the ground for evaluation (as would be permitted by the use of video). In either case, extensive image recording from two or more different angles would be required. Total operation segments would be recorded for all tasks performed outside the space research facility.

By comparison, the operational investigations of thermal coatings, lubricants, and metal fracturing will have minimal data requirements, apart from the extravehicular aspects.

The two experiments, Module Operations (1-OE-4) and Vehicle Support Operations (1-OE-5), will derive experiment information from data that results normally during operations of remote modules and during use of Station facilities. Data characteristics of the Operations Experiments are:

A. Heavy film or video generators, most of which will be evaluated onboard before the next repetition of the particular operation.

B. Post-mission evaluation of control and use data that have been routinely collected in ground monitoring or returned by resupply.

C. Low-rate digital data denoting temperatures, pressure, status, and events.

Space Biology

Space Biology experiments with invertebrates (crabs, cockroaches, and flies) are extensions and elaborations of experiments performed with limited success on unmanned satellites. These experiments are performed in space much as a similar experiment would be performed on the ground. (In fact, they are being performed on the ground for control purposes.)

The parameters to be measured involve photography, recorded activity patterns, detection of mutants, and breeding results. Data will be in the form of images, preserved animals, recorded (written) data, and event records.

The crew activity will consist of counting specimens, sorting males and females, preserving specimens, recording images (video or film), and tending animals. Automatic systems will provide the environment, collect ancillary data on vehicle position and accelerations, and record activity information.

There is a real-time coordination requirement to maintain nearly identical conditions (except for zero gravity) for the control group of animals. Most coordination can be accomplished via voice link.

Principal data products consist of:

A. Images -- 1 hour of motion and several hundred still images.

B. Low-rate digital for orbit dynamics, colony status, and analyses (i.e., radioactive tracer counts, paramagnetic oxygen measurement, and activity events).

C. Written data on colony history and experiment events, i.e., breeding cycles and visual counting.

These experiments are open-ended, as are the other Space Biology experiments, and objective descriptions have been prepared for only an initial set of observations. Space exposure will certainly lead to more extensive and sophisticated measurements. The set of measurements described can be considered the first phase in a continuing series of experiments on invertebrates.

Experiment activities in space-based plant biology are divided into three phases, each of which adds tasks and onboard responsibility to the previous task. Phase I is designed so that few measurements need be made by the crew. Experiment results from Phase I consists of recorded images, requested observations, and samples prepared for return (freeze-dried).

Still and time-lapse photographs are made to record plant growth and diurnal movements. Images can be stored on film or on video.

Electronic data are generated by mass spectrometer and potentiometer. In addition, some digital data are collected from support systems such as temperature, power, illumination, and time.

The digital data rate exceeds 1 kbit/sec. Image data approximates 17,000 stills and time-lapse frames.

Both measurement and equipment sohpistication are added for Phases II and III. Additional data are generated by radiation detectors (pulse height analyzers), a spectrophotometer (absorption band measurement), and amino acid analyzer, a gas chromatograph, and a larger photographic requirement.

Commensurate with the more complex measurement program are the qualifications required on the part of the experimenter. A high degree of skill is required for Phase II, and biologist is needed for Phase III.

Data characteristics for the total program are:

A. Images: about 20,000 still, time-lapse, and micro photographs.

B. Digital data: about 100 32-bit words per second.

C. Voice and video: as required for consultation with the principal investigator.

Space Astronomy

The astronomy experiments represent a special case relative to the other experiments because they will probably be operated apart from the manned space platform in a free-flying module. The size, weight, maneuverability requirements, and high stabilization for long pointing periods would be difficult, if not impossible, to accommodate inside or attached to the manned facility.

Planetary Astronomy and Astronomy Surveys both employ a 1-m, diffraction-limited telescope, with several secondary instruments at the focus, to collect images in five broad bands as well as to make photometric measurements. If vidicons are used instead of film, the photometric data can be derived directly from the video signal. A total of 1,000 images will be taken frequently enough so that short-term surface changes can be recorded, and over a duration long enough to observe long-term changes.

Radio Astronomy consists of a 1-km steerable antenna that will collect radio emissions as it scans the stellar sphere. Scientific data detected as RF spectrum noise will be plotted as a function of look angle to locate discrete radio sources. Subsequent astronomy experiments will attempt to find optical counterparts. The bandwidth of the signal that will be continuously sought is 50 kHz to 1 MHz. Accompanying data showing source direction and module status will be low-rate digital at about 6,400 bits/sec.

X-Ray Astronomy will employ two types of detectors. A proportional counter array collimated to a small acceptance angle (3 by 3 deg) will be used to map known and unknown x-ray sources. A large-area, grazing incidence telescope on the same module will obtain high-resolution images of x-ray sources. The images can be recorded either on film or electronically using an image converter.

Physics and Chemistry

Investigations in the physics and chemistry laboratory will produce little in the way of recorded data. Samples and unique materials produced that require precise annotation and time-lapse motion picture studies of low g-level physical phenomena will not be unlike the data generated in the manned spaceflight life support and protective system experiments. The data are expected to include physical samples to be returned to Earth, still photographic and motion picture film, and voice recordings and recorded environmental parameters.

Cosmic Ray Physics

The cosmic ray physics investigations are expected to present unique problems in the data management area. Scientists are, in essence, looking for unknown phenomena to occur against a strong background of noise. Traditional Earth-gased techniques for data accumulation and analysis have relied on statistical correlation of the observations from which determinations can be made if new events have been encountered. In this sense, the experiments produce significant data only in a few instances when unexpected events occur. Some form of onboard data processing will certainly be required. The exact nature and configuration of the data management system can only be estimated after additional engineering analyses and definitions have been prepared.

Communications and Navigation

The radio-frequency multipath measurement program will use a manned space platform for transmitting signals to cooperating aircraft. The scientific results will be measured and recorded onboard the aircraft, and so the aircraft will perform the bulk of the data handling. The data from the orbiting equipment will be engineering information related to the transmission system mode and status. These data will be in the form of low-rate digital words or PCM. In addition to the normal data path from orbit to ground, this mode and status data could be placed as modulation on the RF link under test so that all of the experiment data could be collected at one point, the receiving test station. Data from this experiment are expected to be:

A. Voice reporting: 2.5-kHz-bandwidth communications link estimated to be operating 60 min daily.

B. Digital data: approximating 1 kbps when operating.

Portions of this type of experiment may incorporate some form of preprogrammed control.

The manned communications and navigation test facility will generate data only as required for the support of other tests and experiments. If erectable antennas are required, the results of their deployment as related to EVA will be noted by the manned spaceflight capability tests under Operations Experiments.

The test facility is expected to contain a variety of laboratory microwave test equipment adapted for the spacecraft environment. For the most part, these instruments will be operated and read manually and will not generate data for transmission to the ground. It is expected that a remote data acquisition terminal will be connected to the spacecraft data bus to handle a minimum amount of digital data. Data are expected to include:

A. Voice: 2.5-kHz-bandwidth, average utilization 1 to 2 hr per day.

B. TV: receiver and camera connected to spacecraft system, estimated utilization less than 20 min per day.

C. Digital data: analog-to-digital conversion incorporated in data acquisition units, approximately 1 kbps when operating.

The orbital tests to develop millimeter and optical wavelength communication systems will not be large generators of onboard data. This type of test is another instance where the link can carry some of its own mode and status data. Operation will generally be manual. Spacecraft-generated pointing signals will be required for the tests involving directable antennas. The data from this experiment group are expected to be:

A. Voice: 2.5-kHz bandwidth, use estimated at 1 to 2 hr/day.

B. Digital data: less than 3 kbps when operating.

Navigation system tests will consist of the operation of prototype navigation systems involving RF and optical transmission and reception at the orbiting spacecraft. These experiments are expected to generate only a modest amount of onboard data that must be transmitted to the ground. Those experiments generating relatively high rates can be scheduled so as not to create peak data loads for the data management system. Pointing information will be required from the data management system for some tests. Data from this experiment group are expected to be:

A. Voice: 2.5-kHz bandwidth, utilization estimated at 1 to 2 hr/day (average).

B. Digital data: includes analog-to-digital conversion, estimated at 1 to 10 kbps when operating.

Earth Observations

Earth Observations remote sensing requirements call for high-resolution images and multispectral narrow-band data collection over target areas with unique observables. These area collection requirements (by virtue of the area to be covered and the coverage obtained from orbit) result in the largest data management load of all the experiments selected. Image data will be collected by vidicon or vidicon-type sensors and photographic film cameras.

Management of Earth Observation experiments will take the form of controlled collection and storage of data with emphasis on limiting data to that which is useful. This will involve evaluation of data both before and after collection for evaluation and recording. Photographic data may present a problem in the evaluation since it may have to be chemically processed.

The Earth Observations research activities will start with evaluation of the sensors to verify that the equipment works as a system and then proceed to verify that data to be of the quality required by the users. The Agriculture/Forestry research cluster was examined in greater detail to determine what data characteristics would be encountered during early or initial experiment operations. This examination revealed that when operation is restricted to truth sites (so that ground-based measurements can be used for verification of orbital data), target overflight times were too rare to accomplish expected results within a reasonable period.

Operations during this period will be designed around truth sites and data will be collected over wide areas that include the site. In this way, sufficient data can be collected to develop baselines for evaluation and analysis.

It has been recognized that the Earth Observation experiments will determine system sizing with regard to data rates and quantity. Further efforts are needed to define and statistically evaluate duty cycle, observation period, target availability, and variables such as illumination and cloud cover limitations. In addition, data flow and user requirements such as real-time data, near real-time data, data form, data processing locations, and equipment interfaces need definition.

Twenty-two primary instruments will be carried aboard the space research facility for the purposes of collecting data from the Earth's surface and atmosphere. These instruments have been chosen to satisfy requirements in:

- Agriculture/Forestry
- Geology
- Geography/Cartography
- Meteorology
- Oceanography
- Hydrology

through a program of periodic sightings of surface and atmospheric features.

Appendix O contains an instrument matrix for the research clusters. Commonality of usage is apparent; less apparent is the redundancy (and uniqueness) of data collected, i.e., the extent to which each group of data collected satisfies all of the measurement requirements for Earth Observations. This area of commonality is affected by:

- Cloud cover limits
- Season of coverage
- Spectral band
- Offset angle limitations

As explained earlier, based on the assumption that the initial operation of the Earth Observation tasks will be restricted to collecting truth data verified and compared with locally sensed data, a more detailed examination of one of the experiments was made to discover the characteristics of coverage as compared with requirements. The results presented show that coverage of the identified truth sites depends on the look angle (β angle) allowed. For example, by limiting the β angle to ± 0.5 deg, as the requirements specify, the target is acquired less than one time per ten days. The β angle must be at least 20 deg before a significant number of truth sites are acquired as often as once per day.

Both spectral and spatial information are affected by the β angle. When the look angle approaches 45 deg the images can no longer be accurately interpreted. Also reflectance characteristics (spectral signatures) change with β angle and illumination angle. Degradation of information quality must be properly assessed before large look angles can be accepted.

An alternate mode of operation that will permit a reasonable data return is to collect data using small look angles over areas contiguous to truth sites scheduled so that the truth itself can be observed on subsequent orbits to provide calibration and data baselines.

GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	ORBIT CONSTRAINTS: POINTING TOLERANCES/STABILIZATION REQUIRED	ORBIT CONSTRAINTS: PREFERRED INCLINATION/ALTITUDE	ORBIT CONSTRAINTS: ILLUMINATION	ORBIT CONSTRAINTS: CRITICAL SCHEDULE FACTOR	CLOUD COVER MAXIMUM	OPERATING CHARACTERISTICS: EXPERIMENT OPERATING DURATION	OPERATING CHARACTERISTICS: OBSERV. CYCLE LENGTH/REP. RATE	OPERATING CHARACTERISTICS: CREW FUNCTIONS INVOLVED	SELECTED INSTRUMENTATION: 1. EEG Sensors	2. Pneumatic Cuff	3. Strain Gauge	4. Manometer	5. Timer	6. X-Ray
1-BM-4	Effects of Weightlessness on Cardiovascular Function	Heart Rate	Heart cycles per unit time					One for each new crew						3 weeks	3 times first week; Twice weekly second and third week	All crew members will be subjected. Member not under test to assist in taking measurements	x					
		Arterial Blood Pressure	Appearance and disappearance of Korstkoff's sounds											3 weeks				x				
		Limb Volume	Net blood flow to limb per unit of time											3 weeks					x			
		Periphal Venous Blood Pressure	Net pressure differential of blood in veins											3 weeks						x		
		Circulation Time	Time to taste sensation											3 weeks							x	
		Heart Size	Appearance on X-ray											3 weeks								x
		Veneous & Arteriolar Reactivity	Ratio of limb volume to cuff pressure											3 weeks								

1-BM-4

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	Constraints	TASK/INSTRUMENT KEY	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE – TIME: CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS
Output of microphone or waveform analysis of ECG	Degradation characteristics of heart rate over period of time	Not critical unless severe degradation begins	CRT's to display data in real time	Sequencing experiment, control of displays & storage of data	Measurement should not be interrupted	1	None required	Artery or vein below loose occlusive cuff	Press on vein or artery	One minute per individual		30 to 200 pulses per minute	Once experiment has begun with any given individual it cannot be interrupted
Microphone output (semi-digital electrical signals)	Change of blood pressure over period of time					2		NA	NA				This device only assists in experiments by providing a stoppage in limb blood flow and does not generate data as such.
Analog electrical signal	Variations of the volume of blood in limb over period of time					3	Output of sensor will need to be balanced to zero before each measurement cycle		Sample sensor output for given period of time	One minute per individual		200-1000ML ± 10ML	
Analog electrical signal	Change in blood pressure over period of experiment					4	Not required		Sample output of sensor for period of time			0-200 mm Hg ± 5 mm Hg	
2 digital start-time delay-stop pulses	Changes of circulation times over experiment period of three weeks					5	None required (The GMT on the Space Station would provide time base)		Depression of timer button starts timer: depression of same button stops timer: elapsed time would be recorded	Variable		10-30 seconds ± 0.5 seconds	
Photographic display of chest showing heart	NA					6	None required	Aim X-ray source at individual's body	2 exposures per individual, one frontal, one from side			2 exposures per week for 3 weeks	
No direct measurements or sensors for this experiment	NA				This measurement is derived from the limb volume and blood pressure measurements as a direct ratio								

SENSOR OUTPUT DATA FORM	TASK/INSTRUMENT KEY	FILM TYPE: EXPOSURE RATE PER MODE CYCLE: CALIBRATE	OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS
Output of microphone or waveform analysis of ECG								
Microphone output (semi-digital electrical signals)								
Analog electrical signal								
Analog electrical signal								
2 digital start-time delay-stop pulses								
Photographic display of chest showing heart	6	None required	Automatic exposure system	X-ray	0%	None	Less than 100 exposures for 6 man crew	
No direct measurements or sensors for this experiment								

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	CONSTRAINTS
Analog voltage	Heart rate in beats per minute (30 - 220)	2 or 3 days for each meas. group but related data is required simultaneously ↓	Meter and from ECG recording on strip chart	Sequencing experiments and control of displays ↓	Heart rate must be limited to 150/min. by reducing stress or load causing high heart rate
Analog voltage of cuff pressure with Korotkoff sounds from microphone superimposed	Arterial systolic and diastolic pressures		Strip Chart		None
Voltage amplitude of RF carrier	Thoracic impedance (Z), calculating ΔZ and ΔŻ.		CRT Digital Display		Method is unproved although some correlation exists between measured cardiac output and thoracic RF impedance dangerous to subject tested
None	Observed affects of O_2 deficiency and high CO_2 levels in air		None		Requires medically qualified testor since test can be
None			None		
Analog voltage	Stress limits for safe body temp range		Meter or CRT if data is digitized		
None	Monitor time for observable or limiting levels of stress develop in crew		None		Same as above
Analog voltage	Absorption of several light wavelengths used to determine O_2 and CO_2 concentrations		CRT Display		
Analog voltages	Integrate flowmeter airflow and reversals and calculate ventilatory response		CRT Digital Display		
Analog voltage	Monitor to maintain acceptable temperature for test subject		Meter or CRT		Temperature must be maintained within acceptable limits for subject
Analog voltages	Monitor metabolic rate		CRT		None
Analog voltages	Indicator of physical fitness status		Meter and CRT		Must be limited to keep heart rate within acceptable limits
Analog voltages (or by chemical analysis)	Determine change from normal		Strip Chart		None
Analog voltage	Amount of water loss during heat stress	↓	CRT	↓	None

ELECTRONIC DATA

TASK/INSTRUMENT KEY	SENSOR OUTPUT RATE PER MODE TIME: CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS
1	Electrodes not calib. but oscillator calibration is applied to analog circuits heart rate meter	NA ↓	Analog circuit detects and integrates "R" waves of ECG	For duration of associated tests ↓	Once/minute	Derived from EEG wave (.05 to 100 Hz) No additional data quantity for heart rate	
2	Calibrated pressures applied to cuff & gauge before each test		Press trans. measures cuff pressure		Once/minute	5-500 Hz A-D conversion	
3	No mic. calib. req'd.		Microphone output added to pressure gauge output		NA		
4	Electrodes not calibrated		Measures RF impedance across chest		Computation once/minute	100 samples per second	Low correlation exists between thoracic impedance and cardiac output
5	By resistance substitution		Resistance change with temperature unbalances bridge		Once/minute		9-skin temp. 1-core temp. 1-thermal encl (air) temp.
6							
7	No calib. required		NA		As required		Used to time events
8	With standard gasses before beginning of each test session		By selective absorption of various light wavelengths measures D_2 and CO_2 partial pressures in respiratory gasses		As required		
9			Pressure diff. across orifice		Computation once minute		
10	Not required		Generates electric power		Once/minute		
11	NA		NA		NA	NA	For hyperthermia test. Does not generate data
12	NA		NA		For use in breathing special gas mixtures. Does not generate data.		
13	Not required		Detects period of suspended chair orbed		Once before and once after each hyperthermia test		
14	NA		NA		Use to suspend subject to determine total weight by period. Test chair does not generate data.		
15	With standard fluids	↓	Lactic and determined by absorption of various light wavelengths	↓	Once/minute during test		

FILM TYPE

TASK/INSTRUMENT KEY	EXPOSURE RATE PER MODE CYCLE: CALIBRATE	EXPOSURE RATE PER MODE CYCLE: OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC GENERATED)	LOGISTICS REQUIREMENTS (LBS PER 90 DAYS)	REMARKS
	NA	NA	NA	NA	NA	NA	NA

									Orbit Constraints					Operating Characteristics			Selected Instrumentation														
Group Number	Group Name	Measurement Objective	Indicative Phenomena	Resolution Requirement Spatial/Spectral	Target Objective	Dimensions of Target Area (Length x Width)	Location of Target	Replication Rate	Pointing Tolerances/ Stabilization Required	Preferred Inclination/ Altitude	Illumination	Critical Schedule Factor	Cloud Cover Maximum	Experiment Operating Duration	Observ Cycle Length/Rep Rate	Crew Functions Involved	1. ECG Electrodes	2. Pneumatic Cuff & GNGE	3. Microphone	4. ZCG Electrodes	5. Thermister	6. Hygrometer	7. Stopwatch	8. Pneumatograph	9. Flowmeter	10. Ergometer	11. Modified Space Suit or Enclosure	12. Mask & Special Gases	13. Accelerometer	14. Suspended Chair or Bed	15. Chem. Analysis (Spectrophotometer)
1-BM-6	Changes in Response to Imposed Environmental Stresses	Heart Rate	Primary indicator of physiological tolerance of stress	NA	NA	NA	NA	For each new crew	NA	NA	NA	NA	NA	Periodically throughout flight. Changes expected to reach a plateau in two to three weeks. Measurement interval will be increased after plateau is reached.	2 to 3 days for each measurement group for 2 to 3 weeks.	Crew members are subjects of test.	■														
		Blood Pressure	Arterial systolic and diastolic pressure by Korotkoff sounds															■	■												
		Cardiac Output	Primary indicator of cardio-vascular status																	■											
		Hypoxia Production	Level of consciousness																					■				■			
		Hypercapnia Production	Acidosis																					■				■			
		Hyperthermia Production	Body core temperature																		■	■					■				
		Time of Useful Consciousness	See Above																				■								
		Alveolar (End Tidal) Partial O_2 Pressure and Partial CO_2 Pressure	Monitor adequately of respiratory and cardio-vascular parameters																					■							
		Respiratory - Minute Volume - (V_E)	Monitor adequate respiration performance																						■						
		Rate - (Breaths/minute)																							■						
		Ventilatory Response (V_E/P_ACO_2)																						■	■						
		Temperatures Core and Skin	Core and average skin temperature																		■										
		Oxygen Consumption CO_2 Production	Indicative of metabolic rate																					■ ■	■ ■						
		Workload	Measure of physical fitness																							■					
		Blood Lactic Acid — Oxygen Debt	Metabolism product in blood reflecting oxygen deficit																												■
		Sweat Loss	Mass determination by oscill. period or accelerometer												Crewman weight determined before and after each hyperthermia test.														■	■	

GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	ORBIT CONSTRAINTS					OPERATING CHARACTERISTICS			SELECTED INSTRUMENTATION				
									POINTING TOLERANCES/ STABILIZATION REQUIRED	PREFERRED INCLINATION/ ALTITUDE	ILLUMINATION	CRITICAL SCHEDULE FACTOR	CLOUD COVER MAXIMUM	EXPERIMENT OPERATING DURATION	OBSERV. CYCLE LENGTH/REP. RATE	CREW FUNCTIONS INVOLVED	1. Temp. Sensors (50) (Thermocouples)	2. Pressure Sensors	3. Mass Spectrometer	4. Gas Chromatograph	5. Power Meters (Electrical) (19 measurements)
1-BR-5	Personal and Social Adjustment	To detect changes in behavior and attitudes of flight crew due to long term flight and to verify behavioral assessment and develop therapeutic techniques	Response to questionnaires: observation records (of TV or video tapes), verbal records, electroencephlogram, and galvanic skin resistance	NA	NA	NA	NA	Repeated for each new crew	NA	NA	NA	NA	NA	One hour per week per crewman for duration of the mission	Weekly cycle repeated each week	Each crewman self administers questionnaire keying response in computer storage and talks to counselor 10 min. each week	NOTE: All hardware requirements are provided by other experiments. Verbal and TV monitoring and GSR and EEG records are obtained without interference with ongoing crew activity. Only self-administered test (questionnaire) and 10 minutes per week conversation with counselor required.				
1-EE3-1	Biowaste Electric Propulsion Reaction Control System (BEPS)	Evaluation of the Performance of Resistojet Using Life Support System Expendables for Propellants	• Pressures • Temperatures • Flows • Power • Combustion of gas	N/A	N/A	N/A	N/A	Data cycle consists of gas generation followed by engine firing	NA	N/A	N/A	Scheduling very flexible	N/A		4 hours per cycle. Rep. rate TBD	EVA for engine repair and replacement	X	X	X	X	X

1-BR-5							ELECTRONIC DATA								FILM TYPE						
							SENSOR OUTPUT RATE PER MODE – TIME								EXPOSURE RATE PER MODE CYCLE						
SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED		TASK/INSTRUMENT KEY	CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS	TASK/INSTRUMENT KEY	CALIBRATE	OPERATE	FILM DATA	ONBOARD, PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS
None - uses data reduced from ongoing experiments	Behavioral changes that may affect mission success.	Requires results of self administered tests, 10 minutes councilling of each crew member plus EFG, GSR and TV and verbal records each week ± 1 or 2 days	None	No additional onboard controls required			NA ←														→ NA
Analog converted to digital	Performance	Operational data can be delayed 0.5 hours																			

GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	ORBIT CONSTRAINTS: POINTING TOLERANCES/ STABILIZATION REQUIRED	ORBIT CONSTRAINTS: PREFERRED INCLINATION/ ALTITUDE	ORBIT CONSTRAINTS: ILLUMINATION	ORBIT CONSTRAINTS: CRITICAL SCHEDULE FACTOR	ORBIT CONSTRAINTS: CLOUD COVER MAXIMUM
2-PL-1 2-PL-2 2-PL-3	Physiologia Plantarum	To investigate the physiological, gross, morphological, and histochemical changes elicited in plants resulting from the absence of gravitational stimulation.	Plant shape	NA	NA	NA	NA	0-10,000 counts per minute	NA	NA	NA	NA	NA
			Glucose-G-Phosphate Dehydrogenase					-.00,'Mn/ mg Protein N					
			Photosynthetic Rate					Parts/ Million					
			Lipid Catabolism/ Beta Oxidation					00/MN/ mg protein N					
			Protein Catabolism/ Amino Acid Pools					Ditto					
			Carbohydrate Metabolism					°C					
			Seed Germination					1 frame per 30 minutes					
			Biochemical abnormalities					Intermittent					

INDICATIVE PHENOMENA	OPERATING CHARACTERISTICS: EXPERIMENT OPERATING DURATION	OPERATING CHARACTERISTICS: OBSERV. CYCLE LENGTH/REP. RATE	OPERATING CHARACTERISTICS: CREW FUNCTIONS INVOLVED	SELECTED INSTRUMENTATION: 1. Liquid Scintillation System	2. Spectrophotometer	3. Mass Spectrometer	4. Gas Chromatogram	5. Amino-Acid Analyser	6. Ph Meter	7. Microtome	8. Command Microscope C Camera	9. Tissue Processor	10. Histochemical Oven	11. Still & Time Lapse Cameras	12. LN_2 Refrigerator
Plant shape	30 minutes	3 times	Highly skilled operator	■					■					■	
Glucose-G-Phosphate Dehydrogenase	2 minutes	3 times	Highly skilled operator		■					■	■	■			
Photosynthetic Rate	Continuous	NA	Highly Skilled Operator			■						■			
Lipid Catabolism/ Beta Oxidation	2 minutes	3 times	Skilled				■								
Protein Catabolism/ Amino Acid Pools	2 minutes	Ditto	Skilled					■	■						
Carbohydrate Metabolism	NA	NA	Minimal skills		■				■						■
Seed Germination	NA	100	Minimal skills											■	■
Biochemical abnormalities	NA	1000	Highly skilled							■			■		■

NOTE: Only selected indicative phenomena shown. The total number of phenomena each of the instruments will be used to monitor is shown below:

Instrument #	Phase I	Phase II	Phase III
1		9 para	59 para
2		18 para	
3	2 para		
4		3 para	
5		3 para	
6	2 para		
7			
8			
9			
10		3 para	
11	20 para	2 para	
12	10 para		

2-PL-1
2-PL-2
2-PL-3

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	
Strip chart recording or digitized analog wave form	Shape change of plant over time	Not critical	Video tube readout	Video tube display selection, history info of experiment storage of data	
Ditto	Amount of GGPD in specimen	Ditto	Ditto	Ditto	
Ditto	(1)		Ditto	Ditto	
Ditto	(2)		Ditto	Ditto	
Ditto	(3)		Ditto	Ditto	
NA	(4)		NA	NA	
Film and samples	Growth of seeds per given time		NA	NA	
Samples	(5)		NA	NA	

(1) O_2 evolved
CO_2 absorbed

(2) Rate of disappearance of fat molecules

(3) Break down of protein

(4) Break down of sugars

(5) Any event which is abnormal

TASK/INSTRUMENT KEY	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE – TIME: CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS
1	System automatically performs quench calibration		Automatic operation after introduction of sample			Graph or analog electrical waveform	Measures radioactive isotopes in sample
2			After calibration the wavelength is set and sample introduced			Strip chart recorder or analog electrical wave form	Measures light absorbed by sample as function of wave length
3			Manual & automatic operations possible				Measures number of ions of each E/M
4	Manual adjustments required before operation					Analog electrical waveform	
5	(See 4 above) Also requires replenishment of reagents		Automatic operation after calibration & sample injection			Electrical analog waveform which requires integration	
6	Electronic calibration using internal standard cell		Automatic operation after calibration			Visual and recorder output - could be a binary BCD signal	
7	None required		Manual operation only				Microtome used to section specimen samples to 1-50
8	None required		Manual operation only				Typical transmittal-replectance microscope with camera + 35mm film
9	None required. Reagents must be added however.		Manual or Cam controlled operation possible				Dehydrates, fixes and infiltrates tissues
10	May require special gauges if amount pressures are not 14.7 psia (vacuum gauge on oven calibrated in psig)		Manual operation only (Automatic temperature control)				Oven temp range 350 to 200°C vacuum from ambient to 10
11							
12	None required		Refill with LN_2 every 3 weeks				

TASK/INSTRUMENT KEY	FILM TYPE: EXPOSURE RATE PER MODE CYCLE: CALIBRATE	OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS PER 90 DAYS)	REMARKS
8	None required	Manual operation only	1-5 exposures 35 mm B&W and color film	0%	1000-5000 lines/inch vidicon		
11	None required	Manual for still camera semi-automatic (timer) for time lapse		0%			

									ORBIT CONSTRAINTS					OPERATING CHARACTERISTICS			SELECTED INSTRUMENTATION											
GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	POINTING TOLERANCES/ STABILIZATION REQUIRED	PREFERRED INCLINATION/ ALTITUDE	ILLUMINATION	CRITICAL SCHEDULE FACTOR	CLOUD COVER MAXIMUM	EXPERIMENT OPERATING DURATION	OBSERV. CYCLE LENGTH/REP. RATE	CREW FUNCTIONS INVOLVED	1. 1 Meter Telescope	2. 3 Meter Telescope	3. Camera Vidicons may	4. Vidicons replace cameras	5. Monitoring Video	6. Grazing Incidence Telescope	7. Proportional Counter Array	8. Camera, Film	3. Camera, Video	10. Pulse Height Analyzer	11. Image Converter	12. Star Trackers (2)
3-OB	Astronomy	1. Synoptic High Resolution Observations of Mercury	Broadband images of planet 2000Å - 1μ	Instrument #1 65.4 - 114.4 km / 4-5 wavelengths 500-1000 Å widths	Planetary surface & atmospheric features	2-9 mm image 5-8 sec	Near ecliptic 10-28° from sun	2-5 images per day min. of 500	<1 sec / .042 sec RMS		Natural: Solar Reflection	≤16 days of maximum elongation 2000Å - 1μ	NA	2 year duration sufficient for temporal observations / 8 months for areal coverage	1-20 sec. for exposure for 3000-7000 Å. One minute per exposure for IR & UV.	• Monitor • Control sequences • Control exposures • Change & retrieve film if used	■		■	■	■							
				Instrument 2 21.8 - 38.2 km / 4-5 wavelengths 500-1000Å widths					< 0.1 sec / .014 sec RMS				NA					■	■	■	■							
		2. Synoptic High Resolution Observations of Mars	Broadband images of planet 2000Å - 1μ	Instrument 1 32.7 - 114.4 km 4-5 wavelengths 500-1000Å widths		3-27 mm at focal plane	Near ecliptic 90-180° from sun	2-5 images per day min. of 500			Same	Same as above	NA				■		■	■	■							
				Instrument 2 10.9 - 38.2 km 4-5 wavelengths 500-1000 Å widths		Same as above	Same as above	2-5 images per day min. of 500			Same	Same as above	NA					■	■	■	■							
3-XR	Astronomy	Precise location, size, and structure of known discrete X-ray sources, and existence of additional unknown sources		1-10 sec / 1-20 Kev	X-ray energy in 2-20 bandwidths	All sky: FOV $1^{\circ} x 1^{\circ}$	To an accuracy of 3-10 min. for unknown weak sources	TBD			Natural 1.6 - 1.6×10^{2} photons per second			Sky survey continuous	4.5 days @ 10 min/sec								■					■
						20% sky: 3' x 3'									31 days @ 10 min/sec													
						2% sky: 3' x 3'	Position of known sources to 10-30 sec.	TBD			Natural 4.7×10^{2} - 4.7×10^{5} photons				14 days @ 1 min/sec								■					■
							X-ray images of strong known sources	TBD						≈100 discrete sources	VS-M: 6 hrs M-MW: 17 days							■					■	■

3-OB
1-XR

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	
Photographic or electronic (optical) images	Temporal surface and atmospheric changes	Resupply interval adequate. If video is used, delivery of interim data would be useful.	Visual display of target parameters	• Target acquisition • Exposure control • Filter select • Calibrate and focus • Status monitoring	Temporal variations will determine exposure rate from minutes to years
Electronic: Pulse height analyzer	Distribution of energies	Resupply interval adequate	• Display of counter array • Video monitor of visible light through a spotting scope	• Start scan • Monitor • Terminate scan	
Electronic or film	Images				

TASK/INSTRUMENT KEY	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE – TIME: CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS	TASK/INSTRUMENT KEY	FILM TYPE: EXPOSURE RATE PER MODE CYCLE: CALIBRATE	OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS
1	Engineering status and checkout 200 sensor points	Video output for visual acquisition (same as primary sensor if vidicon used) 5 min. per acquisition	60 measurements 12.5K bits/sec ≈5 min. per group of images (5 exposures)	1-20 sec. in 3000 - 7000 Å 1 min. in UV and IR for five discrete bands.	Target opportunity continuous Avg. 1 mode cycle/day (5 images)	200 ch. status 10 MHZ video 30 sec/day	The use of film instead of vidicon will eliminate video data	3	Calibration exposures made at least once per day	1 photograph each through 5 filters		Calibration exposures will be processed	No	TBD	
2	Engineering status and checkout 400 sensor points	Same as above	Same as above	Same as above	Same as above	400 Ch. Status data	Same as above	3	Same as above	Same as above	8 x 8 inch image format	Same as above	No	TBD	
4	20-50 images	Use monitor mode				2.5×10^{8} bits per frame	$\approx 12.6 \times 10^{8}$ bits per day								
7	Absolute flux measurements using artificial source	Continuously scanned	≈54 days equivalent 2-20 pulse height channels sampled every second	Peak 50K to 2M counts per second stored in registers Avg. 500 counts per second	Continuous		Quantity of magnetic tapes to be determined								
12		Star trackers for target coordinates	Continuous	X, Y, & Z coordinates sampled 2 per. sec.											
6,9	Artificial source used to focus and calibrate	Mostly predetermined targets manually (& visually) acquired	≈100 source images 6 hrs - 17 days each	2.5×10^{8} bits per frame Avg. TBD	One	2.5×10^{8} bits		6,8 11	Same as before but frequency becomes once per target	Same as with vidicon	Panchromatic	TBD	No	TBD	

GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	ORBIT CONSTRAINTS: POINTING TOLERANCES/ STABILIZATION REQUIRED	ORBIT CONSTRAINTS: PREFERRED INCLINATION/ ALTITUDE	ORBIT CONSTRAINTS: ILLUMINATION	ORBIT CONSTRAINTS: CRITICAL SCHEDULE FACTOR	ORBIT CONSTRAINTS: CLOUD COVER MAXIMUM	OPERATING CHARACTERISTICS: EXPERIMENT OPERATING DURATION	OPERATING CHARACTERISTICS: OBSERV. CYCLE LENGTH/REP RATE (1)	OPERATING CHARACTERISTICS: CREW FUNCTIONS INVOLVED	SELECTED INSTRUMENTATION (2): 1. Telescope (1 or 3 meter)	2. Cameras (one at each foci)	3. TV Cameras (high resolution)	4. Photoelectric Photometer	5. Filter Assembly
3-05	Astronomy	Optical search, survey, and measurement of faint astronomical objects		0.1 $\widehat{sec}$ three standard broadbands (U, B & V)	Globular star clusters				1 $\widehat{sec}$ TBD		Intrinsic: +26 V-Mag				One hour for each target photograph	For all tasks: • Telescope monitor & control • Calibrate, focus & maintain • Change secondary instruments and filters • Preview data (if electronic) • Change film (if not electronic) • Acquire targets • Select operating modes	x	x			x
				0.1 $\widehat{sec}$ standard band (V)	Intergalactic star clusters	0.1 $\widehat{sec}$ to 10 $\widehat{sec}$			1 $\widehat{sec}$/TBD		+24 to +26 V-Mag				One hour for each target photograph		x	x	Video is a replacement for cameras and photometers for all applications		x
				0.1 $\widehat{sec}$ standard bands (B, V)	Medium distance galaxies				1 $\widehat{sec}$/TBD		+26 to +28 V-Mag				One hour for each target photograph		x	x			x
			Angular diameter and relative angular position of stellar objects	$\frac{0.1\ \widehat{sec}}{2000Å - 3000Å}$ U, B, V & 1μ	Optical counter-parts of "invisible" objects	1 $\widehat{sec}$ to 1 $\widehat{deg}$	Nearly all sky	Continuous with low period	1 $\widehat{sec}$/TBD	High/Pref. Sync. for all	+26 to +28 V-Mag	TBD	NA	Approximately one year to obtain a minimal data set	3.5 hours for each target photograph		x	x			x
				$\frac{0.1\ \widehat{sec}}{V}$	Unknown planetary satellites				1 $\widehat{sec}$/TBD		+24 to +26 V-Mag				3.5 hours for each target photograph		x	x		x	x
				$\frac{.1\ \widehat{sec}}{\text{Broad and narrow band } H_\alpha}$	H II in galaxies	0.1 $\widehat{sec}$ to 10 $\widehat{sec}$			TBD		+26 V-Mag				3 hours for each target photograph		x	x			x
				V	Unknown objects				Same as above		Not Known				Requires no additional time for photographs		x	x			x
		Determination of Stellar Magnitudes	Photometric intensity	± 0.03 MAG pe	Globular clusters				1 $\widehat{sec}$/TBD		All V> +21						x			x	x
				± 0.03 MAG pe	Intergalactic star clusters				1 $\widehat{sec}$/TBD								x			x	x
				± 0.05 MAG pe	Medium distance galaxies				1 $\widehat{sec}$/TBD								x			x	x
				± 0.10 MAG pe	Optical counterparts				1 $\widehat{sec}$/TBD								x			x	x
				± 0.10 MAG pe	Unknown planetary satellites				1 $\widehat{sec}$/TBD								x			x	x
				± 0.10 MAG pe	H II in galaxies				1 $\widehat{sec}$/TBD								x			x	x
					Unknown objects												x			x	x

3-OS

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	
Status, calibration and control data is all electronic Scientific data can be either electronic or film	Broad spectra (bands U, B & V) images	The course of experiment progress is dependent upon both quality and content of information. The more timely the data turnaround the better.	•Indications of equipment parameters such as -system power -temperatures -consumable consumption •Indications of operating parameters -direction of point -pointing error -target display -data display	•Calibration source & mode control •Alignment controls for -Filters -Mirrors -Secondary instruments •Experiment Mode Control -Exposure -Filter Selection -Secondary instrument selection -Secondary mode control	
Electronic	Magnitude intensity of comparison stars for calibration of groundbased photometry	Data to be delivered with imagery			

ELECTRONIC DATA

TASK/INSTRUMENT KEY	SENSOR OUTPUT RATE PER MODE - TIME: CALIBRATE	TARGET ACQUISITION	OPERATE (3)	DATA COLLECTION INTERVAL PER MODE CYCLE (4)	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE (5)	REMARKS
1.2	The alignment and calibration of the primary telescope involves 1-2 hours of adjustments and alignments which require images made through the primary optics and evaluated prior to operational validation. It is estimated that up to 10 images of a collimated light source will be needed to perform this task once each week. Calibration data must be retained for subsequent data correction tasks.	Up to 30 minutes may be required to acceptably acquire a target and allow for stable conditions to be restored. Continuous receipt & display of acquisition video is required for this task. The output of the scientific sensor (high resolution video) or the output of a low resolution spotting vidicon may be used for this task. This data is not normally retained longer than its immediate use requires but may be required periodically for crew performance evaluations.	120 exposures for all initial targets	6 hours per target	6 exposures per target	$\approx 2.5 \times 10^8$ bits frame Plus monitor video at an estimated 3.0 MHZ	
			40 exposures for all initial targets	1 hour per target	1 exposure per target		
			200 exposures for all initial targets	4 hours per target	4 exposures per target		Monitor video operates continuously during calibration and target acquisition. It is used periodically during data collection estimated to be 20 minutes per exposure.
			250 exposures for all initial targets	17.5 hours per target	5 exposures per target		
			24 exposures for all initial targets	23 hours per target	8 exposures per target		
			200 exposures for all initial targets	12 hours per target	4 exposures per target		
					No additional exposures		
1.4	Part of calibration included in the above additional exposure readings made on standard source		120 fields	$\approx$10 min. per meas. avg. of 3 comparison measurements per field			
			40 fields				
			200 fields				
			250 fields				
			24 fields				
			200 fields				

FILM TYPE

TASK/INSTRUMENT KEY	EXPOSURE RATE PER MODE CYCLE: CALIBRATE	OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS
1.3	Calibration with film is the same as with electronic sensing	120 exposures	Panchromatic film or plates 2"x2" format	TBD	No identified requirements	TBD	
		40 exposures					
		200 exposures					
		250 exposures					
		24 exposures					
		200 exposures					

NOTES:
1. The observation cycle length is for film. Electronic sensors will reduce the requirements by a factor of ten.
2. Video can replace both photographic cameras and photometers.
3. Operating protocol represents only a start. Observations will undoubtedly triple or quadruple the indicated numbers.
4. Hours are not contiguous.
5. Total data quantity shown (i.e., exposure at 2.5×10^8 bits per frame) is minimum.

Group No.	Group Name	Measurement Objective	Indicative Phenomena	Resolution Required Spatial/Spectral	Target Objective	Dimensions of Target Area (Length x Width)	Location of Target	Replication Rate	Orbit Constraints: Pointing Tolerances/ Stabilization Required	Orbit Constraints: Preferred Inclination/ Altitude	Orbit Constraints: Illumination	Orbit Constraints: Critical Schedule Factor Time Available / Time Required	Orbit Constraints: Cloud Cover Maximum	Operating Characteristics: Experiment Operating Duration	Operating Characteristics: Observ. Cycle Length/Rep. Rate	Operating Characteristics: Crew Functions Involved	Selected Instrumentation: 1. 3 Meter Telescope	2. Photographic Camera (8" x 8" plates)	3. High gain High Res Image Integrator	4. Ultraviolet Photometer	5. UV-Visible IR Spectrograph	5a. Electronic Photometry or Spectrometer Imager	6. IR Radiometer	7. Video Monitoring System
3-OW	Astronomy	1. Provide collection capability for visible, UV, and IR radiations from stellar sphere.	Visible to IR	0.04 $\widehat{sec}$ at λ = 5000 Å	Nonstellar sources	≪1 $\widehat{sec}$ to < 10 $\widehat{sec}$	Stellar fields	Continuous during observation duration	No experiments operated within: 35° of sun 25° of moon 20° of earth		Natural radiations visible, UV, and IR		N/A	1550-1850 hours observing time	Up to 10 hours / TBD	• Assemble • Service • Point • Monitor • Evaluate Data	X							
		2. Obtain spectra and apparent magnitudes of remote galaxies.	Visible to near IR 4000 Å - 1 μ	0.1 $\widehat{sec}$/NA	20-30 fields remote galaxy images	2-5 $\widehat{min}$	90-270° Longitude Sector	TBD	3 $\widehat{sec}$/TBD	TBD		TBD	N/A	200-300 hours image observation time	To ≈ 10 hrs / TBD	As above		X	X					X
			Spectral lines 4000 Å 1 μ	NA/1-10Å	100 galaxy spectra	< 0.1 $\widehat{sec}$ to a few $\widehat{sec}$	Same as above	TBD	≧ 1.0 sec/TBD			TBD	N/A	Time 750 hrs ≈100 spectra	1-10 hrs/ target / TBD	Same as above	X		X		X	X		X
		3. Determine optical angular dimensions and physical properties of emission of quasars.	Angular dimensions 5 different λ	≈0.1 $\widehat{sec}$ corresponds to < 0.02 MM at photographic film	20-50 object images	2-5 $\widehat{min}$	Same as above	TBD	1.0 $\widehat{sec}$/TBD			TBD	N/A	500-1000 hours	1-10 hrs per photo in each of 5 spectra	• Target location • Exposure control • Film Retrieval	X	X	X					X
			Spectral absorption & emission	≈0.1 $\widehat{sec}$/ 1Å	20-50 quasars	TBD	Same as above	TBD	1.0 $\widehat{sec}$/TBD			TBD	N/A	100-250 hours	1-10 hours per target spectra		X		X		X	X		X
			UV Photometry														X	X	X		A			
		4. Determine angular dimensions and broadband flux distributions of nearby and moderately distant galaxies.	Angular dimensions	≈0.1 $\widehat{sec}$	10-20 nearby galaxies	2-5 $\widehat{min}$	Same as above	TBD	1.0 $\widehat{sec}$/TBD			TBD	N/A	Minutes to an hour per target exposure. 30-50 hours total.	1.5 hours per target exposure including acquisition time. 5 wavelength exposures	• Target acquisition • Exposure control • Film handling	X	X	X					X
			IR Radiometry	≈0.1 $\widehat{sec}$/ 1MM	10-20 nearby galaxies	20 $\widehat{sec}$	Same as above	TBD	1.0 $\widehat{sec}$/TBD		Natural IR 5-22 μ				Readings will be taken for several 2 filter positions	• Target acquisition • Exposure control • Resupply - Film - Cryogenics	X						X	
			UV Photometry														X			X				

Sensor Output Data Form	Principal Experiment Information Required (Content)	Principal Experimenter Requirements (Allowable Time Delay)	Onboard Display Requirements	Onboard Controls Required		Task/Instrument Key	Electronic Data: Sensor Output Rate Per Mode - Time: Calibrate	Target Acquisition	Operate	Data Collection Interval per Mode Cycle	Number of Mode Cycles per Target Opportunity	Data Quantity Per Mode	Remarks	Task/Instrument Key	Film Data: Exposure Rate per Mode Cycle: Calibrate	Operate	Film Type	Onboard Process Required (Percent)	Electronic Conversion Required (Bits per Sec. Generated)	Logistics Requirements (lbs. per 90 Days)	Remarks
Collected radiation	Images & Spectra		Video target location	• Pointing • Checkout • Sensor selection • Exposure control • ECS control		1	Engineering status data and checkout ≈400 chan. continuous	Video output for onboard control visibility. Continuous during observation	Same as target acquisition plus 60 meas @ 12.5K bits/sec	Oper. 10 hours / observ Video - 5 min. for acquisition. 5 min. per hr. during cycle	One	4.5-45≈ bits plus status - 400 sensor points 32K bits/sec continuous	Status Oper. 3.2 kb/s plus ≈20 M bits avg. per mode cycle	1	One photo per mode cycle for each camera mode	NA	Panchromatic and IR plates	100%	Not Required	TBD	
Film	Spatial dimensions measured from photo plates and spectral photo	Logistics resupply adequate	• Target location - video • Photographic results for calibration, alignment, and cursory evaluation			2	Telescope pointing system, focus and sensor system parameters displaced onboard for calibration	Visual/auto location and fine pointing 5 min/observ cycle	Image intensification required	1 - 10 hours	Initially One	Status data same as above		2	Camera systems verified by making test exposure	Imagery - 1 exposure each for 20-30 fields	Same as above	10%(est)	TBD		Detailed operating requirements will determine whether onboard processing or conversion of photographic data is req'd.
Film - prime Electrical - alternate	Spectral line identity, width, and intensity	Same as above	• Target monitoring • Calibration results • Camera status	• Exposure controls • Acquisition controls		5 alter	Wave length calibration using line source	Star tracker output for coarse pointing 0th order image for fine tracking	0.5 MHZ during one minute readout	Few minutes to an hour (readout 1 minute)	TBD		Photoelectric spectrum scanning can be used if resolution requirements (1Å) are met (5000 TVL)	5 prime	Spectograph calibrated using line sources within telescope system 1 exposure	Spectra - 1 film strip for each 5 spectra Total TBD	25 x 100 MM film strip	10%	No	TBD	
Film	Images in 5 different wavelengths	Same as above	Same as above	Same as above		2 & 3	Telescope alignment and adjustment verification	Star tracker output for coarse pointing	Image intensification required	1-10 hours per image, 5 images per target	TBD			2	Calibration exposure before each data collection	5 photos per target 20-50 targets	8" x 8" film plates panchro or Shumann emulsion	10%	No	TBD	
						5 alter								5	Same as 5 above	20-50 quasar spectra	25 x 100MM film strip	10%	No	TBD	
Analog Video	Amplitude and coordinates	Logistic return adequate				5 alter	Viewing internal photometric std.			TBD	TBD										
						6	Calibration is accomplished by viewing self contained blackbody	TBD	Sensor maintained at cryogenic temperature 50 measurement points	Status points											

GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	ORBIT CONSTRAINTS: POINTING TOLERANCES/ STABILIZATION REQUIRED	ORBIT CONSTRAINTS: PREFERRED INCLINATION/ ALTITUDE	ORBIT CONSTRAINTS: ILLUMINATION	ORBIT CONSTRAINTS: CRITICAL SCHEDULE FACTOR	ORBIT CONSTRAINTS: CLOUD COVER MAXIMUM	OPERATING CHARACTERISTICS: EXPERIMENT OPERATING DURATION	OPERATING CHARACTERISTICS: OBSERV. CYCLE LENGTH/REP. RATE	OPERATING CHARACTERISTICS: CREW FUNCTIONS INVOLVED
4-P/C-8	Effect of zero gravity on the production of films and foils	Produce films and foils, both single and multi-layered materials, and observe the influence of near-zero/gravity on their nucleation kinetics, sublimation behavior, wetting characteristics, foil thickness and integration, and physical properties of the materials.	Observable properties of films and foils • Production Variables • Product Characteristics	N/A	To produce films and foils 20-1000 Å Thick	N/A	N/A	Production runs each 3 mo. for ~1 year	Low "g" levels $\sim 10^{-4}g$ pointing NA	Acceleration loads in the direction of pull	N/A	Experiment can be performed at any time but once started can not be interrupted	N/A	5 minutes preparation 10 minutes to produce sample	Foils: 1 material 10 thicknesses two trials Films: 1 substitute	Observation & control

SELECTED INSTRUMENTATION (group 4-P/C-8)

	1. Film Thickness Monitor	2. Foil Pull Rate	3. Temperature	4. Accelerometer (3 Axis)	5. Experiment Clock	6. Atmospheric Analyzer	7. Pressure Transducer	8. Voltage & Current
Films	x		x	x	x	x	x	x
Foils		x	x					

Instrumentation and measurements made onboard are for production control. Other measurement objectives by ground analysis.

4-P/C-6

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	
Analog signal (amplitude & frequency) converted to digital	Material deposited & foils produced	Not critical for analysis	• Frequency counter (2 ch.) • Elapsed time indication • Temperature readout • Voltage readout • Pull rate • "g" levels	• Start experiment • Atmosphere & pressure adjustment • Knife edge adjustment • Temperature adjustments	

ELECTRONIC DATA

TASK/INSTRUMENT KEY	SENSOR OUTPUT RATE PER MODE – TIME: CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS
1	Balance oscillator output			Continuous during operation 1 hour (film)	One		
2	Foil pull rate 10 in./sec max.		10 - 8 bit words/sec	10 min operation 80 bits/sec	20 modes per cycle (200 min)	48,000 bits/mode	
3	Temp. calib. during warmup period 5 min.		~ 5 temp. @ 1 sample 8 bit word per sec	Maximum of 1 hour per sample produced	20 sample foils @ 10 min per sample, 1 sample film at 1 hr per sample	600 8-bit words	
4	Vehicle acceleration must be within limits		3 8-bit words 10 per sec (240 words/sec)	10 min per foil 20 foils	2 sets of 10 foils per run	2.8M bits per cycle	
5			Time recorded with production variables	.01 sec			
6			Partial pressures of two gases	1 sample per sec (2 channels) 8 bit words	1 sample produced per hour	60K bits per run	
7			Total pressure	1 sample per sec (1 channel)	1 film produced in 1 hour	30K bits	
8	Sputter power level volts & current set prior to a film production		Voltage & current	Same as above	Same as above	Same as above	

FILM TYPE

TASK/INSTRUMENT KEY	EXPOSURE RATE PER MODE CYCLE: CALIBRATE	EXPOSURE RATE PER MODE CYCLE: OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS

									ORBIT CONSTRAINTS					OPERATING CHARACTERISTICS			SELECTED INSTRUMENTATION										
GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH x WIDTH)	LOCATION OF TARGET	REPLICATION RATE	POINTING TOLERANCES STABILIZATION REQUIRED	PREFERRED INCLINATION ALTITUDE	ILLUMINATION	CRITICAL SCHEDULE FACTOR	CLOUD COVER MAXIMUM	EXPERIMENT OPERATING DURATION	OBSERV. CYCLE LENGTH/REP RATE	CREW FUNCTIONS INVOLVED	1. Superconducting Magnet	2. Total Absorption Counter (TASC)	3. Total Absorption Shower Counter (TASC)	4. Ionization Spectrograph (IS)	5. Scintillation Counter	6. Spark Chamber	7. Cerenkov Counters	8. Proportional Counters	9. Streamer Chambers	10. Liquid Hydrogen Target	11. Transition Radiation Detector
4-CP	Cosmic Ray and High Energy Physics Laboratories	Bending of High Energy Particles	Particle Path	NA	Scanned	NA	NA	TBD	NA	NA	NA	TBD	NA	Few months per objective (per set-up) open ended	Continual and automatic while in operation	Set up monitor. Calibrate repair.	x										
		Particle Identification	Spectra	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	TBD	TBD	• Monitor • Electrical adjustment				x							
		Particle Energy Resolution	Spectra	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	TBD	TBD			x	x		x						
		Particle Position	Spatial Coordinates	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	TBD	TBD	Calibrate and Checkout						x					

4-CR							ELECTRONIC DATA								FILM TYPE						
							SENSOR OUTPUT RATE PER MODE – TIME								EXPOSURE RATE PER MODE CYCLE						
SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED		TASK/INSTRUMENT KEY	CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS	TASK/INSTRUMENT KEY	CALIBRATE	OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS
Digital	Equipment Verification only	Operation data only. Not critical	Meters Counting rates. Dead times Oscilloscopes	• Cryogenic flow • Voltage regulation		1			Engineering parameters only	Continual during operation	TBD	TBD avg. 25K bits	Monitor function only								
Digital	Spectra	TBD	TBD	TBD		4			• Pulse height analyzer output rate TBD • Engineering data	Continual during operation	TBD	TBD									
Digital	Energy and Specie Spectra	TBD	TBD	TBD		2/3	Calibrate at maximum frequency - Rate TBD			30 minutes per day	TBD	TBD									
						2/3			Photo-multiplier tube output rate TBD	TBD	TBD	TBD									
Digital	TBD	TBD				6			TBD	TBD	TBD	TBD									

GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH X WIDTH)	LOCATION OF TARGET	REPLICATION RATE	ORBIT CONSTRAINTS: POINTING TOLERANCES/ STABILIZATION REQUIRED	ORBIT CONSTRAINTS: PREFERRED INCLINATION/ ALTITUDE	ORBIT CONSTRAINTS: ILLUMINATION	ORBIT CONSTRAINTS: CRITICAL SCHEDULE FACTOR	ORBIT CONSTRAINTS: CLOUD COVER MAXIMUM	OPERATING CHARACTERISTICS: EXPERIMENT OPERATING DURATION	OPERATING CHARACTERISTICS: OBSERV. CYCLE LENGTH/REP RATE	OPERATING CHARACTERISTICS: CREW FUNCTIONS INVOLVED
5-CS-1	Millimeter Wave Demonstration	Demonstrate Millimeter Wave Technology in the Space Environment	1. Signal Path Attenuation (Signal Amplitude) 35 GHZ 60 GHZ 94 GHZ 140 GHZ 250 GHZ	N/A ↓	Atmos. Path 100 to 500 NMI Total Path 20,000 NMI ↓	N/A ↓	Ground Lat. & Long. 5^{0} to 90^{0} relative elev. angle	10^{4} to 10^{5} meas. per run	0.01 to 0.05 degrees ↓	Inclination: any; may depend on ground sta. location Altitude: Any low Earth orbit 260 NMI	Function of antenna beam-width of transmitting antenna	Scheduled according to time available. Estimate: Coverage over seasons	One of the parameters to be investigated	Months to one or two years	Run Time: Minutes. Individual measurements made in milli-seconds. Run possible whenever ground target in view. Time between measurements: seconds	Monitor CRT displays, check exp. package operation, initiate and secure exp., voice reports to ground investigators
			2. Signal Phase Coherence vs Bandwidth	↓	↓	↓			↓							
			3. Scatter Detectability at 60GHZ	↓	↓	↓	Target is another space vehicle		↓							
5-N-1	Terrestrial Noise Measurements	Prepare and maintain empirical noise maps of Earth's surface as seen from space at all frequencies used by vehicles. Determine environmental corrections for computation of spacecraft antenna noise temperature.	Noise amplitude Polarization Spectrum distribution Earth's surface noise temp. Range: 100 MHZ to 100 GHZ	Determined by antenna. Wide beam varies with frequency.		↓	Earth's surface	Est. 8 meas. per sweep Total experiment is long term 1-2 yr. Periodic reassessment planned	Spacecraft attitude known to 1 degree	Inclination 55^{0} Altitude 200-1000 MMi ↓	NA	Scheduled according to assigned priority and time available	No maximum. Cloud cover is a recorded item	Months	Variable, on the order of one sec.	Erect antennas. Set up equipment. Calibrate Start up Shut down Reconfigure Visual obs. of weather
5-N-2	Noise, Source Identification	Determine geographic location and radiation characteristic of all significant contributors of RFI at satellite communication frequencies		Varies with frequency and antenna	Target location is objective	↓	Same			↓				Months to years	About every 16 orbits opportunity to repeat a particular measurement occurs	Set up equip. Select bands calibrate start up shut down

SELECTED INSTRUMENTATION

GROUP NUMBER	INDICATIVE PHENOMENA	1. Millimeter Wave Receiver	2. Code Generators	3. Multicoupler & Comparators	4. Antenna Equipment	5. CRT Oscilloscope	6. Spectrum Analyzer	7. Transmitter	8. Receivers, Panoramic	9. Antennas	10. Radiometer	11. RMS Voltmeter	12. Oscilloscope	13. Digital Voltmeter and Frequency Meter
5-CS-1	1. Signal Path Attenuation	x			x	x								
	2. Signal Phase Coherence vs Bandwidth	x		x		x	x							
	3. Scatter Detectability at 60GHZ	x		x	x	x		x						
5-N-1						x			x	x	x	x	x	x
5-N-2						x			x	x	x	x	x	x

The equipment package will be operated as a unit.

5-CS-1
5-N-1
5-N-2

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED		TASK INSTRUMENT KEY	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE TIME: CALIBRATE	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE TIME: TARGET ACQUISITION	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE TIME: OPERATE	ELECTRONIC DATA: DATA COLLECTION INTERVAL PER MODE CYCLE	ELECTRONIC DATA: NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	ELECTRONIC DATA: DATA QUANTITY PER MODE	ELECTRONIC DATA: REMARKS	TASK/INSTRUMENT KEY	FILM TYPE: EXPOSURE RATE PER MODE CYCLE: CALIBRATE	FILM TYPE: EXPOSURE RATE PER MODE CYCLE: OPERATE	FILM TYPE: FILM DATA	FILM TYPE: ONBOARD PROCESS REQUIRED (PERCENT)	FILM TYPE: ELECTRONIC CONVERSION REQUIRED (BITS PER SEC GENERATED)	FILM TYPE: LOGISTICS REQUIREMENTS (LBS PER 90 DAYS)	FILM TYPE: REMARKS
Electronic volts	Operational data and insight into use of EHF (30 GHZ - 100 GHZ) band for space communications	Hours to Days	CRT Oscilloscope, quicklook strip chart recorded, status panel	Manual Control panel. Experiment automation built into exp. package			Same as Operate	Same as Operate	Digital output up to 32 KBPS maximum	Minutes est. 5 to 11	5 freq. per target per pass	TBD									
Electronic volts, digitized volts and freq. band	Noise amplitude Contour plots. Apparent surface noise temperature as contour plots for each freq.	Hours to days	Operating status panel • Freq. band • Sweep rate • Noise amplitude • Noise temp.	Basically manual control. Antenna sweep and band change may be automated		All	Approximately the same as operate periods	NA	TBD	Continuous when operating (minutes to hours). One sec. avg. time per resolution element	Repeated until meas. are statistically significant	TBD									
Electronic volts. Digitized volts. DBM freq.	Power spectral density listing for target							This is the object of the exp	TBD	Continuous when operating	Need to Repeat Measurement	TBD									

Group Number	Group Name	Measurement Objective	Indicative Phenomena	Resolution Requirement Spatial/Spectral	Target Objective	Dimensions of Target Area (Length x Width)	Location of Target	Replication Rate	Orbit Constraints: Pointing Tolerances/ Stabilization Required	Orbit Constraints: Preferred Inclination/ Altitude	Orbit Constraints: Illumination	Orbit Constraints: Critical Schedule Factor	Orbit Constraints: Cloud Cover Maximum	Operating Characteristics: Experiment Operating Duration	Operating Characteristics: Observ. Cycle Length/Rep. Rate	Operating Characteristics: Crew Functions Involved	Selected Instrumentation: Multiband Receiver	Selected Instrumentation: Antenna Structure	Selected Instrumentation: Recording & Digitizing Equipment	Selected Instrumentation
5-P-2	Tropospheric Propagation Measurements	Certain data to define the statistics of propagation thru the troposphere	Frequency	1 MHZ to 1 GHZ depending on frequency band range; 0.1 GHZ to 100 GHZ	NA	Point source of EM radiation	Fixed, ±100 NMI Convenient ground sites	Basic set of measurements repeated every 1/2 hour when exp. is operating	NA	0° 19,327 NMI Longitude: 60°W-130°W	Ground transmitting stations are the signal sources	None - See operating characteristics	—	Long term, perhaps 2 years to cover seasonal variations	Flexible. Measurement will require several minutes < 10 min. Rep. rate: approx 1/2 hour. Cycle: yearly	Minimum. Monitor equipment operation. Reconfigure equipment.	x	x	x	
			Signal direction (AZ, EL)	Approx. 0.1° Range: 0-90° random around line of sight		Same as above	Same as above	Same as above	± 0.1° in roll, pitch, yaw	Same as above.	Same as above	Same as above	—	Same as above	Same as above	Same as above	x	x	x	
			Signal amplitude and phase	± 0.5 DB ± 0.1 RAD Range: 0-100 DB 0-2 RAD		Same as above	Same as above	Same as above	NA	Same as above	Same as above	Same as above	—	Same as above	Same as above	Same as above	x	x	x	
			Meteorological observations	Ground measurements to be defined Meteorological satellite measurements may be used		0 to 10 NMI path thru troposphere	Transmission path	Same as above	NA	NA	NA	Same as above	This is one of the variable parameters	Same as above	Same as above	NA (Ground crew function)				Meteorological instrumentation is a support requirement to be defined.

S-P-2

SENSOR OUTPUT DATA FORM	PRINCIPAL EXPERIMENTER INFORMATION REQUIREMENT (CONTENT)	PRINCIPAL EXPERIMENTER REQUIREMENTS (ALLOWABLE TIME DELAY)	ONBOARD DISPLAY REQUIREMENTS	ONBOARD CONTROLS REQUIRED	REMARKS	TASK/INSTRUMENT KEY
Electrical; digital	Printout of variable parameters: • Signal strength (attenuation) • Incoming signal angle • Phase shift All VS. freq. and time and correlated with meteorological data	Weeks to months delay ok. Daily reporting of interesting information desirable.	Frequency display	Program to change freq. band Equip. On-Off	This experiment should be carried by an unmanned sync. sat.	
Electrical, analog and or digital	Same as above	Same as above	Signal angle (AZ - EL) display	Antenna pointing control		
Electrical, analog and or digital	Same as above	Same as above	Signal strength and phase reference display	Gain controls		
NA ←						

SENSOR OUTPUT DATA FORM	ELECTRONIC DATA: SENSOR OUTPUT RATE PER MODE - TIME: CALIBRATE	TARGET ACQUISITION	OPERATE	DATA COLLECTION INTERVAL PER MODE CYCLE	NUMBER OF MODE CYCLES PER TARGET OPPORTUNITY	DATA QUANTITY PER MODE	REMARKS
Electrical; digital	NA	Same as operate	~16 bits 1 SPS	~5 min. 2 readings per minute	Est. 10 freq. bands per ground station. Est. 1 to 5 active ground stations	Est. 16 bits per freq. band. 10 meas. per target in 5 minutes (32 bits/min)	Additional data taken during periods of tropospheric storms. Total house-keeping data est. 2-64 bit words per minute
Electrical, analog and or digital	NA	Same as above	~24 bits 1 SPS	~5 min. 2 readings per minute	Same as above	Est. 24 bits per meas. (48 bits/min)	Same as above
Electrical, analog and or digital	Same as operate < 1 min. duration	Same as operate	~24 bits 1 SPS	~5 min. 2 readings per min.	Same as above	Est. 24 bits per meas. (48 bits/min)	Same as above
NA	→	→	→	→	→	→	NA

SENSOR OUTPUT DATA FORM	TASK/INSTRUMENT KEY	FILM TYPE: EXPOSURE RATE PER MODE CYCLE: CALIBRATE	OPERATE	FILM DATA	ONBOARD PROCESS REQUIRED (PERCENT)	ELECTRONIC CONVERSION REQUIRED (BITS PER SEC. GENERATED)	LOGISTICS REQUIREMENTS (LBS. PER 90 DAYS)	REMARKS
Electrical; digital								
Electrical, analog and or digital								
Electrical, analog and or digital								
NA								

Group No.	Group Name	Measurement Objective	Indicative Phenomena	Resolution Requirement Spatial/Spectral	Target Objective	Dimensions of Target Area (Length x Width)	Location of Target	Replication Rate	Orbit Constraints: Pointing Tolerances/ Stabilization Required	Orbit Constraints: Preferred Inclination/ Altitude	Orbit Constraints: Illumination	Orbit Constraints: Critical Schedule Factor (Time Available / Time Required)	Orbit Constraints: Cloud Cover Maximum	Operating Characteristics: Experiment Operating Duration	Operating Characteristics: Observ. Cycle Length/Rep. Rate	Operating Characteristics: Crew Functions Involved
6-A/F-1	Location and area of present and potential cultivated, forested and ranged lands.	High spatial frequencies of linear field boundaries and roads	Images: (1) Panchromatic (2) IR	10-200 ft/ typically 100 ft.	Cultivated land inventory	Roads Field boundaries	Selected truth sites Total USA Western Hemisphere	Bi-monthly during late spring and early summer	L.O.S. - NADIR ± 0.5°	45° minimum 55° preferred	Angle from horizon 60° - 80° preferred 30° - 90° acceptable		20-50%	1 year	Seasonal	• Target location • Target acquisition • Equipment maint. & resource management • Data Evaluation • Film Processing • Target Description on voice for correlation (applies to all rows below ↓)
		Broadband color of terrain to differentiate crops, trees, grasslands and soil.	Images: (1) Color film (2) IR color	50-150 ft.	Cultivated land inventory	General cultivated terrain	Same as above	Same as above	L.O.S. - NADIR ± 0.5°	Same as above	Same as above		20-50%	1 year	Seasonal	
		Narrow band reflectance of terrain	Spectral radiance & its spatial distribution	75-150 ft.	Cultivated land inventory	General cultivated terrain	Same as above	Same as above	L.O.S. Accuracy ± 1.5° L.O.S. Rate ≤0.03°/sec For multi-spectral camera	Same as above	Same as above		20-50%	1 year	Seasonal	
									L.O.S. Accuracy ± 2° L.O.S. Rate .05°/sec for scanner	Same as above	Same as above		20-50%	1 year	Seasonal	
		Polarization of UV and visible reflection and mineral luminescence	UV & visible spectra	200 ft.	Surface texture	General cultivated terrain	Same as above	TBD	L.O.S. Accuracy ± 0.5° L.O.S. Rate ± 0.05°/sec	Same as above	Same as above		20-50%	1 year	TBD	
									L.O.S. Accuracy ± 0.5° L.O.S. Rate ± 0.2°/sec	Same as above	Same as above		20-50%	1 year	TBD	
		Spatial distribution of thermal IR emittance	I.R. spectra	100-200 ft.	Cultivated land inventory	General cultivated terrain	Same as above	Bi-monthly during late spring and early summer	L.O.S. Accuracy ± 2.0° L.O.S. Rate 0.5°/sec	Same as above	Same as above		20-50%	1 year	TBD	
		Surface roughness and texture	Angle of polarization - corresponding radiance	200 ft.	Surface roughness	All surfaces	Same as above	Once only	L.O.S. Accuracy ± 0.5° L.O.S. Rate 0.05°/sec	Same as above. Target will be 30° from NADIR	Same as above		100%	1 year	Only once per target	

Selected Instrumentation (KEY: 1. Metric Camera; 2. Multispectral Camera; 3. 10 Band Multispectral Scanner; 4. Radar Imager; 5. Absorption Spectrometer; 6. Multichannel Ocean Color Sensor; 7. Radar Altimeter/Scatterometer; 8. Microwave Scanner Radiometer; 9. Steric Detector, UHF; 10. Data Collection System; 11. Star Tracking Telescope; 12. Zero-g Cloud Chamber; 13. Photo-Imaging Camera; 14. IR Interferometer/Spectrometer; 15. Multispectral Tracking Telescope; 16. Selective Chopper Radiometer; 17. IR Filter Wedge Spectrometer; 18. IR Temperature Sounder; 19. Satellite IR Spectrometer; 20. Temperature Profile Radiometer; 21. Visible Wavelength Polarimeter; 22. UV Imager/Spectrometer)

Measurement Objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
High spatial frequencies of linear field boundaries and roads	(2) X																					
Broadband color of terrain to differentiate crops, trees, grasslands and soil.	(2) X																					
Narrow band reflectance of terrain (multispectral camera)		(6) X																				
Narrow band reflectance of terrain (scanner)			X																			
Polarization of UV and visible reflection and mineral luminescence																						X
Polarization of UV and visible reflection and mineral luminescence (second entry)																					X	
Spatial distribution of thermal IR emittance																	X					
Surface roughness and texture				X																		

6AF1

							Electronic Data								Film Data						
							Sensor Output Rate Per Mode - Time								Exposure Rate per Mode Cycle						
Sensor Output Data Form	Principal Experimenter Information Requirement (Content)	Principal Experimenter Requirements (Allowable Time Delay)	Onboard Display Requirements	Onboard Controls Required		Task/Instrument Key	Calibrate	Target Acquisition	Operate	Data Collection Interval per Mode Cycle	Number of Mode Cycles per Target Opportunity	Data Quantity Per Mode	Remarks	Task/Instrument Key	Calibrate	Operate	Film Type	Onboard Process Required (Percent)	Electronic Conversion Required (Bits per Sec. Generated)	Logistics Requirements (lbs. per 90 Days)	Remarks
Film	Land Utilization Potential	Not critical for analysis 24 hours for control	Video for target location Spotting scope for acquisition	Video monitor Sequencing.		1		See Monitor Video	Engineering status data 1 ch.	5 min. target for monitor continuous for status data			No scientific electronic data generated	1	Photograph star field before and after data run	TBD exposures per target pass	Panchromatic & near I.R. 9 x 14"	Initially all	TBD-If req'd 6000 TVL camera image will be used	TBD	
														1a	1 stellar ref. photo with each metric camera exposure	TBD exposures per target pass - 70 MM					
Film	Crop Identification	Not critical	Same as above	Video monitor Sequencing.		1							No scientific electronic data generated		Same as above		Metric camera color & color I.R.	TBD	Same as above	TBD	Film selected to emphasize 0.53 µ
Film	Soil & Rock Reflectance	Not critical	Same as above	Video monitor Sequencing.		3	3 calibration source, a thermal black body source & one visible source - data rate TBD.			TBD	1	TBD		2		6 exposures simultaneously rate TBD	Panchromatic	TBD	TBD	TBD	
Digital Video		Not critical	Video for target location •Spotting scope for acquisition •CRT for selected processed data			3			5 channels to cover the range of 0.4 - 13 µ x 2.4 megabits = 24.2 megabits/sec. Engineering status data 38 ch.	TBD	TBD	TBD	5 channels to cover the 0.4 - 13 µ range plus one channel at .3 µ								
						2			Engineering status data 1 ch.	TBD	TBD	TBD									
Digital Analog	Soil Radiation and Luminescence	Not critical	Video spotting scope A - scope Lamp indicator	Switches (3)		22	Operate with fibre optics looking at sun as source			TBD	1	TBD									
						22			2 channels of analog equivalent to 40K bits/sec Engineering status data 5 ch.	TBD	TBD	TBD									
Digital	Same as above	Not critical	Same as above	Switches (4)		21	Use of built-in calibration to be defined			1 or 2 sec	1	TBD	Sensor does not cover the 0.3 to 0.8 µ range requested								
						21			16 channels for a total of 160 bits/sec	2 minutes	1	19.2K bits									
Digital	Temperature differences between fields, forest, range, water, etc.	Not critical	Same as above	Switches (3)		17	• Black body source calibration • Functional check • Simulated detection output Data Rate TBD			TBD	TBD	TBD	*This I.R. filter wedge spectrometer has ranges of 1.5 to 6 µ and 8 to 16 µ and does not cover the required 0.8 to 13 µ Also, radiometer in exp. description are not compatible with instrument sheets.								
									2 channels for a total of 125 bits/sec	30 min	TBD	TBD									
Film	Surface elevations	Not critical	•CRT's •Lamp indicators (2) •Film remaining indication	Switches (5)		4	Monitor 50 measurements using 20 stimuli			TBD	TBD	TBD				4 Film channels	Black & White	TBD	None	TBD	Photographing radar CRT displays

									ORBIT CONSTRAINTS					OPERATING CHARACTERISTICS			SELECTED INSTRUMENTATION																					
GROUP NUMBER	GROUP NAME	MEASUREMENT OBJECTIVE	INDICATIVE PHENOMENA	RESOLUTION REQUIREMENT SPATIAL/SPECTRAL	TARGET OBJECTIVE	DIMENSIONS OF TARGET AREA (LENGTH x WIDTH)	LOCATION OF TARGET	REPLICATION RATE	POINTING TOLERANCES/ STABILIZATION REQUIRED	PREFERRED INCLINATION/ ALTITUDE	ILLUMINATION	CRITICAL SCHEDULE FACTOR	CLOUD COVER MAX-IMUM	EXPERIMENT OPERATING DURATION	OBSERV CYCLE LENGTH/REP RATE	CREW FUNCTIONS INVOLVED	1. Metric Camera	2. Multispectral Camera	3. 10 Band Multispectral Scanner	4. Radar Imager	5. Absorption Spectrometer	6. Multichannel Ocean Color Sensor	7. Radar Altimeter/Scatterometer	8. Microwave Scanner Radiometer	9. Sferic Detector, UHF	10. Data Collection System	11. Star Tracking Telescope	12. Zero-g Cloud Chamber	13. Photo-Imaging Camera	14. IR Interferometer/Spectrometer	15. Multispectral Tracking Telescope	16. Selective Chopper Radiometer	17. IR Filter Wedge Spectrometer	18. IR Temperature Sounder	19. Satellite IR Spectrometer	20. Temperature Profile Radiometer	21. Visible Wavelength Polarimeter	22. UV Imager/Spectrometer
6-M-2	Meteorology	UHF Sferics Detection	Cloud Convective Activity	200 feet black & white photography	Isolated Thunder Storms, Tornadoes, Squall Lines, Hurricanes	10 miles x 50 miles maximum	As opportunity arises	As opportunity arises	Not Critical	30^o 200 Mi	No illumination required since lightning generates its own light	Not applicable for targets of opportunity. Very important for catastrophic weather, i.e., hurricanes	Req'd, No Max.	1 year	6 orbits week 20-30 min. per orbit	Target ID Hand-held H-Alpha Viewer Aiming of cameras and sferics detectors	x																					
			Lightning Activity (Radiated Sferics)	NA, NA								Same as above	Req'd, No Max.	1 year	6 orbits, week 20-30 min. per orbit		x								x													
6-M-1		Determination of Boundary Layer Exchange Processes	H_2O and CO_2 absorption bands Reflected and emitted IR radiation	Inst. +GRF 16 - 1.8 NMI 17 - 3.5 NMI 18 - 8.6 NMI 19 - 43 NMI 14 - 8 NMI 20 - 9 NMI 1 - 150 ft. Accuracy: Temp. $\pm 1^oC$ Water vapor / Scale height $\pm 5\%$ Metric -.02 -.05%	•Hot and cold atmospheres •Ice and snow, deserts, ocean, and tropical surfaces •Polar, arctic and tropical air masses •Frontal zones •Cloud Banks •Forested areas	Initially truth sites and targets of opportunity	Ocean, USA, UK, Switz., S. Amer		$\pm 0.5^o$ from nadir $\leq .03^o$/sec	50^o - 70^o preferred 30^o - 50^o acceptable	Reflected sunlight during day - any angle 100-200 NMI preferred 200-300 NMI acceptable	Important during truth site observation	None to full	Continuous - expanding from truth sites to worldwide	10 sec to 10 min for truth sites to two hours per day for extended coverage	• Selecting targets • Acquisition • Data collection	x													x		x	x	x	x	x		

6-M-2
6-M-1

Sensor Output Data Form	Principal Experimenter Information Requirement (Content)	Principal Experimenter Requirements (Allowable Time Delay)	Onboard Display Requirements	Onboard Controls Required		Task/Instrument Key	Electronic Data: Sensor Output Rate per Mode Time: Calibrate	Electronic Data: Sensor Output Rate per Mode Time: Target Acquisition	Electronic Data: Sensor Output Rate per Mode Time: Operate	Data Collection Interval per Mode Cycle	Number of Mode Cycles per Target Opportunity	Data Quantity per Mode	Remarks	Task/Instrument Key	Film Type: Exposure Rate per Mode Cycle: Calibrate	Film Type: Exposure Rate per Mode Cycle: Operate	Film Data	Onboard Process Required (Percent)	Electronic Conversion Required (Bits per Sec. Generated)	Logistics Requirements (Lbs. per 90 Days)	Remarks
Film	Severe weather detection	Not critical unless a good tornado detection scheme is developed which means a real time ground signal would be required	Video monitoring tube Spotting scope	Camera slewing & operation		1	None required	Using Spotting Scope (Hand-held and or Video)	Engineering status data only	NA	NA	NA			None required	Targets of opportunity cause random exposure rates	Panchromatic	0%	4000 TVL would be adequate	TBD	
1 to 80 μ sec electrical pulses Event marker output				Antenna orientation		9	At start and end of flight, also, internal noise generator for calibration		Measurement monitoring, control operation, confidence tests. 300 bits/sec	Intermittent	As appropriate	One channel per measurement 300 bits per sec typically									
Film and electrical	• Vertical temperature profiles • Vertical water vapor profile • Cloud top & surface temperatures	4 weeks for instrument data, voice real time	High resolution video images for target acquisition	• Pointing Display • Calibration • Data Mode Control		1		Visual using video display	Engineering Status	10-15 orbits per week	One for truth sites - Storm coverage maximum - Average cycle duration 30-95 min.	20 bits sec continuous			1 per mode cycle - 5 min.	Depends on truth site location ≈6 locations	Panchromatic and IR film	Optional	Not required	TBD	
						14	Two calib. interferograms per 14 readings • outer space • 300°K black body	None. Image motion compensation required	One interferogram per target pass	51.6 Kbits per 13 sec interferogram	One	TBD									
						16	Once per orbit • Space • Earth • Blackbody	Same as above	Six channels operating continuously over truth sites and opportunity targets	Average 10 minutes per target	10-15 orbits per week	6-8 bit words per 15 seconds. 10 bits/sec for status									
						17	Calibrate for each run	Same as above	125 bits/sec	30 minutes per run	One run per target	125 bits per sec for 30 minutes. 10-15 orbits per week									
						18	Calibrate for each run	Same as above	1000 bits sec	30 minutes per run	One run per target	10-15 orbits per week									
						19	Blackbody Calibration	Same as above	14 channels 90 bits/sec per channel 1.26K bps	Same as above	Same as above	Same as above									
						20	Calibrate on cold space	Same as above	7 channels 1500 bits/sec	Same as above	Same as above	Same as above									

APPENDIX G

INSTRUMENTATION MATRICES AND

CONCEPTUAL CONFIGURATION

LAYOUTS AND DRAWINGS

G-1

APPENDIX G

INSTRUMENTATION MATRICES AND CONCEPTUAL CONFIGURATION DRAWINGS

This appendix presents a series of instrumentation matrices which relate the types of apparatus indentified for each research cluster description. The matrix-type figures are useful in deriving commonality strategies of implementation for grouping of candidate payloads, as described in Section 5 of this report. Conceptual layouts of research laboratory facilities and preliminary sketches of instruments were developed and are included for dimensional purposes. Several of the instrument configurations specified in Astronomy research clusters were correlated with instrument drawings developed for the Orbital Astronomy Support Facility Study (MDAC). These sketches are contained herein as reference material.

RESEARCH CLUSTER MSFC – BIOMEDICAL / INSTRUMENTATION SELECTED	Oscillographic Display	Recorder (strip chart)	Recorder (optical galvanometer)	Magnetic Tape Recorder	Timer	Body Mass Measurement Device	Electrocardiograph	Vectorcardiograph	Phonocardiograph	Ballistocardiograph	Impedance Cardiograph	Electromechanical Delay Electron	Blood Pressure Assembly	Transcutaneous Doppler Flowmeter	Pulse Wave Velocity Electronics	Chest X-ray Unit	Venous Pressure Manometer	Occlusive Limb Cuffs	Rubber Bandage (tourniquet)	Leg Plethysmographs	Plethysmographic Goggles
1-BM-4 Effects of Weightlessness on Circulatory Function	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1-BM-5 Radiation, Toxicology, and Medical Problems					X																
1-BM-6 Effects of Weightlessness on Stress Response	X	X	X	X	X	X	X				X		X								
1-BM-7 Effects of Weightlessness on the Nervous System	X	X	X	X	X																
1-BM-8 Effects of Weightlessness on Gastrointestinal Function				X	X	X															
1-BM-10 Body Fluid Analysis				X	X																
1-BM-12 Studies on Instrumented Animals	X	X	X	X	X																
1-BM-13 Effects of Weightlessness on Pulmonary Function		X			X	X															
1-BM-14 Effects of Weightlessness on Metabolism	X	X		X	X	X	X						X								
1-BM-15 Centrifuge Studies	X	X		X	X		X				X		X							X	

RESEARCH CLUSTER MSFC – BIOMEDICAL / INSTRUMENTATION SELECTED	Carotid Cuff	Rodent Cages	Toxicological Exposure Chamber	Radiation Exposure Chamber	Radiation Exposure Source	Spectrophotometer	Gas Chromatograph	LBNP Device	Bicycle Ergometer	Metabolic Analyzer	Thermal Enclosure	Low O_2 Gas Mixture	High CO_2 Gas Mixtures (3)	Ear Canal Temperature Probe	Skin Thermister	Pneumotachometer	Pulmonary Flowmeter	Rahn End-Tidal Sampler	Electroencephalograph	Electrooculograph	Electromyograph
1-BM-4 Effects of Weightlessness on Circulatory Function	X							X						X							
1-BM-5 Radiation, Toxicology, and Medical Problems		X	X	X	X																
1-BM-6 Effects of Weightlessness on Stress Response									X	X	X	X	X	X	X	X	X	X			
1-BM-7 Effects of Weightlessness on the Nervous System														X					X	X	X
1-BM-8 Effects of Weightlessness on Gastrointestinal Function						X															
1-BM-10 Body Fluid Analysis						X	X														
1-BM-12 Studies on Instrumented Animals																					
1-BM-13 Effects of Weightlessness on Pulmonary Function										X						X	X	X			
1-BM-14 Effects of Weightlessness on Metabolism						X			X	X				X				X			
1-BM-15 Centrifuge Studies																X	X			X	X

RESEARCH CLUSTER MSFC – BIOMEDICAL / INSTRUMENTATION SELECTED	Rotating Litter Chair	Otolith Test Goggles	Reference Sphere	Task Board	Limb Accelerometers	Photocell Reflex Device	Fecal Drying Oven	Special Test Meals	Endoradiosonde	Endoradiosonde Receiver	Radiation Detector	Scintillation Counter	Mass Spectrometer	Clinical Centrifuge	Compound Microscope	Microscope Camera	Cell Counter	Blood Gas Analyzer	Refractometer	Specific Ion Electrodes	Electrophoresis Apparatus
1-BM-4 Effects of Weightlessness on Circulatory Function											X	X	X	X							
1-BM-5 Radiation, Toxicology, and Medical Problems											X	X		X	X	X	X				
1-BM-6 Effects of Weightlessness on Stress Response																					
1-BM-7 Effects of Weightlessness on the Nervous System	X	X	X	X	X	X															
1-BM-8 Effects of Weightlessness on Gastrointestinal Function							X	X	X	X											
1-BM-10 Body Fluid Analysis											X	X	X	X	X	X	X	X	X	X	X
1-BM-12 Studies on Instrumented Animals																					
1-BM-13 Effects of Weightlessness on Pulmonary Function													X					X			
1-BM-14 Effects of Weightlessness on Metabolism							X						X	X							X
1-BM-15 Centrifuge Studies		X	X																		

RESEARCH CLUSTER MSFC – BIOMEDICAL / INSTRUMENTATION SELECTED	Paper Chromatograph	Temperature-controlled Mixer	Chemical Reagents	Fluid Transfer Equipment	Freezer (-70°C)	Freezer (-20°C)	Instrumented Animal Module	Animal Biotelemetry Receiver	Pulmonary Flow Integrator	Pulmonary Pressure Transducer	Esophageal Balloon	Helium Gas Source	He-CO Gas Mixture	Muscle Dynamometers	Bone Densitometer	Tape Measure	Body Volumeter	Human Centrifuge	Cardiotachometer	pH Meter	Specimen Mass Measurement Device
1-BM-4 Effects of Weightlessness on Circulatory Function				X															X		
1-BM-5 Radiation, Toxicology, and Medical Problems		X		X	X	X															
1-BM-6 Effects of Weightlessness on Stress Response						X			X												
1-BM-7 Effects of Weightlessness on the Nervous System																					
1-BM-8 Effects of Weightlessness on Gastrointestinal Function					X	X											X				X
1-BM-10 Body Fluid Analysis	X	X	X	X	X	X														X	X
1-BM-12 Studies on Instrumented Animals							X	X													
1-BM-13 Effects of Weightlessness on Pulmonary Function				X					X	X	X	X	X							X	
1-BM-14 Effects of Weightlessness on Metabolism	X	X	X	X	X	X								X	X	X	X				X
1-BM-15 Centrifuge Studies									X									X			

INSTRUMENTATION MATRIX–MANNED SPACEFLIGHT CAPABILITY (Page 1 of 3)

RESEARCH CLUSTER MSFC-BEHAVIORAL/MAN MACHINE / INSTRUMENTATION SELECTED	Vision Test Module	Audiometer	Movable Sound Source	Tape Recorder	Blindfold	Anomaloscope	Howard-Dolman Apparatus	Orthorater	Accommodation Range Tester	Automated Perimeter Device	Psychomotor Test Module	Cognitive Capabilities Module	Audition Test Module	Human Centrifuge	Rotating Litter Chair	Otolith Test Goggles	Reference Sphere and Pointer	Limb Board	Prototype Training Equipment	Dispersed Microphones
1-BR-1-1 Visual Experiment	X					X	X	X	X	X										
1-BR-1-2 Behavior Effects of Acoustic Environment		X	X	X	X								X							
1-BR-1-3 Psychomotor											X									
1-BR-1-4 Cognitive Capability				X								X								X
1-BR-1-5 Orientation				X	X									X	X	X	X	X		
1-BR-2 Group Dynamics and Personal Adjustment																				X
1-BR-3 Complex Task Behavior				X																
1-BR-4 Skills Retention														X					X	
1-BR-6 Performance Measurement																				X
1-MM-1 Controls and Displays																				
1-MM-2 Locomotion and Restraint				X																
1-MM-3 Habitability				X																X
1-MM-4 Work/Rest/Sleep Cycles				X																
1-MM-5 Performance Aids				X																

RESEARCH CLUSTER MSFC-BEHAVIORAL/MAN MACHINE / INSTRUMENTATION SELECTED	TV Cameras	Video Tape Monitor/Recorder	Still Cameras	Movie Cameras	Film Storage Container	CRT Display	Strip Chart Recorder	Timers	Body Mass Measurement Device	Remote Manipulator	Tracking Device	Tool Kit	Impact Sensing and Recording Device	On-body Accelerometers	Space Suit	Auxiliary Lights	Task Board	Remote Occulometer	Electrocardiograph	Cardiotachometer
1-BR-1-1 Visual Experiment																				
1-BR-1-2 Behavior Effects of Acoustic Environment								X												
1-BR-1-3 Psychomotor	X	X				X		X			X				X	X	X			
1-BR-1-4 Cognitive Capability						X														
1-BR-1-5 Orientation																			X	
1-BR-2 Group Dynamics and Personal Adjustment	X	X						X								X				
1-BR-3 Complex Task Behavior	X	X						X							X	X			X	
1-BR-4 Skills Retention	X	X				X		X								X			X	
1-BR-6 Performance Measurement	X	X	X	X	X			X								X		X	X	X
1-MM-1 Controls and Displays	X	X					X	X								X		X		
1-MM-2 Locomotion and Restraint	X	X					X	X					X	X	X	X				
1-MM-3 Habitability	X	X							X							X			X	X
1-MM-4 Work/Rest/Sleep Cycles	X	X					X	X								X			X	X
1-MM-5 Performance Aids	X	X				X	X	X		X	X	X			X	X	X		X	X

RESEARCH CLUSTER MSFC-BEHAVIORAL/MAN MACHINE / INSTRUMENTATION SELECTED	Electroencephalograph	Electro-oculograph	Ear Canal Temperature Probe	Blood Pressure Assembly	Metabolic Analyzer	Dynamometers	Dexterity Apparatus	Questionnaires	Paper and Pencil Tests	Crew Log	Signal Electronics/Amplifiers	Computer Input Keyboard	Magnetic Tape Storage	Oscilloscope	Prepared Score Sheets	Pressure Sensors	BITE Board	Ear Plugs	Experimental Work Station
1-BR-1-1 Visual Experiment											X				X				
1-BR-1-2 Behavior Effects of Acoustic Environment											X				X				
1-BR-1-3 Psychomotor						X	X				X		X	X		X			
1-BR-1-4 Cognitive Capability											X	X							
1-BR-1-5 Orientation		X		X				X			X		X		X		X	X	
1-BR-2 Group Dynamics and Personal Adjustment								X	X	X	X	X	X						
1-BR-3 Complex Task Behavior					X					X	X	X			X				
1-BR-4 Skills Retention		X		X						X	X	X	X						
1-BR-6 Performance Measurement	X	X		X	X			X	X	X			X	X	X				
1-MM-1 Controls and Displays								X		X	X		X		X				X
1-MM-2 Locomotion and Restraint					X			X		X	X	X	X			X			
1-MM-3 Habitability	X	X	X	X		X		X		X	X	X	X	X					
1-MM-4 Work/Rest/Sleep Cycles	X	X	X	X	X	X		X		X	X	X	X	X					
1-MM-5 Performance Aids					X					X		X	X						

INSTRUMENTATION MATRIX–MANNED SPACEFLIGHT CAPABILITY (Page 2 of 3)

INSTRUMENTATION SELECTED

ID	RESEARCH CLUSTER-MANNED SPACEFLIGHT CAPABILITY	CRT Display	Computer Input Keyboard	Solar Array Drive Assembly and Shaft	Velocity Meters	Pressure Transducer (Capacitance)	Power Supplies (Variable)	Thermal Flow Meter	Oscillograph Recorder/Amp	Attitude Gyroscope with Table	Op Amplifiers	Star Tracker with Mount	Error Servo Drive Amplifiers	Temperature Sensors/Thermocouple	Pressure Sensors/Gage	Mass Spectrometer	Gas Chromatograph	AC/DC Wattmeter	Volt-Ammeter	Resistojet Thruster System	Logic/Recorder and Display Console	Accelerometers with Electronics	Laser Tx - Rx Assembly	Inertial Measuring Unit (IMU)	Sensors (Sun, Horizon, Star)	Landmark Tracking Telescope KLT and ULT	GP Computer (S/C)
1-EE-1	Data Management	X	X						X																		
1-EE-2	Structures			X		X	X							X													
1-EE-3-1	Drift Measurement of Gyroscopic Attitude Controls						X			X	X	X		X							X						
1-EE-3-2	Disturbance Torque Measurements						X				X		X								X	X					
1-EE-3-3	Biowaste Electric Propulsion						X							X	X	X	X	X	X	X	X						
1-EE-4-1	Onboard Laser Ranging						X						X									X	X	X	X	X	X
1-EE-4-2	Interplanetary or Translunar Navigation by Spectroscopic Binary Satellite						X						X											X	X		X
1-EE-4-3	Landmark Tracker Orbital Navigation						X															X		X	X	X	X
1-EE-4-4	Navigation/Subsystem Candidate Evaluation						X																X	X	X	X	X
1-EE-5	Communications						X						X										X		X	X	X
1-OE-1-1	Space Logistics and Resupply																										
1-OE-1-2	Emergency and Rescue Operations																				X						
1-OE-2	Maintenance, Repair, and Retrofit																										
1-OE-3	Assembly and Deployment								X					X													
1-OE-4	Module Operations	X			X																						
1-OE-5	Vehicle Support Operations		X																								
1-LS-1	Phase Change and Thermal Processes					X			X					X	X				X		X	X					X
1-LS-2	Material Transport Processes					X		X	X					X				X	X		X	X					
1-LS-3	Atmosphere Supply Processes					X								X	X												
1-LS-4	Water Management					X	X	X	X					X	X	X	X	X	X		X						X
1-LS-5	Water Electrolysis						X	X	X					X	X	X	X	X	X		X						
1-LS-6	Food Management and Processes						X	X	X					X	X			X	X		X						
1-LS-7	Atmosphere Purification Methods						X		X					X	X						X						
1-LS-8	Life Support Monitoring and Control																										
1-LS-9	Waste Management					X			X					X	X			X	X		X						
1-LS-10	Heat Transport Equipment						X		X												X						
1-LS-11	Crew Equipment and Protective Systems						X		X					X	X	X											X

ID	RESEARCH CLUSTER-MANNED SPACEFLIGHT CAPABILITY	Position Display Console	Printer – Orbit Data	Doppler Receiver - RF	Doppler Receiver - Laser	Subsatellite Beacon Trans	RF/Optical Antenna and Drive System	Sextant	Radar Altimeter	Time Standard	Correlator Signal	Timer	Camera, Motion Picture/TV	Floodlights	Electrocardiograph	Gas Volume Flow Meter	Tape Recorder (Video/Voice)	EVA Tool Kit	IVA Tool/Test Repair Station	Laser Contour/Align Meter	Bubble Tank with Heater Unit	Condensing System with Pump	Water Recovery Test Unit	Water Electrolysis Unit	Atmosphere Purification Unit	Hydrogenomonas Mixing Reaction Unit	Incinerator
1-EE-1	Data Management											X	X	X			X										
1-EE-2	Structures												X	X			X										
1-EE-3-1	Drift Measurement of Gyroscopic Attitude Controls																										
1-EE-3-2	Disturbance Torque Measurements																										
1-EE-3-3	Biowaste Electric Propulsion																										
1-EE-4-1	Onboard Laser Ranging	X	X				X																				
1-EE-4-2	Interplanetary or Translunar Navigation by Spectroscopic Binary Satellite	X	X	X	X	X	X			X																	
1-EE-4-3	Landmark Tracker Orbital Navigation	X	X																								
1-EE-4-4	Navigation/Subsystem Candidate Evaluation	X	X	X	X	X	X	X	X																		
1-EE-5	Communications		X				X			X	X	X															
1-OE-1-1	Space Logistics and Resupply											X	X	X			X										
1-OE-1-2	Emergency and Rescue Operations											X	X	X	X	X	X										
1-OE-2	Maintenance, Repair, and Retrofit											X	X	X	X	X	X	X	X								
1-OE-3	Assembly and Deployment											X	X	X	X	X	X	X	X	X							
1-OE-4	Module Operations											X	X	X	X		X	X									
1-OE-5	Vehicle Support Operations											X	X	X			X										
1-LS-1	Phase Change and Thermal Processes											X	X	X			X				X	X					
1-LS-2	Material Transport Processes											X	X	X													
1-LS-3	Atmosphere Supply Processes																										
1-LS-4	Water Management											X					X						X				
1-LS-5	Water Electrolysis											X					X							X			
1-LS-6	Food Management and Processes															X	X						X	X		X	X
1-LS-7	Atmosphere Purification Methods											X					X								X		
1-LS-8	Life Support Monitoring and Control																										
1-LS-9	Waste Management											X	X	X		X											
1-LS-10	Heat Transport Equipment											X												X			
1-LS-11	Crew Equipment and Protective Systems											X	X	X			X										

ID	RESEARCH CLUSTER-MANNED SPACEFLIGHT CAPABILITY	Test Sample Containers	Densitometer	pH Meter	Microbial Analyzer	Chemical Analyzer	Waste Management Test Unit	Heat Transport Test Unit	Radiation Counter	Crew Protection Console	Standard Cell	Remote Module	A/D Converter	Deep Space Vehicle	Expandable Structures	Metabolic Analyzer	Questionnaire	RF Receiver	Crew Log	EVA Suit	EVA Airlock	EVA Camera Mount	Still Camera	Large Deployable Space Structure	Strain Gages (Deflections)	Skin Temp Probes	View Port
1-EE-1	Data Management																		X								
1-EE-2	Structures										X				X				X				X	X			
1-EE-3-1	Drift Measurement of Gyroscopic Attitude Controls											X															
1-EE-3-2	Disturbance Torque Measurements																										
1-EE-3-3	Biowaste Electric Propulsion																										
1-EE-4-1	Onboard Laser Ranging																										
1-EE-4-2	Interplanetary or Translunar Navigation by Spectroscopic Binary Satellite																										
1-EE-4-3	Landmark Tracker Orbital Navigation																										
1-EE-4-4	Navigation/Subsystem Candidate Evaluation												X														
1-EE-5	Communications													X				X									
1-OE-1-1	Space Logistics and Resupply																		X								
1-OE-1-2	Emergency and Rescue Operations																										
1-OE-2	Maintenance, Repair, and Retrofit															X			X	X	X	X	X				
1-OE-3	Assembly and Deployment																										
1-OE-4	Module Operations											X				X			X	X	X						
1-OE-5	Vehicle Support Operations																X		X								
1-LS-1	Phase Change and Thermal Processes																							X	X	X	X
1-LS-2	Material Transport Processes																										
1-LS-3	Atmosphere Supply Processes																										
1-LS-4	Water Management				X	X																					
1-LS-5	Water Electrolysis																										
1-LS-6	Food Management and Processes	X	X	X	X	X																					
1-LS-7	Atmosphere Purification Methods																										
1-LS-8	Life Support Monitoring and Control																										
1-LS-9	Waste Management				X	X	X																				
1-LS-10	Heat Transport Equipment							X																			
1-LS-11	Crew Equipment and Protective Systems				X	X			X	X																	

INSTRUMENTATION MATRIX–MANNED SPACEFLIGHT CAPABILITY (Page 3 of 3)

INSTRUMENTATION SELECTED

RESEARCH CLUSTER-BIOLOGY	TV Camera	Video Tape Recorder	Still Camera	Motion-Picture Camera	Time-Lapse Camera	Oscilloscope	Multi-Channel Recorder	Magnetic Tape Recorder	Specimen Mass Measurement Device	Accelerometer Unit	Biocentrifuge	Refrigerator	Freezer (-20°C)	Freezer (-70°C)	Liquid Nitrogen Freezer	Compound Microscope and Camera	Dissecting Microscope and Camera	Tissue Culture Microscope	Hand Held Magnifier	Microtome
2-VB-1 Investigations of Biological Processes, using Primates and Small Vertebrates	X	X	X	X	X	X	X	X	X	X	X	X		X			X		X	
2-VB-2 Investigations of Biological Processes, using Primates and Small Vertebrates	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
2-VB-3 Investigations of Biological Processes, using Primates and Small Vertebrates	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
2-IN-1 Preliminary Investigations of Biological Processes, using Invertebrates	X	X	X	X	X				X	X	X	X		X			X		X	
2-IN-2 Intermediate Investigations of Biological Processes, using Invertebrates	X	X	X	X	X				X	X	X	X	X	X	X	X	X		X	X
2-IN-3 Advanced Investigations of Biological Processes using Invertebrates	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X
2-P/T-1 Preliminary Investigations of Biological Processes, using Unicellular Specimens			X		X					X	X	X	X			X		X	X	
2-P/T-2 Intermediate Investigations of Biological Processes, using Unicellular Specimens			X		X					X	X	X	X			X		X	X	
2-P/T-3 Advanced Investigations of Biological Processes using Unicellular Specimens			X		X					X	X	X	X			X		X	X	X
2-PL-1 Investigations of Biological Processes, using Plants	X	X	X		X				X	X	X	X		X	X	X	X			
2-PL-2 Investigations of Biological Processes, using Plants	X	X	X		X				X	X	X	X		X	X	X	X			
2-PL-3 Investigations of Biological Processes, using Plants	X	X	X		X				X	X	X	X		X	X	X	X			

RESEARCH CLUSTER-BIOLOGY	Tissue Processor and Stainer	Micromanipulator	Tissue Homogenizer	Vacuum Infiltration Oven	Lyophilyzer	Slide Warmer	Preservation Equipment	Autoclave	High Temperature Sterilizer	Incubator	Colony Counter	Microbial Air Sampler	Media Preparation Equipment	Aerosolizer	Optical Densitometer	Spectro Photometer	Gas Chromatograph	Mass Spectrometer	Scintillation Counter	Immuno-Electrophoresis Apparatus
2-VB-1							X	X										X		
2-VB-2	X	X		X	X	X	X	X								X	X	X		
2-VB-3	X	X	X	X	X	X	X	X								X	X	X	X	
2-IN-1							X											X		
2-IN-2	X	X		X	X	X	X	X								X	X	X		
2-IN-3	X	X	X	X	X	X	X	X								X	X	X	X	
2-P/T-1	X						X	X	X	X	X	X	X	X	X			X		
2-P/T-2	X						X	X	X	X	X	X	X	X	X			X		X
2-P/T-3	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2-PL-1						X	X										X			
2-PL-2	X	X	X	X	X	X	X								X	X	X			
2-PL-3	X	X	X	X	X	X	X								X	X	X	X	X	

RESEARCH CLUSTER-BIOLOGY	Amino Acid Analyzer	pH Meter	Cell Counter	Kjeldahl Unit	Dialysis Equipment	Constant Temperature Mixer	Fluid Transfer Equipment	Anesthetizer	Seed Handling Equipment	Potentiometer (High Impedance)	Linear Motion Transducer	Audiometer	Activity Platform	Audio-Visual Tactile Stimulator	Animal Maze	Visual Cliff	Flicker Fusion Apparatus	Psychogalvanometer	Multichoice Stimulus Display	Light Discrimination Apparatus
2-VB-1		X						X												
2-VB-2		X		X		X	X	X		X	X	X	X	X	X	X	X	X	X	X
2-VB-3	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
2-IN-1								X												
2-IN-2		X		X		X	X	X		X										
2-IN-3	X	X		X	X	X	X	X		X										
2-P/T-1																				
2-P/T-2		X	X				X													
2-P/T-3	X	X	X	X			X													
2-PL-1									X	X										
2-PL-2		X		X					X	X										
2-PL-3	X	X	X	X					X	X										

RESEARCH CLUSTER-BIOLOGY	Biotelemetry Receiver	Large Animal Enclosures	Small Animal Enclosures	Mouse Module	Primate Module	Drosophila Module	Fiddler Crab Module	Cockroach Module	Habrobracon Module	Housefly Module	Beetle Module	Bacteria Module	Frog Egg Module	Human Cell Module	Aribidopsis Module	Cucumber Module	Potato Module	Marigold Module	Wheat Seedling Module	Pteris Module	Pea Seedling Module
2-VB-1	X			X	X																
2-VB-2	X	X	X	X	X																
2-VB-3	X	X	X	X	X																
2-IN-1	X					X	X	X	X	X	X										
2-IN-2	X					X	X	X	X	X	X										
2-IN-3	X					X	X	X	X	X	X										
2-P/T-1												X	X	X							
2-P/T-2		X	X									X	X	X							
2-P/T-3		X	X									X	X	X							
2-PL-1															X	X	X	X	X	X	X
2-PL-2															X	X	X	X	X	X	X
2-PL-3															X	X	X	X	X	X	X

INSTRUMENTATION MATRIX SPACE BIOLOGY

G-5

Research Cluster–Astronomy / Instrumentation Selected		X-Ray Detector Array	1-M Diffraction Lim Optical Telescope	Large Focussing X-Ray Telescope	3-M Non-Diffraction Limited Optical Telescope	Kilometer Wave Orbiting Telescope	3-M Diffraction Limited Optical Telescope	1.5-M Diffraction Limited Solar Optical Telescope	Spectrograph, Echelle-type	Grating Spectrograph	Slitless Spectrograph (Prime Focus)	Solar Magnetograph	Image Tube Spectrograph	Spectrophotometer	Photoelectric Photometer	Proportional Counter Detector	IR Radiometer	Vidicon Camera (or equivalent)	35-mm Roll Film Camera	70-mm Roll Film Camera	225-mm Plate Camera	TV/Movie Camera (Slit Jaw)	Filters	Remote TV Viewfinder (Telescope, Camera, Transmitter)	EVA Tool Kit	Printer	Photographic Plates and Film	General Purpose Computer	Magnetic Tape Recorder	Command/Control/Display Console
3-OW	Optical Structure of Small Extended Sources						X		X	X	X		X	X	X		X	X	X	X	X		X	X	X		X	X	X	X
3-XR	Precise Location, Size, and Structure of Known Discrete X-ray Sources, and Existence of Additional Unknown Sources	X		X												X				X				X	X	X	X	X	X	X
3-LF	Location and Properties of Discrete LF Radio Sources, and Structure and Properties of Diffuse Sources					X											X								X	X		X	X	X
3-OB	High Resolution Planetary Optical Imagery (In Process)		X				X		X	X	X		X	X	X		X	X	X	X			X	X	X		X	X	X	X
3-OS	Optical (Faint Threshold) Surveys (In Process)		X		X				X	X	X		X	X	X			X	X	X	X		X	X	X		X	X	X	X
3-SO	Solar Optical Observations							X	X	X		X										X	X	X	X		X	X	X	X
3-OP	High Precision Photoelectric Photometry		X		X		X								X								X	X	X			X	X	X

INSTRUMENTATION MATRIX–SPACE ASTRONOMY

RESEARCH CLUSTER–SPACE PHYSICS		Optical Pyrometer	Strain Type Pressure Gage	Movie Camera with Filters	Gas Chromatograph	Mass Spectrometer	Combustion Chamber with Burner	Digital Printer	Calibration Device T°	Timer/Clock	Strobe/Floodlight Assembly	TV Camera and Display	Accelerometers (Low-g)	Liquid Test Tanks	Mass Flowmeter with Power Supply	Rotation Speed Indicator	Tape Recorder (Data/Voice)	Shock Mounted Platform	Variable Voltage Power Supply	Platinum Res Bridge Thermometer	Oscillograph, Multichannel	Ammeter	A/D Converter	Accelerometers (High-g)	Foam Casting Chamber	Pressure Standard Gage
4-P/C-1	Effect of the Space Environment on Chemical Reactions	X	X	X	X	X	X	X	X	X			X										X			
4-P/C-2	Shape and Stability of Liquid-Vapor Interfaces	X		X					X	X	X	X	X	X	X	X	X	X		X						
4-P/C-3	Boiling and Convective Heat Transfer in Zero-G	X	X	X				X	X	X	X	X	X	X			X	X	X	X	X	X	X			
4-P/C-4	Effect of Zero-Gravity on the Production of Controlled Density Materials	X	X	X				X	X	X	X	X	X						X		X		X	X	X	X
4-P/C-5	Effect of Electric and Magnetic Fields on Materials			X						X	X		X				X			X	X		X			X
4-P/C-6	The Use of Zero-Gravity to Produce Materials Having Superior Physical Characteristics	X	X	X	X	X		X	X	X	X		X				X	X	X	X	X		X			X
4-P/C-7	Improvements of Materials by Levitation Melting	X	X	X					X	X	X		X					X		X	X					
4-P/C-8	Effect of Zero-Gravity on the Production of Films and Foils	X	X	X					X	X	X		X		X		X		X		X					
4-P/C-9	Effects of Zero-G on Liquid Releases, Size Distribution of Liquid Drops			X						X	X	X	X	X	X		X				X					
4-P/C-10	Capillary Flow in Zero-G		X							X		X	X					X		X						
4-P/C-11	Behavior of Superfluids in the Weightless State			X					X	X		X	X	X				X		X				X		

RESEARCH CLUSTER–SPACE PHYSICS		Vibrator Stand (Shaker)	Gas Sparger	Variable Atmosphere Environmental Chamber	Foam Mold	Resistance Bridge	EMF Field Strength Meter	Fluid Viscosity Meter	Densiometer	Dielectrophoretic Cell	Induction Furnace	Electronic Pressure Meter	Variable Current Supply	Scientific Airlock	Thermocouples	RF Deposit Thickness Gage	Evaporation/Sputter Deposition	Camera, Still	Laser Holograph Assembly	Wicking Test Chamber	Remote Manipulator Arms	Grid Transparency	Cylinder Resistance Heater	Hygrometer	Accelerometers Vibration	Cryogenic Helium Dewar Bath
4-P/C-1	Effect of the Space Environment on Chemical Reactions																					X				
4-P/C-2	Shape and Stability of Liquid-Vapor Interfaces																									
4-P/C-3	Boiling and Convective Heat Transfer in Zero-G																									
4-P/C-4	Effect of Zero-Gravity on the Production of Controlled Density Materials	X	X	X	X																					
4-P/C-5	Effect of Electric and Magnetic Fields on Materials			X		X	X	X	X	X	X												X			
4-P/C-6	The Use of Zero-Gravity to Produce Materials Having Superior Physical Characteristics			X					X		X	X	X	X	X											
4-P/C-7	Improvements of Materials by Levitation Melting			X							X		X		X											
4-P/C-8	Effect of Zero-Gravity on the Production of Films and Foils										X				X	X		X			X					
4-P/C-9	Effects of Zero-G on Liquid Releases, Size Distribution of Liquid Drops										X	X			X	X	X	X	X					X		
4-P/C-10	Capillary Flow in Zero-G											X			X					X						
4-P/C-11	Behavior of Superfluids in the Weightless State											X			X						X	X			X	X

INSTRUMENTATION MATRIX–SPACE PHYSICS (Page 1 of 2)

RESEARCH CLUSTER–PLASMA PHYSICS		Absorption-type Nuclear Counter	Absorption Shower Cascade Counter	Ionization Spectrograph	Magnetic Spectrometer	Spark Chamber	Oscilloscope	G. P. Computer/Display Console	Movie Camera – W/Filters	Strobe/Floodlight Assembly	Superconducting Magnet	Variable Power Supply	Cryogenic Pump System	Scintillation Counter
4-CR-1 -10	High-Energy Physics Laboratory and Cosmic Ray	X	X	X	X	X	X	X	X	X	X	X	X	X
4-PP-1	Spacecraft Environment Interaction								X					X
4-PP-2	Barium Cloud Injection as a Tracer Experiment from Synchronous Orbit								X					X
4-PP-3	"Catastrophic" Plasma Experiment													X

RESEARCH CLUSTER–PLASMA PHYSICS		Proportional Counter	Streamer Chamber	Pulse Generator	Deuterium or Solid on Liquid H_2 Thinwall Tank	Transition Radiation Detector	Magnetic Tape Recorder	A/D Converter	Frequency Clock and Encoder	Piezo-electric Gravity Wave Detector Assembly	Preamplifier/Amplifier/Counter Electronics	Vacuum Chamber	Oscillograph Recorder	Barium Subsatellite Control
4-CR-1 -10	High-Energy Physics Laboratory and Cosmic Ray	X	X	X	X	X	X	X	X					
4-PP-1	Spacecraft Environment Interaction						X						X	
4-PP-2	Barium Cloud Injection as a Tracer Experiment from Synchronous Orbit						X		X				X	X
4-PP-3	"Catastrophic" Plasma Experiment						X		X					

RESEARCH CLUSTER–PLASMA PHYSICS		Filter Wheel Photometer (Scanning)	TV Camera	Barium Cannister	Magnetometer and Electron Density Transmitter	Magnetometer	Electron Accelerator	Imaging Orthicon Camera	Plasma Wave Detectors	Gas and Solid Cerenkov Counters	Cryostat	Frequency Counter	Three Grid Planar Retarding Potential Analyzer	RF or Quadrupole Mass Spectrometer
4-CR-1 -10	High-Energy Physics Laboratory and Cosmic Ray									X	X			
4-PP-1	Spacecraft Environment Interaction	X	X		X	X							X	X
4-PP-2	Barium Cloud Injection as a Tracer Experiment from Synchronous Orbit	X	X	X		X	X	X	X					
4-PP-3	"Catastrophic" Plasma Experiment					X	X	X						

RESEARCH CLUSTER–PLASMA PHYSICS		Ion and Langmuir Probes	AC Electric Field Detectors	Plasma Wave Detectors	Search Coil Magnetometer	DC-DC Converter	Sawtooth Generator	Amplifier	Still Camera with Filter	Vidicon, TV Camera	Sine Wave Generators	Faraday Cup	Measurements from Subsatellites of Auroral Position Intensity	Electron Energy Analyzer Channeltron
4-CR-1 -10	High-Energy Physics Laboratory and Cosmic Ray													
4-PP-1	Spacecraft Environment Interaction	X	X		X	X	X	X						
4-PP-2	Barium Cloud Injection as a Tracer Experiment from Synchronous Orbit							X	X	X	X			X
4-PP-3	"Catastrophic" Plasma Experiment			X								X	X	X

INSTRUMENTATION MATRIX–SPACE PHYSICS (Page 2 of 2)

INSTRUMENTATION SELECTED

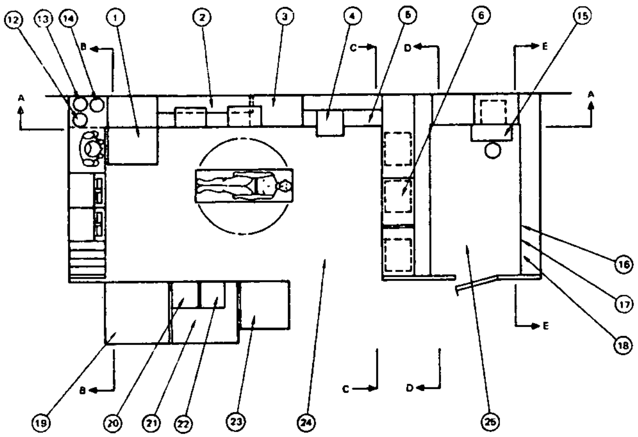
	RESEARCH CLUSTER--COMMUNICATION/NAVIGATION	ANALYZERS: Wave	Spectrum	Signal	Network	Mass Spectrometer	Antenna Pattern	CALIBRATORS: Frequency	Range	COMPARATORS: Impedence	Phase	Attenuation	Calorimeter	Computer (General Purpose)	COUNTERS: Frequency	INDICATORS: Standing Wave Ratio	Null	Noise	METERS AND TEST EQUIPMENT: Attenuation	Audio	Volt-Ohm-Ammeter	Power	Phase	Antenna Position	Impedence	Frequency	Field Strength	Auto-Cross Correlator	Oscilloscope with Camera	Frequency Synthesizer	R-C-L Bridge	STANDARDS: Frequency	Noise	Antenna Gain Horn	RECORDERS: Magnetic Tape (Instru)	Oscillograph (Thermal)	X-Y Plotter	Digital Printer	Film	Reflectometer	Optical Tracker	Clock	Subsatellite	ANTENNAS: Dipole	Dielectric	Helical	Horn	Lens	Log Periodic	Parabolic	Spiral or Conical	Whip	Yagi	Long Wire	Array	Transmission Lines: Coax	Waveguide	COMPONENTS: Amplifiers: Radio Freq (Voltage)	Intermediate Frequency	Video	Audio/DC/Servo	Power (types): Tube	TWT	Klystron	Semi Conductor	Attenuators	Bolometers	Circulators	Commutators	Connectors	Delay Line	Detectors	Diplexers	Directional Couplers	Volt/Power Dividers	Dummy Load	Filters	Junctions	Oscillators	Tuners	Switches/Relays (RF and DC)	Mixers	Modulators and Demodulators	Coders and Decoders	Counters	Converters Frequency or A/D	Power Supply AC and DC	Laser Optics	Integration Amplifiers	Multipliers	Laser Radar System	Telescope Optical System	Star Tracker
5-TF-2	Demonstration and Test (Work Center)																																																																																														
	Experiment Test Bench Console	X	X	X	X	X	X									X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X							X	X															X	X						X			X	X			X								X		X	X				X		X	X							
	Calibration and Repair Bench				X			X	X	X	X	X	X		X					X	X					X	X				X					X																				X	X													X											X				X								
	Experiment Control Console																																																																																												
	Space Station Status																																		X																																			X											X		X	X									
	Computer and Data Handling													X																					X			X	X																																												X												
	Data Display and Signal Monitor													X	X														X							X	X																																																X								
	Power Supply Distribution Panel																																																																																	X												
	RF Shielded Enclosure							X																																														X	X	X												X																							
	Scientific Airlock																																																																																													
	Antenna/RF Patch Panel																																																					X	X													X																							
	RF Component Rack																																																					X	X	X					X	X		X	X	X	X	X	X			X	X	X		X	X		X	X					X		X	X			
	Electronic Component Console/Rasks																																																					X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X		X	X			
	Space Station Remote or External Equipment																									X							X									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																							X							X				X	X
5-N-1	Terrestrial Noise Measurements	X	X	X				X						X		X		X											X				X		X	X		X									X				X					X	X	X	X	X	X					X	X			X		X				X	X		X	X	X	X				X	X		X	X			
5-N-2	Noise Source Identification	X	X	X										X				X						X				X	X						X		X	X									X			X	X					X	X	X	X	X	X					X	X			X		X					X		X	X	X	X				X	X		X				
5-P-1	Ionospheric Propagation Measurements							X						X	X															X		X			X	X		X	X			X	X									X		X		X		X	X	X	X	X				X				X	X	X	X				X		X	X	X	X	X	X		X	X							
5-P-2	Tropospheric Propagation Measurements							X														X	X						X	X		X			X	X						X					X				X		X	X		X		X	X	X	X									X		X					X		X	X	X	X				X	X							
5-P-3	Plasma Propagation Measurements			X		X																		X											X	X	X						X						X	X			X			X	X	X	X	X	X									X		X					X		X	X	X	X				X	X							
5-P-4	Multipath Measurements	X		X	X				X		X			X																X		X					X	X	X			X		X							X					X	X	X	X	X	X								X	X		X				X		X	X	X	X	X	X		X	X							
5-TF-1	Space Deployment and Calibration			X	X		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
5-CS-1	Millimeter Wave Demonstration	X			X						X	X				X		X						X				X					X		X	X											X			X					X		X	X	X	X			X					X		X		X	X		X		X	X	X		X	X	X	X		X	X		X				
5-CS-2	Optical Frequency Demonstration	X			X						X			X										X						X		X									X		X																	X	X				X					X		X					X		X		X	X	X	X		X	X	X	X			X	
5-NS-1	Satellite Navigation Techniques for Terrestrial Users				X			X	X						X																																X		X	X						X		X	X	X	X	X	X							X											X						X						
5-NS-2	Laser Ranging			X					X		X													X																	X	X																	X	X	X				X					X		X					X		X		X	X	X	X		X	X	X			X	X	
5-NS-3	Autonomous Navigation Systems for Space								X					X																																					X					X		X	X	X	X									X											X						X						X
5-NS-4	Surveillance Systems								X																										X								X			X			X	X	X		X		X	X	X	X	X	X			X							X											X						X						
5-NS-5	Collision Avoidance System Techniques							X								X						X							X	X		X										X										X				X	X	X	X	X		X	X	X		X				X		X	X		X		X	X	X	X	X	X	X			X	X			X			
5-NS-6	Search and Rescue Systems								X						X																	X			X																X	X				X		X				X	X						X	X					X				X	X	X		X	X			X							

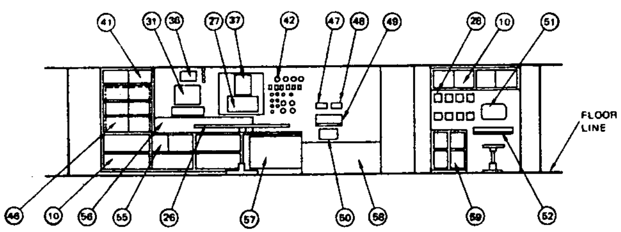
INSTRUMENTATION MATRIX--COMMUNICATIONS AND NAVIGATION

SELECTED INSTRUMENTATION

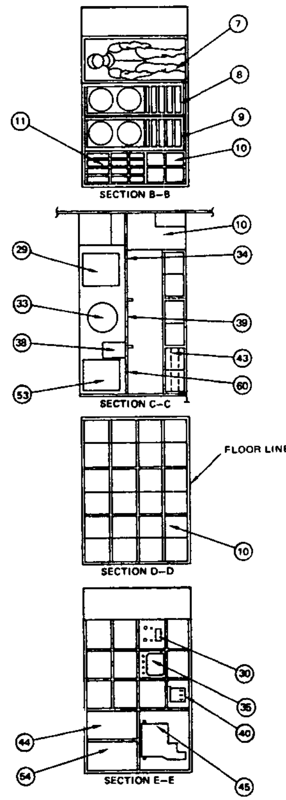
RESEARCH CLUSTER--EARTH OBSERVATIONS		Metric Camera	Multispectral Camera	10-Band Multispectral Scanner	Radar Imager	Absorption Spectrometer	Multichannel Ocean Color Sensor	Radar Altimeter/Scatterometer	Microwave Scanner Radiometer	Sferic Detector UHF	Data Collection System	Star Tracking Telescope	Zero-g Cloud Chamber	Photo-Imaging Camera	IR Interferometer/Spectrometer	Multispectral Tracking Telescope	Selective Chopper Radiometer	IR Filter Wedge Spectrometer	IR Temperature Sounder	Satellite IR Spectrometer	Temperature Profile Radiometer	Visible Wavelength Polarimeter	UV Imager/Spectrometer	TV Camera	Magnetic Tape Recorder (Voice/Video)	Electronics Signal Display Monitor CRT	Sensor Pointing Control Console	A/D and Mag Tape Data Reduction Console	GP Computer	Space Station/Experiment Status Display Console	Cryogenic Cooling System	Calibration Devices/Sources	Boresight Tracking Telescope	Film Developing Facility	Intervalometer	Film Scanning Vidicon
6-A/F-1	Crop Inventory and Land Use	X	X	X	X			X	X						X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6-A/F-2	Soil Type Mapping	X	X	X	X						X				X	X				X			X	X	X	X	X	X	X	X	X	X	X	X	X	X
6-A/F-3	Crop Identification	X	X	X	X				X						X			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6-A/F-4	Crop Vigor and Yield Prediction	X	X	X	X						X				X			X				X	X	X	X	X		X	X		X	X	X	X	X	X
6-A/F-5	Wildfire Detection and Mapping	X	X	X					X	X	X			X	X	X		X							X	X		X	X	X	X	X	X	X	X	
6-EP-1	Photographic Coverage of the Earth	X	X	X																					X	X		X			X	X	X	X	X	
6-EP-2	Identification of Volcanic Activity	X	X	X	X			X	X																X	X	X	X			X	X		X	X	
6-G/C-1	Photographic and Multisensor Mapping	X	X	X																					X	X		X			X	X	X	X	X	
6-G-1	Rock and Soil Type Identification	X	X	X	X		X		X		X				X										X			X			X	X	X	X	X	X
6-G-2	Use of Earth's Crust to Store and Condition Commodities or Waste	X	X	X	X			X	X						X									X	X	X	X	X	X	X	X	X	X	X	X	X
6-G-3	Geologic Disaster Avoidance	X	X	X	X				X		X			X											X	X		X	X		X	X	X	X	X	X
6-G-4	Utilization of Geothermal Energy Sources	X	X	X	X			X	X																X	X	X	X			X	X		X	X	
6-G-5	Mineral and Oil Deposit Discovery	X	X	X	X	X			X																X	X		X	X	X	X	X	X	X	X	X
6-G-6	Identification of Land Forms and Structural Forms	X	X	X	X				X																X	X		X			X	X	X	X	X	X
6-H-1	Determination of Pollution in Water Resources	X	X	X			X				X														X	X		X	X		X	X	X	X	X	
6-H-2	Flood Warning and Damage Assessment	X			X				X		X			X											X	X		X	X			X		X		X
6-H-3	Synoptic Inventory of Major Lakes and Reservoirs	X	X	X	X						X														X			X			X			X	X	X
6-H-4	Synoptic Inventory of Snow and Ice	X		X	X				X		X														X			X			X			X		X
6-H-5	Survey of Soil Moisture in Selected Areas of the North American Continent	X		X	X				X		X														X	X		X			X	X		X		
6-H-6	Location of Underground Water Sources in Selected Areas	X		X							X														X	X		X	X		X	X		X		
6-H-7	Survey of Hydrologic Features of Major River Basins	X	X	X	X						X														X			X			X	X		X	X	X
6-M-1	Determination of Boundary Layer Exchange Processes Using IR Radiometry														X		X	X	X	X	X				X	X		X		X	X	X			X	
6-M-2	UHF Sferics Detection									X															X	X						X				
6-M-3	Atmosphere Density Measurements by Stellar Occultation											X													X			X			X		X			
6-M-4	Zero-g Environment Cloud Physics Experiment												X											X	X			X		X						
6-M-5	Detection and Monitoring of Atmospheric Pollutants					X																			X			X	X	X						
6-M-6	Support of Studies of Special Geographical Areas	X								X					X		X	X	X	X	X				X	X		X		X	X	X		X	X	
6-O-1	Ocean Pollution Identification, Measurement, and Effects	X		X		X	X		X		X														X	X		X	X	X	X	X		X		
6-O-2	Solar Energy Partition and Heating in the Sea Surface Layer	X		X			X	X	X		X														X	X	X	X	X	X	X	X	X	X		
6-O-3	Ocean Population Dynamics and Fishery Resources	X		X			X		X		X														X	X		X			X	X		X		
6-O-4	Ocean Currents and Tides Forecasting	X			X			X			X														X									X		X
6-O-5	Ocean Physical Properties	X			X				X		X														X	X		X						X		X
6-O-6	Ocean Solid Boundary Processes	X	X	X				X			X														X	X	X	X			X	X	X	X	X	
6-O-7	Ocean Surface Activity Forecasting	X						X	X		X														X	X	X	X						X		

INSTRUMENTATION MATRIX–EARTH OBSERVATIONS





SECTION A–A



ITEM	EQUIPMENT	ITEM	EQUIPMENT
1	LEAF TYPE DESK TOP	32	PHYSIOLOGIC PARAMETERS
2	X-RAY ELECTRONICS CONSOLE	33	LOWER BODY NEGATIVE PRESSURE MEASUREMENT DEVICE (STOWED)
3	PRINTER	34	BIOCHEMISTRY
4	COMPUTER KEY BOARD	35	CRT DISPLAY
5	COMPUTER	36	METABOLIC GAS DISPLAY
6	CHEMISTRY AND MICROBIOLOGY LABORATORY	37	PHYSIOLOGIC PARAMETERS
7	SPACE SUIT TYPE FOR THERMAL STRESS TESTING	38	ELECTROMYOGRAM RECORDER
8	VIDEO RECORDER	39	SPECIMEN MASS MEASUREMENT DEVICE
9	AUDIO RECORDER	40	STRIP RECORDER
10	STORAGE	41	NOTEBOOKS—REPORTS ETC.
11	TAPE STORAGE	42	PHYSIOLOGY CONTROLS
12	CO_2 BOTTLES	43	TAPE STORAGE
13	He BOTTLES	44	IVA TOOL KIT
14	O_2 BOTTLES	45	TASK PANEL
15	AUDIO AND VIDEO TEST AREA AND ONBOARD SIMULATOR	46	STOWED DESK TOP
16	TASK BOARD	47	EC/LS DISPLAY
17	EVA TOOL KIT	48	EC/LS STRIP RECORDER
18	IVA TOOL KIT	49	COMPUTER KEYBOARD
19	FREEZER	50	STRIP RECORDER
20	OVEN	51	VIDEO DISPLAY
21	TOXICOLOGICAL CHAMBER	52	CONTROL AND TEST PANEL
22	OVEN (FECAL DRYING)	53	BODY MASS MEASUREMENT DEVICE
23	SCINTILLATOR	54	EVA TOOL KIT STORED
24	PHYSIOLOGY LABORATORY	55	X-RAY
25	BEHAVIORAL LABORATORY	56	X-RAY CONSOLE
26	ROTATING LITTER CHAIR	57	PRINTER
27	METABOLIC AND RESPIRATORY GAS TEST EQUIPMENT	58	COMPUTER
28	VIDEO MONITORS	59	CAMERA LIGHTS STORED
29	ERGOMETER (STOWED)	60	MICROBIOLOGY
30	AUDIOMETER		
31	N_2 ANALYZER		

0 10 30 50 100 150

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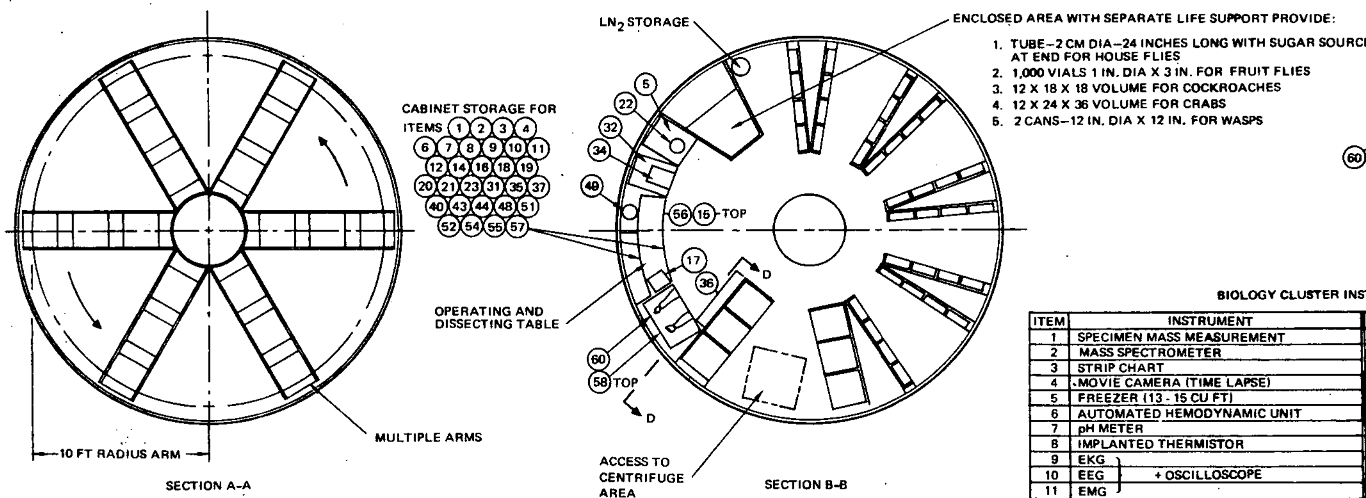
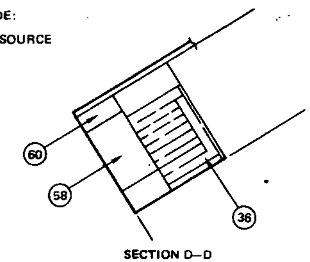
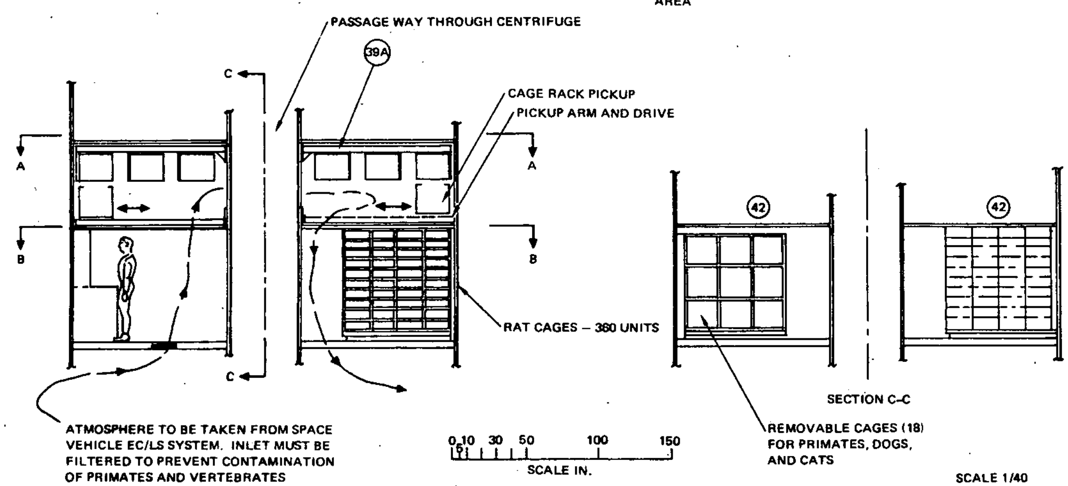


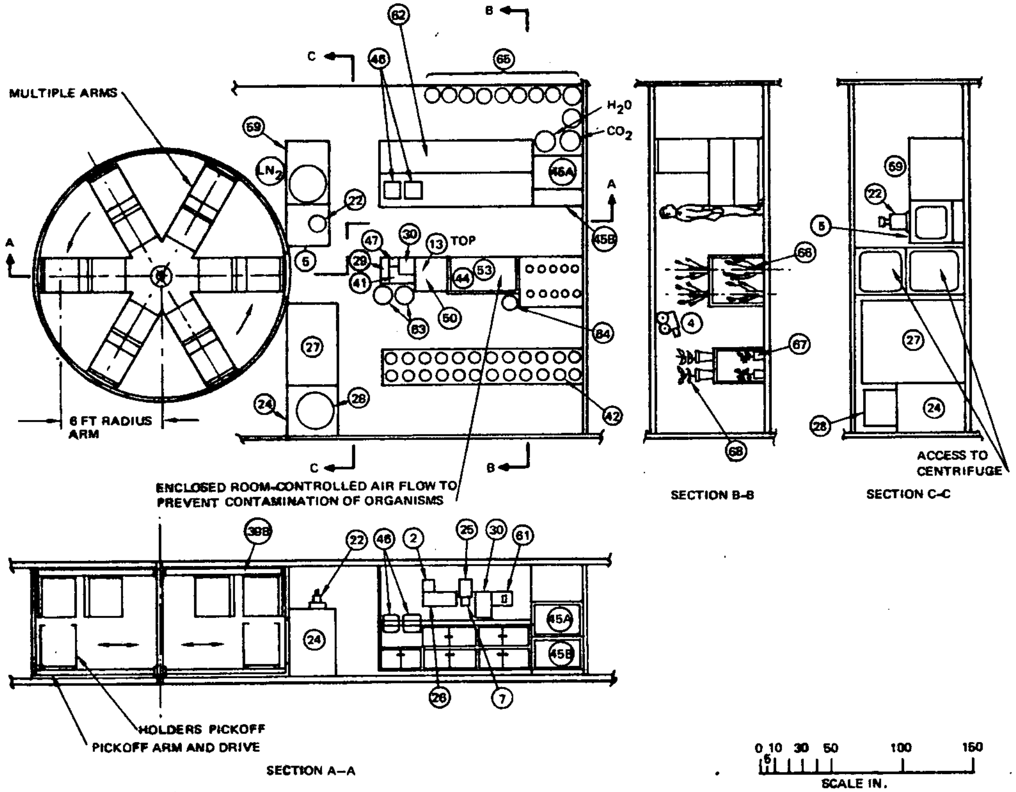




BIOLOGY CLUSTER INSTRUMENT TABULATION

ITEM	INSTRUMENT	ITEM	INSTRUMENT
1	SPECIMEN MASS MEASUREMENT	38	CALORIMETER
2	MASS SPECTROMETER	39	CENTRIFUGE A. 10' ARM 1 OF AT 17 RPM B. 6' ARM 1 OF AT 22 RPM
3	STRIP CHART		
4	MOVIE CAMERA (TIME LAPSE)		
5	FREEZER (13 - 15 CU FT)	39A	CENTRIFUGE WITH ADJUSTABLE CAGE RACK MOUNTS–STANDARD MANIFOLD CONNECTIONS AND SUPPLY
6	AUTOMATED HEMODYNAMIC UNIT		
7	pH METER		
8	IMPLANTED THERMISTOR	40	TACHISTOSCOPE
9	EKG + OSCILLOSCOPE	41	GAS CHROMATOGRAPH
10	EEG + OSCILLOSCOPE	42	ANIMAL CAGES
11	EMG + OSCILLOSCOPE	43	ACTIVITY MONITOR GAGE
12	PSYCHOGALVANOMETER	44	BUNSEN BURNER OR SUBSTITUTE
13	AUTOCLAVE	45	INCUBATOR A. 37°C B. 37°C + 10% CO^2
14	MULTICHOICE STIMULUS DISPLAY/REC		
15	VISUAL CLIFF		
16	AUDIOMETER	46	WATER BATH FLUID HANDLING SYSTEM
17	VIBRATION TABLE (ACTIVITY PLATFORM) RECORDER	47	PARAFFIN OVEN
		48	HOMOGENIZER
18	LIGHT DISCRIMINATION APPARATUS	49	DIALYSIS EQUIPMENT
19	PSEUDO-ISOCHROMATIC PLATES	50	DRYING OVEN
20	FLICKER FUSION APPARATUS	51	PARAMAGNETIC OXYGEN ANALYZER COLLECTOR
21	AUDIO VISUAL TACTILE STIMULATOR		
22	LIQUID NITROGEN REFRIGERATOR	52	BEHAVIORAL REGIMEN & DATA
23	CAMERA (STILL & TIME LAPSE)	53	LAMINAR FLOW BENCH
24	SCINTILLATION COUNTER	54	SURGICAL TOOLS
25	HI-Z POTENTIOMETER RECORDER & ELECTRODES	55	RADIOISOTOPE
		56	AUTOMATED MICROBIAL ID SYSTEM
26	SPECTROPHOTOMETER	57	STERILIZER
27	AMINO ACID ANALYZER	58	GLOVE BOX
28	TISSUE PROCESSOR & STAINER	59	REFRIGERATED CENTRIFUGE
29	VACUUM INFILTRATION OVEN	60	ATOMIC ABSORPTION SPECTROPHOTOMETER
30	MICROTOME	61	MILLIVOLT METER - 10^{13} OHM IMPEDANCE
31	MICROSCOPE WITH CAMERA	62	WORKBENCH/CONSOLE/STORAGE
32	MULTICHANNEL RECORDER	63	GAS STORAGE
33	IMPLANT TRANSDUCER	64	NATURAL GAS STORAGE
34	EM FLOWMETER (BLOOD) DENSITOMETER	65	GAS & LIQUID CONSUMABLES - He, AIR, H_2, N_2, NURHYDRIN, PHENYL-ORAZOLYL, BENZENE
35	LINEAR MOTION TRANSDUCER RECORDER SYSTEM	66	WHEAT SEEDLINGS - 8 PER TUBE - 160 TOTAL
36	ANIMAL MAZE	67	MARIGOLDS - 50 EACH
37	MYOGRAPHIC STRAIN GAGE	68	BEAN PLANTS - 24 EACH

Earth Orbital Experiment Program and Requirements Study–Space Biotechnology Laboratory (Plate 1)



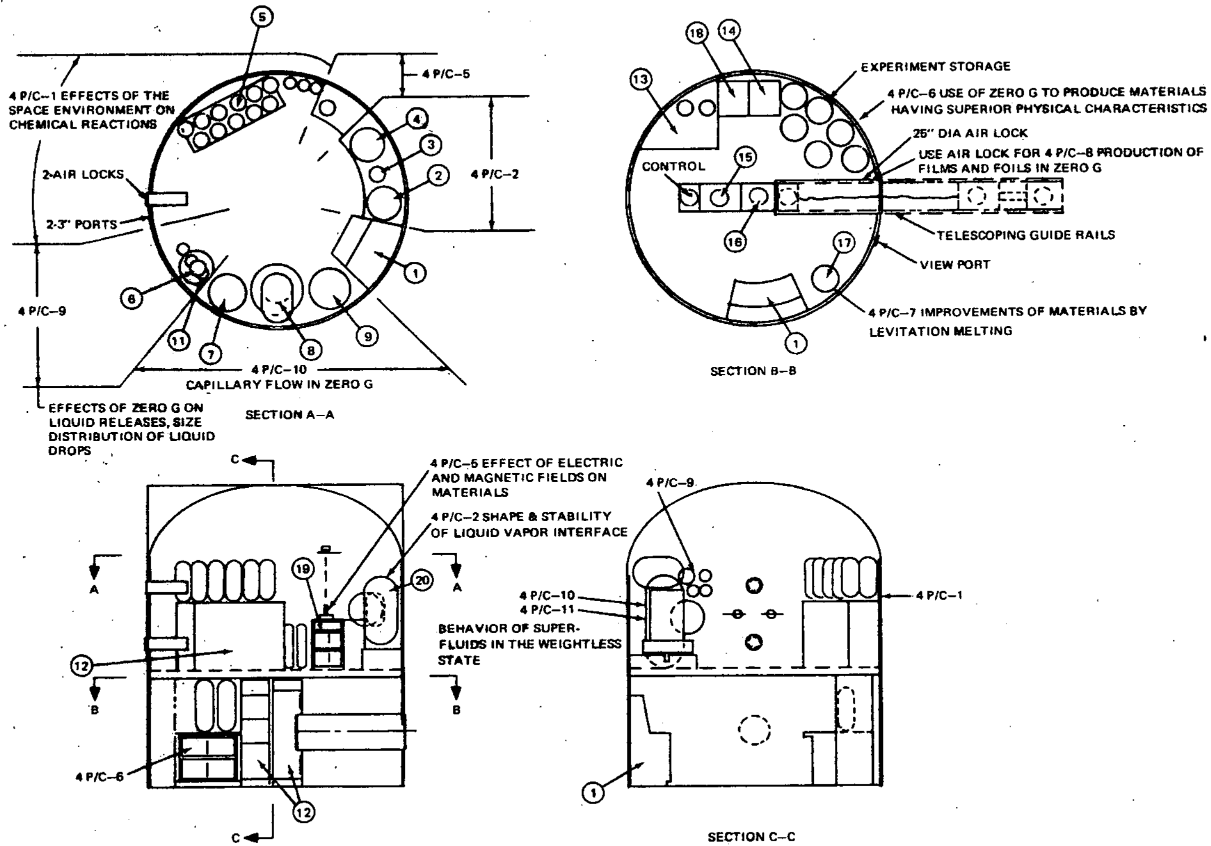
SCALE 1/40 IN.

BIOLOGY CLUSTER INSTRUMENT TABULATION

ITEM	INSTRUMENT
1	SPECIMEN MASS MEASUREMENT
2	MASS SPECTROMETER
3	STRIP CHART
4	MOVIE CAMERA (TIME LAPSE)
5	FREEZER (13 - 15 CU FT)
6	AUTOMATED HEMODYNAMIC UNIT
7	pH METER
8	IMPLANTED THERMISTOR
9	EKG } + OSCILLOSCOPE
10	EEG } + OSCILLOSCOPE
11	EMG } + OSCILLOSCOPE
12	PSYCHOGALVANOMETER
13	AUTOCLAVE
14	MULTICHOICE STIMULUS DISPLAY/REC
15	VISUAL CLIFF
16	AUDIOMETER
17	VIBRATION TABLE (ACTIVITY PLATFORM) RECORDER
18	LIGHT DISCRIMINATION APPARATUS
19	PSEUDO-ISOCHROMATIC PLATES
20	FLICKER FUSION APPARATUS
21	AUDIO VISUAL TACTILE STIMULATOR
22	LIQUID NITROGEN REFRIGERATOR
23	CAMERA (STILL & TIME LAPSE)
24	SCINTILLATION COUNTER
25	HI-Z POTENTIOMETER RECORDER & ELECTRODES
26	SPECTROPHOTOMETER
27	AMINO ACID ANALYZER
28	TISSUE PROCESSOR & STAINER
29	VACUUM INFILTRATION OVEN
30	MICROTOME
31	MICROSCOPE WITH CAMERA
32	MULTICHANNEL RECORDER
33	IMPLANT TRANSDUCER
34	EM FLOWMETER (BLOOD) DENSITOMETER
35	LINEAR MOTION TRANSDUCER RECORDER SYSTEM
36	ANIMAL MAZE
37	MYOGRAPHIC STRAIN GAGE

ITEM	INSTRUMENT
38	CALORIMETER
39	CENTRIFUGE A. 10' ARM 1 OF AT 17 RPM B. 6' ARM 1 OF AT 22 RPM
39A	CENTRIFUGE WITH ADJUSTABLE CAGE RACK MOUNTS—STANDARD MANIFOLD CONNECTIONS AND SUPPLY
40	TACHISTOSCOPE
41	GAS CHROMATOGRAPH
42	ANIMAL CAGES
43	ACTIVITY MONITOR GAGE
44	BUNSEN BURNER
45	INCUBATOR A. 37°C B. 37°C + 10% CO^2
46	WATER BATH FLUID HANDLING SYSTEM
47	PARAFFIN OVEN
48	HOMOGENIZER
49	DIALYSIS EQUIPMENT
50	DRYING OVEN
51	PARAMAGNETIC OXYGEN ANALYZER COLLECTOR
52	BEHAVIORAL REGIMEN & DATA
53	LAMINAR FLOW BENCH
54	SURGICAL TOOLS
55	RADIOISOTOPE
56	AUTOMATED MICROBIAL ID SYSTEM
57	STERILIZER
58	GLOVE BOX
59	REFRIGERATED CENTRIFUGE
60	ATOMIC ABSORPTION SPECTROPHOTOMETER
61	MILLIVOLT METER - 10^{13} OHM IMPEDANCE
62	WORKBENCH/CONSOLE/STORAGE
63	GAS STORAGE
64	NATURAL GAS STORAGE
65	GAS & LIQUID CONSUMABLES - He, AIR H_2, N_2, NURHYDRIN, PHENYL-ORAZOLYL, BENZENE
66	WHEAT SEEDLINGS - 8 PER TUBE - 160 TOTAL
67	MARIGOLDS - 50 EACH
68	BEAN PLANTS - 24 EACH

Earth Orbital Experiment Program and Requirements Study—Space Plant Biology Laboratory (Plate 2)



ITEM	INSTRUMENT
1	WORKBENCH–STORAGE
2	TANK 24" OC x 48" PLEXIGLAS
3	TANK 12" OD x 24"
4	TANK 24" OD
5	GAS & LIQUID STORAGE (O_2, N_2, etc)
6	PRESSURE SPHERE 28" OD
7	TANK, ETHANOL 19 FT^3
8	TANK, METHANOL 6 FT^3
9	TANK, PENTHANE 25 FT^3
10	TANKS, 8" OD (4 EA.)
11	COMBUSTION CHAMBER (ATMOS.)
12	RACKS, ELECTRONIC
13	BENCH, STORAGE
14	RECORDER, STRIP
15	FURNACE, INDUCTION
16	CASTING CHAMBER (VAC)
17	CHAMBER, HEATING
18	RECORDER, MAG TAPE
19	MAGNET
20	CHAMBER, VACUUM

NOTE: DESIGNATION 4 P/C–REFERS TO RESEARCH CLUSTER

0 10 30 60 100 150
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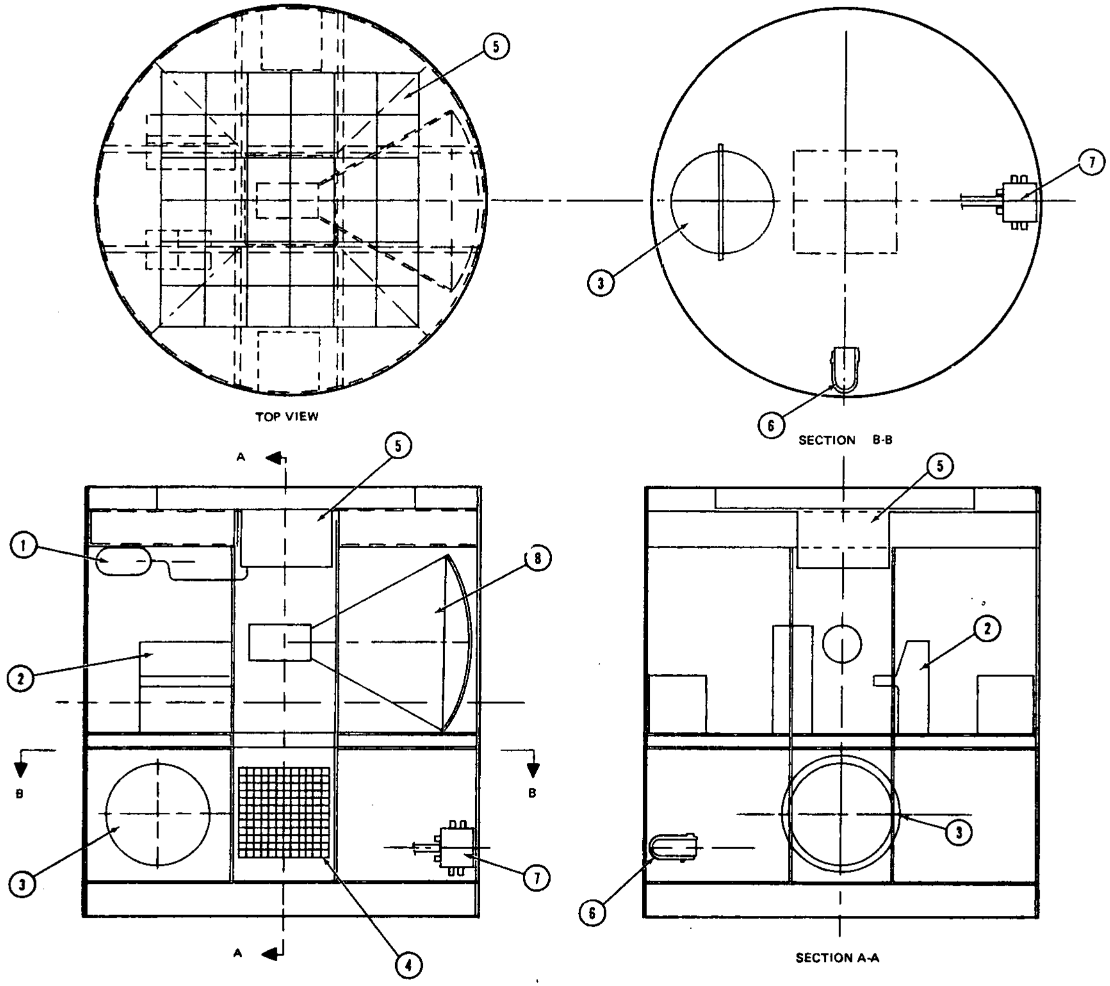
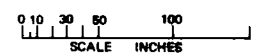


ITEM	INSTRUMENT
1	CRYOGENIC SYSTEM
2	CONSOLE, COMPUTER AND DISPLAY
3	SUPERCONDUCTING MAGNET
4	SCINTILLATION COUNTER
5	PROPORTIONAL COUNTER
6	SPARK CHAMBER
7	SOLID STATE COUNTER
8	CERENKOV COUNTER



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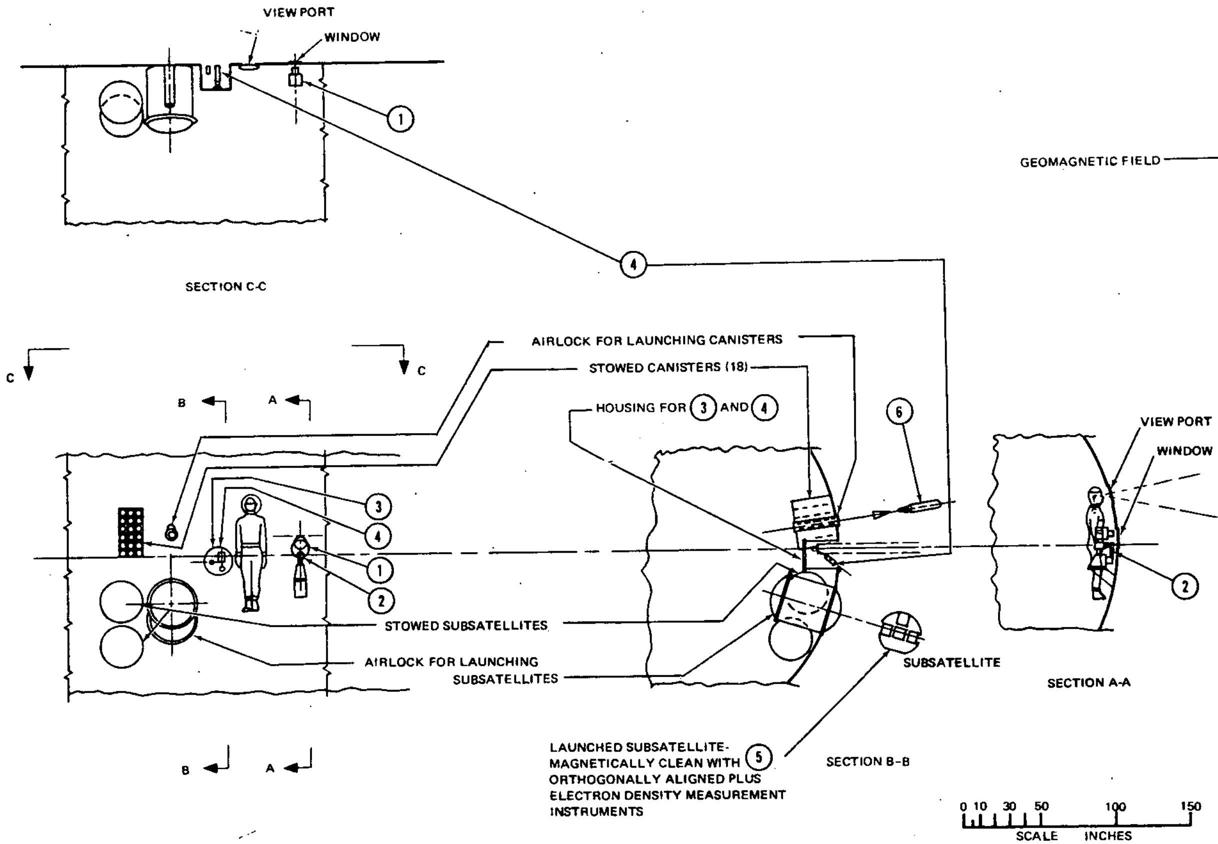
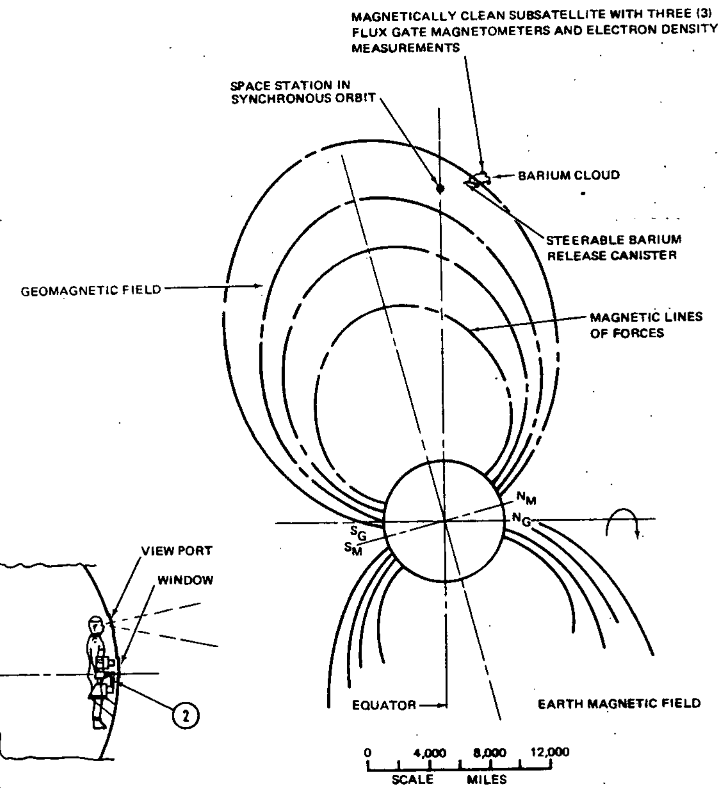
ITEM	INSTRUMENT
1	VIDICON
2	CAMERA–6 IN. F.L. WITH FILTERS
3	PHOTOMETER W/FILTER WHEEL
4	SCANNING PHOTOTUBE – ROTATING MIRROR
5	FLUX GATE MAGNETOMETERS – 3 EA
6	STEERABLE BARIUM RELEASE CANISTER





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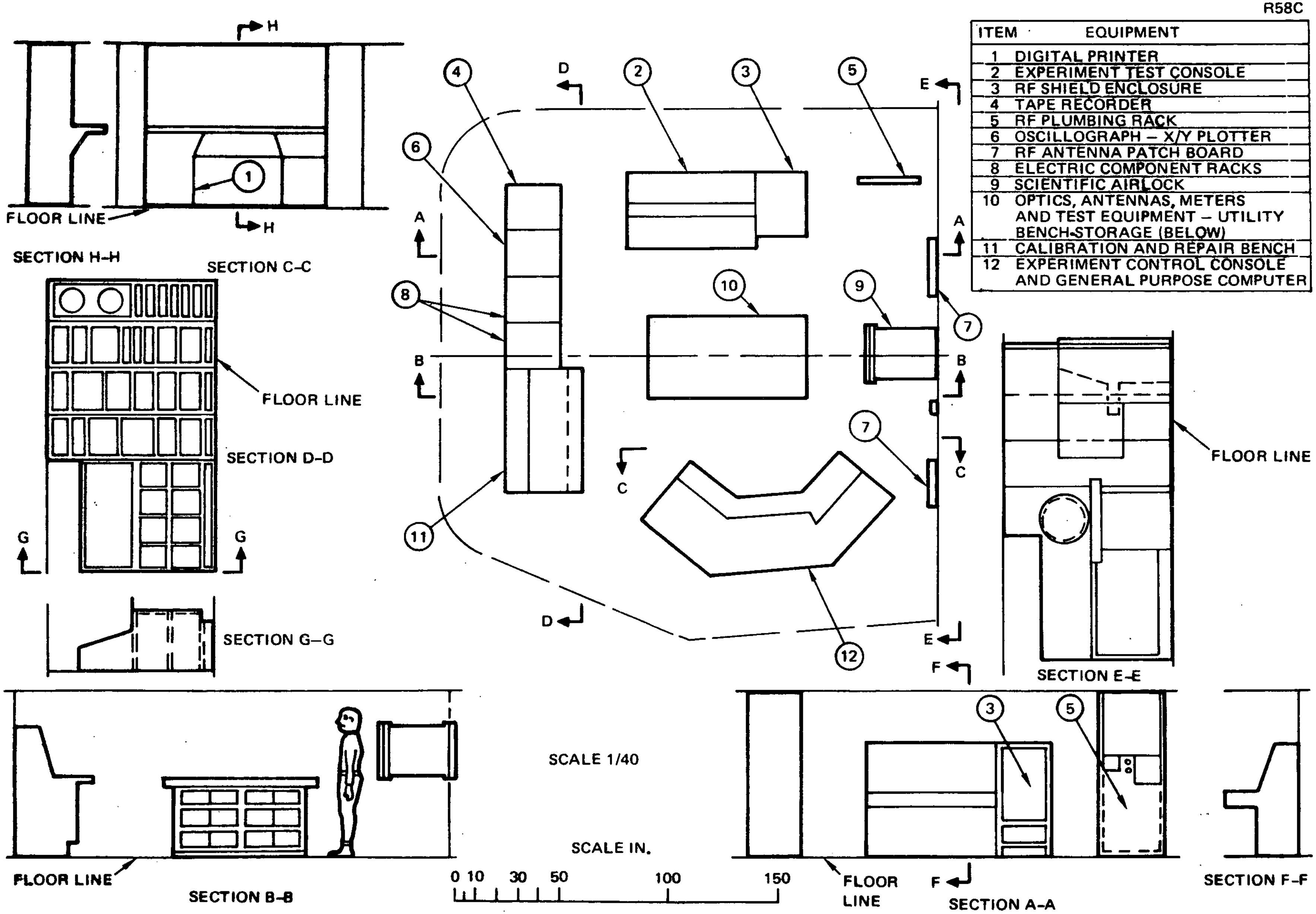
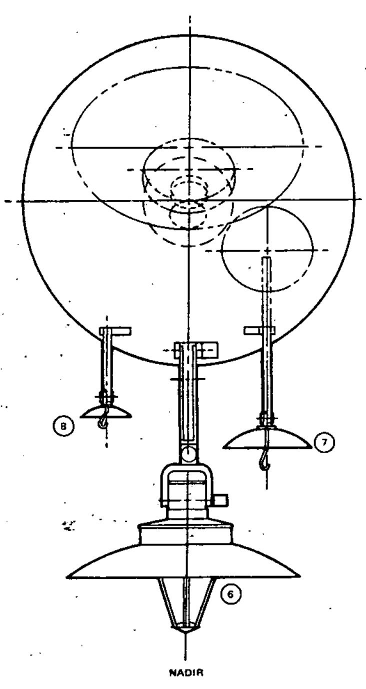
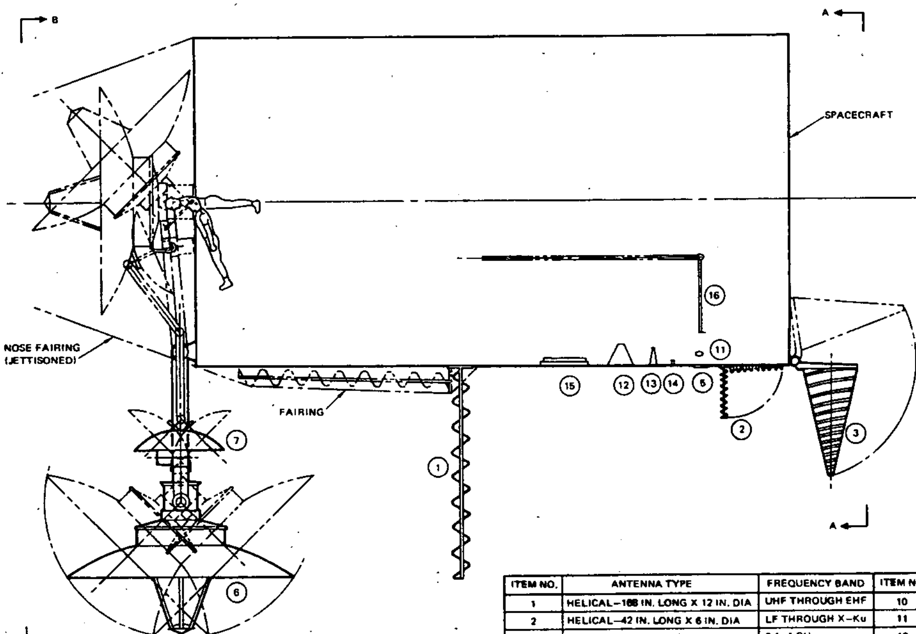
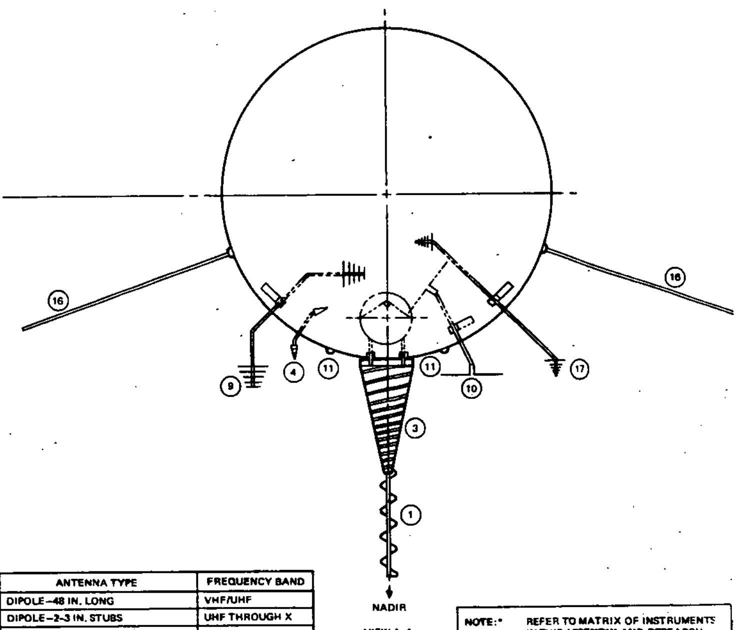


ITEM	EQUIPMENT
1	DIGITAL PRINTER
2	EXPERIMENT TEST CONSOLE
3	RF SHIELD ENCLOSURE
4	TAPE RECORDER
5	RF PLUMBING RACK
6	OSCILLOGRAPH – X/Y PLOTTER
7	RF ANTENNA PATCH BOARD
8	ELECTRIC COMPONENT RACKS
9	SCIENTIFIC AIRLOCK
10	OPTICS, ANTENNAS, METERS AND TEST EQUIPMENT – UTILITY BENCH-STORAGE (BELOW)
11	CALIBRATION AND REPAIR BENCH
12	EXPERIMENT CONTROL CONSOLE AND GENERAL PURPOSE COMPUTER

Earth Orbital Experiment Program and Requirements Study—Communication/Navigation Research Facility



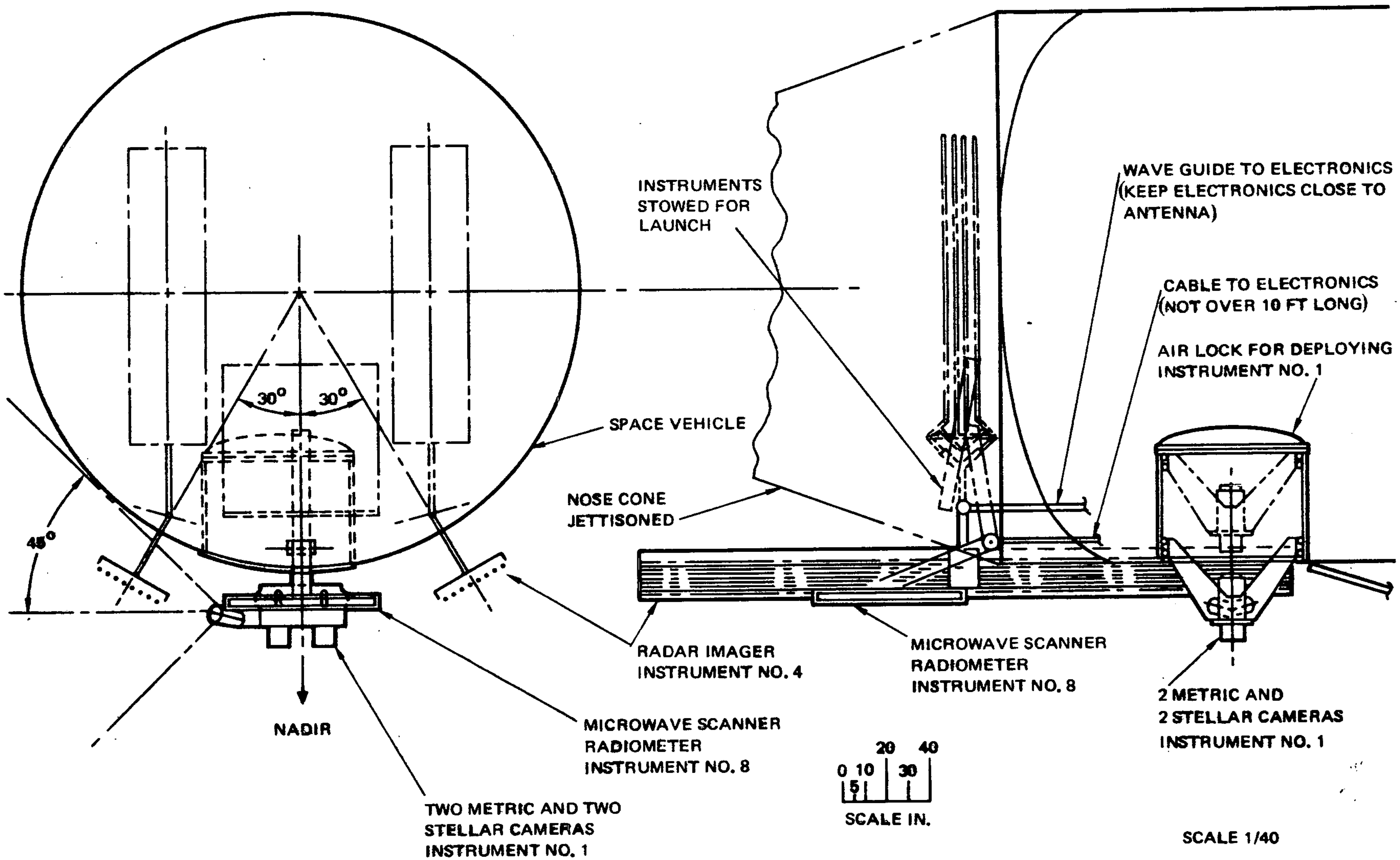




ITEM NO.	ANTENNA TYPE	FREQUENCY BAND	ITEM NO.	ANTENNA TYPE	FREQUENCY BAND
1	HELICAL—168 IN. LONG X 12 IN. DIA	UHF THROUGH EHF	10	DIPOLE—48 IN. LONG	VHF/UHF
2	HELICAL—42 IN. LONG X 6 IN. DIA	LF THROUGH X—Ku	11	DIPOLE—2-3 IN. STUBS	UHF THROUGH X
3	SPIRAL—LOG CONICAL	0.1—1 GHz	12	HORN—21 IN. DIA	L
4	SPIRAL—LOG CONICAL	1—10 GHz	13	HORN—6 IN. DIA	X
5	SPIRAL—CAVITY BACKED	10—15 GHz	14	HORN—1-1/2 IN. SQ	EHF
6	PARABOLIC—15 FT DIA	UHF THROUGH EHF	15	ARRAY (SLOTTED LINE)	X THROUGH EHF
7	PARABOLIC—6 FT DIA	X THROUGH EHF	16	WHIP	VHF/UHF
8	PARABOLIC—3 FT DIA	X THROUGH 100 GHz	17	LOG PERIODIC	UHF THROUGH S
9	YAGI	UHF—300 MHz			

NOTE:* REFER TO MATRIX OF INSTRUMENTS IN THIS APPENDIX AND RESEARCH CLUSTER DESCRIPTIONS, APPENDIX C (BOOK 9) FOR ASSIGNMENT OF ANTENNA TYPES.

Earth Orbital Experiment Program and Requirements Study—Communicati
Navigation Antennas Installation*



Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instruments No. 1, 4, and 8

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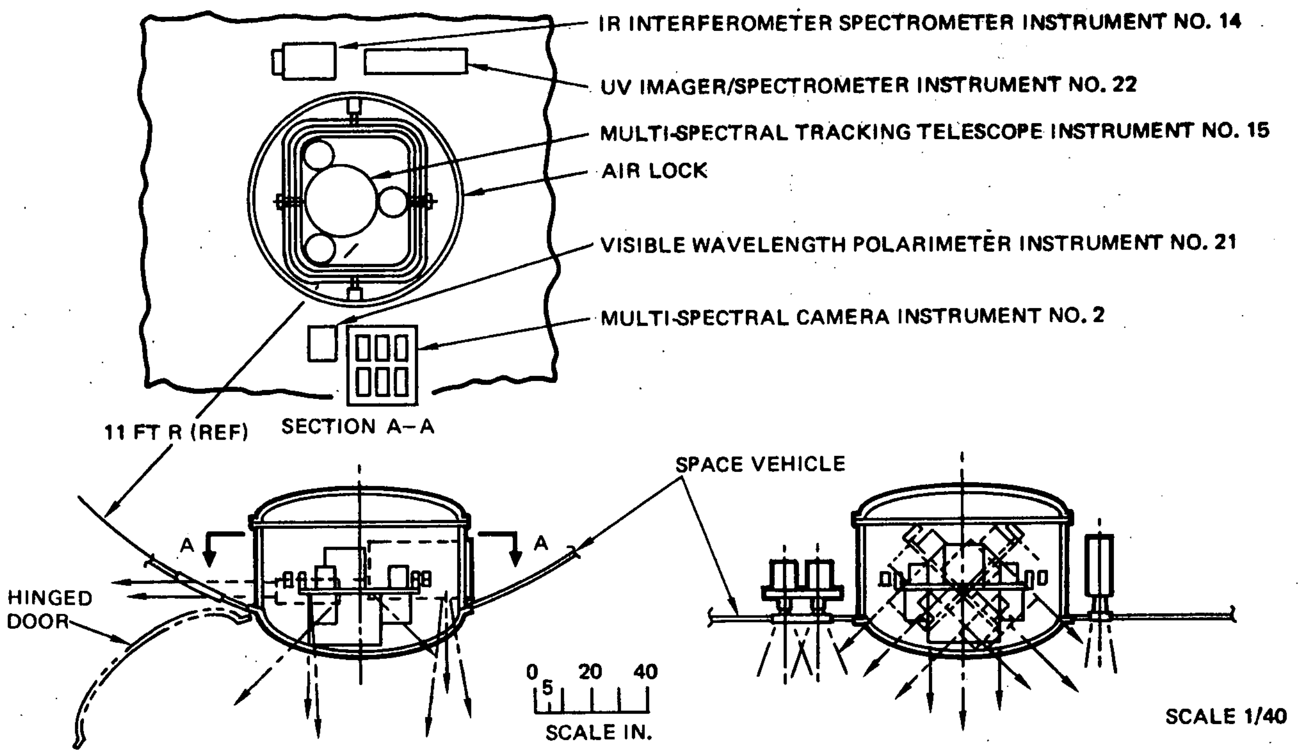

Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instruments No. 2, 14, 15, 21, and 22

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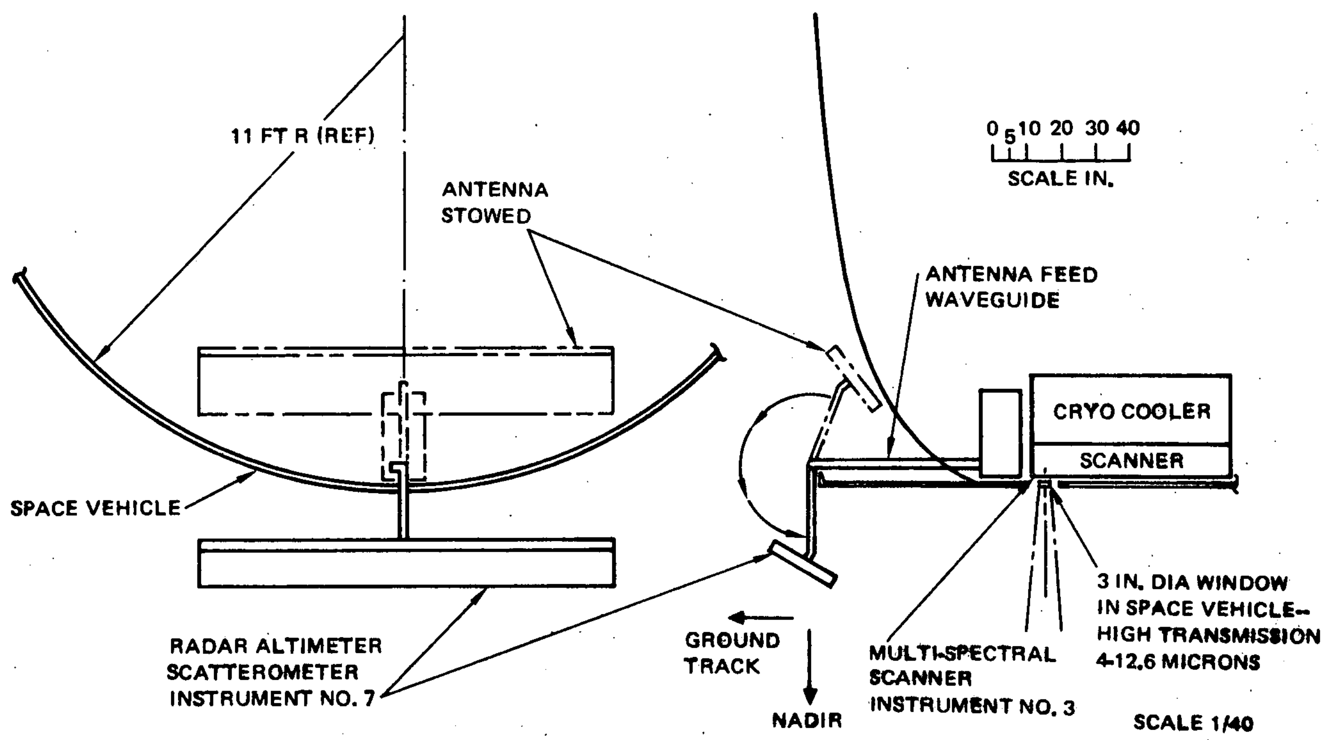
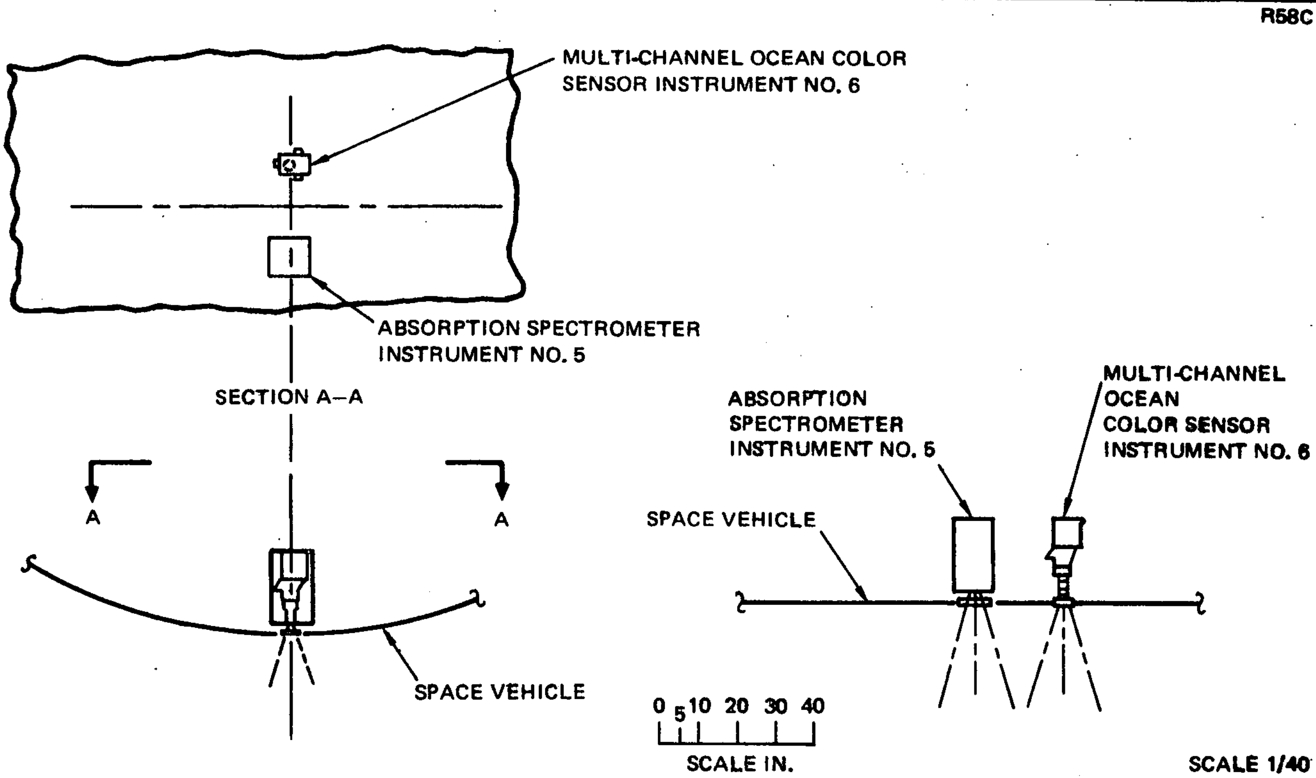
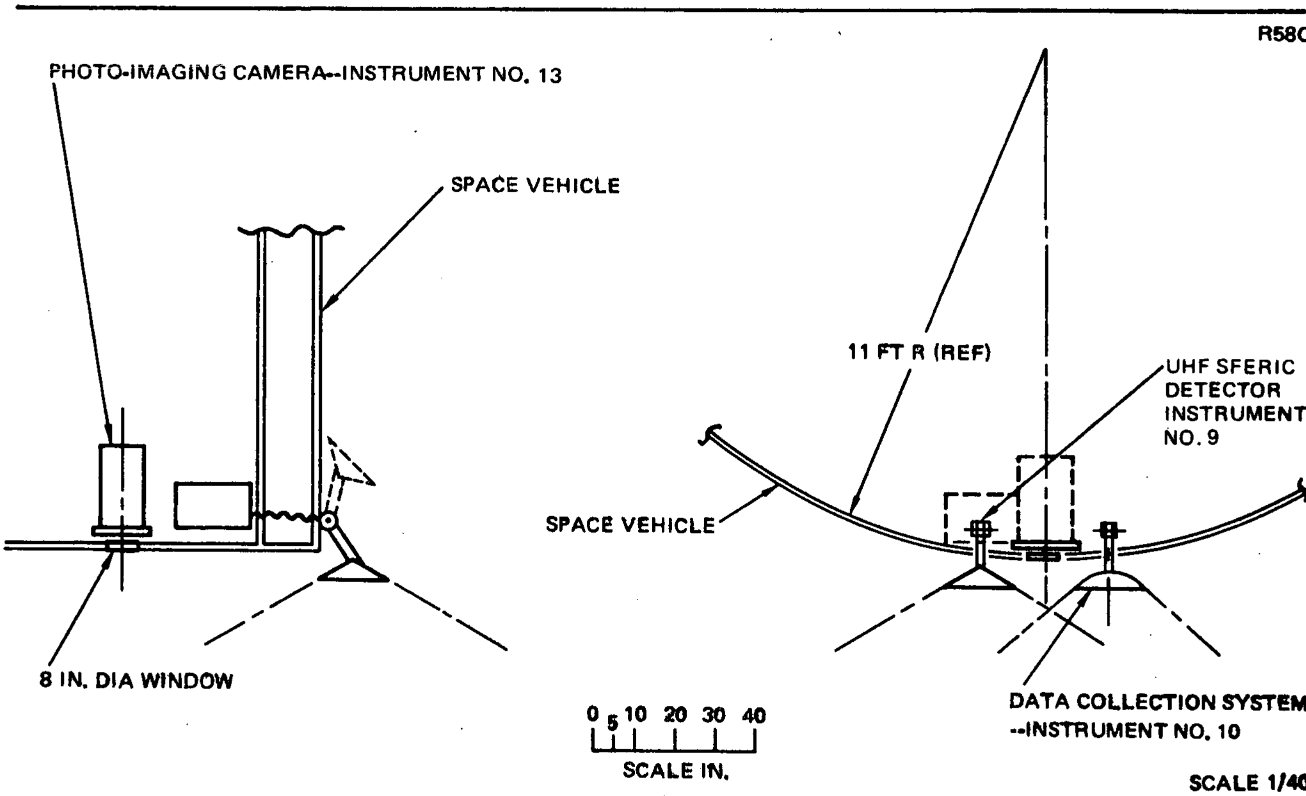


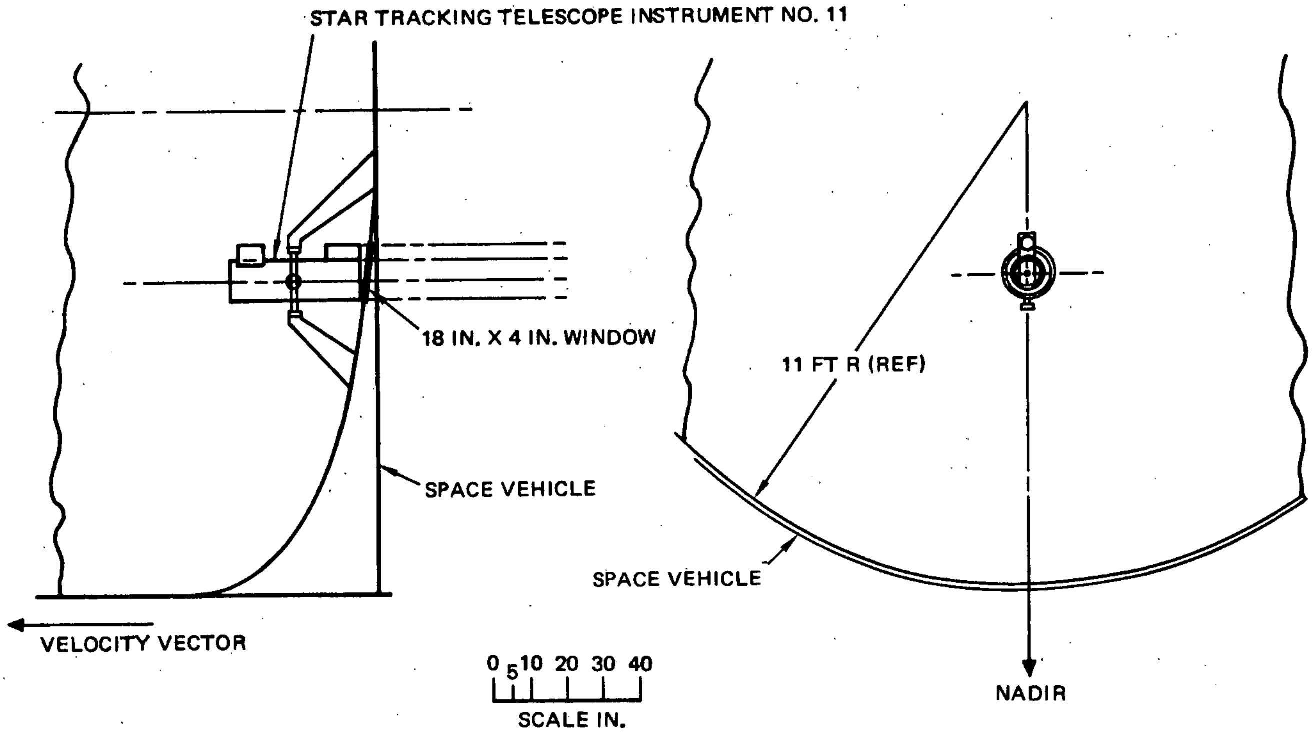
Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instruments No. 3 and No. 7



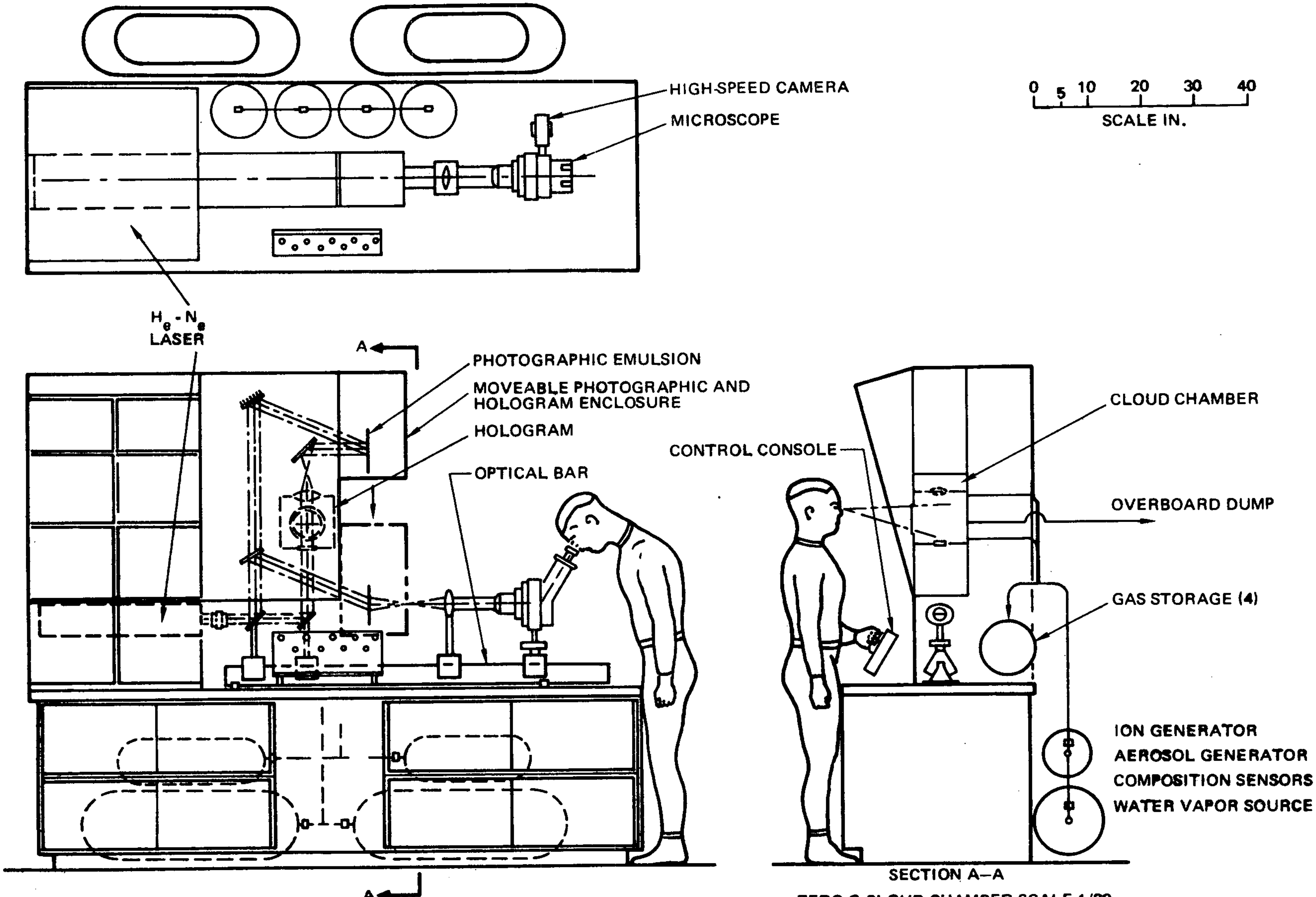
Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instruments No. 5 and No. 6



Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instruments No. 9, 10, and 13



Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instrument No. 11



SECTION A–A

ZERO-G CLOUD CHAMBER SCALE 1/20
INSTRUMENT NO. 12

Earth Orbital Experiment Program and Requirements Study—Earth Observations Installation Instruments No. 12

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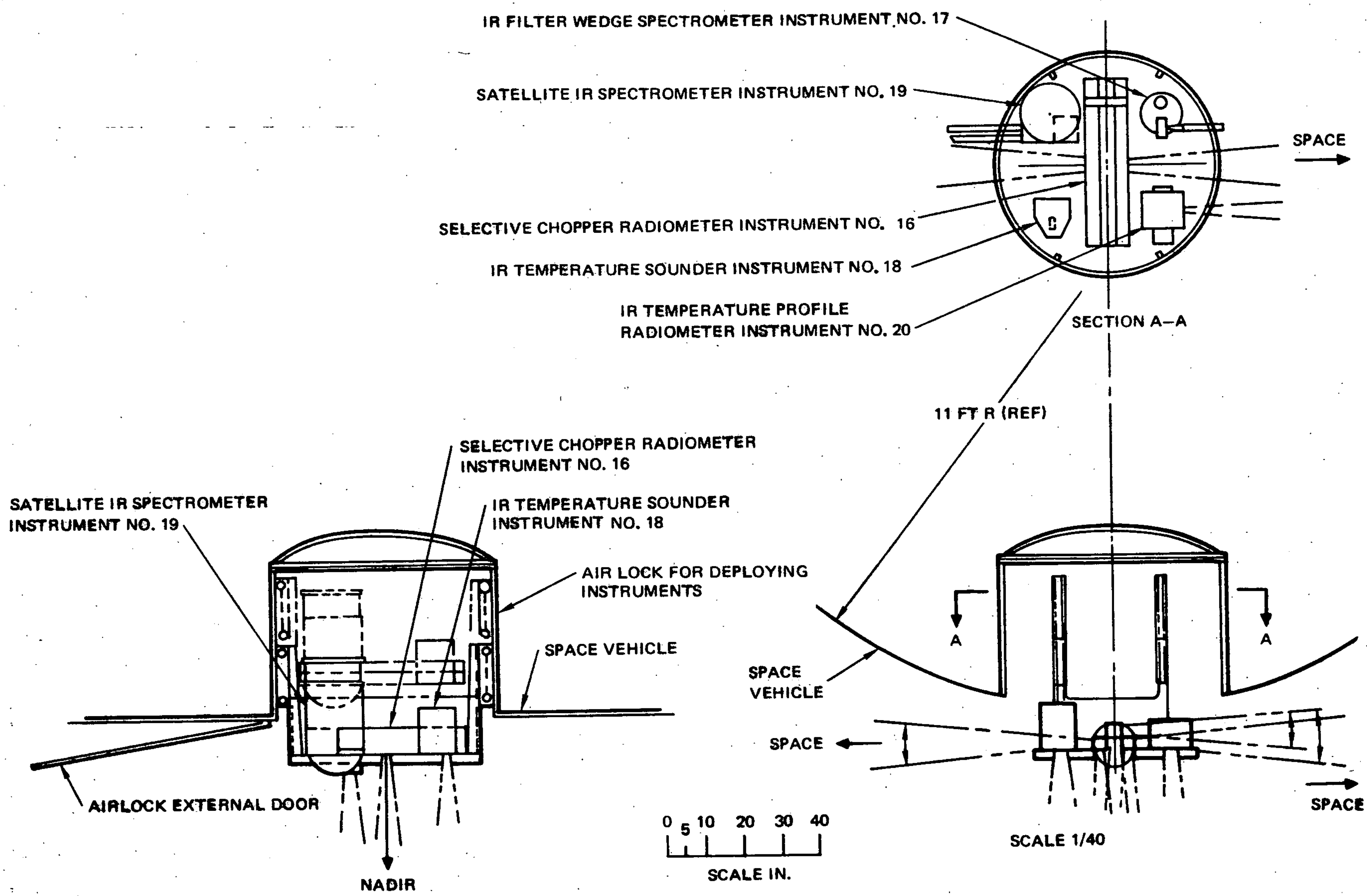

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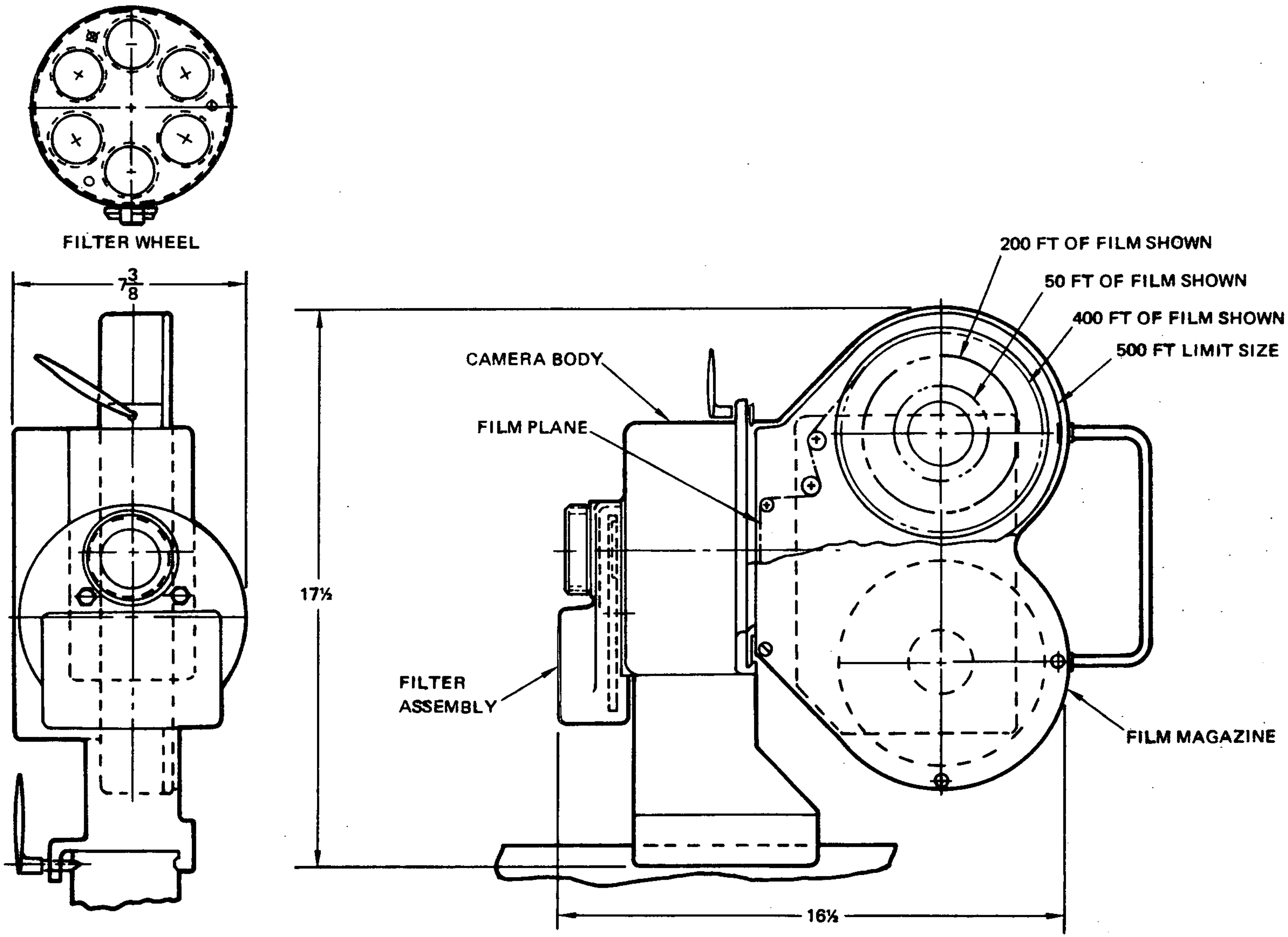
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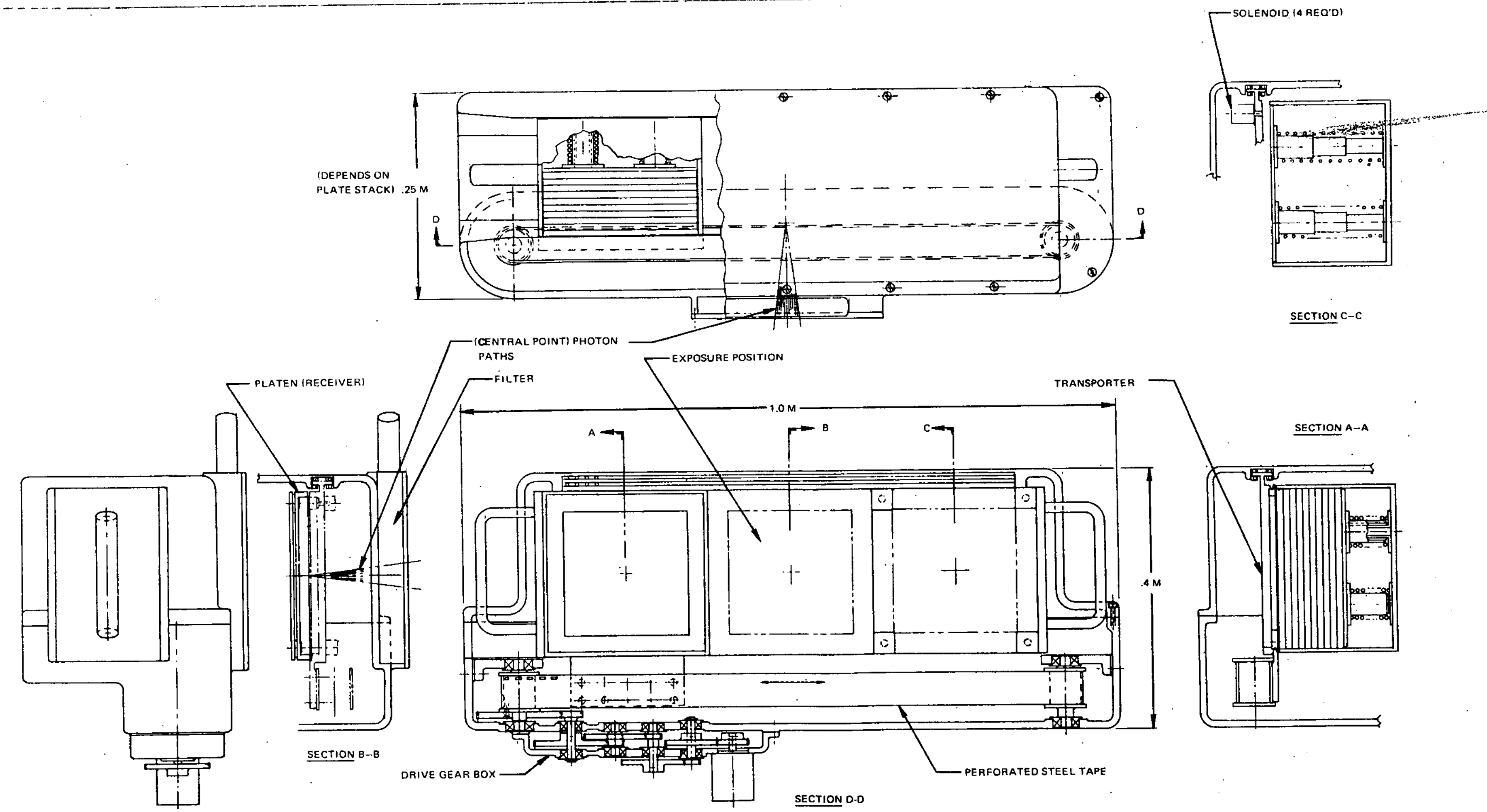
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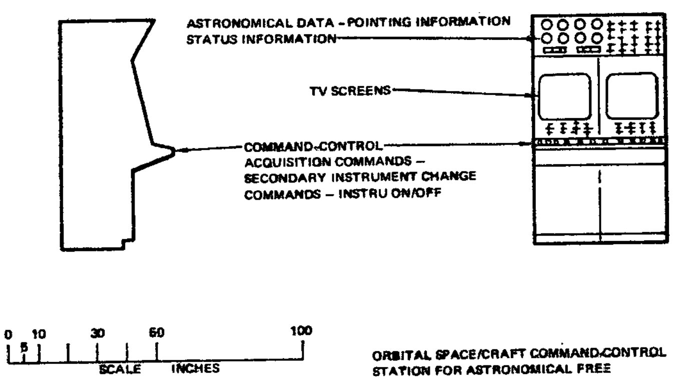

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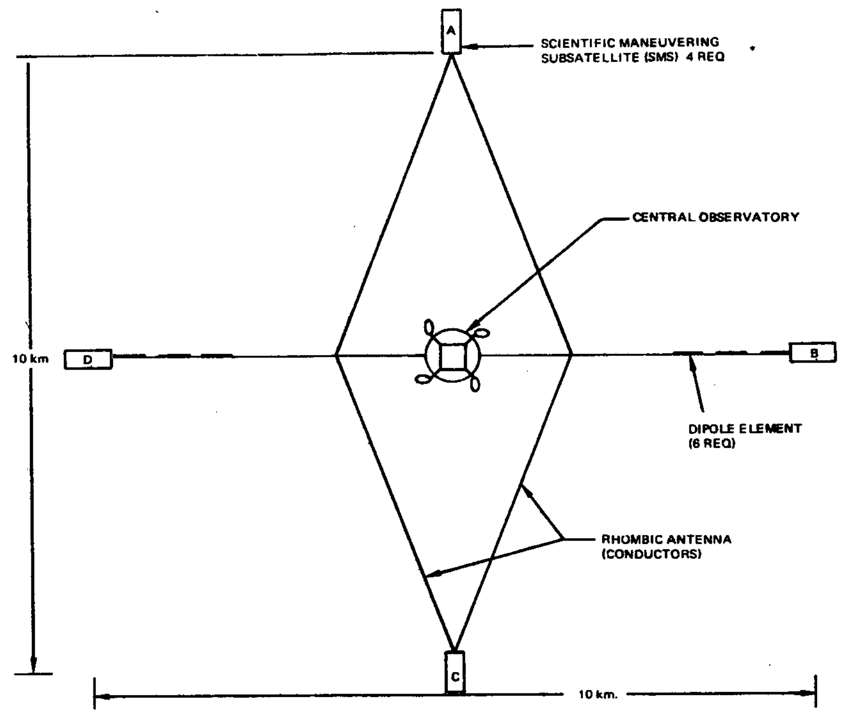

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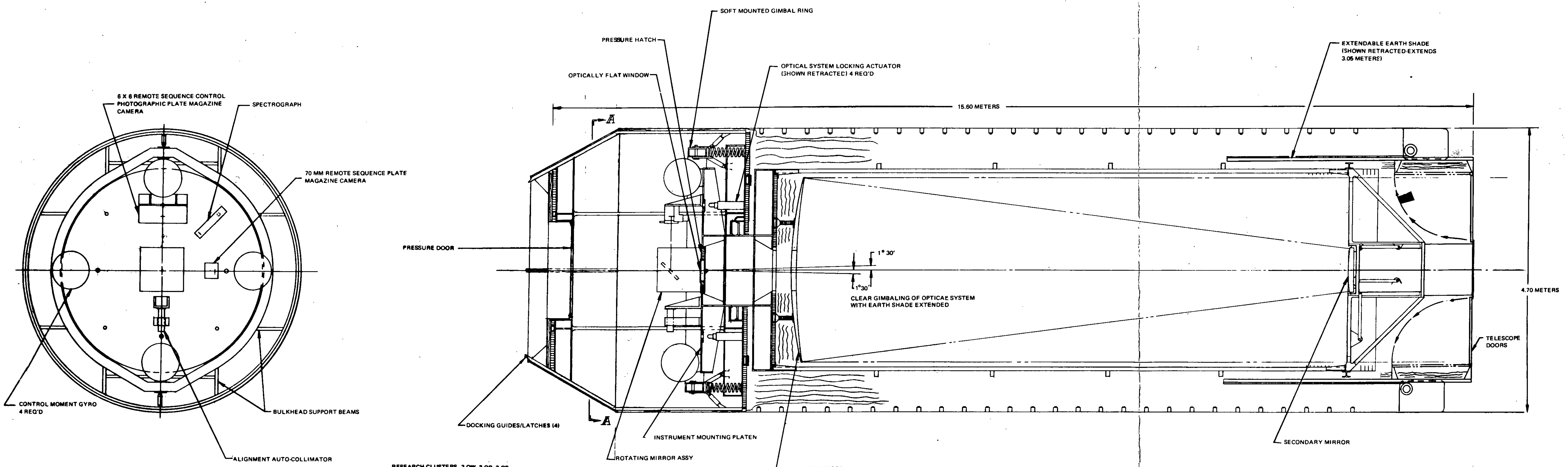
KWOT Configuration

OASF Instrument No. 41



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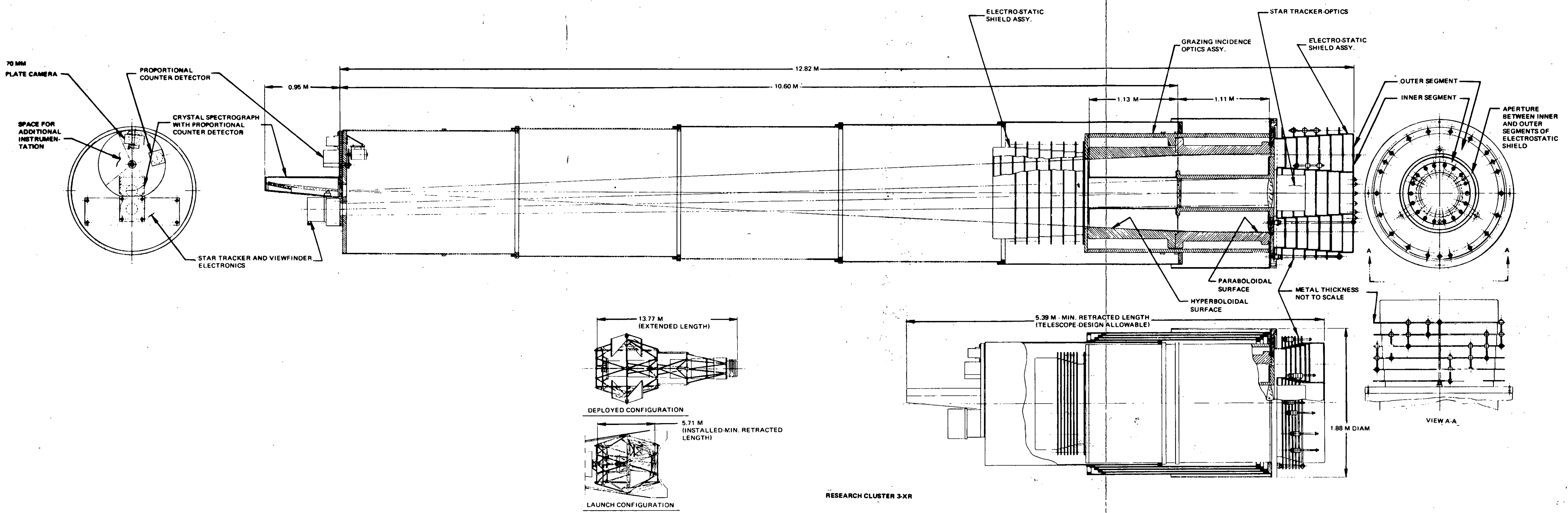

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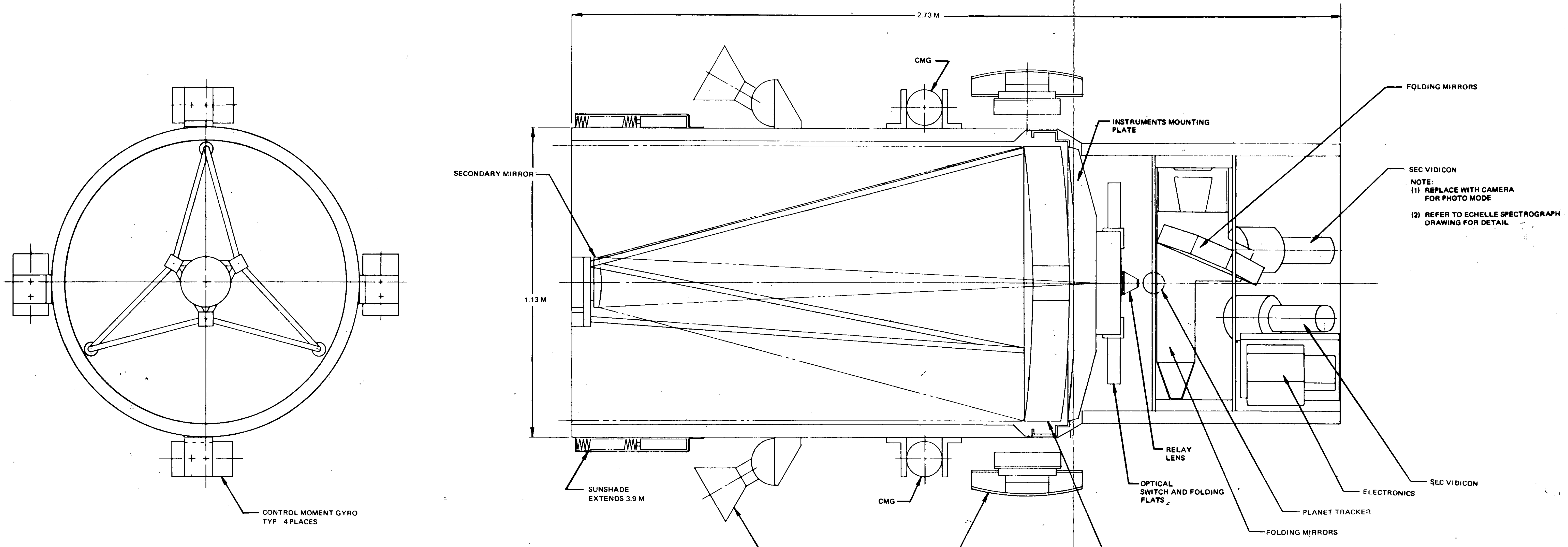

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1-Meter Diffraction-Limited UV-Visible-IR
Telescope, Stellar. OASF Instrument No. 34

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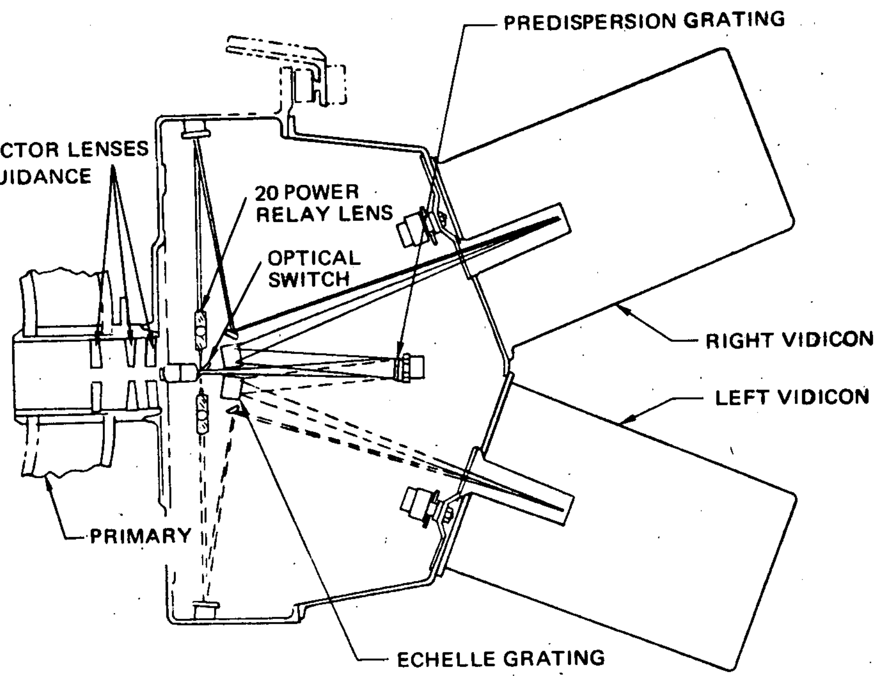

RESEARCH CLUSTERS 3-OS, 3-OW, 3-OB

Echelle Spectrograph and Photographic Optical Layouts

APPENDIX H

RELATED BIOTECHNOLOGY LABORATORY EXPERIMENTS

MANNED SPACEFLIGHT CAPABILITY

11-C

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INTRODUCTION

The experiments described in this appendix were prepared under NASA contract NAS1-9248 "Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions" and are referenced in Appendix C of this report. The results of that study are contained in NASA CR 111794 - 1 & 2.

The primary purpose of that study was the preparation of descriptions of the equipment and facilities requirements of the Biotechnology Laboratory in two manned Earth-orbiting laboratory facilities; one of limited capabilities, such as Skylab B; the other of expanded capabilities, such as the NASA Space Station.

In the above mentioned study, four specific steps were followed in defining the Biotechnology Laboratory requirements. (1) Information needs (research requirements) in each of four areas-Biomedicine, Man-Systems Integration, Space Biology, and Life Support and Protective Systems-were arranged in sequential order beginning with the successful accomplishment of the Skylab I research missions and proceeding through a Skylab II mission and the early years of Space Station operation. (2) Identification was made of the specific research activities or experiments by which these information needs could be met; and a sequence of research activities for both the Skylab II and Space Station missions was prepared. (3) Each of the research activities was then analyzed to identify the associated measurements, equipment, and support requirements. (4) The cumulative requirements of all of the research activities assigned to the Skylab II program and to the Space Station program were analyzed to determine the requirements for the Biotechnology Laboratory on each of these missions. In addition, supporting research and technology (SRT) requirements were derived from the requirements of the individual experiments and from the support requirements for the laboratories. These are summarized in Tables H-1 through H-5.

Many of the experiments prepared for the Biotechnology Laboratory Skylab B mission have been referenced in Appendix C of the present report in the discussions of the research requirements for Manned Spaceflight Capability and Space Biology. For the convenience of the reader, an extract from the descriptions of these experiments is provided in this appendix. Each extract includes a statement of the experiment objective and relevancy and an outline of the experiment routine. Further information concerning these experiments may be found in Volume II of the above mentioned Biotechnology Laboratory Requirements Study report.

BIOMEDICAL RESEARCH PROGRAM

EXPERIMENT DESCRIPTIONS FOR SKYLAB B

1-101	Time course of blood volume changes and the effect of exercise on the changes
1-102	Mechanisms of blood volume changes and the effects of LBNP conditioning
1-103	Time course of changes in orthostatic tolerance and the effect of exercise on the changes
1-104	Mechanisms of orthostatic tolerance changes
1-105	Changes in circulatory dynamics potentially associated with orthostatic tolerance changes
1-106	Changes in cardiac activity and the effects of exercise on these changes
1-107	Changes in pulmonary function
1-108	Changes in blood gas transportation
1-109	Changes in EEG patterns associated with sleep
1-110	EEG patterns associated with performance tasks involving attention and alertness
1-111	An investigation of vestibular effects indicated by the results of Skylab A experiments
1-112	See Note
1-113	A study of blood and urine for chemical changes and the effects of exercise on the changes
1-114	A study of urine ADH, urine aldosterone and renal blood flow in association with urine and blood volume changes
1-115	Time course of change in exercise tolerance and the effects of exercise on the changes
1-116	Mechanisms involved in changes in exercise tolerance
1-117	Time course of changes in muscle size and strength and the effects of exercise on the changes
1-118	The relationship of changes in muscle size and strength with changes in nitrogen balance
1-119	See Note

1-120 The time course of changes in bone density and the effects of exercise on the changes

1-121 The relationship of changes in the density of various bones with changes in calcium balance

1-122 Changes in blood cell morphology, the time course of the changes, and the effect of exercise on the changes

1-123 A study to determine the existence of changes in the clotting mechanisms

1-124 Establishment of an exercise conditioning regimen

1-125 Establishment of an LBNP conditioning regimen

1-126 See Note

1-127 See Note

1-128 The effectiveness of exercise conditioning in reversing physiological changes

1-129 A study of changes in microbial contamination of air and selected surfaces

1-130 A study of the histochemical changes in the primate

Note: Specific research activities originally identified with these numbers have been combined with others or deleted.

TITLE: 1-101 - Time course of blood volume changes and the effect of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the extent of cardiovascular adaptation to weightlessness

Experiment Objectives -

a. Determine the time course of blood volume changes.

b. Determine the maximum extent of the blood volume change.

c. Determine the progress of the change during the duration of the crew cycle.

d. Determine the effectiveness of exercise conditioning as a countermeasure.

Decreases in blood volume have been noted in ground-based simulation studies, post-flight measurements on Gemini crewmen, and in the primate biosatellite experiment.

Serious decreases in blood volume could adversely affect tissue oxygenation thereby degrading all levels of performance.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.1.2 Blood Volume
1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M113 (Blood volume and red cell life span). (Note: This experiment will detect the occurrence of a change with pre- and post-flight measurements, but will not show the trend or the maximum change if a reversal should occur during flight.)

Concurrent Experiments -

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

I-115 (Time course of change in exercise tolerance and the effects of exercise on the changes)

I-124 (Establishment of an exercise conditioning regimen)

Successor Experiments -

I-102 (Mechanisms of blood volume changes and the effects of LBNP conditioning)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Establish specific experimental details using the designated isotopes and activity schedule.

b. Develop radiation detection and associated electronics specific for detecting and distinguishing between P-32 and CR-51 radiations and I-125 radiations.

c. Establish pre-flight baselines on crew subjects.

d. Develop techniques for handling excreted isotopes in water reclamation systems.

Successor Research -

a. Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

Independent determination of RBC mass (volume) and plasma volume by means of radioisotopic tags is the most accurate method of blood volume determination. Plasma volume measurement by dye dilution and RBC volume measurement by hematocrit is a frequently used but less accurate method. The more accurate procedure is recommended for the program.

In order to determine the time coarse of the change, rather frequent measurements will be required during the early period of the flight. An isotopic tag which will disappear with sufficient rapidity from the plasma but which will have a sufficient half life for extended measurements will be required. P-32 as the RBC tag with a disappearance rate of 6 percent/hour and a half-life of two weeks, along with I-125 for the plasma appear to be likely candidates.

P-32 attaches itself to a sample of the subjects cells in vitro, with a short incubation, and is then reinjected into the subject; radio-iodinated albumin is commercially prepared.

Six subjects will be used, three unconditioned and three exercise conditioned. Blood samples will be taken from each subject, and the cells separated and incubated with the P-32. The cells are then washed, recombined with the plasma to which the radioiodinated albumin has been added, and injected into the subject. In a short time (approximately 10 min) a sample of blood is removed and simultaneously counted for P-32 and I-125 concentrations.

Measurements will be made once every three days for the first three weeks of flight.

Extended measurements are desirable; and for this purpose, the I-125 with a half-life of 56 days should be adequate; the half-life of P-32 will, however, be insufficient and CR-51 with a half-life of 26.5 days should be available as a red cell tag (used exactly as P-32) for later measurements. These will be made once every two weeks.

TITLE: 1-102 - Mechanisms of blood volume changes and the effects of LBNP conditioning

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective -

a. Determine the extent of cardiovascular adaptation to weightlessness.

b. Describe the qualitative and quantitative alterations evoked by space relative to biochemical effects.

Experiment Objectives -

a. Determine changes in total body water, urine volume, urine Na and pH.

b. Determine changes in RBC survival and RBC fragility.

c. Correlate changes in "a" with observed changes in plasma volume.

d. Correlate changes in "b" with observed changes in RBC volume.

e. Evaluate the effectiveness of an LBNP conditioning program as a countermeasure.

If changes occur in plasma volume in Experiment 1-101, it will be desirable to determine if they are accompanied by a net loss in total body water and to determine the role of urine volume and its controlling mechanisms in the loss. Similarly, it will be of interest to evaluate the role of possible changes in RBC survival time and fragility in any changes in RBC volume observed in Experiment 1-101.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.1.2 Blood Volume
1.1.1.1.5.4 Fluid Balance
1.1.1.2.5.4 Redistribution of Blood Volume

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M113 (Blood volume and red cell life span)

Skylab A Experiment M071/M073 (Bioassay of body fluids)

1-101 (Time course of blood volume changes and the effect of exercise on the changes)

Concurrent Experiments -

1-125 (Establishment of an LBNP conditioning regimen)

Successor Experiments -

1-114 (A study of urine ADH, urine aldosterone and renal blood flow in association with urine and blood volume changes)

1-206 (Changes in kidney function)

1-207 (Tests of urine concentration and dilution)

1-208 (Evaluation of fluid and electrolyte balance)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Prior to flight all of the methods suggested in this experiment must be examined and evaluated in reference to the water reclamation system of the spacecraft and other aspects of the closed life support system for potential recycling of the various isotopic tags among the crew. The suggested measurement frequency and tag quantities may be impractical in that situation and the subject's urine may have to be disposed of during the period of the experiment. In addition, baseline data must be taken on the crew subjects.

Successor Research -

Post-flight data on returned subjects.

2. <u>EXPERIMENT DESCRIPTION</u>

If changes in plasma volume and RBC volume are observed in Experiment 1-101, it will be desirable to investigate some physiological functions potentially associated with the changes.

Measurements of total body water; urine volume; urine Na, pH, specific gravity; and RBC fragility should elucidate some of the involved mechanisms. Measurements of plasma volume and RBC volume will also be made to ensure that the changes observed in Experiment 1-101 are being repeated in the present experiment.

The time history of changes in Experiment 1-101 will govern the measurement period in the present experiment; it is expected to coincide with the first three weeks of the crew cycle. During this period all measurements will be made twice weekly. Three unconditioned crewmen will be utilized as experimental subjects for these measurements.

The repetition of blood volume measurements will afford an excellent opportunity to compare the effectiveness of LBNP conditioning as a countermeasure with the previously investigated exercise conditioning. In addition, therefore, to the unconditioned subjects, three subjects involved in LBNP conditioning will be observed. Only measurements of plasma volume and RBC volume will be made on the conditioned subjects. During the first three weeks, the measurement schedule will be the same as that for the unconditioned subjects; in addition, subsequent measurements will be made once every three weeks for the duration of the crew cycle.

The techniques for plasma volume and RBC volume measurements will be identical to those described in Experiment 1-101. Total body water will be measured by the deuterium oxide method, with D_2O administered orally and subsequently measured in the urine with the mass spectrometer, urine volume measured directly, urine sodium by a Na^+ ion electrode, specific gravity by refractometry, urine pH by means of a pH meter, and RBC fragility by osmotic fragility.

Age-dependent erythrocyte destruction and mean red cell life span will be measured by the administration of C-14 glycine (injection into an arm vein) before flight. The C-14 glycine will be incorporated into the hemoglobin of developing erythrocytes. Sequential blood sampling during flight will then give the percentage of the label in the blood at a given time. By plotting these data a survival curve can be obtained. Blood samples involved in blood volume measurements will be used for this purpose.

Twenty-four-hour urine volumes will be collected and measured on all subjects. Aliquots will be removed and stored frozen at -70°C, (-20°C, if desired). The samples will be subsequently analyzed for specific gravity, Na, and pH. Samples will be taken daily for the first three weeks of the crew cycle.

Body mass will be derived from the measurements made during regular medical monitoring.

TITLE: I-103 - Time course of changes in orthostatic tolerance and the effect of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the extent of, and develop methods for assessing, cardiovascular adaptation to acceleration, weightlessness, and artificial subgravity states.

Experiment Objectives -

a. Determine the occurrence of changes in orthostatic tolerance.

b. Determine the time course of their occurrence.

c. Determine the maximum extent of the change.

d. Determine if and when the change reaches a plateau.

e. Determine the development of the change for the duration of the mission.

f. Determine the effects of exercise on the changes.

Blood pooling and orthostatic intolerance have been noted during tilt-table testing in ground simulations and post-flight studies on Mercury and Gemini astronauts and, to a lesser extent, in the Apollo crews.

Orthostatic intolerance indicates an inability of the circulatory reflexes to maintain adequate circulation in response to a gravitational stress. Such a deterioration could have serious consequences on return to earth after an extended mission, and may also be reflected in an inappropriate reading of the sympathetic nervous system.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.1.4 Compensatory Reflexes
1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiments M091 and M092 (LBNP)

Concurrent Experiments -

1-101 (Time course of blood volume changes and the effect of exercise on the changes)

1-115 (Time course of change in exercise tolerance and the effects of exercise on the changes)

1-124 (Establishment of an exercise conditioning regimen)

Successor Experiments -

1-104 (Mechanisms of orthostatic tolerance changes)

1-105 (Changes in circulatory dynamics potentially associated with orthostatic tolerance changes)

1-125 (Establishment of an LBNP conditioning regimen)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

The LBNP stress can result in vagovasal collapse; research should be performed to establish signs related to acceptable end points to reduce the risk of provocative testing. Pre-flight baselines should be established on the actual subjects.

Successor Research -

Follow-up studies on returned subjects.

2. EXPERIMENT DESCRIPTION

The experiment will utilize the lower body negative pressure (LBNP) device as a mechanism for blood pooling in the legs and lower abdomen, thereby simulating the gravitational hydrostatic effect. The cardiovascular compensatory reactions will be assessed by heart rate and blood pressure measurements.

Since exercise evokes similar cardiovascular compensatory reflexes, exercise conditioning is a potential countermeasure to this change. Three unconditioned and three exercise-conditioned subjects will be utilized for the experiment (two each if six are not available).

Frequent measurements will be made during the first two weeks during the period of maximum anticipated change. Measurements will then be made at a reduced rate for the crew cycle duration.

ECG leads and the blood pressure cuff (blood pressure assembly) will be applied to the subject. He will enter the LBNP device and remain at rest until his heart rate stabilizes. Resting heart rate and blood pressure are recorded. The pressure within the device is lowered in accordance with the rates and levels established for the specific subject before flight. Heart rate is measured and displayed continuously and recorded at 1-min intervals; blood pressure is measured and recorded at 1-min intervals throughout the stress (approx 15 min). Pressure is returned to normal and measurements are continued for 10 min. The experiment is terminated and subjective comments are solicited.

TITLE: 1-104 - Mechanisms of orthostatic tolerance changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine cardiovascular adaptation to weightlessness.

Experiment Objectives -

a. Determine changes in leg blood volume, cardiac output, and urine stress hormones in association with measurements of orthostatic tolerance.

b. Evaluate the role of the various parameters in orthostatic tolerance changes.

Observed reductions in orthostatic tolerance could be due to a greater tendency toward blood pooling, a reduction in cardiac output resulting from deficient compensatory reflexes, or a reduction in stress hormone secretion. The role of the various potential mechanisms in the change should be evaluated.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC-G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.1.4 Compensatory Reflexes
1.1.1.1.1.3 Circulatory Dynamics

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

Successor Experiments

1-105 (Changes in circulatory dynamics potentially associated with orthostatic tolerance changes)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Baseline data on crew subjects

b. Devise non-invasive technique for cardiac output

Successor Research -

Post-flight data on returned subjects. Possible analysis of returned urine samples for stress hormones.

2. EXPERIMENT DESCRIPTION

If a reduction in orthostatic tolerance is established, as anticipated, the physiological mechanisms associated with the changes would be of interest and will be studied on a subsequent crew.

The extent of blood pooling, and the potential reduction in cardiac output, as well as changes in the elaboration of stress hormones possibly play a role in orthostatic tolerance reduction.

These factors will be measured in three unconditioned subjects at rest, during LBNP stress, and during recovery.

The measurements will be made semi-weekly during the period of orthostatic tolerance change established during the previous experiment, probably the first three weeks of the crew cycle.

The subject will void immediately prior to the test and the urine discarded. ECG, blood pressure assembly, leg plethysmograph, and cardiac output sensors will be applied and the subject will enter the LBNP device. The electrocardiogram and heart rate will be sensed and displayed continuously for safety monitoring but recorded only at 1-min intervals. All other parameters will be measured and recorded at 1-min intervals throughout the LBNP schedule established before flight for the specific subject (approx 10-min pre-stress, 15-min stress and 10-min post-stress is estimated). Changes in cardiac output and blood pooling will be evaluated as potential mechanisms for reduction in tolerance to the LBNP stress.

TITLE: 1-105 - Changes in circulatory dynamics potentially associated with orthostatic tolerance changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective -

a. Determine the extent of cardiovascular adaptation to weightlessness

b. Define and develop predictive, diagnostic, and therapeutic procedures.

Experiment Objectives -

a. To measure pulse-wave contour, pulse-wave velocity and peripheral venous pressure in association with the lower body negative pressure stress.

b. To correlate changes in the above measurements with decrease in orthostatic tolerance.

In order to derive a better understanding of the effects of weightlessness on cardiovascular function as a whole, circulatory phenomena which may be involved in association with or secondary to changes in orthostatic tolerance should be examined. Potential diagnostic or therapeutic procedures may be suggested from the results.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.1.4 Compensatory Reflexes
1.1.1.1.1.3 Circulatory Dynamics

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

1-104 (Mechanisms of orthostatic tolerance changes)

Successor Experiments -

1-201 (Circulatory response to blood volume shifts produced by val salva maneuvers and occlusive limb cuffs)

1-202 (Changes in venous compliance and pressures during unstressed activities)

1-203 (Phenomena associated with cardiovascular changes)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects.

Successor Research -

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

Changes in heart rate, blood pressure, and leg blood volume are the normal criteria used to evaluate compensatory reactions to leg blood pooling in the orthostatic situation and to diagnose deterioration of the compensatory mechanisms. The measurement of additional parameters in association with orthostatic stimulation would be of value.

Three unconditioned subjects will be used for this experiment. Pulse-wave contour, pulse-wave velocity and peripheral venous pressure will be measured in association with LBNP stress with heart rate and blood pressure monitored as criteria of stress compensation. Measurements will be made twice weekly during the period of orthostatic tolerance changes established in Experiment 1-103, anticipated to extend over the first three weeks of the crew cycle.

Each subject will be tested singly. Two transcutaneous doppler flowmeters will be applied at a measured distance to selected sites over the brachial and radial arteries of an arm. The opposite arm will be equipped with a blood pressure assembly and a single set of ECG leads will be applied in the sternal configuration.

The subject will be placed in the LBNP device and measurements taken at 2-min intervals during a 10-min pre-stress period, at 1-min intervals during a 15-min stress period, and at 2-min intervals during a 10-min post-stress period.

TITLE: 1-106 - Changes in cardiac activity and the effects of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine cardiovascular adaptation to weightlessness.

Experiment Objectives -

a. Determine changes in the electrocardiogram, phonocardiogram, vectorcardiogram, ballistocardiogram and electro-mechanical delay.

b. Related observed changes to functional alterations of the cardiovascular system.

Although no changes have been observed in cardiac function in USA spaceflight, the Russians reported some alterations in their early flights ("A few problems of physiology of circulation during weightlessness," R.M. Bayevsky and O.G. Gazenko, USSR Academy of Sciences, Moscow). The significance of the changes is not well understood and further investigation of this very important function should be pursued in better-controlled experiments.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company.

1.1.1.1.1.1 Cardiac Activity
1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M093 (Vectorcardiogram)

Concurrent Experiments -

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

1-124 (Establishment of an exercise conditioning regimen'

Successor Experiments -

Animal studies on coronary blood flow. Diurnal variations in cardiac activities.

1.3 RELATED GROUND RESEARCH

Predecessor Research Development of Ballistocardiographic Technique Using a Six-Degree-of-Freedom Simulator -

Baseline on crew subjects.

Successor Research -

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

Some Russian reports ("A few problems of physiology of circulation during weightlessness," R.M. Bayevsky and O.G. Gazenko, USSR Academy of Sciences, Moscow) have indicated the occurrence of cardiac changes during spaceflight. Although no alterations have been noted in previous US flights, the function is of sufficient physiological importance to warrant investigation.

All measurements, with the exception of the ballistocardiogram, will be made weekly on three unconditioned crewmen and on three crewmen involved in exercise conditioning. Measurements will continue for the duration of the crew cycle.

A subject will be instrumented for vectorcardiographic and phonocardiographic measurements. Recordings from each of the 12 ECG leads will be made for approximately 30 sec each with the subject at rest. Phonocardiographic recordings will be made simultaneously with two ECG lead recordings. The records will be analyzed for electromechanical delay as well as for each recorded parameter.

Vectorcardiographic recordings will follow the above measurements utilizing the appropriate ECG leads.

The technique of weightless ballistocardiography needs to be investigated and the results correlated with cardiovascular function. It is anticipated that measurements will be made on two subjects once every two weeks during the crew cycle.

TITLE: 1-107 - Changes in pulmonary function

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the effects of space flight on respiratory physiological parameters.

Experiment Objectives -

a. Determine changes in pulmonary function.

b. Correlate changes with alterations in exercise tolerance.

Although no gross changes have been observed in pulmonary function in previous space flights, the potential exists for subtle but significant changes in flights of longer duration. This important function should, consequently, be investigated.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.2.1 Pulmonary Function

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

Successor Experiments -

1-108 (Changes in blood gas transportation)

1-204 (Changes in the distribution of inspired gases and lung diffusing capacities)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects.

Successor Research -

Postflight data on returned subjects.

Note: Baseline data should be collected under atmospheric conditions as similar as possible to those anticipated during flight.

2. EXPERIMENT DESCRIPTION

Changes in pulmonary function are not necessarily expected during spaceflight, but should be checked because of the importance of the function.

The experiment requires no predecessor experiments and, although it is suggested for the second crew cycle, it may be performed during any.

Three unconditioned subjects will be utilized. Measurements will be made weekly for the first four weeks and once every two weeks thereafter for the duration of the crew cycle.

All test and measurements included in this experiment can be performed with an accurate pulmonary flowmeter and an associated strip chart recorder and oscilloscopic display.

Vital capacity, timed vital capacity, inspiratory capability, expiratory reserve, tidal volume, minute (tidal) volume, maximum inspiratory and expiratory flows, and maximum breathing capacity will be measured on each subject. The procedures will be very similar to the standard methods used in terrestrial laboratories.

TITLE: 1-108 - Changes in blood gas transportation

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Describe the qualitative and quantitative alterations evoked by space flight relative to hematolic, immunologic and biochemical effects.

Experiment Objectives -

a. Determine alveolar gas concentrations.

b. Determine blood gas tensions.

c. Determine blood oxygen capacity and hemoglobin concentrations.

d. Determine lung diffusion capacity.

e. Analyze changes and correlate them with changes in exercise tolerance and RBC morphology.

Changes in blood gas transportation are not expected to be a primary change induced by weightlessness but may result secondarily from changes in blood volume and blood morphology.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.2.2 Gas Exchange and Transportation

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-107 (Changes in pulmonary function)

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

1-122 (Changes in blood cell morphology, the time course of the changes, and the effect of exercise on the changes)

Successor Experiments -

1-204 (Changes in the distribution of inspired gases and lung diffusing capacities)

1-215 (Response to hypoxia)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects

Successor Research -

Post-flight data on returned crewmen.

2. EXPERIMENT DESCRIPTION

Changes in blood volume and potential changes in blood cell morphology and pulmonary function could influence the oxygen and carbon dioxide content in the blood. The experiment is planned for conduct in the third experimental group and, consequently, blood volume and pulmonary function changes should have been established prior to performance of this experiment.

Three unconditioned subjects will be utilized. Alveolar O_2 and CO_2 will be determined by end-expired exhalation into the metabolic analyzer. Arterial blood samples will be obtained and analyzed for O_2 and CO_2 content, O_2 capacity, and pH. Hemoglobin concentration and mean corpuscular hemoglobin (derived from hemoglobin concentration and RBC count) may be performed on this sample or on a venous sample related to some other experiment (e.g., Experiment 1-105). Lung diffusing capacity will be performed by the carbon monoxide method utilizing a CO sensor (mass spectrometer). Body core temperature will be derived from the regular crew health measurements.

The measurements will be performed sequentially and need not be closely related in time. Measurements of a particular type will be performed on all subjects prior to measurements of another type rather than completing all measurements on a single subject proceeding to the next.

B

TITLE: 1-109 (2-117) - Changes in EEG patterns associated with sleep

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine and Man-Systems Integration

NASA Specific Objective -

a. Evaluate the effects of space flight on neurophysiological function including sleep and alertness.

b. Develop techniques for assessing the effects of stress and fatigue on the ability of the crew to perform their assigned tasks.

Experiment Objectives -

Determine whether changes occur in normal sleep patterns including:

a. Frequency and duration of the various sleep stages.

b. Subjective sensations of rest associated with sleep patterns.

c. Changes in performance after arousal from various stages of sleep.

Removal of the spacecraft from normal day-night cycles may affect sleep patterns which should be reflected in EEG records. With changes in sleep patterns the amount of rest gained from a sleep period and performance after arousal may be secondarily altered.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.3.3 Electroencephalographic Patterns
1.1.1.1.3.7 Integrative and Cognitive Processes

1.2 PREDECESSOR/CONCURRENT SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M133 (Sleep monitoring)

Concurrent Experiments -

2-113 (A study of blood and urine for chemical changes and the effects of exercise on the changes)

Successor Experiments -

1-110 (EEG patterns associated with performance tasks involving attention and alertness)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Determination in crew subjects of EEG patterns associated with defined sleep stages.

b. Correlation in crew subjects of the frequency and duration of determined EEG patterns with the degree of restfulness of the sleep period.

c. Measure and quantify in crew subjects the degradation in performance associated with arousal from the various sleep stages.

d. Determine the role of rapid eye movements (REM) in the definition of sleep stages and the degree of restfulness of the sleep period.

Successor Research -

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

This experiment is designed to investigate possible changes in normal sleep patterns during spaceflight. Evidence of changes will be derived from EEG records, EOG records of rapid eye movements, subjective sensations of rest, and alertness following arousal.

Twelve subjects will be used for the experiment, three from each crew cycle. They may be either conditioned or unconditioned insofar as there is no reason to anticipate effects associated with physical conditioning. For each crew cycle, the three subjects will be measured on separate days, twice weekly for the first three weeks, then weekly for the duration of the crew cycle.

During the test, the electroencephalogram of the sleeping subject will be recorded from occipital leads (one data channel; prior ground research may suggest additional leads) and the electro-oculogram will be recorded from sensors situated in the lateral and medial corners of the eye (a single data channel). The outputs of the EEG and EOG will be transmitted to a computer, programmed for the identification of sleep stages and rapid-eye-movement sleep. Typical stored data would consist of the identification of a pattern, registering the time of onset and the time of termination of the pattern, and 3 min of recording of the EEG and EOG during (1) each of the four stages of sleep, (2) REM sleep, and (3) consciousness.

Questionnaires designed to elicit subjective impressions of sleep characteristics such as restfulness, amount of dreaming, etc., will be presented daily to each member of the crew. Correlation between electrophysiological data and subjective sensation will be attempted.

On alternate tests nights for each subject (once/week/subject for the first three weeks and once every two weeks/subject thereafter for the crew-cycle duration). The subject will be awakened from either stage-four sleep (deep sleep) or rapid-eye-movement sleep (dreaming) and be presented with a CRT task to test his alertness, reaction time, and eye-hand coordination. EEG will be recorded during the test. The selection of stage-four sleep or REM sleep on a given night will be programmed prior to flight. The subject will be awakened by a personal alarm system triggered by the identification of the selected pattern by the computer.

All inflight data will be compared with pre-flight baselines to determine changes.

The experiment program will be repeated during the three subsequent crew cycles. Protocol changes will be made only when indicated by earlier findings.

TITLE: 1-110 - EEG patterns associated with performance tasks involving attention and alertness

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Investigate and evaluate the effects of space flight on neurophysiological function including equilibrium, coordination, sleep, alertness, biorhythms, visual, and other special senses.

Experiment Objectives -

a. To record EEG patterns during the performance of specified tasks.

b. To examine the records for changes in alpha blocking and associated phenomena.

c. To correlate the EEG changes with alterations in performance.

It has been suggested that weightlessness will reduce the totality of inputs to the sensory system potentially reducing the alerting capacity of the reticular activating system. The above experiment should yield information on this possibility.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Sutdy, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.3.3 Electroencephalographic Patterns
1.1.1.1.3.5 Motor Performance
1.1.1.1.3.7 Integrative and Cognitive Processes

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab B Experiment M133 (Sleep monitoring)

1-109 (Changes in EEG patterns associated with sleep)
2-117 (Sleep behavior)

Successor Experiments -

*1-223 (Changes in the electrical activity of higher centers in cats)

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*Animal Research

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Investigate the effects of confinement on EEG and alertness.

b. Baseline data on crew subjects.

Successor Research

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

A reduction of sensory inputs from the vestibular apparatus and possibly from touch receptors may alter the alpha-blocking activity of the reticular activating system. EEG patterns associated with vigilance and response tasks would be of interest.

Three unconditioned subjects will be utilized. The tasks will be performed in conjunction with performance studies.

Measurements will be made semi-weekly for the first three weeks of the crew cycle, and weekly thereafter for the cycle duration.

The subject will be seated at the test panel for the "Task Times and Errors" test. Five min of resting EEG will be taken with the subjects' eyes closed. An alarm will signal the commencement of the performance test. The test will continue for 15 min with continuous EEG recordings. A 5-min post-test EEG record will be taken.

A single occipital lead will be used for the EEG unless predecessor ground research demonstrates that additional leads are of value.

TITLE: 1-111 - An investigation of vestibular effects indicated by the results of Skylab A experiments

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Evaluate the effects of spaceflight on neurophysiological function including equilibrium and coordination.

Experiment Objectives -

Skylab A Experiment M131 appears to be rather complete in investigating changes in vestibular function on human subjects. Results of Experiment M131 will, however, undoubtedly suggest additional experiments of value to verify or further define observed changes. The present study is incorporated to allow such investigations.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.3.1 Vestibular Function
1.1.1.1.3.6.2 Autonomic Reflexes

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M131 (Human vestibular function)

Successor Experiments -

1-212 (Cardiovascular and vestibular effects of centrifugation)

1-224 (Changes in the electrical activity of the vestibular apparatus and related structures in cats)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects.

Successor Research -

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

Depending upon the results of Experiment M131, various aspects of vestibular function will be further investigated such as the effects of conditioning programs in preventing nausea, verification of results, etc.

Three crewmen will be utilized. Experiments may be conducted two times/week for the first four weeks of the crew cycle.

The experiment so placed in the fourth crew cycle to allow for experimentation during rotation if it occurs during the last 30 days of the fourth cycle.

TITLE: 1-113 - A study of the blood and urine for chemical changes and the effects of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective -

a. The assessment of renal and body fluid/electrolyte changes incident to space flight.

b. Describe the qualitative and quantitative alterations evoked by space flight relative to biochemical effects

Experiment Objectives -

a. Determine changes in urine volume, pH, Na, K, Cl, Ca, PO_4, and proteins

b. Determine blood changes in Na, K, Cl, Ca, PO_4 and proteins.

c. Determine the time course of the above changes

d. Determine the correlation between changes in orthostatic tolerance, blood volume, exercise tolerance, and bone density with the appropriate changes in the blood and urine.

e. Determine the effects of exercise conditioning on the changes.

Many of the changes investigated on other experiments are expected to produce concomitant electrolyte changes. This experiment will serve as a corollary to several others.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company.

1.1.1.1.7.4 Plasma Proteins
1.1.1.1.7.5 Serum Electrolytes
1.1.1.1.5.2 Urine

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiment -

Skylab A Experiment M071/M073 (Bioassay of body fluids)

Concurrent Experiments -

1-101 (Time course of blood volume changes and the effect of exercise on the changes)

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

1-120 (The time course of changes in bone density and the effects of exercise on the changes)

Successor Experiments -

1-208 (Evaluation of fluid and electrolyte balance)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects.

Successor Research -

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

The present experiment, while giving important information on fluid and electrolyte changes per se, is most important as a corollary to other experiments performed during the same crew cycle (Experiments 1-101, 1-103, 1-115, and 1-120). The phenomena investigated in these concurrent experiments will be better defined and more clearly understood if examined against a background of related changes in the blood and urine.

Once every three days for the first three weeks of the crew cycle, and weekly thereafter for the cycle duration, blood samples will be taken from all crew members. The samples, when convenient, may be taken in conjunction with the sampling activities of Experiment 1-101. On each day that the blood samples are taken the 24-hour urine volume of each crewman will be collected, measured, and an aliquot removed for analysis. All samples will be frozen at -70°C (urine at -20°C if desired) and stored. Samples will be analyzed onboard at the end of each fifth measurement period (30 blood and 30 urine samples). The number of samples in the final analysis period will depend upon the duration of the crew cycle.

TITLE: 1-114 - A study of urine ADH, urine aldosterone, and renal blood flow in association with urine and blood volume changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective -

a. The assessment of renal and fluid/electrolyte changes incident to space flight.

b. Define the effect of spaceflight on the endocrine system.

Experiment Objectives -

a. To investigate some of the mechanisms potentially responsible for changes in urine volume during weightless exposure.

b. To understand and thereby develop countermeasures to plasma volume reductions occurring during space flight.

If a relationship between blood volume changes and urine volume changes is established in earlier crew cycles (the relationship is anticipated from ground-based studies), further investigation should be made on the basis of the diuresis--a decreased secretion of antidiuretic hormone (ADH) from the pituitary, a decrease in aldosterone release from the adrenal cortex, or an increase in renal blood flow.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.5.1 Kidney Function
1.1.1.1.5.2 Urine
1.1.1.1.8.3 Hormone Control and Regulation

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-101 (Time course of blood volume changes and the effect of exercise on the changes)

1-113 (A study of blood and urine for chemical changes and the effects of exercise on the changes)

1-102 (Mechanisms of blood volume changes and the effects of LBNP conditioning)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects.

Successor Research -

Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

Reductions in plasma volume may result from a diuresis produced by an inhibition of the release of ADH and aldosterone by volume receptors stimulated by an initial increase in thoracic blood. Some investigators have suggested that changes in renal blood flow may play a role.

Three unconditioned subjects will be used for the experiment. The duration will be established in Experiments 1-101 and 1-102 and is not expected to exceed three weeks.

Twenty-four hour urine volumes will be measured daily for each subject. Two aliquots will be removed from each 24-hour sample; one will be frozen and returned for ADH and aldosterone analysis; the other will be stored (frozen at -20°C or lower) for weekly measurements of specific gravity, Na, and pH.

Renal blood flow will be measured once/week on each subject by paraaminohippuric acid (PAH) clearance. PAH is administered intravenously. A urine sample is voided immediately prior to administration and used as a blank. A second sample is voided at a given period of time following PAH injection. Simultaneous with this collection, a venous blood sample is taken. Both blood and urine are analyzed for PAH spectrophotometrically. The two urine samples may be discarded after analysis and not mixed with the 24-hour sample; however, their volumes should be added to the 24-hour total.

Body mass will be derived from measurements made in association with regular medical monitoring.

TITLE: 1-115 - The time course of change in exercise tolerance and the effects of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Assess the metabolic cost of physical activity at null and subgravity levels.

Experiment Objectives -

a. Determine the metabolic cost of a calibrated workload.

b. Evaluate the status of cardiorespiratory fitness during the exercise.

c. Compare exercise tolerance in unconditioned and exercise-conditioned subjects.

Post-flight reductions in exercise tolerance have been measured in Gemini astronauts. Also probable manifestations of tolerance reduction have been observed in association with EVA activities. Quantification of the anticipated changes and the evaluation of conditioning as a countermeasure will be of value in programming astronaut workloads and assessing their ability to react to spacecraft emergencies.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.6.2 Energy Metabolism
1.1.1.2.5.2 Exercise Conditioning
1.1.1.3.6 Exercise Tolerance

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M171 (Metabolic Activity)

Concurrent Experiments -

1-101 (Time course of blood volume changes and the effect of exercise on the changes)

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

1-117 (The time course of changes in muscle size and strength and the effects of exercise on the changes)

1-124 (Establishment of an exercise conditioning regimen)

Successor Experiments -

1-116 (Mechanisms involved in changes in exercise tolerance)

1-108 (Changes in blood gas transportation)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Baseline studies on experimental subjects.

Successor Research

a. Follow-up studies on returned subjects.

2. EXPERIMENT DESCRIPTION

Changes in exercise tolerance have been noted on previous spaceflights. The time course of these changes, the maximum extent of the changes, and the effects of an exercise conditioning program would be of interest.

Cardiovascular, metabolic, and respiratory parameters will be measured at rest, during work on a bicycle ergometer, and during recovery on three unconditioned and three conditioned subjects.

In order to avoid conditioning from the test itself, the frequency of measurement will be restricted to once/week/subject for the crew cycle duration.

The relationship among heart rate, oxygen consumption and work output is expected to be indicative of the fitness of the subject and to reflect any deterioration in exercise tolerance.

The ECG leads, ear canal temperature probe and mask associated with the metabolic analyzer will be applied to the subject. He will seat himself on the ergometer and rest until his heart rate stabilizes over the consecutive readings taken at 1-min intervals. Ten min of pre-exercise data, 15 min of exercise data, and 10 min of post-exercise data will be taken on each subject. Heart rate will be monitored and displayed continuously and recorded at 1-min intervals. All other parameters including ergometer work load during exercise will be measured and recorded at 1-min intervals. The workload will conform to levels established for each subject prior to flight.

TITLE: 1-116 - Mechanisms involved in changes in exercise tolerance

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Assess the metabolic cost of physical activity at null and subgravity levels.

Experiment Objectives -

a. Determine changes in cardiac output, maximal oxygen consumption, and oxygen debt in association with exercise tolerance tests.

b. Evaluate the role of the various factors in changes in exercise tolerance.

The role of aspects of cardiorespiratory fitness should be evaluated in order to understand more fully the bases of changes in exercise tolerance.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.6.2 Energy Metabolism
1.1.1.1.2.2 Gas Exchange and Transportation
1.1.1.3.6 Exercise Tolerance

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

Concurrent Experiments -

1-106 (Changes in cardiac activity and the effects of exercise on these changes)

1-107 (Changes in pulmonary function)

1-117 (The time course of changes in muscle size and strength and the effects of exercise on the changes)

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Successor Experiments -

1-108 (Changes in blood gas transportation)

1-210 (Changes in the accumulation of oxygen debt with calibrated exercise)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Non-invasive methods of cardiac output and central venous pressure measurements. Baseline data on crew subjects.

b. Exercise rates will be established based on each subject's anerobic threshold.

Successor Research -

a. Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

If a decrease in exercise tolerance is established as anticipated in Experiment 1-115, a greater understanding of the changes will be gained if some related phenomena are measured in a subsequent crew.

Cardiac output at rest and during exercise, maximal oxygen consumption, and the oxygen debts related to specified workloads will be measured on three unconditioned subjects on a schedule similar to that of the predecessor experiment. Exercise tolerance will be checked to ensure similarity of conditions in the experimental subjects.

Measurements will be made weekly for the first four weeks or until a plateau is reached in changes in exercise tolerance.

With the subject seated at rest on the bicycle ergometer, heart rate, cardiac output, oxygen consumption, and body core temperature will be measured simultaneously for 10 min.

The subject will then exercise for 15 min at a work rate previously established as that producing an oxygen consumption 700 ml/min above his anerobic threshold (classified as hard work). The resting measurements will be continued.

Following exercise, the measurements will continue through a 15-min recovery period.

Analysis will be based on the interrelationship of the various parameters.

Maximal oxygen consumption will be measured on the same schedule as the above measurements but on different day for the same subject. Maximal oxygen consumption will require the subject to exercise for 10 min at each work level commencing with that equivalent to the anerobic threshold and increasing in 25-w increments until oxygen consumption reaches a plateau.

TITLE: 1-117 - Time course of changes in muscle size and strength and the effects of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the extent to which the musculoskeletal system adapts to spaceflight and subgravity states.

Experiment Objectives -

a. Determine the time course of changes in muscle size.

b. Determine the time course of changes in muscle strength.

c. Compare the changes in unconditioned and conditioned subjects.

Muscle size and strength are normally maintained by repeated contractions produced both by voluntary actions and the myotatic reflex. Confinement within the spacecraft is likely to reduce normal activity, and weightlessness is likely to reduce the stimulus to the myotatic receptors. A reduction in the size and strength of muscles is a potential result. Exercise is a probable countermeasure.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.6.3 Muscle Size and Strength
1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiments M151 (Time and Motion Study) and M171 (Metabolic Activity)

1-120 (The time course of changes in bone density and the effects of exercise on the changes)

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

1-124 (Establishment of an exercise conditioning regimen)

Successor Experiments -

1-118 (The relationship of changes in muscle size and strength with changes in nitrogen balance)

1-226 (Changes in protein metabolism and muscle fatigue)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Develop dynamometers for onboard use on selected muscle groups.

b. Baseline data on crew subjects.

Successor Research -

a. Post-flight data on returned subjects

2. EXPERIMENT DESCRIPTION

Because of the reduced activity of a spacecraft crew and the reduced stimulation to the myotatic reflexes, a reduction in the size and strength of muscles, particularly the antigravity muscles, is anticipated in the unconditioned subject.

Muscle size and muscle strength (by dynamometry) will be measured on the arm, leg, and back in three unconditioned and three exercise-conditioned subjects.

Measurements will be made once every two days for the first three weeks and weekly thereafter for the duration of the crew cycle.

Muscle size will be measured as a function of the circumference of the following: upper arm, forearm, mid-thigh, mid-calf, chest (expanded and relaxed) and neck. Measurements will be made with a tape and manually recorded.

Muscle strength will be measured as a function of the amount of resistance that can be overcome in the following movements: hand flexion (grip), elbow flexion, elbow extension, knee extension, thigh flexion, and back extension. The resistance will be produced by specially constructed dynamometers. The maximal force will be registered on a gauge and manually recorded. The maximum force exerted in three attempts will be recorded.

TITLE: 1-118 - The relationship of changes in muscle size and strength with changes in nitrogen balance

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the extent to which the musculoskeletal system adapts to spaceflight.

Experiment Objectives -

a. Establish changes in nitrogen balance and the time course of the changes.

b. Relate changes in muscle size and strength to changes in nitrogen balance.

c. Investigate the relationship of the above changes to alterations in Serum Glutamic Oxaloacetic Transaminase (SGOT) and Serum Glutamic Pyruvic Transaminase (SGPT) levels.

Deteriorations occurring in muscle size and strength are potentially related to a negative nitrogen balance. The establishment of this relationship during spaceflight would contribute to a greater understanding of the nature of the changes. SGOT and SGPT levels are frequently elevated in pathological conditions involving tissue (muscle) degenerations; serum levels should be tested in the space situation for increased understanding and for a potential diagnostic variable.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.6.3 Muscle Size and Strength
1.1.1.1.6.1.3 Protein Metabolism

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

1-117 (The time course of changes in muscle size and strength and the effects of exercise on the changes)

Concurrent Experiments -

1-121 (The relationship of changes in the density of various bones with changes in calcium balance)

NOTE: (Concurrency based primarily on special diet and return of fecal samples.)

Successor Experiments -

1-226 Changes in protein metabolism and muscle fatigue

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Prior to flight, safety limits for muscle deconditioning should be established by means of a determination of the relationship between muscle size and strength and performance during bed-rest or water-immersion studies.

b. Baseline data on crew subjects.

Successor Research -

a. Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

If reductions in muscle size and strength are established as anticipated in Experiment 1-117, the relationship of muscle degradation to nitrogen balance and the serum levels of glutamic-oxaloacetic transaminase (SGOT) and glutamic-pyruvic transminase (SGPT) will be investigated. The chronological relationship between the various factors will be of interest.

Dietary nitrogen will be specified and incorporated into special meals packaged before flight. Each subject will be encouraged to consume his entire meal. If he cannot, the remainder will be labelled, frozen, and returned for analysis.

Twenty-four-hour urine volumes will be measured for each subject and an aliquot removed for analysis. The samples will be stored at -20°C or lower and returned for post-flight analysis for nitrogen.

The feces from each defecation will be weighed wet on the specimen mass measurement device, dried, labelled, and stored sealed at ambient temperatures for return for nitrogen analysis.

The above measurements and operations can most conveniently be performed in conjunction with Experiment 1-121 insofar as both require special meals, and fecal and urine analyses.

Venous blood samples will be taken from each subject - probably in conjunction with either Experiments 1-102, 1-105 or 1-108 - the serum extracted and analyzed for SGOT and SGPT. Samples will be stored refrigerated at -70°C and analyzed at the conclusion of the experiment.

Measurements of muscle size and strength as described in Experiment 1-117 will be repeated in the present experiment to ensure that the time history of the changes in this experiment were similar to the changes in the earlier experiment and to establish a definitive chronological relationship between muscle changes and nitrogen balance.

The duration of the measurement period will be established from the results of Experiment 1-117, it is expected to be approximately the first three weeks of the crew cycle. During this time, daily urine and fecal samples will be taken and the special diet consumed daily. Blood samples for SGOT and SGPT levels will be taken in conjunction with other experiments but at least twice weekly. Muscle size and strength measurements on selected muscles will be made every other day. Body mass measurements will be derived from those made in association with regular medical monitoring.

Three unconditioned crewmen will serve as experimental subjects.

TITLE: 1-120 - Time course of changes in bone density and the effects of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the extent to which the musculoskeletal system adapts to spaceflight and subgravity states.

Experiment Objectives -

a. Determine changes in density of selected bones.

b. Establish trends for the changes.

c. Compare density changes in unconditioned and exercise conditioned crewmen.

Bone density changes are among the most significant alterations observed in spaceflight and ground-based simulations. All experiments prior to Skylab B will have measured changes pre- and post-flight. A knowledge of the time course of the changes, the maximum extent of the changes, and the direction of change after an initial plateau is reached is necessary for an assessment of crew safety during reentry and return to a 1-g environment.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.6.4 Calcium and Phosphorus Metabolism
1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M072 (Bone densitometry)

Concurrent Experiments -

1-117 (The time course of changes in muscle size and strength and the effects of exercise on the changes)

1-124 (Establishment of an exercise conditioning regimen)

Successor Experiments -

1-167 (Relationship of bone density to Ca balance)

1-232 (Changes in healing of traumatic injuries in rats)

1.3 Related Ground Research

Predecessor Research -

a. Study to determine bones which are characteristic of changes in entire skeletal system.

b. Definition of safe endpoint for bone-density reduction.

c. Development of equipment and technique for onboard bone-density measurement.

d. Baseline data on crew subjects.

Successor Research -

a. Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

Bone-density changes have been observed in both ground simulation studies and post-flight measurements. They are thought to be related to a reduction of muscle tension on the bones. The time course and maximum extent of the changes and the effects of exercise on the changes is one of the most important studies that can be made in space.

Changes in bone density will be measured by X-ray densitometry or other acceptable methods. If feasible, measurements will be made every second day for the first two weeks, twice weekly for the following two weeks, and weekly for the duration of the crew cycle. Three unconditioned and three exercise-conditioned subjects will be utilized.

Each subject will have selected bones X-rayed following the X-ray of a calibration wedge. The film will be stored and returned for development and analysis.

TITLE: 1-121 - The relationship of changes in the density of various bones with changes in calcium balance

I. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Determine the extent to which the musculoskeletal system adapts to space flight and subgravity states.

Experiment Objectives -

a. Determine changes in calcium and phosphate balance.

b. Correlate the changes with changes in bone density.

Any reduction in bone density should be accompanied by an increase in either serum or urine calcium concentration, or both. An investigation of this relationship during spaceflight will increase our understanding of the change, relate the density changes in the measured bones to the total calcium loss, and permit the development of diagnostic procedures.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.6.4 Calcium and Phosphorus Metabolism
1.1.1.1.5.6 Body Fluid Electrolyte Content
1.1.1.1.5.2 Urine

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-120 (The time course of changes in bone density and the effects of exercise on the change)

Successor Experiments -

Dietary calcium experiments

Parathyroid hormone, calcitonin, or related hormone treatments.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Study to determine bones which are characteristic of calcium loss from skeletal system. Baseline studies on experimental subjects.

Successor Research -

Follow-up studies on returned subjects, Post-flight analyses of fecal Ca and PO_4 (returned samples) and bone X-ray films.

2. EXPERIMENT DESCRIPTION

If changes in bone density are established as anticipated in Experiment 1-120, the relationship of the changes to calcium loss in the urine will be investigated. If the phenomena are closely associated, urine calcium may then be used as a valuable diagnostic measurement.

Dietary calcium will be specified and monitored; fecal and urinary losses will be measured on daily samples for the first three weeks of the crew cycle, or for a period corresponding to the period of density change established during the predecessor experiment. Phosphate concentrations of the urine and fecal samples will be measured for additional information (fecal samples post-flight), as will serum concentrations of Ca, PO_4, and alkaline phosphatase.

Bone densities will be checked on a weekly basis and several bones will be monitored to determine which ones most closely reflect the measured calcium losses.

Three unconditioned crewmen will serve as subjects.

TITLE: 1-122 - Changes in blood cell morphology, the time course of the changes, and the effect of exercise on the changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Describe the alternations evoked by spaceflight relative to hematologic effects.

Experiment Objectives -

a. Determine changes in blood count including RBC count, WBC count, and differential

b. Compare the changes in unconditioned and exercise-conditioned subjects

Although no definitive changes have been observed in blood cell morphology following spaceflight some suggestions of slight abnormalities have been noted. Frequent counts during spaceflight should reveal any changes that may occur.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.7.1 Blood Element Morphology
1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M111 (Cytogenic studies of the blood)

Concurrent Experiments -

1-111 (An investigation of vestibular effects indicated by the results of Skylab A experiments)

1-124 (Establishment of an exercise conditioning regimen)

Successor Experiments -

1-108 (Changes in blood gas transportation)

1-102 (Mechanisms of blood volume changes and the effects of LBNP conditioning)

1-227 (Leukocyte dynamics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline data on crew subjects.

Successor Research -

Post-flight data on returned subjects.

Bone marrow studies on returned primates (Experiment 1-130).

2. EXPERIMENT DESCRIPTION

Although changes are not necessarily anticipated, complete blood counts including RBC, WBC, differential, and platelets will be performed on three unconditioned and three exercise-conditioned crewmen twice weekly for the first two weeks, and weekly thereafter for the duration of the crew cycle. Changes would be of great significance as well as serving as an indicator of the well-being of the crew.

Blood will be withdrawn from the antecubital vein of the subjects either for the present experiment alone or in association with either Experiments 1-101 or 1-113 when convenient. Five ml will be diluted and placed in the automatic counter. The remaining undiluted blood will be used as needed for slide preparation. The medical technician will monitor the count and prepare and stain the slides. The slides will be returned for analysis unless other data warrant immediate examination.

TITLE: 1-123 - A study to determine the existence of changes in the clotting mechanisms

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Describe the qualitative and quantitative alternations evoked by spaceflight relative to hematologic effects.

Experiment Objectives -

To measure and observe phenomena that will indicate whether or not changes have occurred in blood coagulation and hemostasis during prolonged exposure to weightlessness.

Although there is no direct hypothesis for blood clotting changes with weightlessness, the potential alterations in protein metabolism associated with muscle deterioration observed in bedrest studies and in some space flights could have an effect on the nature and distribution of plasma proteins including fibrinogen. It is felt that some preliminary measurements should be made of this important function.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.7.3 Clotting and Hemostasis

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-122 (Changes in blood cell morphology, the time course of the changes, and the effect of exercise on the changes)

Concurrent Experiments -

1-117 (The time course of changes in muscle size and strength effects of exercise on the changes)

Successor Experiments -

1-226 (Changes in protein metabolism and muscle fatigue)

1.3 RELATED GROUND RESEARCH

Processor Research -

Baseline data on crew subjects.

Successor Research -

Post-flight data on returned subjects including measurements of fibrinogen concentration, fibrinolytic activity, platelet adhesiveness, and plasma thromboplastein component if changes are observed during flight.

2. EXPERIMENT DESCRIPTION

All crewmen will be utilized as experimental subjects. Measurements will be made each 7 to 10 days throughout the crew cycle.

A skin puncture wound is made in the subject's finger or ear lobe and the blood drawn into several capillary tubes. The tubes are subsequently broken at 30-sec intervals and the time of appearance of fibrin strands noted. The wound is wiped with absorbent material (gauze pad) and the time of cessation of bleeding noted.

Approximately 5cc of blood are withdrawn from the antecubital vein of the subject and placed in a test tube. The blood is incubated for 1 hour at 37°C and visually examined for clot retraction.

The measurements should commence within the first week of the crew cycle.

TITLE: I-124 - Establishment of an exercise conditioning regimen

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objectives -

a. Provide countermeasures to assure maintenance of the physiological integrity of the musculoskeletal system.

b. Define and develop therapeutic procedures to maintain the health and well-being of the crew.

Experiment Objectives -

a. To prevent the occurrence of deleterious physiological changes due to prolonged exposure to weightlessness.

b. To determine the minimum amount of exercise capable to counteracting zero-g deconditioning.

Many of the compensatory mechanisms of the body associated with the maintenance of physiological homeostasis under the gravitational stress of 1g are the same as those that function during an exercise stress. It has been suggested that exercise may be substituted for gravity as a stimulus for the compensatory reflexes during weightless spaceflight to prevent physiological deconditioning.

Exercise programs during bed rest studies and early space missions have tended to corroborate this hypothesis in preliminary findings.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.2.5.2 Exercise Conditioning

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M171 (Metabolic activity)

Concurrent Experiments -

1-101 (Time course of blood volume changes and the effect of exercise on the changes)

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

1-106 (Changes in cardiac activity and the effects of exercise on these changes)

1-113 (A study of blood and urine for chemical changes and the effects of exercise on the changes)

1-115 (The time course of change in exercise tolerance and the effects of exercise on the changes)

1-117 (The time course of changes in muscle size and strength effects of exercise on the changes)

1-120 (The time course of changes in bone density and the effects of exercise on the changes)

1-122 (Changes in blood cell morphology, the time course of the changes, and the effect of exercise on the changes)

Successor Experiments -

1-128 (The effectiveness of exercise conditioning in reversing physiological changes)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

An exercise program involves the intensity of the exercise, and its duration and frequency. The most desirable program for a space station would be one that would accomplish its therapeutic goals while minimizing crew time and energy expenditure. A program should be developed prior to flight in association with confinement, bed-rest or water-immersion studies. In addition, pre-flight baselines should be established on the crew subjects associated with the concurrent flight experiments.

Successor Research -

Post-flight data should be collected on the returned subjects related to concurrent flight experiments.

2. EXPERIMENT DESCRIPTION

Three of the six crew subjects will participate in the exercise conditioning regimen.

An ergometer equipped with a hysteresis brake will be used so that the set workload will be independent of pedal speed. A workload will be determined for each subject before flight that will produce a steady-state heart rate of approximately 150 beats per minute.

Exercise for each participating subject will occur twice daily. Each exercise period will be of 15 min duration.

Heart rate will be measured by a cardiotachometric analysis of the electrocardiogram.

Note: The above-suggested exercise program may be modified in intensity, duration or frequency because of predecessor ground research.

An ergometer with a cardiotachometric controller could be utilized to maintain exercised heart rate at a preset level.

An ear lobe pulse sensor may be used to measure heart rate instead of the ECG.

TITLE: 1-125 - Establishment of an LBNP conditioning regimen

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective -

a. Provide appropriate corrective measures as indicated by an assessment of renal and fluid/electrolyte changes incident to spaceflight.

b. Define and develop therapeutic procedures to maintain the health and well-being of the crew.

Experiment Objectives -

a. To prevent the occurrence of deleterious physiological changes due to prolonged exposure to weightlessness.

b. To determine the duration and degree of lower body negative pressure required to counteract deconditioning.

Cardiovascular deconditioning and changes in fluid and electrolyte balance are potentially derived from the reduced requirement for the cardiovascular system to work against the hydrostatic pressures of the blood. By substituting artificial-pressure gradients in the vascular bed, the work of the cardiovascular system will be increased and deconditioning may be prevented.

This research activity is partially or wholly responsive to the information needs of the following critical issues which are identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.2.5.4 Redistribution of Blood Volume

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M092 (Inflight LBNP)

1-103 (Time course of changes in orthostatic tolerance and the effect of exercise on the changes)

1-104 (Mechanisms of orthostatic tolerance changes)

Concurrent Experiments -

1-102 (Mechanisms of blood volume changes and the effects of LBNP conditioning).

1-105 (Changes in circulatory dynamics potentially associated with orthostatic tolerance changes)

Successor Experiments -

1-214 (Establishment of a centrifuge conditioning regime)

1.3 RELATED GROUND RESEARCH

Precessor Research -

Similar to exercise conditioning, the most desirable LBNP program is one that would occupy as little of the crew time as possible. A program should be developed prior to flight in associated with bed-rest or water-immersion studies to define the duration of LBNP exposure, the extent of reduced pressure, and the frequency of exposure required to maintain cardiovascular conditioning. In addition, pre-flight baselines should be established on the crew subjects associated with the concurrent flight experiments.

Successor Research -

Post-flight data should be collected on the returned subjects related to concurrent flight experiments.

2. EXPERIMENT DESCRIPTION

Three of the six crew subjects will participate in the LBNP conditioning regimen.

The LBNP device will be used. The pressure (negative) setting will be determined for each subject. The duration and frequency of exposure will be established in predecessor ground research. It is assumed for purposes of this description that exposure will be for a duration of 15 min once per day each day of the crew cycle.

Heart rate will be measured by a cardiotachometric analysis of the ECG and blood pressure will be automatically measured at 2-min intervals. Heart rate and blood pressure will be monitored for safety purposes only and will neither be routinely recorded nor stored although both may be at the observer's discretion.

TITLE: 1-128 - The effectiveness of exercise conditioning in reversing physiological changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objectives -

a. Provide countermeasures to assure maintenance of the physiological integrity of the musculoskeletal system.

b. Define and develop therapeutic procedures to maintain the health and well-being of the crew.

Experiment Objectives -

a. To reverse the course of physiological deconditioning in subjects already exposed to weightlessness for an extended period.

b. To evaluate the capability of an exercise-conditioning program or produce this reversal.

In order to evaluate the physiological effects of weightlessness as an independent variable, subjects unassociated with any conditioning program will be required. It will be subsequently desirable to reverse undesirable physiological changes while the crewmen are still in flight. Exercise conditioning is a potential candidate for a reconditioning program.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1. 1. 1. 2. 5. 2 Exercise Conditioning
1. 1. 1. 2. 5. 7 Reversal of Change

1.2 PREDECESSOR/CONDURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

1-124 (Establishment of an exercise conditioning regimen)

Predecessor and Concurrent Experiments -

(The subject changes will be followed prior to and during the exercise conditioning program)

1-104 (Mechanisms of orthostatic tolerance changes)

1-106 (Changes in cardiac activity and the effects of exercise on these changes)

1-107 (Changes in pulmonary function)

1-116 (Mechanisms involved in changes in exercise tolerance)

1-117 (The time course of changes in muscle size and strength and the effects of exercise on the changes)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Physiological danger points should be established for all anticipated changes.

Establishment of an exercise-conditioning program as described in Experiment 1-124.

Preflight baselines on the crew subjects as described in Experiment 1-124.

Successor Research -

Post-flight data should be collected on the returned subjects related to concurrent flight experiment.

2. EXPERIMENT DESCRIPTION

The second crew cycle will commence with three subjects involved in an exercise conditioning program and three subjects unconditioned.

Measurements on physiological changes will proceed as described in the various experiments selected for the second crew cycle until the changes reach a plateau. At this time, or at least 30 days prior to return if changes are still continuing, the three unconditioned subjects will commence the exercise conditioning program identical to that described in Fxperiment 1-124.

The physiological measurements associated with the other experiments will continue.

TITLE: 1-129 - A study of changes in microbial contamination of air and selected surfaces

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective - Identify and control the potential microbial problems of man in spacecraft.

Experiment Objectives

a. Determine the occurrence of changes in the types of microorganisms consistently found to be contaminants of Skylab air and surfaces.

b. Determine whether or not pathogenic or potentially pathogenic species become the predominant contaminants.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.2.2 Microbial Infections

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

None.

1.3 Related Ground Research

Predecessor Research -

a. MDAC's 90-day Space Station Simulation test in progress at this writing.

2. EXPERIMENT DESCRIPTION

Weekly air samples will be taken with a Reynier Air Sampler or equivalent, and Rodac plates will be used weekly to sample selected surfaces throughout the Skylab. The agar plates (Reynier and Rodac) will be incubated 48 hours at 37°C, the colonies counted, and morphologically different colonies picked and streaked in nutrient agar plates for isolation. After 24 hours incubation at 37°C the isolated colonies will be picked, sample grams stained, and samples transferred to nutrient broth as well as appropriate differential and/or selective media. Appropriate biochemical tests will be utilized to identify the microorganisms to genus and species.

TITLE: 1-130 - A study of the histochemical changes in the primate

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Biomedicine

NASA Specific Objective -

a. Describe the qualitative and quantitative alterations evoked by spaceflight relative to hematologic, immunologic, and biochemical effects.

b. Define and develop predictive, diagnostic, and therapeutic procedures.

Experiment Objectives -

a. Determine the effects of weightless spaceflight on primates in a minimal stress situation to evaluate their usefulness as subjects in space experiments.

b. Evaluate behavioral changes during flight as a function of normal activities.

c. Assess the inflight status of the subjects by: appearance, body temperature, and heart, and respiratory rate.

d. Return the animals for extensive post-flight histochemical and histopathological evaluation.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.1.1.1 Cardiac Activity
1.1.1.1.3.1 Vestibular Function
1.1.1.1.6.4 Calcium and Phosphorus Metabolism
1.1.1.1.6.2 Energy Metabolism
1.1.2.4 Diagnostic Signs

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiment -

Biosatellite III Primate Experiment

Concurrent Experiment -

3-135 (Physiological studies on instrumented primates)

Successor Experiments -

*1-219 (Relationship of cardiac output to regional blood flow in primates)

*1-220 (Cardiovascular reflex activity in primates)

*1-221 (Cardiac work capacity against an induced arterial, back pressure in dogs)

*1-223 (Changes in the electrical activity of higher centers in cats)

1-224 (Changes in the electrical activity of the vestibular apparatus and related structures in cats)

3-218 (Behavioral studies with primates in zero gravity)

3-235 (Extended physiological studies on instrumented primates in space)

1.3. RELATED GROUND RESEARCH

Predecessor Research -

Development and tests of the following subsystems:

a. Cage and retrieval

b. Waste management

c. Environmental control

d. Metabolic support

e. Behavioral task

f. Primate monitoring

Development of ECG and temperature sensors that will withstand long-duration implantation and not compromise the physiological integrity of the subjects.

Conduct autocontrol baselines including preflight biopsies on the actual primate subjects and a year-long ground-simulation experiment prior to flight.

Concurrent Research -

Run a group of ground-control subjects matched to the space primates concurrent with the space experiment. The ground controls would be subjected to simulated launch and re-entry

*Animal research

acceleration profiles and all other environmental conditions of the spaceflight subjects which can be practicably simulated.

Successor Research -

a. Immediate sacrifice and extensive histopathological and histochemical examination of one of the returned subjects.

b. Long-term observation and tests of the second returned primate.

c. Eventual sacrifice and histopathological and histochemical examination of the second returned primate.

2. EXPERIMENT DESCRIPTION

Two laboratory-bred Macaca mulatta (rhesus monkeys) will be subjected to weightless spaceflight for a period of about 200 to 300 days. They will be unrestrained and minimally instrumented with only implanted temperature and ECG sensors. They will be maintained in a gaseous atmosphere with typical sea level conditions. Social stimulation between the monkeys during the test will be provided by a "social window" between the two individual enclosures.

Inflight measurements will include television monitoring for the assessment of general appearance, movement and activity patterns, and specific induced responses. Implanted temperature and ECG sensors will allow continuous monitoring of body temperature, heart rate, respiratory rate, and level of activity from changes in transmitter signal strength. Inflight behavioral assessment will involve analysis of involuntary, voluntary, and conditioned behaviors and will include tasks for earning food and water, responses to auditory stimuli, and patterns and periodicity of normal activities.

Following the desired period of the flight the animals will be enclosed in a recovery canister for return to earth. Upon return one animal will be immediately sacrificed and subjected to extensive histochemical and histopathological examination; the other will be maintained in a ground simulator to follow recovery and long-term effects. The second primate will eventually be sacrificed and studied in comparison to the first.

Controls will involve extended baseline studies and preflight tissue biopsies on the actual subjects as well as a concurrent ground simulation control with the subjects duplicating all stresses of the flight pair other than weightlessness. The findings of the examinations of the flight subjects and ground controls will be made in an effort to isolate the effects of weightlessness.

MAN-SYSTEMS INTEGRATION RESEARCH PROGRAM

EXPERIMENT DESCRIPTION FOR SKYLAB B

2-101	Visual capabilities in weightlessness and partial gravity
2-102	Orientation capabilities in weightlessness and partial gravity
2-103	Behavioral effects of the acoustic environment
2-104	Effects of space flight on crew structure and group behavior
2-105	See Note
2-106	See Note
2-107	Skill retention in extended space flight
2-108	Off-duty activities and facilities
2-109	See Note
2-110	Evaluation of locomotion aids and techniques
2-111	Advanced controls and displays
2-112	Advanced personal hygiene concepts
2-113	Assessment of circadian rhythm changes
2-114	Maintenance activities and tool evaluation
2-115	Evaluation of man-remote manipulator interface
2-116	Reconfigurable interior configurations and decor
2-117	Sleep behavior

Note: Specific research activities orginally identified with these numbers have been deleted.

TITLE: 2-101-Visual capabilities in weightlessness and partial gravity

I. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Quantify human capabilities for performing physical and mental work as an operator and maintainer of space systems and equipment and as a scientific investigator, and to provide data for decisions on the appropriate man/machine mix.

b. Investigate and evaluate the effects of spaceflight on neuro-physiological functions, including visual senses.

Experiment Objectives -

Determine changes in visual capabilities:

a. With extensions of stay in zero gravity.

b. With introduction of partial gravity,

and correlate these changes in visual capabilities with changes in physiological and environmental conditions.

Experiments on earth have shown changes in visual performance when physiological deconditioning environmental degradations such as reduced atmospheric pressures and oxygen, or increases in atmospheric contaminants, vibrations, or accelerations are introduced. An investigation of this relationship during spaceflight will increase our understanding of changes, relate the changes to physiological or environmental parameters so steps can be introduced to control these changes, and help direct our introduction of solutions at the appropriate man-machine interfaces.

This research activity is partially or wholly reponsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.1.1.1.3 Visual

E

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Informal astronaut observations, e.g., Lovell's complaint that he could not see in earthshine during lunar orbit, and Armstrong's complaint of vision difficulties when in the shadow of the lunar module.

Skylab Experiments -

M-055 (Time and Motion Studies)
M-051 (Cardiovascular Function)
1-128 (The effectiveness of exercise conditioning in reversing physiological changes)
1-106 (Changes in cardiac activity and the effects of exercise on these changes)
1-110 (EEG patterns associated with performance tasks involving attention and alertness)

Experiment M-055 (Time and motion studies) will measure the astronauts' performance on tasks imposing demands on visual capabilities. Experiments M-051, 1-106, 1-110, and 1-128 will include measurements of the astronauts' physiological and psychological condition. Changes in these conditions then will be correlated with Time and Motion task performances to better understand causes of performance variations and identify possible controlling or remedial actions.

Successor Experiments -

2-206 (Visual capabilities in experiment support)
2-105 (Evaluation of design for preventing behavioral degradation)
1-214 (Establishment of a centrifuge conditioning program)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline studies to obtain parametric vision reference data on each subject before he is exposed to mission stresses.

Successor Research -

Follow-up studies on returned subjects to determine recovery and rates.

2. EXPERIMENT DESCRIPTION

This experiment requires frequent measurement of all Visual Test Battery (see Table 1) parameters during the first two weeks which should be the period of maximum change; then measurements approximately every 20 days for the duration of the crew cycle. The schedule will be repeated for each artificial-g level introduced. Measurements can be obtained with a self-test technique and will require only the time of the experimental subject. Each subject will be seated at a console and shielded from extraneous light and distractions either by conducting the test in a light-controlled compartment or by using a hood with the test apparatus.

Table 1

VISUAL TEST BATTERY

Vision Parameter	Description	Units in Which Measured (IMBLMS specified)
Part I		
Acuity	The smallest space the eye can see between parts of a target, target at various distances and levels of illumination. Low levels of background illumination increase test sensitivity for detecting subject's changes in acuity.	Millimeters to better than one decimal point
Field	Size of arc through which moving objects can be detected	Ninety degrees peripherally in all 12 principal meridians
Phorias	Horizontal and vertical deviations from center of fixation for both far and near vision	Degrees from center of fixation
Critical Flicker Fusion Frequency	Frequency at which pulsed light appears to be of constant intensity	Neighborhood of 40 cps
Depth Perception	Discrete identification of objects judged to be equidistant at various distances and levels of illumination	Percent distance traveled
Color Perception	Perception of each of full range of colors, red through yellow	Hues
Accommodation	Visual acuity for distance after fixating near object	Diopter
Visual Illusions	Data gathered opportunistically in verbal form on questionnaire as experiences occur during mission.	
Part II		
Dark Adaption	Time to adapt to darkened conditions and level of brightness required to detect a light	Millilamberts and minutes of time
Brightness Threshold	Smallest unit of light of given frequency that can be seen under darkened conditions	Micromicrolamberts or 10^{-9} millilamberts
Glare Recovery	Time to recover from exposure to glare and see a light of given brightness	Seconds of time and millilamberts (10^{-1} and 10^{3})
Complex Pattern Recognition	Minimum presentation time for recognition as same or different	Seconds required to correctly recognize patterns
Visual Illusions	Data gathered opportunistically in verbal form on questionnaire as experiences occur during mission.	

TITLE: 2-102 - Orientation capabilities in weightlessness and partial gravity

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Quantify human capabilities for performing physical and mental work as an operator and maintainer of space systems and equipment and as a scientific investigator and to provide data for decisions on the appropriate man/machine mix.

b. Investigate and evaluate the effects of spaceflight on neurophysiological function including equilibrium, coordination, and other special senses.

Experiment Objective -

a. Determine man's ability to detect motion in zero and artificial g as compared to that of earth.

b. Determine man's ability to sense his limb positions and movements in zero and artificial g as compared to that of earth.

c. Determine illusions relating to orientation that are experienced during long-duration spaceflight.

Previous Research

Illusions of spinning and motion sickness have been experienced in zero g. Individual differences also have been observed, e.g., non-test pilot cosmonauts have been more susceptible to illusions and motion sickness than astronaut test pilots. Informal astronaut and cosmonaut reports of nausea, motion sickness, and sensations of spinning resulted in extensive pre- and post-flight testing of the orientation capabilities of Gemini, Apollo, Vostak, and Voskhod flight personnel plus analytic and experimental studies using animals and man to better understand, and be able to control, the phenomenon.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.1.1.1.4 Orientation

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M-131 (Human vestibular function)

Successor Experiments -

1-214 (Establishment of a centrifuge conditioning regimen)
2-105 (Evaluation of design for preventing behavioral degradation)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline studies to obtain benchmark data on each subject's ability to detect motion, limb position and movement, body position and movement, and target position and movement in 1-g prior to launch and before he is exposed to mission stresses.

Successor Research -

Follow-up studies on returned subjects to determine recovery and rates of recovery.

2. <u>EXPERIMENT DESCRIPTION</u>

This experiment requires administration of the Orientation Test Battery to each crewman three times during the mission, with an approximate 30-day interval between testing periods. Measurements will require both the time of an experiment subject and an observer. Parameters measured and devices employed are listed in Table 1. A litter chair, a framed device for restraining the astronaut, provides controlled accelerations up to 30 RPM to stimulate the subject. It is used in a rotating mode to test his ability to detect angular acceleration and foreign presence of the occulógyral illusion, and in a tilt mode to test his ability to sense body position. Another device, the limb board, is a motor-driven plank which supports and tilts the arm or leg when testing the astronaut's ability to perceive limb position and movement. Otolith test goggles provide a visual target for the occulogyral illusion and when testing the ability to sense body position using outside references (eyes open). When testing the ability to sense body position with eyes closed, subject reports his perceptions by moving a magnetic pointer about a reference sphere held on the back of his left hand. In all of these tests the subject expresses his judgments and the observer records them. The experimenter initiates the test, and the subject responds to a pre-established set of questions, providing description of his perceptions for the observer to record at the end of each trial. When a parameter test requires it, the subject is provided with blindfold and earplugs to insulate him from outside sensory cues of changes that are introduced, and restrained for provision of controlled rate and direction in change of position. There will be replication (five trials) on each parameter during each test battery administration.

Alternate Approach

An elaborate, multiple-purpose device which could be used to obtain more diverse and detailed measurements of orientation capabilities is the onboard centrifuge. Another approach which is less controllable and less manipulatible is a spinup of the entire station. When this station spinup has been introduced, a complete administration of the test battery will take place.

Table 1

PARAMETERS AND MEASUREMENTS

Parameter	Devices	Description	Measurement
Angular Acceleration	Litter Chair (Rotating Mode)	Subject is blindfolded and secured in litter. He announces start of rotation as soon as he detects it. The observer records time of detection or degrees the litter has moved.	Time from onset of rotation to detection of motion.
Oculogyral Illusion	Litter Chair (Rotating Mode) Biteboard Otolith Test Goggles	Subject wearing goggles and headset, secured biteboard on litter. Closes eyes. Litter rotation started. Automatic stop. Observer signals subject to open eyes and report apparent target motion/non and right/left direction.	Apparent movement of visual target in direction and amount.
Sensing Body Position	Litter Chair (Tilt Mode) Reference Sphere Otolith Test Goggles Biteboard	Subject wearing goggles and headset, secured biteboard, closed eyes. Chair positioned by observer. Subject opens eyes. Sets pitch and roll, signalling the observer to record. Repeat test but keep eyes closed at all times, reporting position by setting magnetic pointer with right hand onto reference sphere held by magnetic strap worn on left hand. Observer records.	Direction and amount in degrees of apparent body tilt.
Sensing Limb Position	Limb Board	Subject is blindfolded. Oberver places subject's arm or leg and asks for a report of its position, which he then records.	Difference between subject's report and actual limb position in direction and amount.
Sensing Limb Movement	Limb Board	Subject is blindfolded, with forearm lightly strapped on a support that is moveable about a ball joint under the elbow. He reports movement when detected, and observer records time.	Time from onset of to its detection and direction of change.
Motion Sickness		Recording of dizziness or nausea in crew log whenever it occurs during mission. Unstructured, opportunistic observations.	

TITLE: 2-103 - Behavioral effects of the acoustic environment

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Quantify human capabilities for performing physical and mental work as an operator and maintainer of space systems and equipment and as a scientific investigator and to provide data for decisions on the appropriate man/machine mix.

b. Understand man's reaction to noise so that noise-reduction efforts can be most effective.

Experiment Objectives -

Determine the behavioral effects of the acoustic environment with extensions of stay in zero g, and correlate these changes in auditory capabilities with changes in physiological and environmental conditions.

Experience in space cabin simulators has provided data showing significant hearing loss when subjects are exposed to excessive ambient noise levels continuously for 60 days. Conversely, experience has shown that absence of noise may lead to hypersensitivity and reduction in tolerance levels as noise is introduced. Reduction in auditory capabilities at the higher frequencies has been shown as the result of changes in environmental conditions such as a shortage of oxygen. An investigation of these relationships during spaceflight will increase our understanding of changes, relate the changes to physiological or environmental parameters so steps can be taken to control these changes, and help direct our introduction of solutions or resolutions at the appropriate man-machine interfaces.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.1.1.1.1 Auditory

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M487 (Habitability/crew quarters)

Successor Experiments -

2-205 (Habitability for large crews)
2-105 (Specific research activities originally identified with these numbers have been deleted)
2-111 (Advanced controls and displays)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Baseline studies to obtain Acoustic Test Battery reference data on each subject before he is exposed to mission stresses.

Successor Research -

Follow-up studies on returned subjects to determine recovery and rates.

2. EXPERIMENT DESCRIPTION

For each of the crew cycles, this experiment requires frequent measurement of auditory parameters and acoustic background during the first two weeks of the mission during which significant change or adaptation to the acoustic environment might occur, then measurements approximately every 20 days for the duration of the cycle. All measurements may be obtained with a self-test technique and require only the time of experimental subjects. Each subject will be tested in an area shielded from unusual noises, movement, and other distractions.

TITLE: 2-104 - Effects of space flight on crew structure and group behavior

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. To identify individual characteristics and group structures which are predictive of successful adaptation to the conditions of extended-duration spaceflight.

b. To develop methods and design criteria to produce habitable living areas in space vehicles (design for privacy).

Experiment Objectives -

a. To determine if crew productivity changes as a function of mission duration, crew composition, and crew mood.

b. To identify changes in interpersonal relationships as a function of mission duration.

c. To identify design characteristics which are conducive or detrimental to crew productivity and stable interpersonal relationships.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company.

1.1.2.1.3 Group Structure Dynamics

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M-151 (Time and motion study)
Skylab Experiment M-487 (Habitability/crew quarters)

Concurrent Experiments -

2-103 (Behavioral effects of the acoustic environment)
2-113 (Assessment of circadian rhythm changes)
1-110 (EEG patterns associated with performance tasks involving attention and alertness)

Biomedical Experiments collecting data on general crew physical condition (e.g., Heart Rate O_2 Consumption, Muscle Strength)

Successor Experiments -

Continuation of Experiment 2-104 into Space Station for expanded studies on larger size crews

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Ground-based space cabin confinement studies (e.g., Tektite, McDonnell Douglas 90-day test, Gulfstream)

b. Collection of baseline data on crews scheduled for the Skylab B missions.

Successor Research -

Post-flight analysis of data collected inflight.

2. EXPERIMENT DESCRIPTION

Small group research, the anecdotal literature on isolated groups, and the results of ground simulation research on confinement and isolation all lead to the conclusion that the effects of the individual and combined stresses of extended spaceflight on flight crews may be deleterious in terms of individual and group productivity and breakdown of interpersonal relationships and that design improvements in the habitable environment may be used to prevent or ameliorate such effects. Empirical data are needed from repeated precise measurements of the group activities of crews of different sizes and compositions, for missions of varying length and type. Types of measurements are presented below.

This experiment, to be conducted through crew cycle number one of Skylab B and repeated on each of the three subsequent crew cycles, is the first step in a long-range investigation of this problem area.

Two types of crew behavior will be observed in the conduct of this experiment: Crew performance of scheduled tasks and activity of crew members while engaging in group pursuits. Each of these is described below:

a. Performance of Scheduled Tasks: Measurement of effectiveness in performing selected tasks will provide data on crew productivity as influenced by length of mission, crew composition, and crew mood. Three tasks will be selected based on the criteria that (1) they are repetitive and thus can be measured at least three times during a 90-day cycle; (2) they require approximately 30 min to perform; and (3) they require cooperative effort of two or more crew members. Task time and error will be measured by direct observation of task performance using TV cameras and video tape playback on the ground. Corrollary data on crew composition will be obtained prior to flight through administration of a battery of personality tests (e.g., Biographical Inventories, FIRO-B, Edwards Personal Preference Schedule, MMPI) and on crew mood through periodic administration in flight of mood measurement tests such as Primary Affect Scales, Subjective Stress Scales, Anxiety Inventories, Isolation Symptomatology Questionnaires, Mood Adjective Check Lists. Design data will be collected by identifying design features which appear to facilitate or degrade task performance through careful analysis of the videotape recordings and by analysis of the subjective comments of crewmen subjects.

b. Group Activity: Periodic observations of normal crew activities over the length of each crew cycle will be conducted using TV cameras and microphones to obtain physical and verbal interaction data. Physical interaction data of interest include physical location of each crewman relative to other crewmen, pattern of movements of crewmen from one location to another, and specific activities being performed by each crewman. Verbal interaction data of interest include amount of communication between each combination of crewmen pairs and content of verbal communication classified in a manner similar to the Bales Interaction Categories. Four-hour measurement sessions (separated by 10 to 20 days) will be scheduled to take advantage of opportunities for maximum crew interaction.

Experimental data will be stored onboard on videotape and in the computer storage and transmitted to the ground either by telemetry or by logistics resupply at the end of the crew cycle. Analysis of the data will be done on the ground. The only requirement for onboard display of the data is to assure proper functioning of the measurement equipment.

TITLE: 2-107 - Skill retention in extended space flight

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective - Develop methods for crew selection, proficiency assessment, maintenance of skills, and to identify training requirements.

Experiment Objectives -

Identification of skills expected to degrade under the stresses experienced during extended space missions, evaluation of methods for controlling degradation of those skills, and identification of onboard training equipment as may be required to maintain skills at required levels.

a. Select example significant vehicle and mission-oriented operator and maintenance tasks that may be expected to degrade during the stresses of a space mission. Perform these tasks under simulated conditions onboard the spacecraft during the mission to determine skill retention problems.

b. Identify possible methods for simplifying the tasks to resolve retention problems.

c. Test the impact of refresher training on proficiency.

d. Identify necessary onboard training equipment.

Continual refresher training is necessary on earth to maintain skills such as playing a piano or flying an airplane. These skills are very complex, involving sensory, psychomotor and cognitive capabilities and their interactions. Space flight introduces a variety of unique traumas and stresses to degrade these skills plus factors such as weightlessness and physiological change to further confound the picture. And some tasks must be accomplished in an extremely short period of time, without opportunity to make changes if initial inputs need correction. Skill proficiency will be dependent upon the number of practice trials, length of time lapse and the space stresses experienced since the last practice, their interactions, and other variables that may arise. An investigation should identify skills critical to mission success that are expected to degrade space missions, determine whether significant degradations occur, identify procedures that may be followed to maintain proficiency, and identify training aids and equipment necessary to accomplish these procedures.

The four example tasks selected are (1) controlling a spacecraft through re-entry to a safe landing, (2) activating the appropriate switch for each of a series of switching functions, (3) compensatory tracking of stellar and planetary bodies, and (4) monitoring visual displays and activating one of a number of systems in accordance with the information presented.

The results of the research can have a significant effect on the tasks assigned to man during spacecraft design, the role given man as an operator and maintainer on certain missions, and the schedule he will use when meeting those assignments.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.1.5 Crew Selection and Training
1.1.2.1.6 Performance Monitoring and Assessment

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Both the astronaut and cosmonaut groups have received pre-launch overtraining on manual backup re-entry tasks to accomplish if automatic systems fail. Both groups have utilized these skills to accomplish successful re-entry when hardware systems failed. Space flights to date generally have been for less than a two-week period.

Successor Experiments -

Experiment 2-203 (Evaluation of training devices)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Analyze vehicle post-launch tasks to identify those critical to vehicle survival that may pose skill-retention problems.

b. Analyze mission-oriented post-launch tasks to identify those that are critical to mission accomplishment that may pose skill-retention problems.

c. Perform these tasks in a simulated space mission environment to screen for potential skill-retention problems and possible task simplification solutions, pre-launch methods for retention control, and necessary training equipments.

F

Successor Research -

Follow-up studies to determine proficiency levels of returned subjects in simulated space mission environment.

2. EXPERIMENT DESCRIPTION

This experiment requires pre-launch, orbital, and post-mission measurement of proficiency in accomplishing operator and maintenance time stress and non-time-stress tasks. Apparatus involved for task simulation includes a CRT display under development (IMBLMS) which provides alphameric display with test patterns and tracking features (computer controlled) and a Task Board under development (IMBLMS) which includes tools, wires, switches, displays, fitted shapes and the like, which provides tests for skills retention and time and accuracy performance on psychomotor tasks. The data gathering procedure is described in the Measurement/Operation Description titled: Obtaining Video and Audio Data on Crew Activities. The operator activity includes tasks required to accomplish re-entry and landing manually if automatic systems fail. The subject will be seated at a console, making his inputs generally without opportunity to make changes if initial inputs are incorrect (extreme time duress). The task imposes sensory, psychomotor, and cognitive demands when these demands may degrade during extended exposure to space stresses. The non-time-stress operator task will be mission-oriented, the compensatory tracking of stellar and planetary bodies. This skill is basic to several critical manual control functions that will be required of astronauts in long-duration missions, and the task is easily simulated using the computer-driven CRT display. The time-stress maintenance activity will be activation of the appropriate switch on the Task Board for each of a series of switching functions. The non-time-stress maintenance activity will be the monitoring of visual displays and activating one of a number of systems in accordance with the information presented. The first is a simple serial-motor sequence, decision making in its simplest form. The second is diagnosis of a system state from many simultaneous stimulus inputs, a complex decision-making activity. Both tasks will be presented on the Task Board, and performance monitored via TV.

All crew members will serve as subjects during the individual, self-administering test program. The number of pre-launch practice trials will be the same for each subject on each problem. The type of testing schedule presented in Table 1 will be utilized during the first three crew cycles, while members of the fourth crew cycle will use a repeat of the lowest time interval schedule (e.g., 60 days) showing a significant loss (e.g., significant as related to proficiency required for successful re-entry). This test schedule will be used for both the operator and the maintenance tasks. The four tasks may be scheduled for accomplishment on the same day or may be scattered for accomplishment on two, three or four different days, whatever is convenient for merger with the rest of the crew task schedule. However, consistency in task sequencing will be observed.

Table 1

OPERATOR AND MAINTENANCE TASK SCHEDULING

Subject	Approximate Days from Launch: 30	60	90	Total Test Time (hours)
1	X	X	X	12
2		X	X	8
3			X	4

Set-up and test time will approximate 1 hour/subject/test or a total of 4 hours/session for the four tests. Each subject will accomplish his test in an area that is isolated from other personnel and distractions which could cause variations in performance.

TITLE: 2-108 - Off-duty activities and facilities

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective - To develop methods and design criteria to produce habitable living areas (recreational facilities) in space vehicles.

Experiment Objective - Determine crew acceptability and preferences for various types of off-duty equipment and facilities. Evaluate the schedule of usage of the equipment and facility. Provide an evaluation of the adequacy of the off-duty activity (equipment, facility, and schedule) in terms of crew preference as a function of time. Evaluate length of time and frequency of use of equipment and facility as a comparison to observed and recorded crew evaluation of the same activity. To achieve these objectives the off-duty experiment is divided into four activity categories: (1) games (active and passive), (2) reading, (3) audio visual entertainment, and (4) exercise provisions. To obtain valid test results, each subject is required to utilize all equipment and facilities on a rigid schedule. Each subject is then permitted to delete items of low preference, and finally allowed to utilize or not utilize any equipment or facility on his own terms and schedule. This procedure is cycled three times per crew cycle. Accumulated experiment data will provide answers to the aforementioned objectives and, in addition, provide an index of crew boredom and morale. A further evaluation is to compare the cycle performance characteristics of other experiments with the results of the off-duty experiment. A successful off-duty experiment will reduce crew tension and stress that would, in turn, positively influence other experiments and activities. Conversely, a negative to the off-duty experiment should affect other experiments or activities in a like manner.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.2.3.2.8 Environment-Attitude
1.1.2.2.3.2.11 Environment-Frequency of Use
1.1.2.2.3.3.2 Personal Support-Physical Fitness
1.1.2.2.3.3.3 Personal Support-Recreation and Leisure

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

None.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Design and development of off-duty equipment for Skylab B.

Test and qualification of off-duty developed equipment.

Use of duplicate off-duty experiment in closed chamber runs of same duration as Skylab B.

Successor Research -

Analysis of experiment results, design, and test of new off-duty equipment. Test in chamber run prior to space station flight.

2. EXPERIMENT DESCRIPTION

Crew off-duty activity is divided into four activity categories: (1) games, (2) reading, (3) audio-visual, and (4) exercise provisions. The 90-day crew stay time is divided into three equal segments of 30 days each. In turn, each of the 30-day segments is divided into three equal periods of 10 days each. Each of the three time periods of 10 days is repeated three times to give nine test or evaluation periods. It is planned to repeat each segment in order and to have the routine of each period repeated.

The first time period of each segment (days 1 to 10, days 31 to 40, days 61 to 70) will be structured to require each crewman to utilize each piece of equipment in each category. This equipment will be utilized on a scheduled basis for the duration of that period.

The second time period of each segment (days 11 to 20, days 41 to 50, days 71 to 80) will be organized to permit each crewman to select the off-duty equipment of his choosing. The use time per period will be equal to the use time of the structured period.

The third time period of each segment (days 21 to 30, days 51 to 60, days 81 to 90) will be non-structured and will permit the crewman to do anything that he desires. The time period of this activity or lack of activity will equal the organized time period.

The purpose of the three periods per segment and repeating of the segment three times is to (1) assure crewman familiarity of equipment and purpose, (2) determine preference for equipment and activity, (3) define alternate crew activity and improvisation for off-duty time. The repetition of the segments will aid in relieving monotony by providing a short 10-day time period, and integrate the positive or negative aspects of a long-term (90 day) mission.

At the conclusion of each of the nine periods, each crewman will answer a questionnaire. The questionnaire will be designed to define the crewman's preference or lack of preference for the activity and equipment and his rationale for the choice(s). Equipment and activity utilized would be identified on the questionnaire.

Improvised activity and equipment will also be identified on the questionnaire. Selected portions of crew off-duty activity will be recorded by the non-obtrusive TV monitoring cameras. The camera coverage is not unique to this experiment but will be utilized as required on an as-available basis.

The analysis of the questionnaires and TV coverage will establish guidelines and baselines for space station off-duty experiments and future equipment and activity concept and direction.

The time consumed by this experiment will not exceed that time allocated to off-duty activity by the final timeline.

TITLE: 2-110 - Evaluation of locomotion aids and techniques

1. <u>SCIENTIFIC AND TECHNICAL OBJECTIVES</u>

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective - Develop operator equipment and technology for crew and cargo transfer, assembly, and maintenance internal and external to the space vehicle.

Experiment Objectives - Evaluate the effectiveness of various items of locomotion and restraint equipment when used by the crew in a space environment. To be evaluated in terms of crewman's body position, body movement, time to perform, locomotion task or restraint utilization, accuracy of locomotion path, and overall ability to locomote. Above to be evaluated in zero g and varying degrees of artificial g. Performance in varying degrees of artificial g will determine the crossover point for need versus no need for locomotion and restraint aids. Adaptability of the aids to a crewman in shirt sleeves versus pressure suit assembly will be determined. Shirt-sleeve experiment runs will be performed within the vehicle as will pressure suit assembly runs utilizing the same aids. Evaluation of EVA aids will be performed within the vehicle with the crewman in the pressure suit assembly. The energy expenditure of the subject crewman will be determined as a part of the evaluation of all aids utilized. Aspects of EVA and IVA assembly and maintenance activities will be conducted within the vehicle with and without the pressure suit assembly, respectively. The objective of this maintenance action is to evaluate the restraints in relationship to assembly and maintenance activity. Various configurations and concepts of aids will be evaluated. A representative sample would include compression walking versus magnetic (shuffle) shoes, ladder versus fire pore or pegged pole, parallel hand rails versus staggered hand holds, powered conveyor versus crewman-powered conveyor, etc., as available at time of Skylab B flight.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.2.2.1 Metabolic Cost of Work
1.1.2.2.2.2 Acceleration Profiles
1.1.2.2.2.3 Crew Ability to Use Restraints
1.1.2.2.2.4 Partial G vs Zero G
1.1.2.2.2.6 Restraint vs Sleep Effectiveness
1.1.2.2.2.7 Powered vs Unpowered Locomotion
1.1.2.2.2.8 Restraints vs Crew Time
1.1.2.2.2.9 Spacecraft Support Requirements

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M-509 (Astronaut maneuvering equipment)

Skylab Experiment T-020 (Foot controlled maneuvering unit)

Successor Experiments -

2-207 (Assembly and deployment capabilities)
2-208 (Cargo handling capabilities)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Design and development of locomotion and restraint equipment

Long life and performance testing of equipment

Concurrent Research -

Evaluation of equipment flown by first crew cycle to impact on third cycle by update and revision as required.

2. EXPERIMENT DESCRIPTION

This experiment will utilize the locomotion and restraint aids developed for and included in Skylab B. Special aids (as mechanical assist for locomotion) will be added as they become available. The evaluation and testing of this equipment will be conducted through the first and second crew cycle. Equipment will be updated and improved and subsequently added to the third and fourth crew cycles. Individual tests and evaluations of these specific equipments will be conducted as required. The restraints and locomotion aids will be utilized and evaluated in zero g and when the Skylab B is being spun up to various g levels. The aids will be evaluated at artificial-g levels of 0.1, 0.2, 0.3, and 0.4. The usefulness of the aids at these various levels will be recorded.

This experiment will permit the crews to become proficient in the use of the equipment in zero g before requiring test and evaluation procedures. The crew's progress in proficiency of their use of the locomotion and restraint aids will be documented to establish a learning curve that will be utilized as a comparison to a 1-g learning curve as well as comparison to like experiment procedures. The restraint and locomotion aids will be utilized in their normal locations within the laboratory and will be evaluated by the crew through the filling out of a prepared questionnaire. Selected segments of crew utilization of the aids will be recorded on TV tape.

Strain gages, pressure transducers and torque pickups will be built into selected pieces of the locomotion and restraint aids. (As an alternate, the above force detection equipment could be portable and transferred from restraint aids and locomotion aids as required.)

In addition to the above, a maze will be erected by the crewmen from provided construction materials and directions. The maze will provide a difficult locomotion path for the crewmen to traverse. The maze will be reconfigurable and will be included in the consideration of Experiment 2-116, "Interior Reconfiguration." The purpose of the maze is to duplicate the worst possible locomotion conditions and require the crewmen to traverse through it with the aids provided onboard and as part of this experiment. Recorded data derived from this experiment will be utilized to update and revise the locomotion and restraint aids on crew cycles three and four and successor flights.

TITLE: 2-111 - Advanced controls and displays

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective - Quantify human capabilities for performing physical and mental work as an operator and maintainer of space systems and equipment, and as a scientific investigator, and to provide data for decisions on the appropriate man-machine mix.

Experiment Objectives - Evaluate differences in the use of controls and displays by man in a zero-g space environment as compared to the use of controls and displays by man in an artificial-g space environment. The results of the zero-g and artificial-g experiments will then be compared to an established earth environment controls and displays baseline. To achieve this, a series of experiment runs with different crewmen will be performed on a controls and displays task board. The information derived will be recorded and evaluated by the crewmen. These records and evaluations will be analyzed on the ground. This experiment must be performed during both zero-g and artificial-g portions of the Skylab B mission flight. Findings through the analysis will be utilized to define human engineering design standards for future displays and controls for zero-g and artificial-g long-duration spaceflight.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.2.1 Controls and Displays

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

2-101 (Visual capabilities in weightlessness and partial gravity)

2-102 (Orientation capabilities in weightlessness and partial gravity)

2-110 (Evaluation of locomotion aids and techniques)

2-114 (Maintenance activities and tool evaluation)

Successor Experiments -

2-111 (Evaluation of computer-generated electronic displays)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Detail design of total experiment and experiment task board - ground run through and check out of procedures and recording techniques. Evaluation of testing to achieve validation of test procedures.

Concurrent Research -

Ground evaluation of experiment, changes in event sequencing or experiment plan to come from ground control.

2. EXPERIMENT DESCRIPTION

A task board will be utilized as the basis of this experiment. The board will contain an array of classical display and control components. In addition, it will contain current state-of-the-art display and control equipment. Experiment procedures will be developed to identify differences in controls and displays used by man in a zero-g environment as compared to those controls and displays required for an artificial-g environment. The results of the zero-g and artificial-g experiments will then be compared to an established earth environment controls and displays baseline. These procedures will consider various arrangements of controls and displays considering their intended use by man as well as grouping and functional layout parameters considered to be "acceptable design" practice. It is desirable to evaluate this "acceptable design" practice in space and possess the capability to reconfigure to adapt to a space environment for further evaluation. These arrangements will consider the orientation of the operator to the controls and displays. The orientation will also consider individual control and display elements as well as overall functions and groupings. All of the above described operator control-display interactions will be recorded by the unobtrusive TV monitors. The monitors will be repositioned to provide maximum coverage of the experiment activity. Voice comments by the crew during the recording runs will be recorded. Concise questionnaires will be filled in by the crewman after each experiment run. All displays and controls will have known forces, torques and pressures required to activate or adjust them. All restraints utilized by the operator to perform this experiment will be instrumented to record forces, torques, and pressures transmitted through the operator.

Data from the above forces, torques and pressures will be recorded and coded to the unit used, crewman involved, and time of use. The purpose is to provide an index capability to permit later evaluation of the crewman's physical location, position, restraint used and technique of operation.

This experiment will be performed in conjunction and shared with Experiment 2-114 "Maintenance activities and tool evaluation," and Experiment 2-110 "Evaluation of locomotion aids and techniques."

Three crewmen will participate in this experiment. Modification or revision of the experiment will be achieved upon direction and consultation with the ground control.

TITLE: 2-112 (4-120) - Advanced personal hygiene concepts

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Develop the technology for habitable living areas for space vehicles.

b. Develop technically and esthetically acceptable techniques and hardware for providing personal accommodations in the area of personal hygiene.

Experiment Objectives -

a. To evaluate various advanced personal hygiene concepts (equipment and techniques) in terms of crew acceptability, crew time requirements, spacecraft support requirements, and hygienic effectiveness under extended spaceflight conditions of zero g and artificial g.

b. To determine suitability and verify design of advanced personal hygiene systems for extended duration space flight in zero g and artificial g.

Background -

In the short-duration space missions to date personal hygiene and sanitation did not pose major problems. Inconveniences, difficulties in use, total lack of facilities, and the resulting lowering of personal hygiene standards were accepted by the highly motivated crews of Gemini and Apollo. For longer duration missions, these attributes may prove to have long-term effects which lead to performance decrement and crew dissatisfaction. Suggestions have been made that conditions of extended spaceflight approximate as nearly as possible those to which the crews are accustomed on earth. Advanced concepts, such as whole body showers, have been proposed in response to these suggestions. This experiment will evaluate advanced concepts for body cleansing, oral hygiene, and excess hair removal.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.1.2.2.3 Microbial Infections
1.1.2.2.3.2.7 to .11 Environment
1.1.2.2.3.3.4 Personal Support
1.1.3.7.1.4.1 Biological Control

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M-487 (Habitability/crew quarters)

Concurrent Experiments -

1-129 (A study of changes in microbial contamination of air and selected surfaces)

4-120 (Personal hygiene systems)

4-110 (Advance control and monitoring of microbial levels in life support systems)

Successor Experiments -

2-205 (Habitability for large crews)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Ground-based space cabin confinement studies (e.g., Tektite, McDonnell Douglas 90-day test, Gulfstream)

Baseline collection of data from Skylab B crews.

Successor Research -

Post-flight analysis of data collected in flight.

2. <u>EXPERIMENT DESCRIPTION</u>

This experiment will be conducted during Skylab B crew cycles three and four. Three specific areas of personal hygiene techniques and equipment will be studied: body cleansing, oral hygiene, and hair removal. All crewmen will use the advanced techniques and equipment during the entire 90-day cycle. The experiment will be repeated in crew cycle four to verify that results were not unique to the crew composition of cycle three and to incorporate and evaluate any changes in techniques and equipment indicated by the results of cycle three. Measurements will be made of crew acceptability, crew time, spacecraft support requirements, hygienic effectiveness, and design adequacy.

Though the devices and techniques will be used throughout the mission, experimental observations and measurements will be done at 10-day intervals. Crew acceptability of the techniques and devices will be measured by periodic administration of questionnaires, by measurements of frequency of use, from crew log entries, and by indications of rejection during use. Crew time will be measured by activation of onboard timers by the crewman subject and recording of the time in a crew log following use. Spacecraft support requirements will be measured by onboard monitoring equipment, such as water flow meters. Hygienic effectiveness will be measured by oral examinations, micro-organism counts, and skin and scalp examinations. Design adequacy will be indicated by trouble-free operation, difficulties encountered by the crew in using the equipment, and from crew comments on acceptability.

This experiment will consume very little crew time since the activities to be observed and measured are a normal part of the mission. It will require specialized crew skills in performing oral, skin, and scalp examinations and in taking micro-organism samples.

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TITLE: 2-113 - Assessment of circadian rhythm changes

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Investigate and evaluate the effects of spaceflight on neurophysiological functions including biorhythms.

b. Determine man's individual behavior characteristics in space.

Experiment Objectives -

a. To identify flight crew circadian rhythm changes in human behavior (e.g., level of activity, manual dexterity, food and water intake, alertness, social activity, time perception, sleeping, motivation) and their relationships to physiological rhythm changes under conditions of extended weightlessness and the combined stresses of spaceflight.

b. To determine the relationship between circadian rhythm changes and task performance effectiveness.

c. To discover the implications of circadian rhythm changes for work/rest/sleep scheduling.

d. To identify patterns of circadian rhythm changes over time in space for a sufficiently large sample of crew members to identify regularities and individual differences.

Background -

Circadian rhythm changes may be thought of as one of the potential stresses of spaceflight. Disrupted circadian rhythms was seen as a potential problem in space by the NASA Symposium on the Effects of Confinement in Long Duration Space Flight (November 1966). One of the symposium conclusions was that research is required to determine the effects of altered diurnal cycles on circadian rhythms and its relation to work schedules. At a Workshop on Circadian Rhythms held at the University of California at Davis in August 1969, the participants questioned whether circadian rhythms may influence experimental results obtained in long-duration spaceflight. Considerable ground research has been done on physiological indicators of circadian rhythm changes (variations in cardiovascular response to exercise, variations in steroid and catecholamine levels, variations in thermoregulatory responses, etc.), influence of various "zeitgebers" on rhythms (light, ionizing radiation, electric fields), and pharmacological manipulation of biorhythms, but very little is known about social and behavioral circadian variations.

Experiment 2-113

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.2.4.1 Rhythms and Cycles
1.1.2.2.4.2 Sleep
1.1.2.2.4.3 Work/Rest

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment S061 Potato respiration

Skylab Experiment S071/072 Circadian rhythm - pocket mice/ vinegar gnat

Concurrent Experiments -

2-104 (Effects of space flight on crew structure and group behavior)

2-107 (Skill retention in extended space flight)

2-109, 2-117 (Sleep behavior)

2-114 (Maintenance activities and tool evaluation)

All Biomedical experiments producing physiological measurements applicable to circadian rhythm changes.

Successor Experiments -

2-214 (Evaluation of scheduling techniques)

3-213 (Verification of S061, potato respiration rhythms)

3-214 (Verification of S071, circadian rhythm of pocket mice)

3-215 (Verification of S072, circadian thythm of vinegar gnat (Drosophila))

3-221 (Further investigation of the effect of weightlessness and the earth orbital environment or biorhythms of mice)

3-222 (Effect of weightlessness and the earth orbital environment on cockroach circadian rhythms)

3-223 (Effect of weightlessness and earth orbital environment on tidal rhythms of the fiddler crab)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Research studies on (1) correlation between physiological indices of circadian rhythm changes and social and behavioral indices, (2) identification of additional criteria for establishing rhythms and their normal patterns, and (3) influence of social stimuli as an influencer (zeitgeber) of circadian variations.

b. Preflight baseline measurements of flight crew to determine earth-based patterns.

Concurrent Research -

None.

Successor Research -

Post-flight analysis of flight data.

2. EXPERIMENT DESCRIPTION

This experiment will be conducted throughout all four Skylab B crew cycles and all crew members will serve as subjects. It will require no measurement program of its own but will depend upon measurements already identified for other biomedical and man-systems integration experiments plus environmental data collected from the onboard life support system. More frequent measurement of some of these parameters may be required to accommodate the periodic requirements of this experiment, however.

The table below includes a tentative list of measurements required:

Biomedical	Behavioral	Environmental
Body Temperature	Activity Level	Temperature
Heart Rate	Time Perception	Humidity
EEG	Sleep Behavior	Light Level
Metabolic Rate	Food and Water Intake	Sound Level
Arterial Blood Pressure	Hunger Cycling	
Urine and Serum Analysis	Social Behavior	
	Crew Mood	
	Manual Dexterity	
	Alertness	
	Motivation	
	Task Performance Measures	

Time Perception, the only item on this list not required by other experiments, will be measured by presentation to the subject of two tones (or alternatively visual signals on the CRT) separated by an interval of 3 sec to 10 min and having the subject record the time between stimuli.

Available measurements should be gathered, segregated, and collated on a scheduled basis which ensures data are available for each crewman for at least 20 days during the 90-day crew cycle. Four data points should be obtained for each of these days: one during the first 4 hours after awakening, and one in each of the next three 4-hour periods. It is not necessary that all of the measurements identified above be collected at each data point.

TITLE: 2-114 - Maintenance activities and tool evaluation

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Quantify human capabilities for performing physical and mental work as a maintainer of space systems and equipment.

b. Develop methods for maintenance of skills and identify training requirements.

c. Develop operator equipment and technology for maintenance internal and external to the space vehicle.

Experiment Specific Objectives -

a. To determine the effect of mission duration, zero g, space suit encumbrances, restraints, and design characteristics of tools and prime equipment on task times, task errors, forces, and energy expenditures in performing maintenance activities in space.

b. To determine effects of mission duration on degradation of seldom-used maintenance skills.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study; Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.1.2	Human Capabilities
1.1.2.1.5.4	Degradation of Skills
1.1.2.2.2	Locomotion and Restraint
1.1.2.2.5.1	Tools
1.3.2	Maintenance, Repair and Retrofit

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiments M171, M507, M508

Concurrent Experiments -

Skylab B Experiments 2-107 and 2-115

Successor Experiments -

Space Station Experiments 2-204, 2-212, and 4-228

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Ground-based space cabin confinement studies (e.g., Tektite, McDonnell-Douglas 90-day test, Gulfstream)

b. Underwater simulation research using tools developed for space use.

c. Evaluation of tools and maintenance techniques on air-bearing and other ground devices.

d. Collection of baseline data on crews scheduled for Skylab B missions.

Successor Research -

a. Post-flight analysis of data collected in flight.

b. Research as indicated above on devices improved as result of flight experience.

2. EXPERIMENT DESCRIPTION

Tool experiments (IVA and simulated EVA) will be conducted using task boards incorporating removable components, fasteners, and electrical and fluid lines. The boards will be instrumented with strain gages (for sensing forces and torques) connected to bridge circuits for converting strain gage displacement into electrical signals.

This experiment will be performed on each crew cycle of Skylab B with different tool/maintenance activity combinations being utilized for each crew cycle. The tool/maintenance activity combinations will be maintenance tasks designed to be compatible with the task board and (1) sample the various powered and unpowered tools anticipated for future space missions, (2) sample the various types of maintenance activities for which data are required, and (3) require approximately 30 min of crew task time each.

For each crew cycle two tool/maintenance activity combinations will be selected for test. Each will be performed by three crew members using the task board and in three suited configurations: unsuited, suited pressurized, and suited unpressurized. Each task in each suited configuration will be repeated at 20-day intervals during the mission, thus requiring four repetitions during a normal 90-day cycle. Experimental design is as follows:

	Unsuited	Suited Pressurized	Suited Unpressurized
Crewman 1	2 T/MA's x 4 repetitions	2 T/MA's x 4 repetitions	2 T/MA's x 4 repetitions
Crewman 2	2 T/MA's x 4 repetitions	2 T/MA's x 4 repetitions	2 T/MA's x 4 repetitions
Crewman 3	2 T/MA's x 4 repetitions	2 T/MA's x 4 repetitions	2 T/MA's x 4 repetitions

T/MA = Tool/Maintenance Activity Combination

Task times and errors, forces applied, crew body motions, and energy expenditure will be measured/observed. Data will be obtained by automated recording of forces, with TV cameras augmented by onboard timers, physiological measurements, and subjective comments from crew members. Data will be telemetered and/or returned to earth by logistics vehicle for ground analysis.

TITLE: 2-115 - Evaluation of man-remote manipulator interface

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration.

NASA Specific Objectives -

Develop operator equipment and technology for crew and cargo transfer, assembly, and maintenance internal and external to the space vehicle and extraterrestrial surfaces.

Experiment Objectives -

a. To evaluate man's capability under weightlessness and the combined stresses of space flight to perform maintenance and cargo-handling tasks remotely using an electrical-panel-controlled manipulator.

b. To identify design criteria for advanced-space remote-manipulator systems.

Background -

A variety of remote manipulators have been developed during the past 25 years, primarily for use in nuclear ground facilities, propulsion plants, and in laboratories where dangerous chemicals are handled. Since 1947 the Argonne National Laboratory has developed and tested devices for use in radioactively hot cells. The Aerospace Medical Research Laboratory at Wright Patterson AFB has examined human factors aspects of remote manipulators since 1959. The NASA Jet Propulsion Laboratory has concentrated on remotely controlled equipment to be used on the lunar surface. The Moon-Digger in the Surveyor Program demonstrated the feasibility of such devices. Remote manipulators are being considered for in-space use for situations in which it is unsafe or not feasible for astronauts to personally perform tasks.

Research results indicate that a shirt-sleeved operator using a master-slave manipulator can perform simulated space tasks about equally as well as an astronaut in a pressurized space suit. Questions which require answers in space include those addressed to crew time requirements in using manipulators, accuracy and precision with which tasks can be performed, and design requirements in terms of feedback needs, power use, design of control work spaces.

This research activity is partially or wholly responsive to the information needs of the following critical issues which are identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.2.5.2 Manipulators and Force Assistive Devices

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

None.

Concurrent Experiments -

2-114 (Maintenance activities and tool evaluation)

Successor Experiments -

2-204 (Advanced remote manipulator concepts)

2-208 (Cargo handling capabilities)

2-207 (Assembly and deployment capabilities)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Development of panel-controlled remote manipulator in configuration appropriate to Skylab B and development and tryout of space experimental maintenance and cargo transfer tasks.

b. Collection of baseline task data on Skylab flight crews using the developed hardware and tasks.

Concurrent Research -

Development and tryout of revised procedures for later crew cycles.

Successor Research -

a. Post-flight analysis of experimental data.

b. Development and tryout of revised procedures for advanced manipulator systems.

2. <u>EXPERIMENT DESCRIPTION</u>

This experiment will be conducted on the first crew cycle of Skylab B, repeated on crew cycle number two and expanded and revised as necessary on Skylab B crew cycles three and four. In the first and second crew cycles remote maintenance tasks using a task board will be performed. On crew cycles three and four additional tasks of cargo handling will be introduced and necessary changes to the maintenance task will be made.

The maintenance task will be designed to be performed within a 30-min time period on a task board and will be representative of the type of activities envisioned for both IVA and EVA maintenance conditions in which remote operations would be indicated. It should include removal of fasteners, removal and replacement of components, and making and breaking electrical and fluid connections. For comparison purposes the task must be performed both directly and remotely. In the direct mode it should be performed both suited and unsuited.

The cargo-handling task will be designed to simulate activities in transferring cargo from logistics vehicles to spacecraft, moving objects from one portion of the spacecraft to another, and moving objects EVA from one position to another on the spacecraft exterior. Dimensions and masses of the cargo items will be representative of those anticipated in actual operations. Again this task should be performed both directly (suited and unsuited) and in the remote mode.

The remote operating device to be used in this early experiment is an electrical, unilateral, panel-controlled manipulator. This device offers less versatility than a bilateral master/slave device but is lighter in weight, requires less volume for the operator and controls, and uses less power.

Measurement sessions should be scheduled so that (1) as large a sample of different crew members as possible will be tested, (2) effects of mission duration can be assessed, and (3) at least three repetitions for each crew member occur during a 90-day crew cycle. This dictates that each crew member will serve as a subject, experiments must start within the first 30 days, approximately 20-day intervals should be allowed between individual crew members measurement sessions, and the experiment should be repeated on two crew cycles.

Measurement parameters of interest include task time and error, energy expenditures, power expended in the remote mode, forces and torques transmitted to the manipulated objects, and subjective comments of crewman subjects.

Experimental data will be obtained primarily with TV camera observations of performance of the remote task (i.e., cameras will be watching the remote operation, not the crewman at the operating panel).

TITLE: 2-116 - Reconfigurable interior configurations and decor

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective - Develop the technology for habitable living areas for space vehicles.

Experiment Objectives -

a. Evaluate performance in space of techniques for reconfiguring various elements of habitability subsystems in terms of crew time, tool requirements, and crew acceptability.

b. Determine crew needs in long-duration space flight for changes in various elements of habitability subsystems (volume and configuration, color and lighting, decor, and sleeping accommodations).

c. Demonstrate that reconfigurable crew systems can be utilized successfully in zero-g and artificial-g environments.

Background-

Review of the literature on extended confinement and isolation reveals that as duration of isolation continues individuals make alterations to their habitable environment. These changes may (1) increase or decrease personal privacy, (2) increase or decrease the individual's ability to interact with others, (3) reorient the individual's position for normal activities such as working and sleeping, (4) individualize the environment (personal pictures, mementos, etc.), (5) make the environment lighter or darker, etc. It is hypothesized that without the capability to make such changes the habitability provisions of a long-term space vehicle will become unacceptable to the crew after a certain duration and this may lead to degradation in performance, monotony and boredom, interpersonal stress, and degraded interpersonal relations. This experiment does not attempt to test that hypothesis, but rather assumes a Skylab B system that permits the interior to be reconfigured while the mission is in progress. This experiment will be performed in zero and artificial g. Movable modular panels that comprise the floor, ceiling, and walls will be capable of being reconfigured to alter area, shape, and volume of crew-occupied areas. These reconfigurable panels will be capable of texture and color changes with a minimum of time and energy expenditure by the crew members. The system will be self-contained, self-supporting, and require construction by one crewman with standard tools.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.2.2.3 Habitability
1.1.2.2.3.1 Space
1.1.2.2.3.2 Environment
1.1.2.2.3.3 Personal Support

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M-487 (Habitability/Crew Quarters)
Skylab Experiment M-151 (Time and Motion Study) 90-Day Run - Langley, MDAC

Concurrent Experiments -

2-102 (Orientation capabilities in weightlessness and partial gravity)

2-104 (Effects of space flight on crew structure and group behavior)

2-110 (Evaluation of locomotion aids and techniques)

2-114 (Maintenance activities and tool evaluation)

Successor Experiments -

2-205 (Habitability for large crews)

2-213 (Food management for large crews)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Work required to determine reconfigurable panel design definition.

b. Tests to be defined and baseline results to be established.

c. Evaluation of interior design and arrangement of prior 60- and 90-day runs performed by MDAC for NASA Langley.

Concurrent Research -

a. Evaluation and comparison of on-orbit test results.

Successor Research -

a. Utilize test results from this experiment in advanced space systems and closed run evaluation and tests.

2. EXPERIMENT DESCRIPTION

Prior to Skylab A (Experiment M-487 Habitability/crew quarters) necessarily little effort has been expended on creature comforts. M-487 is the first step toward ascertaining what the design criteria for long-term habitability in space should be. The results of M-487 will be incorporated into this experiment as appropriate but it is anticipated that the results will consist of a basic learning curve with little quantitative information.

This experiment will supply the crewmen with reconfigurable interior panels that will be set up per a plan and time schedule. The crew will then work and live in the constructed area. At designated times the areas will be altered by a change in lighting, color, and texture. For the duration of this interior configuration the crew will make subjective judgments of the basic arrangement and the subsequent alteration to lighting, color, and texture. In the same time period the work efficiency and productivity of the crew will be measured in an objective quantitative manner. Subjective evaluations will be conducted during the same time period. The above sequence describes one interior configuration cycle. At a designated time the original setup is reconfigured for a change in volume and floor plan. The basic cycle is repeated as described for configuration 1. Only planned reconfiguration and planned lighting, color and texture changes will be permitted. Work tasks as required by Skylab B will be performed by the crew in the reconfigured areas. Selected segments of the tasks will be capable of quantitative scoring. The scores will be a comparative measure of crew performance as related to a reconfigurable crew area. Compiled test data are expected to indicate a significant trend when related to a volume, size, color, texture, and light level preference. These data will be utilized as baseline habitability design criteria for future space systems.

TITLE: 2-117 (1-109) - Sleep Behavior

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration and Biomedicine

NASA Specific Objective -

a. Evaluate the effects of spaceflight on neurophysiological function including sleep and alertness.

b. Develop techniques for assessing the effects of stress and fatigue on the ability of the crew to perform their assigned tasks.

Experiment Objectives -

a. Determine whether changes occur in normal sleep patterns including:

1. Frequency and duration of the various sleep stages.

2. Subjective sensations of rest associated with sleep patterns.

3. Changes in performance after arousal from various stages of sleep.

Removal of the spacecraft from normal day-night cycles may affect sleep patterns which should be reflected in EEG records. With changes in sleep patterns the amount of rest gained from a sleep period and performance after arousal may be secondarily altered.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company.

1.1.1.1.3.3 Electroencephalographic Patterns
1.1.1.1.3.7 Integrative and Cognitive Processes
1.1.2.2.4.2 Sleep

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab A Experiment M133 (Sleep monitoring)

C3

Concurrent Experiments -

2-113 (Assessment of circadian rhythm changes)

Successor Experiments -

1-110 (EEG patterns associated with performance tasks involving attention and alertness)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

a. Determination in crew subjects of EEG patterns associated with defined sleep stages.

b. Correlation in crew subjects of the frequency and duration of determined EEG patterns with the degree of restfulness of the sleep period.

c. Measure and quantify in crew subjects the degradation in performance associated with arousal from the various sleep stages.

d. Determine the role of rapid eye movements (REM) in the definition of sleep stages and the degree of restfulness of the sleep period.

Successor Research -

a. Post-flight data on returned subjects.

2. EXPERIMENT DESCRIPTION

This experiment is designed to investigate possible changes in normal sleep patterns during spaceflight. Evidence of changes will be derived from EEG records, EOG records of rapid eye movements, subjective sensations of rest, and alertness following arousal.

Twelve subjects will be used for the experiment, three from each crew cycle. They may be either conditioned or unconditioned insofar as there is no reason to anticipate effects associated with physical conditioning. For each crew cycle, the three subjects will be measured on separate days, twice weekly for the first three weeks, then weekly for the duration of the crew cycle.

During the test, the electroencephalogram of the sleeping subject will be recorded from occipital leads (one data channel; prior ground research may suggest additional leads) and the electro-oculogram will be recorded from sensors situated in the lateral and medial corners of the eye (a single data channel). The outputs of the EEG and EOG will be transmitted to a computer, programmed for the identification of sleep stages and rapid-eye-movement sleep. Typical stored data would consist of the identification of a pattern, registering the time of onset and the time of termination of the pattern, and 3 min of recording of the EEG and EOG during (1) each of the four stages of sleep, (2) REM sleep, and (3) consciousness.

Questionnaires designed to elicit subjective impressions of sleep characteristics such as restfulness, amount of dreaming, etc., will be presented daily to each member of the crew. Correlation between electrophysiological data and subjective sensations will be attempted.

On alternate tests nights for each subject (once/week/subject for the first three weeks and once every two weeks/subject thereafter for the crew-cycle duration) the subject will be awakened from either stage-four sleep (deep sleep) or rapid-eye-movement sleep (dreaming) and be presented with a CRT task to test his alertness, reaction time, and eye-hand coordination. EEG will be recorded during the test. The selection of stage-four sleep or REM sleep on a given night will be programmed prior to flight. The subject will be awakened by a personal alarm system triggered by the identification of the selected pattern by the computer.

All inflight data will be compared with preflight baselines to determine changes.

The experiment program will be repeated during the three subsequent crew cycles. Protocol changes will be made only when dictated by earlier findings.

SPACE BIOLOGY RESEARCH PROGRAM
EXPERIMENT DESCRIPTIONS FOR SKYLAB B

3-101	Effect of weightlessness on frog egg fertilization and morphogenesis
3-102	Behavior, reproduction, and development of small mammals in space
3-103	Effect of weightlessness on primate body fluid balance and selected cardiovascular parameters
3-104	*Arabidopsis* plant growth and development in weightlessness
3-105	Role of gravity in lignification (cucumber)
3-106	*Drosophila* behavior and life cycle phenomenon in weightlessness
3-107	Bacterial growth and morphology studies in weightlessness (*E. coli*)

TITLE: 3-101 - Effect of weightlessness upon frog egg fertilization and morphogenesis

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective - Determine the role of gravity in growth, development, physiology, and behavior of organisms.

The frog egg morphogenesis experiment specifically addresses itself to understanding the effects of weightlessness upon fertilization, the "rotation of orientation," and subsequent cellular division and differentiation into a bilaterally symmetrical organism.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

2.1.4.1.1.1.1 Fertilization
2.1.4.1.1.1.2 Cleavage
2.1.4.1.1.1.3 Differentiation
(all those under Differentiation)

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Biosatellite II carried a frog egg experiment that is the direct predecessor of this advanced Skylab experiment. Data on fertilized eggs indicate that the period during and directly following fertilization is probably when differentiation is most affected by gravity. Weightlessness had no apparent effect on the rate or course of development when exposed after the mid-two-cell stage.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Development of laboratory strain of Rana pipiens, and automated nutrient supply for 100 days.

Concurrent Research -

Identical packages for ground control (simulation of launch and recovery stresses, as well as duplication of preservation routines).

Successor Research -

Histological, biochemical, and ultrastructure studies on preserved and live returned specimens. Yolk-cytoplasmic gradient maintenance will be investigated, as well as density of the vegetal and animal poles.

2. EXPERIMENT DESCRIPTION

a. Pre-launch: harvest sperm and eggs from adult frogs (Rana pipiens).

b. Place in capsules of spring water, then into temperature- and atmospheric-controlled frog egg module.

c. In orbit, automatic actuation mixes sperm and eggs in all capsules and begins time-lapse photography to record fertilization in six capsules.

d. Continued time-lapse photography records cell-divisions, differentiation, and any developmental abnormalities.

e. In the remaining 14 capsules, preservation reagent (2.3 percent gluteral dehyde fixative in sucrose osmotically conditioned Sorensen PO_4 Buffer) will be automatically released on the following schedule:

Hours	Embryonic Stage of Development
0	fertilization
1	grey crescent (yolk lowermost)
4	2-cell stage
5	4-cell stage
6	8-cell stage
26	dorsal lip stage
34	mid-gastrulation
42	late gastrulation
68	tail bud stage
Days	
6	hatching (embryo leaves jelly)
12	early larval stage
30	development of legs
60	development of lungs
90-100	experiment termination

f. After 90 days, the experiment will be terminated and the frog egg module packaged and returned to earth for post-flight analysis of live embryos in six capsules and preserved specimens in 14 capsules.

TITLE: 3-102 - Behavior, reproduction, and development of small mammals in space (mice)

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective - Determine the role of gravity in growth, development, physiology, and behavior of organisms.

Experiment Objectives -

a. Establish a healthy, reproducing colony of mice which can be used for future In-Space Biology research requiring small mammals.

b. Assess behavioral changes imposed by the weightless environment; such as, in locomotion, reflex responses, feeding and mating behavior.

c. Determine whether or not normal reproductive processes in mammals are affected by zero-g.

d. Evaluate mammalian growth and development during extended weightlessness.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

2.1.3.2.1.1	Organism Activity Rhythms
2.1.3.2.1.2	Organism Feeding Rhythms
2.1.4.1	Development (all those included under this heading)
2.1.5.1.2.1.1	Voluntary Neural Control of Muscular System
2.1.5.1.2.2.1	Locomotion
2.1.5.2	Behavioral Organization

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

None.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

The life support and data acquisition facilities have been designed as individual compartments housing 6 to 8 mice.* It is now necessary to determine the logistics, crew involvement (time and effort) and ground support necessary to maintain an animal colony in space.

Concurrent Research -

Identical mouse modules for ground control will simulate launch and recovery stresses, inflight temperature and humidity profiles, and day/night cycles.

Successor Research -

Histological examinations will be made on returned preserved specimens. Extensive research will be conducted on mice returned alive during crew rotation periods.

2. EXPERIMENT DESCRIPTION

a. Six young adult mice (3 males and 3 females) will be carried onto the Skylab in the carry-on/carry-off mouse module. Each male-female pair will be placed into a separate, self-contained compartment consisting of living and nesting area, life support and environmental control systems, and a television monitoring and backup data collection system.

b. Food intake, water intake, locomotion, mating behavior, activity cycles, and body weight will be monitored by the data collection system.

c. When litters are born, parturition, nursing and other parent-offspring behavior will be monitored by the TV system.

d. When the young are approximately two weeks old, the compartments must be opened, and the young examined for developmental abnormalities and then separated by sex into their own compartments (eight modules). The LS/ECS's are activated in these modules and data on weight gain and growth rate are then collected.

e. When the young mature (approximately 2 to 3 months from birth), they may be placed in pairs in new compartments to produce new litters. By repeating this process a "0-g line" of mice may be maintained and a colony of small mammals for future research established.

*Meehan, J. P., et al., "Design, Development and Test Hardware Producing a Long Term Space Environment for Mammalian Growth and Development," Air Force Contract, No. 29600-67-C-0010, 1969.

TITLE: 3-103 - Effect of weightlessness on primate body fluid balance and selected cardiovascular parameters

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective - Understand the effects of weightlessness in producing abnormalities and modifying functional mechanisms in organisms.

Aid in developing programs to predict the cumulative effects of altered gravity and other space environmental effects on terrestrial organisms (including man).

Experiment Objectives -

a. To determine the changes in metabolism, cardiovascular function, and water balance produced in the primate by long-duration exposure to weightlessness.

b. To correlate these findings to changes in humans previously observed in weightlessness and ground simulation.

c. To establish criteria and baselines for application to future use of primates in space experiments.

Many of the measurements required to quantify the changes observed in weightlessness are too traumatic or restrictive to use on the crew of a space vehicle. An instrumented primate will make an acceptable subject from which data may be extrapolated to man.

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiment - (all Skylab experiments)

Biosatellite III
M071/73 (Bioassay of body fluids)
M072 (Bone densitometry)
M093 (Vectorcardiogram)
M171 (Metabolic activity)

Concurrent Experiment -

1-113 (A study of blood and urine for chemical changes and the effects of exercise on the changes)

1-120 (The time course of changes in bone density and the effects of exercise on the changes)

1-106 (Changes in cardiac activity and the effects of exercise on these changes)

1-104 (Mechanisms of orthostatic tolerance changes)

1-130 (A study of the histochemical changes in the primate)

Successor Experiments -

*1-219 (Relationship of cardiac output to regional blood flow in primates)

*1-220 (Cardiovascular reflex activity in primates)

*1-221 (Cardiac work capacity against an induced arterial back pressure in dogs)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Development of module and sensors for implantation. Experimental program with restrained primate identical to flight program except for weightlessness.

Concurrent Research -

Ground-control-duplicating flight program except for weightlessness.

Successor Research -

Post-flight data on actual flight subject.

2. <u>EXPERIMENT DESCRIPTION</u>

The present experiment is designed to collect sufficient metabolic and cardiovascular data on a restrained primate to allow the detection and quantification of functional changes in these systems.

A single <u>Macaca nemestrina</u> (pig-tailed monkey) will be restrained in a couch designed to support the animal during flight acceleration and to function as base for attachment of the measuring instruments.

Food and water will be dispensed and measured separately, sometimes in association with performance tasks. The data will be used both as indication of food intake for metabolic balance and for behavioral characteristics.

*Animal research

Urine excretion will be collected by ureteral catheters and measured at 3-hour increments. Each 3-hour sample will be stored and preserved for post-flight analyses. Feces will be collected as 24-hour samples and preserved in the frozen state.

Oxygen consumption, CO_2 production, water vapor production, and heat production of the subject will be calculated from a measurement of the composition, flow rate, and temperature of the incoming and outgoing air.

Chronic catheters implanted in the aorta, vena cava, pulmonary artery, and left atrium will be used to measure blood pressures at these sites. Aortic blood temperature will be measured by means of a thermister in the aortic catheter; the catheter will then be led through a densitometer for arterial O_2 saturation. Records of the ECG and heart rate as well as respiratory rate will be determined by means of an ECG implanted in the abdominal cavity. One electrode of the unit will be imbedded in the crest of the ilium and the other sutured to the base of the diaphragm.

The primate module will maintain a two-gas atmosphere, O_2 (20 percent) and N_2 (80 percent) at a pressure of 760 mm H_g. Carbon dioxide will be held at 6 to 12 mm H_g, water vapor at 12 ±3 mm H_g and temperature at 28 ±2.5°C; trace contaminants will be controlled at levels acceptable for man, or less; and air velocity maintained at ±2 meters/min over the body surface of the primate.

The experiment should extend through two crew cycles which do not include a period of spacecraft rotation. At the conclusion of the experiment the primate will be returned to earth for post-flight studies.

TITLE: 3-104 - Arabidopsis plant growth and development

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective - Determine the gravity sensors of plants and the role of gravity in growth, development, physiology, and behavior of organisms.

This experiment specifically addresses itself to understanding the effects of weightlessness upon the growth and life cycle of the higher plant, Arabidopsis.

The general hypothesis on which current flight research is planned is that the pattern of development of a higher plant will differ qualitatively and quantitatively growing under the conditions of weightlessness from the normal developmental pattern in the earth's gravitational field. The mechanism whereby gravity directs plant morphogenesis is unknown and descriptive data on growth in subnormal g fields is desired.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

Post-flight Analysis -

2.1.1.1.1	Energy Storage Elements
2.1.1.1.1.1	Carbohydrates
2.1.1.1.2	Structural Elements
2.1.1.1.2.1	Carbohydrates
2.1.1.1.2.2.2	Non-Skeletal Minerals
2.1.1.1.3	Regulatory Elements
2.1.1.2.1.1	Plant hormones
2.1.2.1.1	Aerobic Mechanisms
*2.1.3.1.1	Geotropic Response
*2.1.4.1.1.2	Plant Sexual Reproduction

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

None.

*In Flight

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Basic research has been and is being conducted to gain baseline data for this inflight experiment.

Concurrent Research -

Identical plant modules for ground control will simulate launch and recovery stresses, inflight temperature, pressure, and humidity profiles, and day/night cycles. Clinostat and erect controls will be included.

Successor Research -

Post-flight morphological, histological and biochemical analysis of preserved and surviving plants will be carried out.

2. EXPERIMENT DESCRIPTION

a. Preflight: Arabidopsis seeds and seedlings will be planted in transparent rectangular test tubes (1 x 1 x 6 in.) containing a nutrient agar medium and then placed in each of seven areas of the Arabidopsis module.

b. In orbit two cameras will photograph the plants intermittently to provide stereo and time-lapse records of morphological changes during growth. The plants complete an entire life cycle in 21 days, so two to three subsequent generations may be followed throughout a crew cycle.

c. Samples in the first six of the seven module areas will be automatically preserved with gluteraldehyde (one area every three days, with all the plants in the one area being preserved). After 21 days, plants in the seventh area will be removed by an astronaut after a 15-min module decompression. Seeds will be harvested and placed into 70 new test tubes (previously refrigerated). The new test tubes will be placed in the Arabidopsis module, and the preserved specimens will be stored. The adult plants whose seeds were harvested will be placed in frozen storage (-70°C) for post-flight studies.

d. The F_1, F_2, and F_3 generation plants will be treated as in Step 3.

e. At the termination of the experiment (elapsed crew cycle), the preserved plants and the frozen plants will be returned to earth in their test tubes.

f. Post-flight morphological, histological and biochemical analysis of preserved and surviving plants will be carried out.

TITLE: 3-105 - Role of gravity in lignification

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective - Determine the role of gravity in growth, development, physiology, and behavior or organisms.

The objective of this experiment is to determine what order of magnitude of gravity is required for the lignification process. The extent and pattern of lignification in cucumber plants grown from seed during extended earth orbital flight will be studied by postflight analysis.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

2.1.1.1.2.1.6 Lignin

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

None.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Basic research has been and is being conducted to gain baseline data for this inflight experiment.

Concurrent Research -

Identical plant modules for ground control will simulate launch and recovery stresses, inflight temperature and humidity profiles, and day/night cycles.

Successor Research -

Major cell-wall constituents will be extracted and analyzed quantitatively and qualitatively for alterations caused by growth in the absence of gravity. Histological and biochemical examination will be made of fibrovascular tissue, extravascular mechanical tissues, and epidermis. Electron microscopy will also be carried out on these tissues.

2. EXPERIMENT DESCRIPTION

a. Pre-flight dry cucumber seeds will be planted in anchored trays or flats containing a suitable substratum, and the trays placed into an environmentally controlled module.

b. In-orbit automated hydration of the substratum containing the preplanted seeds will take place to initiate growth.

c. The seeds will germinate, grow to seedlings and into mature plants for return to earth.

d. Upon completion of the mission, one astronaut will package the plants for return.

e. Post-flight histological and biochemical examination will be made of fibrovascular tissues, extravascular mechanical tissues, and epidermis. Cell walls will be examined with the electron microscope and all other major wall constituents will be fractionated and analyzed for lignin.

TITLE: 3-106 - Drosophila behavior and life cycle phenomena in weightlessness

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective -

a. Determine the role of gravity in growth, development, physiology, and behavior of organisms.

b. Understand the effects of weightlessness in producing abnormalities.

Experiment Objectives -

a. Establish a healthy, reproducing source of fruit flies which can be used for future in-space biology research requiring statistical studies of large numbers of invertebrates.

b. Assess behavioral changes imposed by the weightless environment; such as in locomotion, feeding, and mating behavior.

c. Determine whether or not normal reproductive and life-cycle phenomena are affected by zero g.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

2.1.3.2.6.9	Eclosion Rates
2.1.4.1	Development (all c.i.'s under animal development)
2.1.4.1.1.1.4	Metamorphosis
2.1.5.2	Behavior

Post flight

2.1.4.2	Genetics
2.1.1.1	Anabolism
2.1.1.2	Catabolism
2.1.2.1.1	Aerobic Mechanisms

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Biosatellite II data indicate that weightlessness enhances the rapidity of aging and causes chromosome damage in actively growing and metabolizing organisms.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Basic research has been and is being conducted to gain baseline data for this inflight experiment.

Concurrent Research -

Identical fruit fly modules for ground control will simulate launch and recovery stresses, inflight temperature, pressure humidity, and day/night cycles.

Successor Research -

Genetic studies will be conducted with live specimens returned at experiment termination. Histochemical analysis will be carried out on preserved specimens to detect subcellular abnormalities caused by weightlessness.

2. EXPERIMENT DESCRIPTION

a. Pre-launch, adult flies (Drosophila melanogaster) will be placed into transparent capsules with solid culture media anchored by a wire or plastic (large-holed) mesh. The culture media will be inoculated with a suitable yeast culture. Empty capsules layered with agar, but free of yeast, will be sealed and stored, along with caked-yeast cultures, under refrigeration. These extra capsules and yeast cultures will be used to support offspring generated in orbit.

b. As eggs are deposited, the batch number will be recorded on film for post-flight analysis, or, if time is available, one astronaut will count the eggs with the aid of dissecting microscope.

c. Adult flies will be removed from the egg-containing capsules, segregated by sex, and placed in separate capsules. Prior to inclusion of the flies, the agar will be inoculated with viable yeast. Separation will be done by first anesthetizing the organisms with a CO_2 anesthesia unit, and then manually separating males from females.

d. An astronaut will analyze the offspring for abnormalities, divide some by sex into separate capsules, place some virgin females and males of the F_1 generation together for mating, and sacrifice some to control growth of the colony.

e. After F_1 eggs have been laid by mated females, Steps c and d will be repeated.

f. Step e will be repeated with the F_2 generation and continued for each subsequent generation.

g. The F_1 generation flies will be kept for the duration of the mission (90 to 270 days) to gain life-span data.

h. Periodically an astronaut will chemically preserve selected flies and place them in labeled thimble-sized containers for post-flight analysis.

i. This protocol will be repeated until sufficient data satisfactory to the PI have been obtained and the colony has been successfully established. Live specimens in various stages of development will be returned to earth for analysis.

TITLE: 3-107 - Bacterial growth and morphology studies in weightlessness

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Space Biology

NASA Specific Objective - Determine the role of gravity in growth, development physiology, and behavior of organisms.

Experiment Objectives -

a. Determine changes in the rate of growth of bacterial populations.

b. Determine the source of change in growth rate, i. e., a decrease in generation time due to altered metabolic or reproductive functions, or a decrease in the lag phase caused by continuous exposure to nutrients in the weightless environment.

c. Determine the alterations in bacterial colonial morphology which occur in weightlessness.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

2. 1. 4. 1. 2 Development Through Asexual Reproduction

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Experiments conducted during the flight of Biosatellite II indicated that bacterial growth rate was increased in the weightless environment. It has not yet been determined whether this was an actual decrease in generation time or was simply caused by more consistent exposure to the nutrient medium.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Colonial morphology changes during simulated weightlessness (clinostat) are being investigated at Langley Research Center and definite alterations are indicated. (No space-borne experiments have been done on colonial morphology.)

Concurrent Research -

Identical bacterial culture modules for ground control will simulate launch and recovery stresses, and inflight temperature profiles with and without simulated zero g.

2. EXPERIMENT DESCRIPTION

a. Test tubes containing nutrient broth and semi-solid agar will be inoculated immediately pre-flight with E. coli or other suitable bacterium. The test tubes will be placed in the balsawood 6 x 6 x 6 in. module compartments in racks and refrigerated until launch. The balsawood compartments will be sealed into the E. coli module just prior to launch.

b. In-orbit automatic temperature control will be actuated and raise the module's internal temperature to 37°C. This procedure initiates the experiment.

c. At hourly intervals thereafter automatic photographs will be taken of the cultures growing in semi-solid agar; automatic optical densitometer measurements will be taken of the broth cultures every 15 min for the first hour and every hour thereafter.

d. Photographs will be returned to earth for post-flight analysis and comparison with controls.

e. Optical densitometry readings will be recorded by the spacecraft and telemetered for ground-based analysis.

f. Experiment duration will not exceed 48 hours, and crew involvement is limited to destruction of the cultures by sterilization and storage of the film pack upon completion of the experiment.

LIFE SUPPORT AND PROTECTIVE SYSTEMS RESEARCH PROGRAM EXPERIMENT DESCRIPTIONS FOR SKYLAB B

TITLE: 4-101 - Nucleate boiling

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems, Nucleate Boiling

NASA Specific Objective - To develop thermal techniques for environmental thermal control life support system including the provision of thermal energy in reclamation processes, removing and rejecting waste heat from the EC/LS subsystems and the electronic and experimental equipment.

The basic objective of this experiment is to study the effect of gravity on incipient and nucleate boiling from a variety of surfaces submerged in a liquid at varying conditions of gravity, heat flux, and orientations. Data on low-g nucleate boiling is necessary in order to design boiling heat transfer equipment in as much as this process is common to virtually all of the life support components and systems with phase change processes.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.1.1.1.1.2	Atmosphere Supply Heat Transfer Problems
1.1.3.1.1.1.3.1	Cryogenic Storage Thermodynamic Considerations
1.1.3.1.1.1.3.8	Kinetic and Dynamic Characteristics of Cryogenic Bubbles
1.1.3.3.2.2.2	Fluid Transport Systems
1.1.3.4.2.2.1.1	Boiling Heat Transfer Problems in Air Evaporation Processes

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

This experiment should be one of the first Life Support and Protective Systems experiments as it provides data needed for virtually all life support components and systems with phase-change processes.

Concurrent Experiments -

4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Nucleate boiling tests in a pool bubble tank to verify theory.

2. EXPERIMENT DESCRIPTION

This experiment consists of evaluation and confirmation of theory regarding the processes involved in nucleate boiling under zero-g conditions. A variety of geometric surfaces immersed in a liquid will be heated at various flux levels and incipient boiling observed.

Nucleate boiling research relates to the broad objectives for development of technology for highly reliable systems to support and protect man and enhance his capability to perform spaceflight operations, and is applicable for developing life support systems for long-duration missions which are essential to lower-cost centralized earth-orbiting bases, long-duration specialized stations, and lunar and planetary exploration vehicles.

This experiment will provide basic data necessary to design and qualify efficient and practical life support equipment which rely on boiling heat transfer as an integral process. The research results will take the form of heat fluxes versus heating element temperature at varying pressures and accelerations. Additionally, movie film records will provide data on bubble generation, breakoff, and motion which are essential to the satisfactory solution of phase separation problems in very low-g equipment.

A tank, 2 feet in diameter and 2 feet tall, with transparent sides, is filled with a liquid. At the tank bottom are several shaped surfaces (sphere horizontal plate, thin tall plate, etc.) imbedded with electric heaters. A spring-held porous membrane at the top of the tank separates the ullage (gas) space from the liquid. In the tank are also a digital timer and a scale. A TV/cine camera is used to record the bubble formation and activity as the surfaces are heated. The field is illuminated by a 100-w bulb back-lighting a screen. A schematic is shown in Figure 1.

The experiment is conducted at each selected g level. The surface to be tested is heated, the start of bubble formation, number of bubbles, bubble size and velocity, g level and direction, surface temperature, liquid temperature and pressure are all noted.

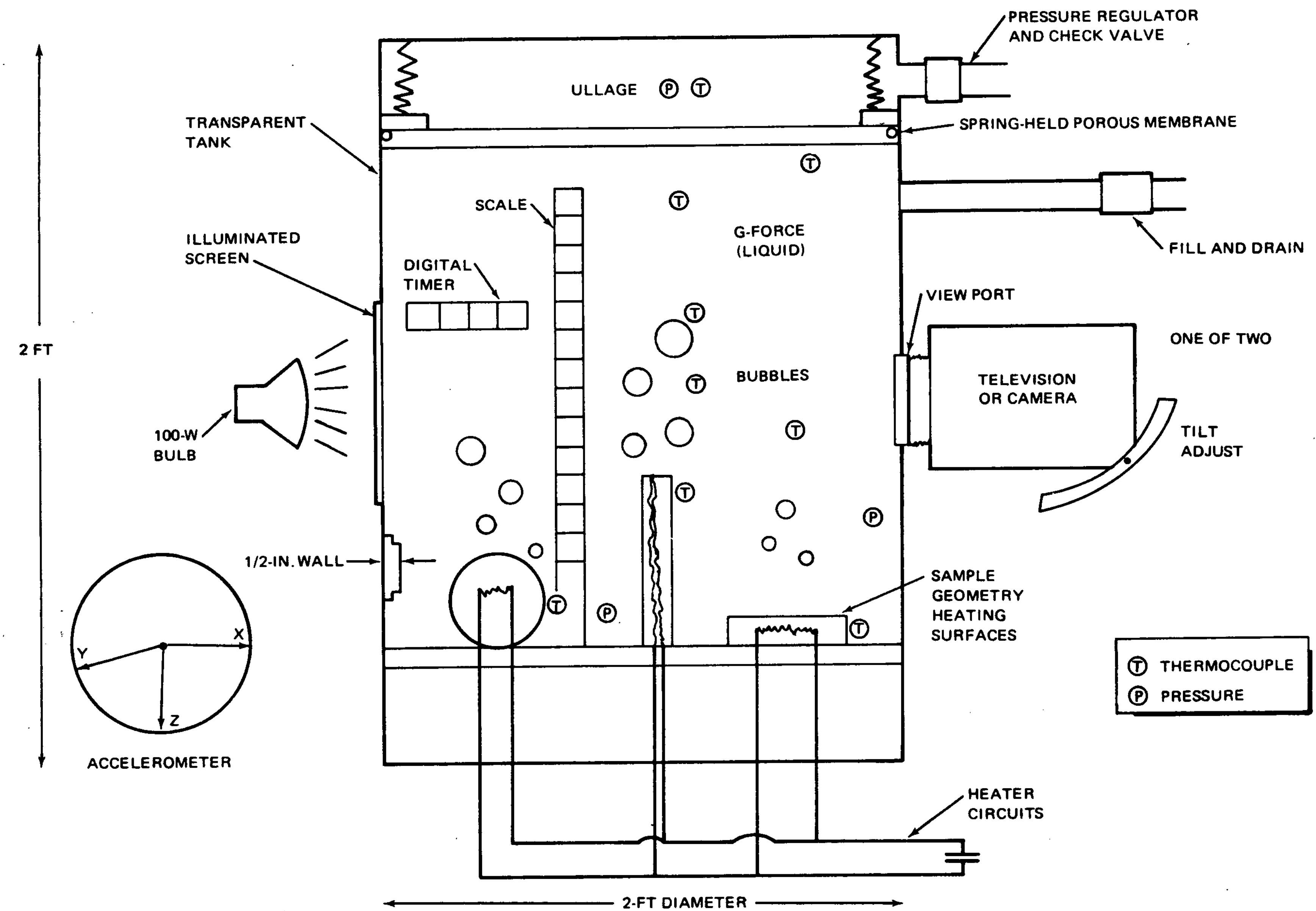


Figure 1. Bubble Tank

TITLE: 4-102 - Flow regime characteristics

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for providing and removing thermal energy from fluid flows in environmental control and life support systems and electronic and experimental equipment.

The object of the experiment is to examine and verify the theory relating to the various flow regimes occurring in a tube occupied by a two-phase fluid subject to adiabatic or diabatic conditions at low-g levels. The alteration of the accepted flow regimes (bubble, plug, stratified, spray annular and mist) will have a profound effect on heat transfer component design. The relation of the dimensionless groups Froude, Weber and Bond to the Baker plots will be established to better define the regimes of liquid/gas interface behavior. The relative importance of gravity, inertia and surface tension can thus be correlated to provide a better understanding of multi-phase fluid flows in life support and and protective systems in the zero-g environment. Data obtained from this experiment are essential for the proper design of virtually all life support subsystems and components.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.1.1	Atmosphere Supply
1.1.3.1.1.1.3.7	Interface Phenomena of Liquid-Gas Systems
1.1.3.1.1.2.2.1.1	Heat Transport Problems in Sabatier Reactor
1.1.3.4.2.2.1.3	Mixing Characteristics of Fluids for Air Evaporation Processes

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

4-101 (Nucleate boiling)
4-103 (Convection heat transfer)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Establishment and limited verification of theory describing flow regimes at varying g levels. Also, the development of reliable fluid quality measurement device.

2. EXPERIMENT DESCRIPTION

This experiment seeks to confirm the theoretical predictions of the onset of various two-phase fluid flow regimes in a tube or channel subject to a low-g environment. A two-phase fluid will be passed through a conducting passage and the onset of the flow regime will be observed for varying sets of environmental conditions.

A set of transparent tubes of varying dimensions will be fed with a liquid and/or vapor. The tube wall temperature will be regulated via heaters or coolers and the flow regimes observed for varying conditions of flow rate initial mixture quality, temperature, pressure, heating conditions, g level, and direction. Both visual and TV/cine camera recordings will be made of the flow regimes and the data noted. The nature of the research is such that the observations must be subject to an in-depth evaluation at a later date.

TITLE: 4-103 - Convection Heat Transfer

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To obtain representative convective heat transfer data adaptable to dimensionless relationships for use in predicting convective heat transfer coefficients between equipment and cabin atmospheres, cabin walls and cabin atmospheres, and crewmen and cabin atmospheres.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.2.3.3.2	Heat Transfer Problems in Humidity Control
1.1.3.8	Integrated Life Support Systems
1.1.3.3.2.1	Active Thermal Control Heating Systems
1.1.3.3.1.2.2.1	Mechanism and Material Research with Respect to Variable Surface Insulation

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-102 (Flow regime characteristics)
4-106 (Diffusion convection)
4-108 (Film stability and transport)

Concurrent Experiments -

4-104 (Advanced fluid storage and management)
4-112 (Water condenser-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space station simulator.

Concurrent Research -

Control test in a manned space station simulator.

2. EXPERIMENT DESCRIPTION

Flatplate, cylindrical, and spherical surfaces are to be provided with controllable surface temperatures and heat flux capabilities.

A means of controlling gas velocities in the vicinity of these surfaces is to be provided. Heat fluxes, temperature profiles on the surfaces and in the adjacent gas stream, and gas velocities will be measured. The experimental subsystem will be selected and instrumented so that during the course of testing subsystem meaningful convection heat transfer data can be obtained.

A suitable portion of the vehicle's cabin wall will be instrumented so that convective heat transfer data can be obtained. This experiment is extremely sensitive to vehicle accelerations, so it is required that a range of low-level accelerations be imposed on the vehicle during the course of this testing.

C

TITLE: 4-104 - Advance cryogenic fluid storage and management

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for long-term cryogenic storage of oxygen and nitrogen for life support system application.

The experiment is used to verify the flight performance of cryogenic storage in a zero-g and low-g (intermittent) space environment at fluid use rates required for life support system applications. Another objective is to better understand the heat transfer, fluid stratification and liquid/vapor interface problems in controlled low-g environments at various fluid extraction rates (including zero flow).

The research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.1.1.1.3	Cryogenic Storage
1.1.3.3.1.1.1.1	High Vacuum Convective Heat Transfer Measurements
1.1.3.3.1.1.3.1	Heat Path Characteristics of Conduction Insulation

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

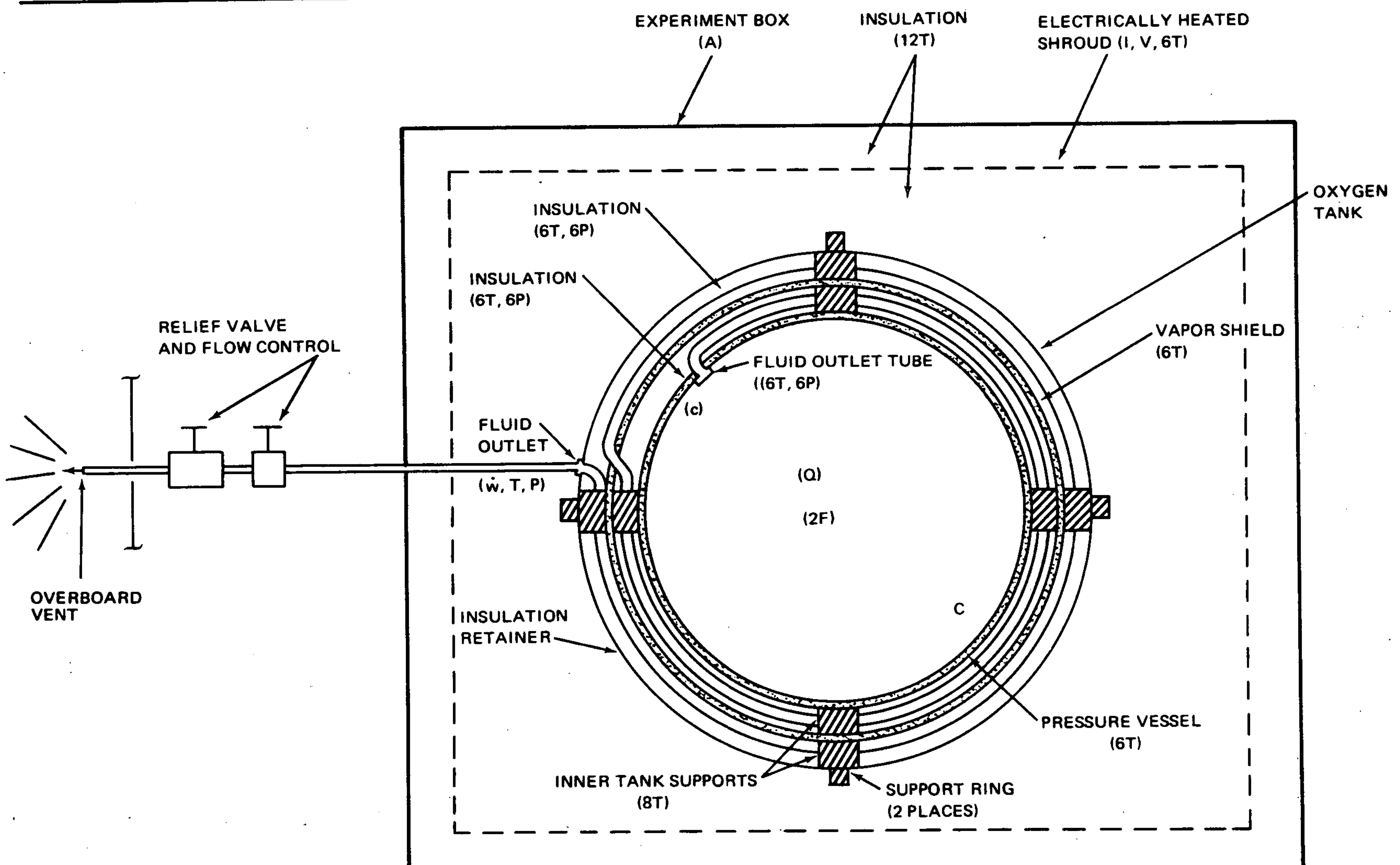
Concurrent Research -

Control experiment in a research laboratory.

2. EXPERIMENT DESCRIPTION

The experiment consists of a 3-ft-diameter liquid oxygen tank sized to provide 700 lb of fluid, which is sufficient for three men at 7 lb/day for 90 days with approximately 10 percent reserve. The tank is designed to hold fluid for 2 years with either a constant use rate, or no flow, as would be typical of a N_2 leakage-makeup, or an O_2 repressurization system for interplanetary application, respectively. The other extreme is a 20 lb/hr flow rate, which simulates a repressurization cycle.

The tank is vented overboard through a controllable relief valve and flow regulator to maintain suitable tank-pressure and flow rates. A schematic of the experiment is shown in Figure 1. The tank is enclosed in an insulated box with an electrically heated shroud to provide controlled tank wall temperatures. The box is located in a low-temperature region of the spacecraft (0^oF or colder). The most difficult problem is measuring the location of the liquid/vapor interface under various heating, acceleration, and drain rate conditions. This is accomplished with a radio frequency (rf) device, liquid-vapor indicators, and TV cameras. The electrically heated shroud is used to provide controlled tank wall temperatures. Tank acceleration is calculated for low values below the sensitivity of available accelerometers.



ẇ – FLOW
T – TEMPERATURE
P – PRESSURE
Q – FLUID QUANTITY (rf)
F – LIQUID/VAPOR INDICATOR

I – CURRENT
V – VOLTAGE
C – TV CAMERA
A – ACCELEROMETER

Figure 1. Advance Fluid Storage and Management System Schematic

TITLE: 4-105 - Water electrolysis system

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for the electrolysis of water.

The experiment will be used to verify the flight performance of the most promising concepts which have been proved previously in integrated system tests in manned space station simulators.

The basic objective of this experiment is to test the performance characteristics of the liquid-feed water-electrolysis unit for spacecraft life support systems and to verify its operation for long durations in zero-g environment. The alkaline electrolyte used in the liquid-feed water-electrolysis unit consists of potassium hydroxide. The potassium hydroxide is circulated between the dual asbestos matrix of the water-electrolysis cell and is cooled by a heat exchanger that is external to the cell. The electrolyte temperature can be regulated with the external heat exchanger and thus the water vapor content of the oxygen and hydrogen gases generated in the cell can be controlled. In addition, circulation of the electrolyte minimizes concentration polarization and also decreases the time required to reach steady-state operation after either start-up or adding makeup water to the electrolyte.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.1.1	Atmosphere Supply
1.1.3.1.1.2.2.2	Water Electrolysis
1.1.3.5	Waste Management

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condenser-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space cabin simulator.

Concurrent Research -

Control test in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

The liquid-feed water-electrolysis system will be a single unit supported by a gas chromatograph, mass spectrometer and the instrumentation necessary to determine the operational characteristics of the system. The experiment will include power regulation and controls, water feed supply, heat transport loop and effluent gas storage tanks for continuous operation of the liquid-feed water-electrolysis system.

The liquid-feed water-electrolysis cell consists of a housing and matrix screen spacers that are cast from an epoxy resin. The dual matrix located on either side of the electrolyte pocket consists of fuel cell asbestos sandwiched between a nickel matrix support screen and a fuel cell electrode. Nickel electrode support screens and electrical leads are spot-welded to the electrodes. The electrical lead is nickel sheet cut in a picture frame configuration and spotwelded around the edge of an electrode. The modules are sealed with O-rings and are fastened together by end plates and bolts. The electrodes from adjacent cells are supported by four intercell spacers. A liquid level sensor in the electrolyte reservoir located external to the cell provides the signal for adding makeup water to the module when it is in operation. A differential pressure controller maintains the pressure in the gas manifolds higher than the electrolyte pressure to prevent the electrolyte from passing through the matrix and into the gas manifolds.

The water electrolysis system includes a reservoir and potassium hydroxide fill connector, storage tanks for the effluent gases, circulation pumps, oxygen vacuum pump and pressure and flow control valves as shown in Figure 1. In addition, an ion exchange membrane is included for purification of the input water and a heat exchanger is included to permit regulation of the electrolyte temperature and the water vapor content of the effluent gases.

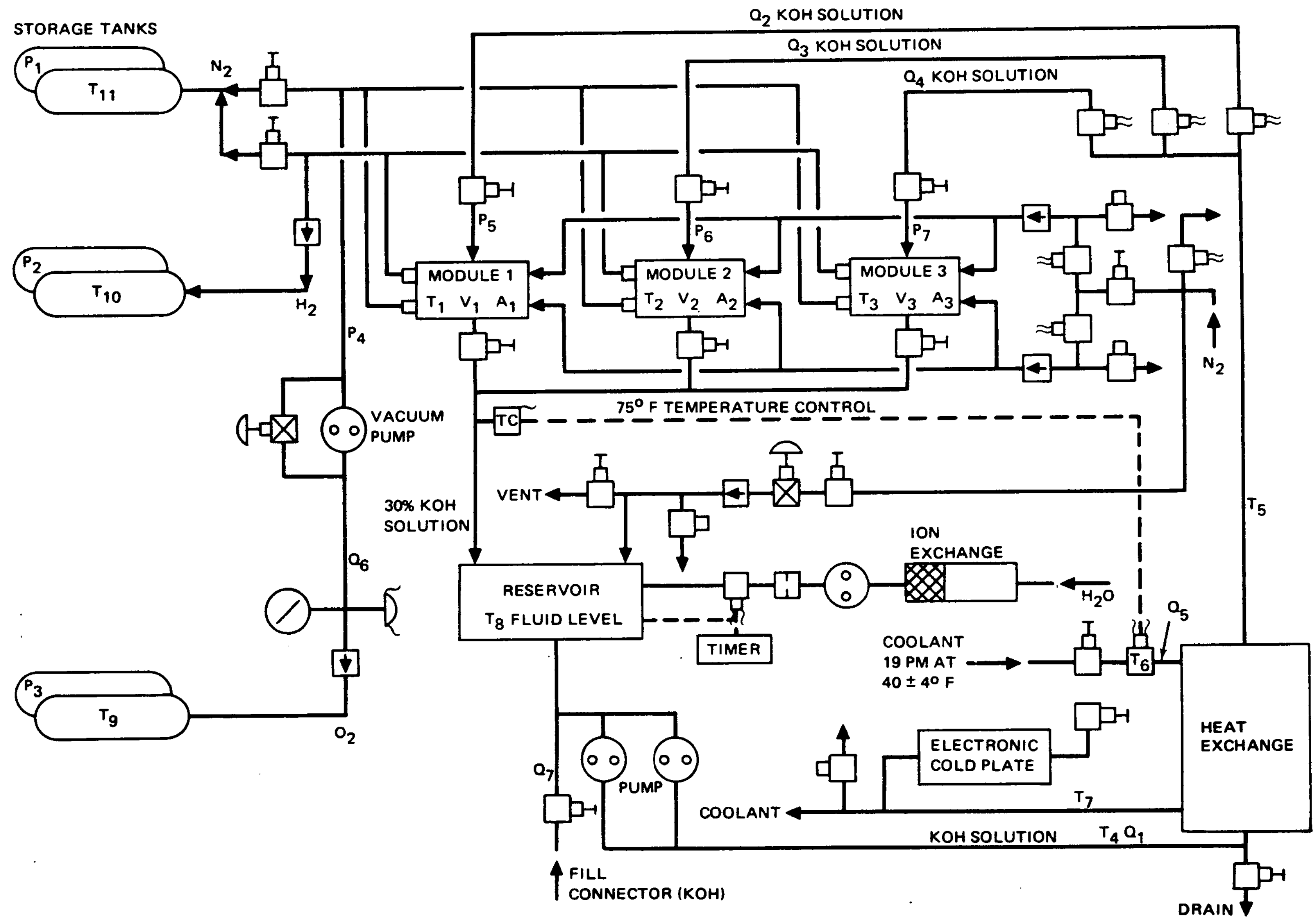


Figure 1. Three-Man Water Electrolysis System

TITLE: 4-106 - Diffusion convection

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective -

a. To develop techniques and hardware for maintaining the carbon dioxide, humidity and contaminant characteristics of the cabin atmosphere within acceptable limits.

b. To develop techniques and hardware for the reclamation and sterilization of potable water from waste water.

This experiment will be performed to verify the analytical models* describing the phenomenological behavior which characterizes a process stream in which diffusive and convective mechanisms dominate such as in a humidification/dehumidification process. Diffusion convection is primarily defined by the parameters relating to the evolution of diffusion in a convection medium where co-current and counter-current diffusion may exist with the single or two-component diffusion as an uncertainty.

The verification for a variety of space test conditions will provide the basis for the design and development of hardware utilized in a cabin air humidification/dehumidification system as well as in other life support subsystem processes which depend on controlling the vapor content of a gas stream such as in vapor diffusion stills, electrodialysis, air evaporation and carbonation cell units.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.1.2	Cabin Atmosphere Pressure Control
1.1.3.2	Atmosphere Purification and Control
1.1.3.2.2	Trace Contaminants
1.1.3.1.1.2.1	Carbon Dioxide Decomposition
1.1.3.4.2	Water Management Reclamation
1.1.3.7.1.2	Atmosphere Contaminants Control

*Reference: Gravity-Sensitivity Assessment Study, General Dynamics-Convair Final Report, Contract NAS1-8494, 1970.

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space cabin simulator.

Concurrent Research -

Control test in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

The proposed experiment is performed to verify the analytical models describing the diffusion/convection processes involved in a humidification/dehumidification stream. A processed air/vapor mixture is passed through a porous plate condenser which separates the water from the air stream. Observations are made of the liquid/vapor interface for a variety of test conditions.

The experimental hardware consists of an air blower, a plenum, a humidity source (water-injection nozzles), three plexiglass working sections containing a porous plate condenser/vaporizer, cooler/heater assembly and water collector. Each section has a varying geometry but all are fed from the same plenum. The exiting processed air is mixed with the recycled cabin air while the collected condensate is recycled to the water-injection section. The system is shown in Figure 1.

The test will consist of running the humidifier/dehumidifier system at a variety of flow rates, heat additions, geometries and g levels and directions, and observing system performance. The behavior of the gas/liquid interface in the porous plate will also be observed.

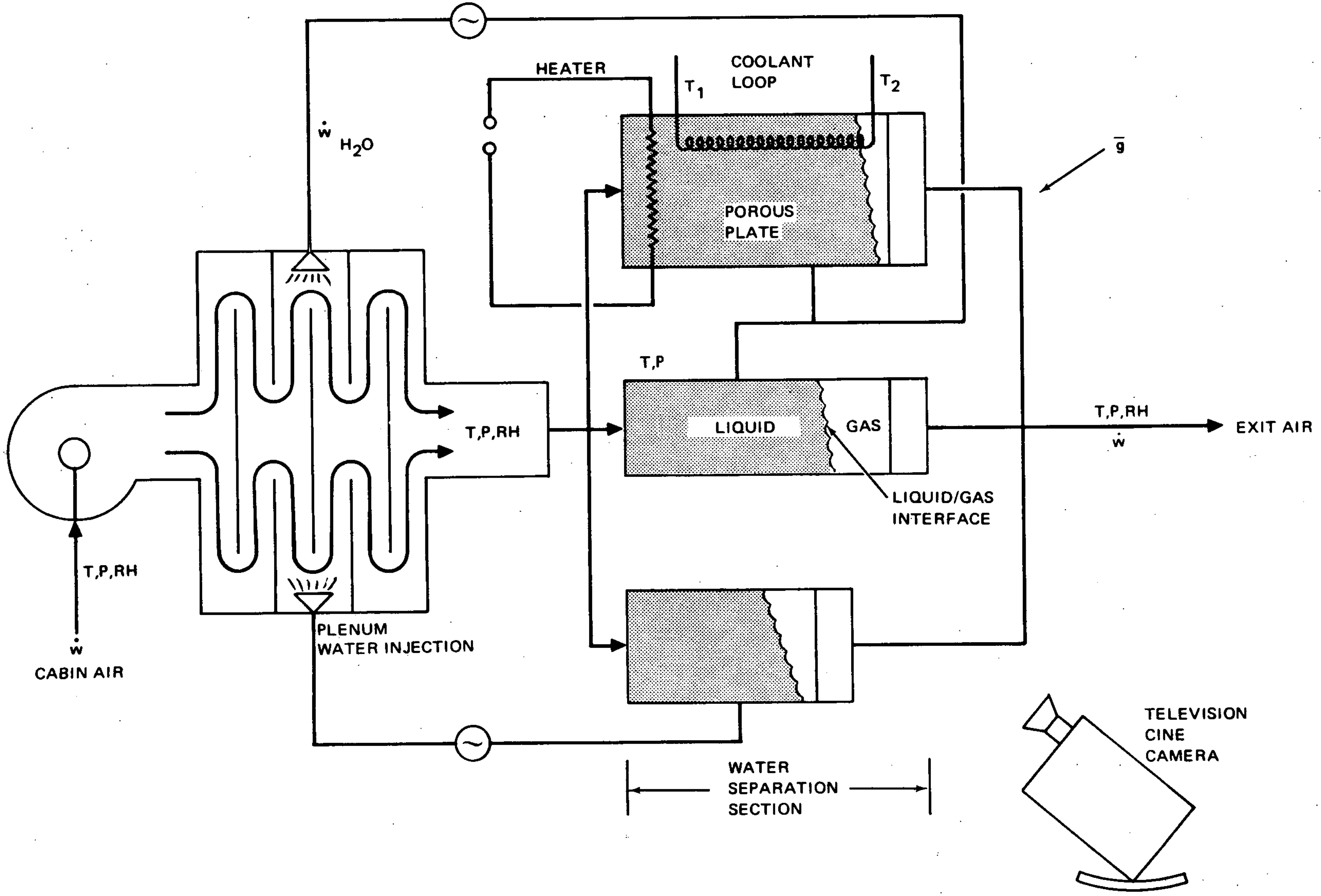


Figure 1. Diffusion Convection Test

TITLE: 4-107 - Inertial separation

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - This experiment will be used to examine the behavior of liquid dispersions in a gas stream as related to the development of techniques and hardware for reclamation and sterilization of potable water from waste water, such as urine, wash water, and humidity condensate.

This experiment investigates and confirms the predictions of the analytical models* with respect to the behavior of the liquid gas components of mixed phase transport and separation processes.

The life support system processes frequently involve hardware for the separation of two-phase liquid/gas mixtures. The problem is intensified in the absence of a steady-g force, hence zero-g separation must be employed. The analytical models proposed for two processes (1) hydrophobic screens, and (2) centrifugal separation must be verified in extended zero-g tests prior to the development of reliable and efficient hardware subsystems.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.3.2.1.1.1.4	Liquid/Solid/Gas Separation Devices in Heat Storage Systems
1.1.3.3.2.2.1.2.1.3	Liquid Gas Separators in Condensing Radiator Systems
1.1.3.4.2.2.1.4	Gas Liquid Separating Device in Air Evaporation Process
1.1.3.2.4.2.3.1	Aerosol Centrifugation Subsystems

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-108 (Film stability and transport)

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*Reference: Gravity-Sensitivity Assessment Study, General Dynamics-Convair Final Report, Contract NAS1-8494, 1970.

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Establish theoretical models, computer analysis, limited concept component hardware design.

Concurrent Research -

Short-duration zero-g testing of concepts.

2. EXPERIMENT DESCRIPTION

The purpose of this experiment is to verify two models postulated for separation of liquid/gas mixtures, hydrophobic screens, or mechanical centrifuge. The experiment will determine the efficiency of separation subject to a variety of parameters including gravity, droplet size, gas velocity, screen characteristics, pressure drop, etc.

The test rig consists of a gas blower, a spray chamber for the injection of liquid droplets with thermal control components, and two test sections which are used alternately to test hydrophobic screens and the centrifuge process (Figure 1).

The experiment procedure will consist of introducing the gas (air) into the blower which leads to the spray chamber. Cooling and heating elements regulate the temperature. Liquid injectors of varying hole size are used to introduce the liquid droplets into the gas stream. The two-phase mixture enters a short duct section where the flow is developed. It is then diverted into one of two desired test sections. The hydrophobic screen section will involve testing with varying pore size and screen angle, while the centrifuge will test funnel rotation rate and geometry.

A TV camera will be used to record droplet size, screen retention buildup, and centrifuge film buildup.

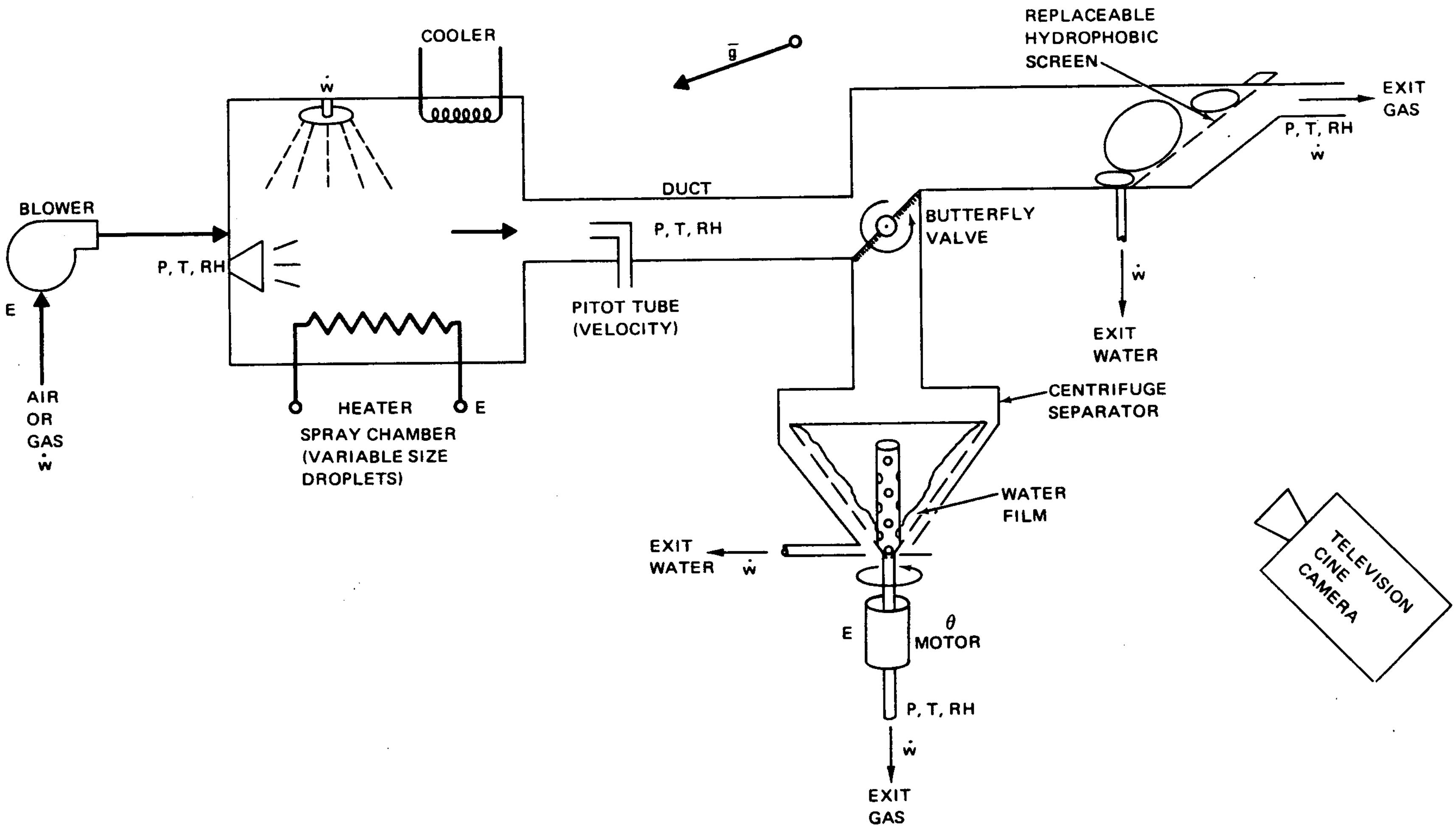

Figure 1. Inertial Separator Test

TITLE: 4-108 - Film stability and transport

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for providing thermal energy used in reclamation processes, removing and rejecting waste heat from the cabin atmosphere, EC/LS, electronic, and experimental equipment.

The objective of this experiment is to augment and confirm the theory relating to film stability associated with flow in tubes and contained volumes where a gas/liquid interface exists and mass transfer takes place. The behavior of the film influences the degree of mass transfer hence the design of hardware components utilizing two-phase flow. Since the EC/LS utilizes two-phase flow repeatedly in the subsystem process, an understanding of the basic phenomena under zero-g conditions is necessary to ensure reliable, optimum design. What is involved is the liquid-film stability under two sets of conditions: (1) transport of film along a flat surface dominated by interfacial gas/liquid shear forces, and (2) transport on a conical surface dominated by liquid surface effects (wetting).

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.1.1.1.3.7	Interface Phenomena of Liquid-Gas Systems for Cryogenic Storage
1.1.3.1.1.2.2.2	Water Electrolysis
1.1.3.2.3.3	Humidity Condensation/Separation
1.1.3.3.2.2.1.2.12	Configurations for Condensing Space Radiators
1.1.3.4.2.2.12	Flow Regimes in Air Evaporation
1.1.3.5.1.1.1	Phase Separation and Liquid Flow Characteristics Urine Collection System

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

4-101 (Nucleate Boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-106 (Diffusion convection)
4-107 (Inertial separation)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Development of theoretical relations, computer programs, and limited laboratory experiments.

2. EXPERIMENT DESCRIPTION

This experiment is proposed to verify the theoretical equations* relating to the film stability and mass transport associated with two-phase flow condensing and boiling processes. It consists of observing the film formation and behavior on surfaces for varying conditions.

The film stability and transport test unit shown in Figure 1 consists of the following: a gas blower, a gas conditioner plenum , a flow diverter and two alternately used test sections; one is a clean lucite channel containing a flat porous plate through which liquid seeps at a controlled rate and over which the gas passes at a controlled velocity. The second test section consists of a lucite funnel with liquid introduced from a ring injector. The gas, at a controlled velocity enters the wide end of the funnel and passes through. A variety of gases and liquids will be used and the behavior of the film will be observed via recording sensors, film, and direct viewing. The funnel shapes will be altered by replacement geometries.

The g magnitude and direction will be recorded for both steady-state and transient vehicle control conditions.

*Reference: Gravity-Sensitivity Assessment Study, General Dynamics Convair Final Report, Contract NAS1-8494, 1970.

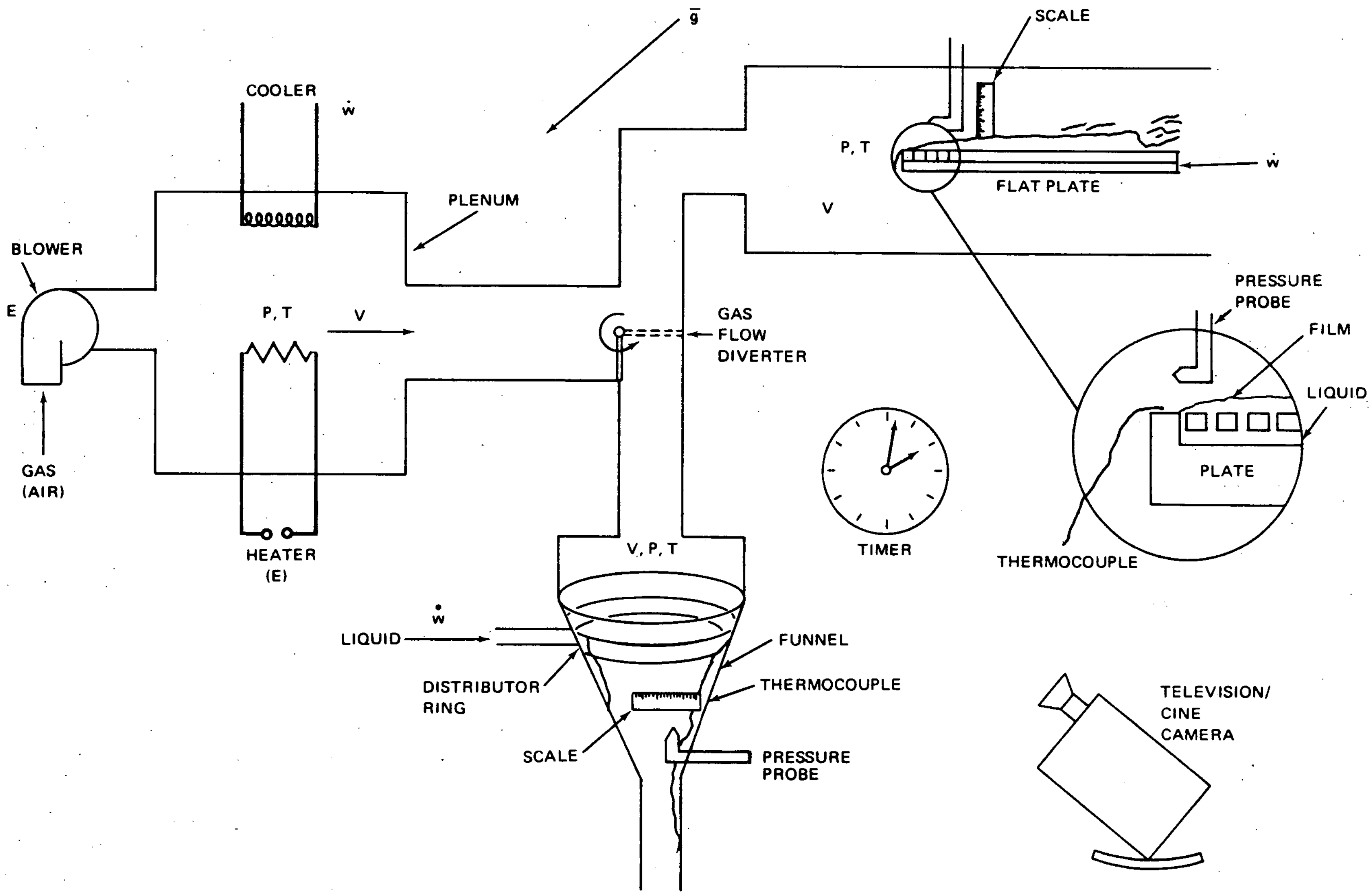

Figure 1. Film Stability and Transport

TITLE: 4-109 - Hydrogen-depolarized carbonation cell CO_2 collector

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for maintaining the CO_2 concentration of the cabin atmosphere within acceptable limits.

The basic objective of the experiment is to test the performance characteristics of a carbonation cell CO_2 collector subsystem for spacecraft EC/LS systems; also, to verify its operation for long durations in a zero-g environment. Carbonation cells are electrochemical devices which promise significant potential savings in weight, volume, and power requirements over other CO_2 collectors, as well as more simplicity in handling and operation.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.2.1 Carbon Dioxide Atmosphere Purification and Control

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments:

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condenser-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Long-life performance tests of carbonation cells.

Concurrent Research -

Control test of carbonation cells as a part of an integrated life support system in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

The carbonation cell CO_2 collector will be a single hardware unit supported by a gas chromatograph and a mass spectrometer. Separation of CO_2 from cabin air for further processing and recovery of O_2 will be accomplished by an electrochemical process; the cells used will consist of porous electrodes separated by asbestos capillary matrices which contain an electrolyte such as K_2CO_3.

When the carbonation cell CO_2 collector is being tested, it will replace the Skylab B baseline CO_2 collection unit. Air will be supplied to the carbonation cells from downstream of the spacecraft humidity control unit. A heat exchanger, with hot transport fluid and independent temperature control, will be provided to control the temperature of the air entering the test device.

The carbonation cell CO_2 collector will be operated continuously for one crew cycle. Data collection will be wholly automated.

A system schematic of a carbonation cell CO_2 collection unit is shown in Figure 1. The system is composed basically of three cells staged such that the output from each stage is processed further by the following stage. Cabin atmosphere is drawn by the blower through a water vapor exchanger where it picks up both moisture and heat from the return gas processed in Cell I. The moisture-laden atmosphere is routed from the water vapor exchanger to Cell I, where it is stripped of most of its CO_2, and then returned to the opposite side of the water-vapor exchanger. More heat and water are extracted from this return gas in a condenser/water separator before it is routed back to the cabin. Water collected by the water separator is fed into the H_2O feed tank. Further concentration of CO_2 is achieved in Cells II and III. CO_2 can temporarily be stored in the accumulator before its processing in a CO_2 reducer. Some residual hydrogen may be found in the CO_2 concentrate; however, this hydrogen contamination is not detrimental if CO_2 reduction is to be done in a Sabatier or Bosch unit. Some carbonation cells do not include the introduction of hydrogen for their operation. However, excluding hydrogen results in a high electrical power consumption for the unit. The process diagrammed is more attractive insofar as the unit acts partially as a fuel cell in combining hydrogen and oxygen, and a proportional amount of electrical engergy is produced in the reaction.

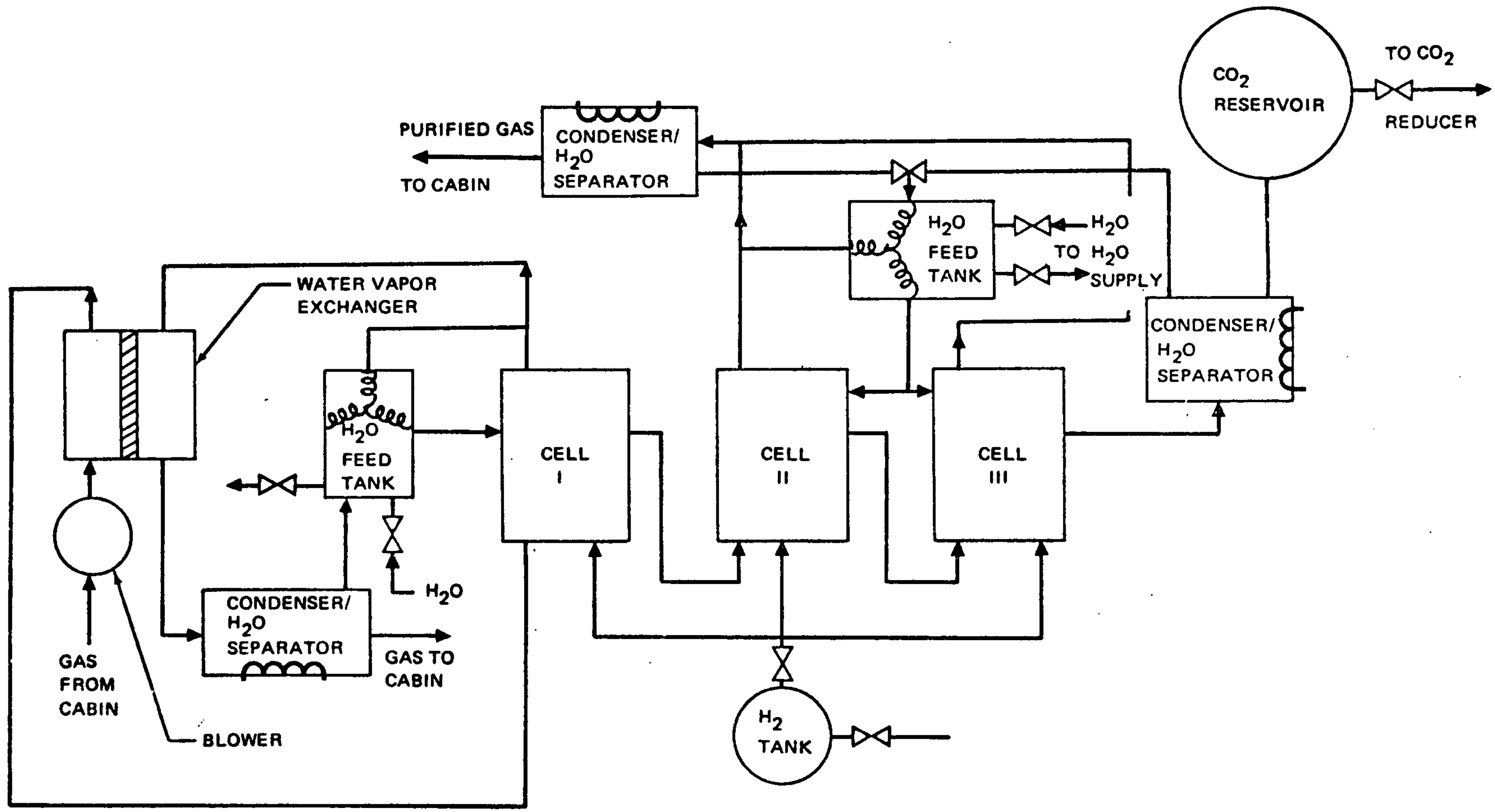

Figure 1. Carbonation Cell CO_2 Collector

TITLE: 4-110 - Advance control and monitoring of microbial levels in life support systems

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop the instrumentation for monitoring and controlling the chemical and microbial contaminant levels, and septum functions to ensure a safe, comfortable, and efficiently operated habitable spacecraft. The experiment will be used to verify the flight performance of the most promising concepts which have been proved previously in integrated system tests in manned space station simulators.

The basic objective of this experiment is to test the performance characteristics of microorganism control and monitoring equipment for use in spacecraft life support systems; also to verify its operation for long duration in a zero-g environment. This experiment will utilize a number of promising concepts for monitoring and controlling microorganisms in the spacecraft environment. Water potability testing as well as air testing are considered. The equipment will attempt to identify the quantity of contamination in as short a time period as possible. Techniques considered applicable for this experiment include (1) millipore field monitoring, (2) ATP bioluminescence monitoring, (3) FMN bioluminescence monitoring, (4) fluorescence, (5) phosphorescence, and (6), all specifically applicable to water potability monitoring.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Progeam and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.4 Water Management
1.1.3.4.1.2 Chemical Preservation
1.1.3.4.1.3 Pasteurization
1.1.3.2.2 Trace Contaminants
1.1.3.7.1.4 Biological Control

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Concurrent Experiments -

4-112 (Water condensor-separator characteristics)
4-114 (Reverse osmosis water recovery system)
4-115 (Vacuum drying waste management system)
4-116 (RITE waste management system)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space cabin simulator.

Concurrent Research -

Control test in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

Numerous techniques are presently being investigated to rapidly determine the quantity and type of microorganisms found in reclaimed water. Other methods are being developed for determining the biological contamination in air streams, on equipment surfaces and on personnel. This experiment will consider the monitoring and control of microorganisms found in reclaimed water by the methods described in the following:

1. ATP Bioluminescence Monitoring

   This procedure utilizes the bioluminescence of the firefly enzyme (luciferase) when reacted with the adenosine triphosphate (ATP) that is found in contaminated water to determine the degree of water contamination. The firefly enzyme reaction mixture is prepared in advance and stored for future use. A small quantity of the enzyme is mixed with a sample of the suspect water in a cuvette. A photocell is used to measure the intensity of the light produced by the reaction of the firefly enzyme with the ATP.

2. FMN Bioluminescence Monitoring

   This procedure involves the flavin mononucleotide (FMN) luciferase reaction carried out by photobacteria. FMN in reduced form is specifically required for bacterial luminescence in vitro, but not in firefly luminescence. The same type of apparatus developed for the ATP method is used for the FMN assay. Backterial luciferase catalyzes the reaction of reduced FMN and a long-chain aldehyde, in the presence of oxygen, to produce light, which is detected by a photomultiplier tube and measured on an oscilloscope. The light intensity is directly related to the concentration of reduced FMN. The reaction is also very rapid (peak light response in 1 sec) and sensitive (down to 10 picograms of FMN). FMN has an advantage over ATP in being more stable chemically and in higher concentration in spores than the latter.

3. Phosphorescence

Phosphorescence assay has been developed recently that is specific for identifying microorganisms. In this method microorganisms or their components phosphoresce under ultraviolet radiation. At a fixed optimal wavelength, this phosphorescence exhibits decay characteristics which last up to 30 sec. A computerized analysis of this decay produces a linear logarithmic plot of emission intensity versus time, resulting in a signature readout that is characteristic of an organism and can differentiate one strain from another.

4. Gas Chromatography

Analysis of the end products of metabolism by gas chromatography to detect and identify various strains of bacteria has been accomplished. This method employs two highly sensitive detectors, electron capture, and flame ionization. The method requires injection into the chromatograph of a microsample (3.0 μl) of extract (1.5 μl for each detector) and results in a signature of chromatographic peaks of various volatile compounds that, like phosphorescence, can differentiate between one strain and another. The method is very sensitive detecting down to 5 picograms of diacetyl and 22 picograms of acetone with the electron capture detector.

TITLE: 4-111 - Comfort zone and cabin air distribution evaluation

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To obtain scientific and subjective data pertinent to the physiological and thermodynamic characteristics of crewmen performing at a range of metabolic rates. The thermodynamic characteristics of the crewmen's environment with variations in the ventilation system operating conditions will also be measured. Space station comfort criteria will be established from these data .

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1. 1. 3. 8 Integrated Life Support System
1. 1. 3. 3 Thermal Control
1. 1. 3. 2. 3 Humidity
1. 1. 3. 1. 2 Cabin Atmosphere Pressure Control

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-103 (Convection heat transfer)
4-106 (Diffusion convection)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space station simulator.

Concurrent Research -

Control test in a manned space station simulator.

2. EXPERIMENT DESCRIPTION

The crewmen will be tested for comfort data at selected metabolic levels and with selected clothing variations. Required metabolic levels will be obtained through use of an ergometer or other suitable exercise device. The test area will satisfy the requirements of Paragraphs 4. 3 and 4. 4. Variations in the thermodynamic environment due to wall and other surface temperatures, atmosphere temperatures and velocities, and humidity will be imposed on the tested crewmen. Crewman temperatures, oxygen consumption, clothing temperatures, environmental temperatures, gas velocities, and humidity will be measured. These data will be subsequently used in a computer program which models the test setup, including the crewmen and the environment, to determine transient heat storage data. These data will be used in establishing comfort criteria.

4. SUPPORT REQUIREMENTS

4.1 MISSION REQUIREMENTS

None.

TITLE: 4-112 - Water condenser/separator characteristics

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Spectific Objective - To develop techniques and hardware for maintaining humidity and for heat transfer, condensation and gas/liquid separation functions in life support systems.

The basic objective of the experiment will be to test and evaluate the most promising advanced condenser/water separator units. The condensation process usually involves the removal of heat from the vapor mixture by heat exchangers or gas expansion mechanisms, followed by the separation of liquids from the gas phase. Candidate condenser/separator units, under various degrees of development, include the following:

a. Condenser with hydrophobic/hydrophilic separators

b. Condenser with wick separator

c. Condenser with porous plate separator

d. Condenser with membrane separator

e. Condenser with mechanical spin separator

f. Condenser with elbow or baffle separators

g. Condenser with vortex separator

h. Condenser with electropheresis

Liquid/gas separation applications are encountered in the following life support system applications:

a. Thermal and humidity control systems

b. CO_2 reduction systems

c. CO_2 concentration systems

d. Electrolysis units

e. Water recovery systems

f. Waste water collection units

g. Crew washing devices

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.2.3.3	Condensation/Separation Humidity
1.1.3.3.2.2.1.2.1	Cooling Systems Condensing
1.1.3.3.2.2.2.2	Liquid/Gas Separation Problems in Condensers
1.1.3.4.2.16	Gas/Liquid Separation in Reverse Osmosis Water Recovery Units
1.1.3.4.2.2.1.4	Gas/Liquid Separation in Air Evaporation Processes
1.3.4.2	Reclamation

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Performance tests of condenser/water separators in integrated life support system tests in space cabin simulators.

2. EXPERIMENT DESCRIPTION

This experiment will evaluate three of the most promising advance types of condenser/liquid-gas separator units to be used in life support systems. Each one of the three units will be brought on stream and operated for a period of one month as a substitute to a baseline condenser/liquid-gas separator. The three units chosen for this experiment are described briefly below:

a. Condenser with Hydrophobic/Hydrophilic Liquid/Gas Separator

This unit incorporates a conventional-type condenser heat exchanger and a hydrophobic (non-wetting)/hydrophilic (wetting) liquid/gas separator. The moist gas stream contacts a conical-shaped screen, with the apex of the cone facing the gas stream, the screen cone is coated with a hydrophobic material. The free water droplets are deflected to the base of the cone while the gas flows through the screen. A hydrophilic sump is provided at the base of the cone around its circumference. A pressure differential maintained across the sump by a pressure-controlled pumping system transfers the water to storage tanks.

b. Condenser with Baffled Porous Plate Liquid/Gas Separator

This unit combines a conventional-type condenser heat exchanger with a baffled porous-plate liquid/gas separator. The separator also combines two separation principles: capillary, by the utilization of porous plates, and inertial, by the circulation of the moist gas stream through porous-plate baffles. A differential pressure, below the bubble point of the porous plate, is used to transfer the liquid to a sump provided with the unit.

c. Condenser with Elbow-Wick Liquid/Gas Separator

This unit also combines a condenser with a separator that employs both inertial and capillary forces to separate the liquid from the gas stream. As the gas enters the wick-lined 90-deg elbow the inertial forces direct the heavier water particles to the wicking where the capillary forces, under a pressure differential, transfer the liquid to a built-in sump.

For this experiment, two units of each of the three types listed above will be tested simultaneously for a period of 30 days. One of the two units will replace the Skylab B baseline humidity control system condenser/separator while the other, which is of a different size, will replace the oxygen recovery system condenser/separator. The purpose of using two units is to obtain performance data for both a high gas-to-liquid ratio unit (humidity control) and a low gas-to-liquid ratio unit (oxygen recovery). The process streams will be routed to each of the units tested. Coolant fluid will also be supplied to each of the two units. After the 30-day test period is completed the two units under test will be disconnected and replaced with the two units of a different type to be tested in the following 30-day period. Data collection will be wholly automated.

TITLE: 4-113 - Spillage handling and recovery

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

FIELD - Life Support and Protective Systems

NASA Specific Objective - To develop technically and esthetically acceptable techniques and hardware for handling, collection, and recovery of spilled fluids and solids within a space vehicle operating at reduced or zero g in order to ensure a safe and efficiently operated habitable spacecraft.

This experiment will be used to verify the flight performance of the most promising concepts which have been proved previously in integrated system tests in manned space station simulators.

The basic objective of this experiment is to test the performance characteristics of equipment for handling and recovery of fluid and solid spillage for spacecraft life support systems; also to verify its operation for a variety of materials that may be caustic, acidic, or contaminated, as well as noncontaminated materials. This equipment will be tested for its long-duration potential in the zero-g environment. This equipment will consist of regenerable filters, screens, blowers, vacuum pumps, sponges, brushes, etc. The specific combination of equipment most useful for the variety of materials to be handled, collected, and recorded will evolve only after considerable experience is gained in the reduced-g environment.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.7 Crew Protective System
1.1.3.7.1.1 Fire
1.1.3.7.1.2 Atmosphere Contaminants Control
1.1.3.7.1.3 Thermal Protection
1.1.3.7.1.4 Biological Control

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-102 (Flow regime characteristics)
4-104 (Advanced fluid storage and management)
4-107 (Inertial separation)
4-108 (Film stability and transport)

Concurrent Experiments -

4-112 (Water condenser-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Experiments -

Integrated system test of component in a manned space cabin simulator*.

Concurrent Research -

Control test in a manned space cabin simulator*.

2. EXPERIMENT DESCRIPTION

Numerous techniques are presently being researched to develop methods of handling spillage and recovering fluids and solids spilled. A wide variety of fluids such as water (both contaminated and uncontaminated), coolants, and chemical solution (caustic and acid) can be expected on future space vehicles. Solid and semi-solid materials can also spill and cause clogging of filters, injuries to eyes, noses, and mucous membranes of the mouth. No specific technique has been shown to be adequate for all types and quantity of spillage. Those being considered as most applicable include:

a. Vacuum system includes a suction pump, collection bag or chemical sorber, and filters and, when toxic or hazardous materials are being collected, some type of neutralizer to prevent corrosive action within the collection system. Potassium hydroxide, the electrolyte in a water-electrolysis system, is a typical example of a caustic and corrosive material that can cause problems in the compartment to equipment and structure as well as to the personnel and collection systems. After collection the spilled substance will be neutralized and then recovered or discarded from the collection bag, or the chemical sorber will be regenerated by heat or steam depending on the sorber and the material collected.

b. Sponge materials have shown some promise for collecting both large and small quantities of spilled fluid and solid materials. For toxic or corrosive materials the sponge towel or sheet is coated or saturated with a neutralizing agent. Recovery from the sponge material is less complete than in the vacuum system chemical sorber. Some materials can be removed by pyrolysis; others can be removed by liquid flushing, compression, and steam heating. In a limited number of cases the material spilled will be recovered without change. In most cases, the solids will be lost to waste and the liquids processed through the contaminated water purification system or discarded (depending on the hazard).

In all cases of material spillage it will be necessary to protect the crew with adequate garments and face masks. Insulated gloves,

*Limited value because of the 1-g condition in ground testing in a space cabin simulator.

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non-permeable coveralls, and non-conducting equipment should be included and evaluated as part of this experiment.

4. SUPPORT REQUIREMENTS

4.1 MISSION REQUIREMENTS

None.

4.2 EXPERIMENT SUBJECTS AND CONSUMABLES

Consumables include helium, hydrogen and replacement columns for the gas chromatograph.

4.3 EQUIPMENT AND MATERIALS

See Tables 4-25 and 4-27, Volume I, for details about the following: Handling and Recovery Equipment, Mass Spectrometer, Gas Chromatograph.

4.4 FACILITY REQUIREMENTS

Integration of experiment equipment with the baseline EC/LS system of the Skylab B. Venting to vacuum for the mass spectrometer.

TITLE: 4-114 - Reverse osmosis water recovery system

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for reclamation and sterilization of potable water from waste water such as wash water and humidity condensate.

The experiment will be used to verify the flight performance of the most promising concepts which have been proved previously in integrated systems tests in manned space station simulators.

The basic objective of this experiment is to test the performance characteristics of the reverse osmosis water recovery unit for spacecraft life support systems; also to verify its operation for long duration in a zero-g environment. The reverse osmosis unit is a compact water recovery unit which uses high pressure to force water from a solution through a semi-permeable membrane into a less concentrated solution. The semi-permeable membrane prevents the passage of solids and other contaminants including microorganisms. The use of this system is restricted to waste water with a relatively low level of contaminants such as wash water, humidity condensate, or mixtures of wash water and condensate, because the amount of water that can be recovered from urine is quite small at reasonable pressures. Present designs utilize an operating pressure of about 150 psia to give a recovery efficiency of approximately 80 percent for wash water.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.4	Water Management
1.1.3.4.1.2.2	Chemical Preservation
1.1.3.4.1.3	Pasteurization
1.1.3.4.2.1	Membrane/Filtration Reclamation
1.1.3.4.2.2.2.1	Membrane Diffusion Problems in Vapor Diffusion Process

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-105 (Double-membrane electrolysis unit)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space cabin simulator.

Concurrent Research -

Control test in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

The reverse osmosis potable water recovery system will be a single unit supported by a gas chromatograph, a mass spectrometer and standard potable water testing instrumentation.

The reverse osmosis unit employs a pressure vessel containing the semi-permeable membrane. The membrane can take one of several froms depending on the material from which it is made. The essential configuration is two parallel flow passages separated by the membrane. In addition to the reverse osmosis unit, the system employs a circulation pump, accumulator, holding tanks, port treatment filters, and a high-pressure gas source. A schematic is shown in Figure 1.

In this system, waste water consisting of wash water and condensate is received and stored in holding tanks. Two tanks are used; one receives waste water while the other discharges the water, at intervals, into the circulation loop which includes the accumulator and the reverse osmosis unit. After the loop is filled the waste water is pressurized to approximately 150 psia from a high pressure source through the accumulator and circulated around the loop. In the reverse osmosis unit, the high pressure forces the water through the semi-permeable membrane, having the solids in the circulation loop. Each module contains a total of 5 sq ft of membrane. Power is required only for pumping. The processed water is continuously removed and pumped through a series of charcoal and bacteria filters. If either of the two conductivity sensors indicate unsatisfactory water, the processed flow is automatically diverted to the urinal. At the same time, the process feed valve is closed and a shutdown warning signal given that repairs may be made. When one pretreatment tank is empty the feed valve automatically closes the empty tank. When the solids concentration in the circulation loop reaches a level equivalent to the desired water recovery efficiency, pressure is released and the contents of the loop discharged to the primary water recovery device. A fresh charge of waste water is then drawn in from the pretreatment tank, the pressure reapplied, and processing resumed.

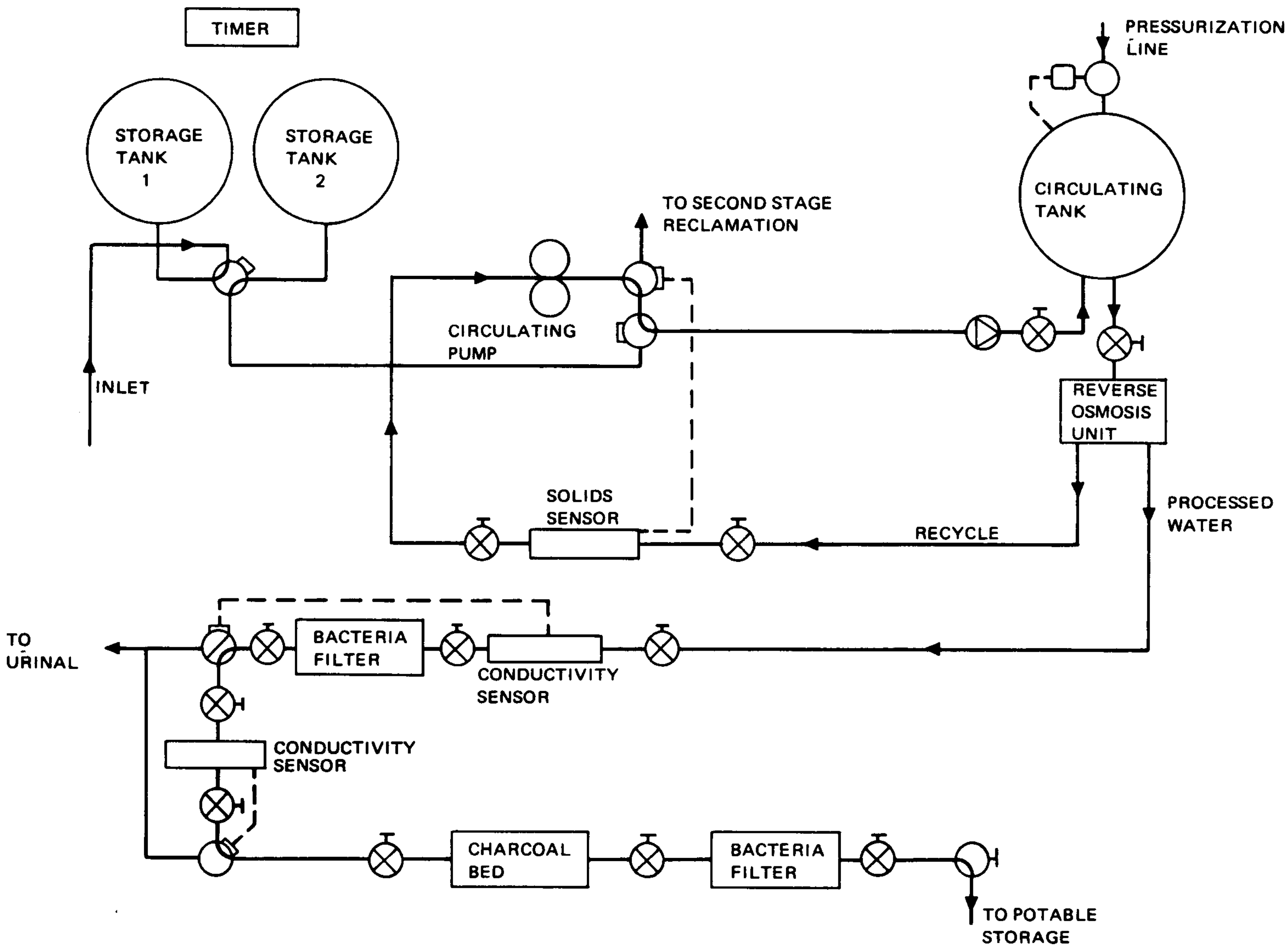

Figure 1. Reverse Osmosis

TITLE: 4-115 - Vacuum drying waste management system

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop technically acceptable techniques and hardware for providing personal accommodations in the area of waste management. The experiment will flight qualify and/or verify a waste management system in which the solid wastes, while stored, are vacuum-dried by exposure to hard space vacuum.

Vacuum drying waste management system prototypes have been built and tested in ground simulators. This type of system requires minimum power requirements, as no heating source is required. It also promises to provide a system with minimum overall weight penalty if recovery of fecal water is not required.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.5	Waste Management
1.1.3.5.1	Collection
1.1.3.5.1.2	Feces/Refuse Flow Characteristics
1.1.3.5.3	Storage
1.1.3.5.3.2.2	Heat and Mass Transfer Problems in Drying and Mixing of Feces and Refuse

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condenser-separator characteristics)

Successor Experiments -

4-116 (RITE waste management system)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Long-life performance tests of vacuum drying waste management systems.

Concurrent Research -

Control test of vacuum drying waste management system as a part of an integrated life support system in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

The vacuum drying waste management system used in this experiment will be used as the operational unit for the Skylab B in lieu of the base-line system which will be kept on standby status for the duration of the experiment. The test equipment comprises the functions of urine and feces collection, the vacuum drying and storing of feces, and the disposal of urine either by transfer to the water recovery system or to the dump vent. The waste management system includes the urinal, chemical pre-treatment injector, phase separator, filter, blower, and a pump. Included also are the container assembly containing a liner, slinger motor, and bacterial filter, and support system of seat, seat valve, control valves, blower and sampling and disinfecting assemblies. Figure 1 presents a schematic of the system.

In the commode, airflow is made to direct the stool into a rotating impeller. The stool is shredded and spread uniformly along the bag container wall. This achieves dense packing of the feces and allows quick vacuum drying of the resulting thin layer of moist feces. After the crewman uses the system he wipes himself with tissue in the normal manner, deposits the tissue in the commode, pushes the disinfect button and disinfectant is sprayed into the commode. After closing the seal valve, the unit is switched back to vacuum, the feces are dried, and the unit is ready for the next use.

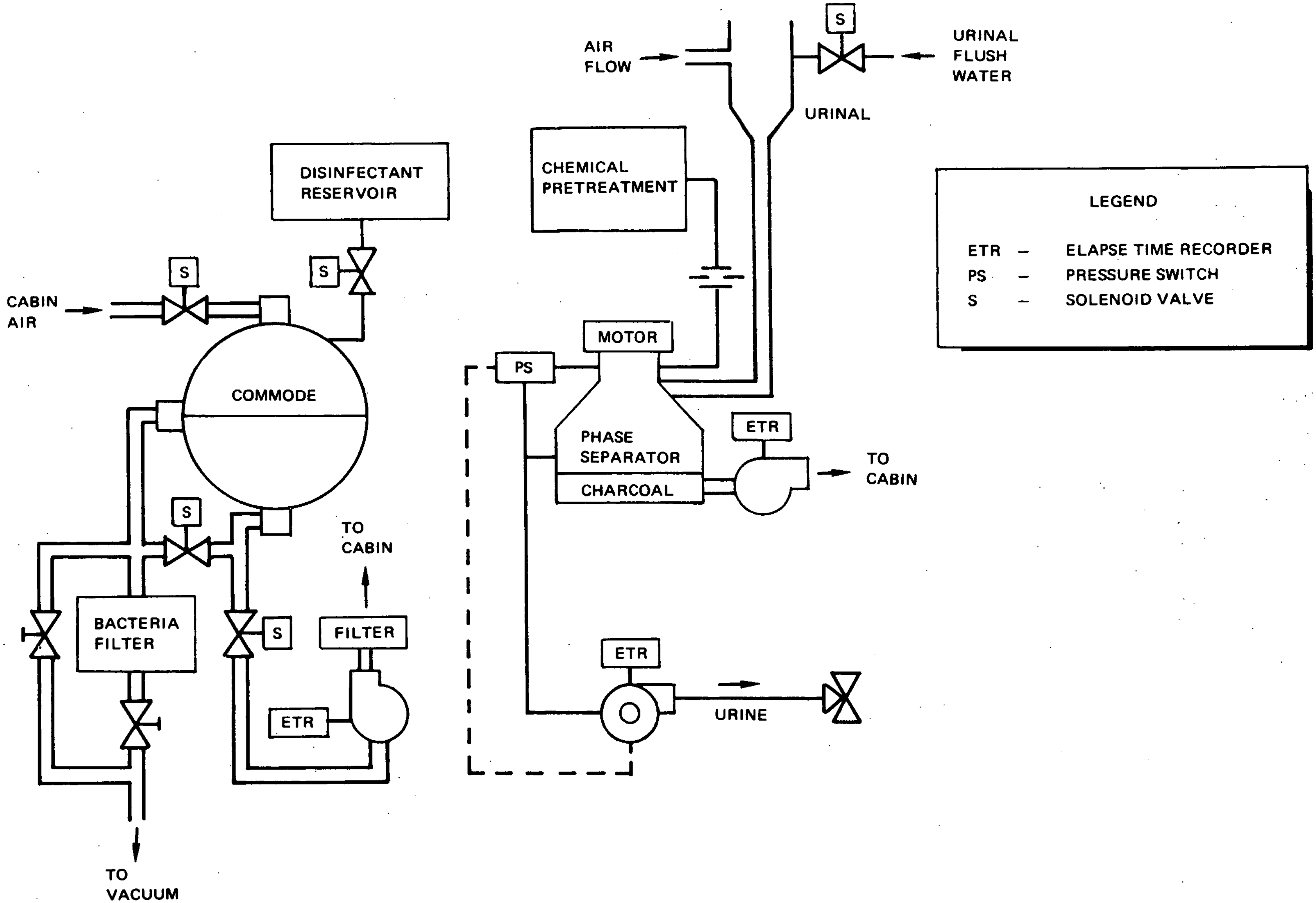

Figure 1. Waste Management System

TITLE: 4-116 - Radioisotope for thermal energy waste management-water system (RITE WM-WS)

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop technically and esthetically acceptable techniques and hardware for providing personal accommodations in the area of waste management and to develop techniques and hardware for the reclamation and sterilization of potable water from waste water, such as urine, wash water, and humidity condensate.

The basic objective of the experiment will be to test the performance characteristics of the integrated waste management - water system, with a radioisotope heat source, and to verify its operation for long duration in a zero-g environment. The RITE WM-WS is a compact water recovery system which utilizes a radioisotopic heat source and promises significant savings in overall system weight, volume, and power requirements. The RITE WM-WS also promises to eliminate the need for pretreating the wastes and post-treating the distillate, thus eliminating the requirements of associated equipment.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.4	Water Management
1.1.3.4.1.3.1	Pastuerization - Modes of Heat Transfer
1.1.3.4.2.2.4	Vapor Pyrolysis/Catalysis
1.1.3.4.2	Reclamation
1.1.3.3.2.1	Heating Systems
1.1.3.3.2.1.2	Radioisotope Management and Control Characteristics with Fluid Transport Systems

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condensor-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space cabin simulator.

Concurrent Research -

Control test in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

The RITE waste management-water system will be a single unit supported by a gas chromatograph, a mass spectrometer and a standard potable testing instrument. The RITE WM-WS employs a catalytic oxidation process using radioisotopes for thermal energy.

The RITE WM-WS combines the collection of urine, condensate, feces and other solid wastes, the incineration of wastes, and the reclamation of potable water from urine. Thermal energy for evaporation of water, incineration of solid wastes and pyrolysis of reclaimed water vapor is provided by a Pu-238 radioisotope heat source. Major components in the system are the urine accumulator, Pu-238 radioisotope-heated evaporator, catalytic oxidation chamber and incinerator, solids pump, condenser, transfer pumps, and potable water tanks. A schematic of the system is shown in Figure 1.

In this system, chemically treated urine and other waste water are pumped into the evaporator into which feces, flush water, and solid wastes are also deposited. Wet solids are transferred by a solids pump to the incinerator. Necessary oxygen for combustion is supplied to the incinerator, while the product ashes are removed periodically from the incinerator. Steam produced in the evaporator, is admitted to the pyrolysis chamber where it is passed over a 1200°F catalyst. The water vapor, after its purification in the catalytic oxidation unit, is routed to the condenser where it is condensed and pumped to the potable water accumulator. A potability monitor, consisting of a conductivity sensor and a pH meter, is used to check water quality before it is delivered to the potable water accumulator. If unacceptable, the water is routed to the evaporator for reprocessing.

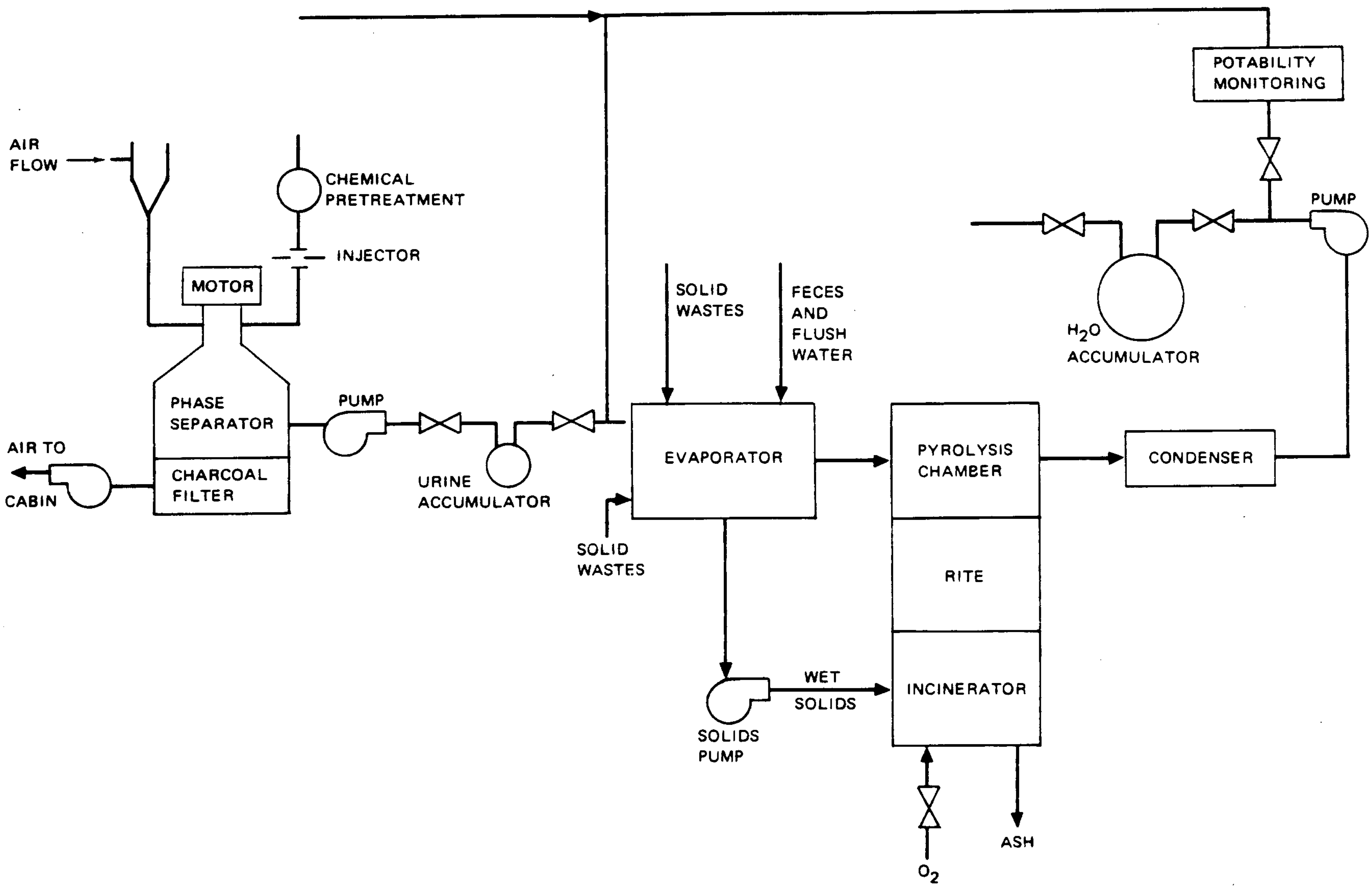

Figure 1. RITE Waste Management – Water System

TITLE: 4-117 - Food storage, preparation and feeding methods

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop technically and esthetically acceptable techniques and hardware for providing personal accommodations in the area of food management.

The object of this experiment is to test the performance and crew acceptability of food storage, preparation, and feeding methods under prolonged spaceflight conditions. Food storage methods such as freezing, freeze drying, and irradiated/canned will be evaluated with regard to preservation effectiveness and palatability. Food preparation devices such as microwave ovens, infrared ovens, and food reconstitution hardware will be evaluated with regard to convenience of operation and quality of food produced. Feeding methods will be judged on convenience of use, effectiveness under zero-g operation and acceptability by the crew.

The results of this experiment will lead to flight qualification of food storage, preparation, and feeding methods which efficiently provide food which is highly acceptable to space crews. This is essential for maintaining efficient flight crews for long-duration missions.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.6	Food Management
1.1.3.6.1.11	Stored Freeze-Dried Food Management Components
1.1.3.6.1.1.4	Verification Testing of Freeze-Dried Food Management Systems
1.1.3.6.1.2.2	Refrigeration Requirements
1.1.3.6.1.3	Irradiated/Canned

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condensor-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Long-term endurance testing of food management equipment. Testing of preservation effectiveness for extended time.

Concurrent Research -

Control test of food storage, preparation and feeding devices in a manned space cabin simulator. Determination of food acceptability by a crew under confined long-duration conditions

2. EXPERIMENT DESCRIPTION

This experiment will consist of quantitative testing to determine equipment and method performance followed by qualitative performance evaluation regarding convenience of use and acceptability by the crew. During the quantitative portion of the testing, effectiveness of food storage method is evaluated by bacterial and chemical analyses of the food, as well as color and appearance to measure preservation effectiveness. Temperatures are recorded in storage areas to isolate temperature effects on storage.

Food preparation devices will be tested under zero g to determine their effectiveness. Microwave and infrared ovens will be tested to measure ability to heat different types of foods, and to measure power consumption, cooling requirements, and temperatures. Food reconstitution devices will be tested to determine degree of reconstitution, time requirements, and resulting food consistency and temperature.

Feed methods will be evaluated primarily qualitatively regarding adequacy and convenience of use.

Qualitative crew evaluation will be performed on the various food management methods regarding ease of operation and quality of food produced.

The experiment should be performed during long durations to test preservation of food and life of equipment. The entire crew should participate in the experiment to obtain a better sampling of qualitative data although the total time required will not be large.

TITLE: 4-118 - Protective clothing and IVA suit assemblies

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop the garments and portable EC/LS systems for astronauts to perform intravehicular tasks.

Basic objectives of the experiments are to test and evaluate advanced concepts for protective clothing and IVA suit assemblies. Various materials and garment designs will be evaluated for wear characteristics and comfort. IVA suit assemblies will be performance-tested under conditions expected to occur during manned missions.

Improvements will be required for protective clothing designs used in Apollo and Gemini because, on longer missions, a greater variety of tasks must be performed and long-term wear and comfort are required. On earlier manned space programs, IVA was provided in the form of a space suit with suit-loop or portable life-support unit and possible tasks were limited. Long-duration missions consistent with NASA long-term goals will require a much greater activity variety and improved performance.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.7	Crew Protective Systems
1.1.3.7.2.2.1	Test Flight of Radiation Suits
1.1.3.7.1	Internal Hazards
1.1.3.7.2.4.3	Component Testing of Space Suit Subsystems

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condenser-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Perform ground tests on protective clothing and IVA suit assemblies to determine characteristics which can be validly tested without space environment. Such characteristics include fire retardation, thermal resistance, tear resistance, garment comfort and suit mobility. Ground testing is also needed to verify operational procedures for IVA activity.

Successor Research -

Returned samples are evaluated for general condition and for any changes in characteristics measured in predecessor research.

2. EXPERIMENT DESCRIPTION

This experiment consists of testing performance and life characteristics of protective clothing and IVA suit assemblies. Candidate clothing items will be worn for prolonged time periods by the crew. They will be evaluated for comfort, convenience of use, soiling resistance, wearing quality, tearing resistance and washing qualities.

IVA suit assemblies will be tested for performance during various work tasks anticipated for long-duration missions. These tasks will include suited IVA in pressurized and unpressurized compartments using portable and plug-in life support assemblies. Additionally, unsuited IVA tasks will be included with carry-around oxygen bottles and umbilicals for life support functions.

Crew involvement in protective-clothing research will consist of wearing and evaluating clothing candidates during their normal duty schedule. Only brief periods will be required for the crew to evaluate each clothing concept.

During IVA suit assembly testing, the crew will go through simulated IVA schedules and collect data on performance parameters. Work tasks performed in the unpressurized mode can be performed in an airlock to reduce gas lost overboard and to minimize impact on other activities.

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TITLE: 4-119 - EVA suit and biopack systems

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop the garments and other aids for astronauts to perform extravehicular tasks. Basic objectives of this experiment are to evaluate EVA suits and biopacks under actual spaceflight conditions operating at various performance levels and space environments. Results will take the form of performance and life data.

Project Gemini EVA and apollo lunar surface data formed a base for development of expanded capability EVA suits and biopacks. Expanded capability is necessary for long-term space missions where EVA is performed as a routine operation in support of experiments and repair of externally located equipment. EVA suits for these tasks must be reliable, require minimum expendables, and possess long life.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company.

1.1.3.7.2	External Hazards
1.1.3.7.2.2.3	Testing of Radiation Suits
1.1.3.7.2.3.4	Component Testing of EVA Suit Subsystem
1.1.3.7.2.4.2	Component Testing of Flexible Airlocks and Space Suit Subsystems

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-101 (Nucleate boiling)
4-102 (Flow regime characteristics)
4-103 (Convection heat transfer)
4-104 (Advanced fluid storage and management)
4-106 (Diffusion convection)
4-107 (Inertial separation)
4-108 (Film stability and transport)
4-112 (Water condenser-separator characteristics)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Related ground research will take the form of manned chamber tests to establish operational procedures and to obtain sufficient base data to act as a control.

Concurrent Research -

Analytical development to provide the tools to analyze test data and predict performance at off-design points.

2. EXPERIMENT DESCRIPTION

New concepts and designs for EVA suits and biopacks will be tested under spaceflight conditions. Effects of environments which cannot be exactly duplicated on the ground will be examined in detail. This includes zero g, very low vacuum, radiation, thermal environment, and meteoroids.

The first portion of the testing will test the entire system under a simulated EVA work schedule designed to impart worst-case conditions on the EVA suit and biopack. The experiment duration will be equal to the design mission length of the biopack being tested which should not exceed 6 hours (including checkout). Two crewmen will be required for each test. At least one test run will be made on each EVA suit and biopack configuration. Performance evaluations will be made on all aspects of performance including suit donning and doffing ease, comfort, thermal performance and mobility. The biopack will be evaluated by adequacy of performance.

The second portion of testing will involve exposing suit materials to the space environment and determining the material degradation due to effects of radiation, vacuum, meteoroids, and thermal extremes. The tests will be performed during the entire mission but are passive in nature thereby requiring little crew involvement.

TITLE: 4-120 (2-112) - Advanced personal hygiene concepts

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Man-Systems Integration

NASA Specific Objective -

a. Develop the technology for habitable living areas for space vehicles.

b. Develop technically and esthetically acceptable techniques and hardware for providing personal accommodations in the area of personal hygiene.

Experiment Objectives -

a. To evaluate various advanced personal hygiene concepts (equipment and techniques) in terms of crew acceptability, crew time requirements, spacecraft support requirements, and hygienic effectiveness under extended space flight conditions of zero and artificial g.

b. To determine suitability and verify design of advanced personal hygiene systems for extended duration space flight in zero and artificial g.

Background -

In the short-duration space missions to date personal hygiene and sanitation did not pose major problems. Inconveniences, difficulties in use, total lack of facilities, and the resulting lowering of personal hygiene standards were accepted by the highly motivated crews of Gemini and Apollo. For longer duration missions, these attributes may prove to have long-term effects which lead to performance decrement and crew dissatisfaction. Suggestions have been made that conditions of extended spaceflight approximate as nearly as possible those to which the crews are accustomed on earth. Advanced concepts, such as whole body showers, have been proposed in response to these suggestions. This experiment will evaluate advanced concepts for body cleansing, oral hygiene, and excess hair removal.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.7 Crew Protective Systems
1.1.3.7.1.4 Biological Control
1.1.3.7.1.4.1 Testing of Personal Hygiene Subsystem

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

Skylab Experiment M-487 Habitability/Crew Quarters

Concurrent Experiments -

1-129 (A study of changes in microbial contamination of air and selected surfaces)

4-120 (Personal hygiene systems)

4-110 (Advance control and monitoring of microbiol levels in life support systems)

Successor Experiments -

2-205 (Habitability for large crews)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Ground-based space cabin confinement studies (e. g., Tektite, McDonnell Douglas 90-day test, Gulfstream).

Baseline collection of data from Skylab B crews.

Successor Research -

Post-flight analysis of data collected in flight.

2. EXPERIMENT DESCRIPTION

This experiment will be conducted during Skylab B crew cycles three and four. Three specific areas of personal hygiene techniques, and equipment will be studied: body cleansing, oral hygiene, and hair removal. All crewmen will use the advanced techniques and equipment during the entire 90-day cycle. The experiment will be repeated in crew cycle four to verify that results were not unique to the crew composition of cycle three and to incorporate and evaluate any changes in techniques and equipment indicated by the results of cycle three. Measurements will be made of crew acceptability, crew time, spacecraft support requirements, hygienic effectiveness, and design adequacy.

Though the devices and techniques will be used throughout the mission, experimental observations and measurements will be done at 10-day intervals. Crew acceptability of the techniques and devices will be measured by periodic administration of questionnaires, by measurements of frequency of use, from crew log entries, and by indications of rejection during use. Crew time will be measured by activation of onboard timers by the crewman subject and recording of the time in a crew log following use. Spacecraft support requirements will be measured by onboard monitoring equipment, such as water flow meters. Hygienic effectiveness will be measured by oral examinations, microorganism counts, and skin and scalp examinations. Design adequacy will be indicated by trouble-free operation, difficulties encountered by the crew in using the equipment, and from crew comments on acceptability.

This experiment will consume very little crew time since the activities to be observed and measured are a normal part of the mission. It will require specialized crew skills in performing oral, skin, and scalp examinations and in taking microorganism samples.

TITLE: 4-121 - Leak detection

1. SCIENTIFIC AND TECHNICAL OBJECTIVES

1.1 DISCUSSION OF OBJECTIVES

Field - Life Support and Protective Systems

NASA Specific Objective - To develop techniques and hardware for monitoring and controlling the atmospheric composition against excessive losses due to external leakage and excessive contamination due to internal leakage from onboard equipment and fluid systems.

The experiment will be used to verify the flight performance of the most promising concepts that have been proved previously in integrated systems tests in manned space station simulators.

The basic objective of this experiment is to test the performance characteristics of different, yet promising, techniques of leak detection for use as part of spacecraft life support systems; also to verify their operation for long duration in a zero-g environment. The leak detection concepts being tested involve the analysis of the signature produced by the event that is being monitored. The signatures produced by the various types of leaks will be evaluated as to sensitivity of the device, accuracy of detecting the location of the leak, and simplicity of design to accommodate the types and variety of leaks anticipated on space vehicles operating in orbit for long durations. Outward leaks result in reduced atmospheric pressure and increased gas consumption. Inboard leaks originate from tankage or process fluid lines in the space station systems. The internal pressure of these components will decrease when a leak occurs and the decrease may be sensed by a partial pressure/total pressure or a total pressure detector. The leakage of a process fluid into the space vehicle atmosphere also produces an increased concentration. This can be monitored by a partial-pressure sensor.

This research activity is partially or wholly responsive to the information needs of the following critical issues which were identified in the Earth Orbital Experiment Program and Requirements Study, Final Report number MDC G0680, McDonnell Douglas Astronautics Company:

1.1.3.7	Crew Protective Systems
1.1.3.7.2.4.3	Component Testing of Leak Detection and Repair Subsystem
1.1.3.8.1	Verification testing of maintenance and Repair Procedures

1.2 PREDECESSOR/CONCURRENT/SUCCESSOR EXPERIMENTS

Predecessor Experiments -

4-102 (Flow regime characteristics)
4-105 (Double-membrane electrolysis unit)
4-107 (Inertial separation)
4-108 (Film stability and transport)

1.3 RELATED GROUND RESEARCH

Predecessor Research -

Integrated system test of components in a manned space cabin simulator.

Concurrent Research -

Control test in a manned space cabin simulator.

2. EXPERIMENT DESCRIPTION

This experiment will use, in a series of tests, a number of different leak detecting and locating techniques. Some of these techniques will be part of the EC/LS system and others will be part of the structure. Identified and discussed below are four of the promising techniques that are considered for this experiment.

a. The cabin outboard leakage detection function is combined with the atmosphere supply function in the two-gas controller. This unit admits to the atmosphere fixed-quantity pulses of O_2 and N_2, the frequencies of which are proportional to the sensor error signals. It maintains a stable atmosphere by altering the pulse rate as needed. This rate is directly translatable to consumption data and N_2 consumption data can be used to quantify the outboard leakage. An increased error signal causes a steeper integration vamp that reaches the preset limit more rapidly. This produces a higher pulse rate which is then read as increased N_2 consumption; i.e., leakage.

b. The inboard leak detection system will comprise a number of partial pressure sensors in various process streams and tanks. Other partial pressure sensors can be installed in the atmosphere to record changes in concentration of such substances as CO and CO_2. A gas chromatograph will also be used to identify small, low-pressure leaks not detectable by other means. Versatility is a problem with this device and the testing of various columns would be desirable. In order to make this concept meaningful it will be necessary to have knowledge of the types of contaminant that can emanate from a process stream of tank.

c. For a large distribution of hole sizes and pressures, gas flow through an orifice results in the generation of ultrasonic energy in the frequency range of 35 to 50 KHz. A typical sensor consists of a barium-titanate transducer which converts acoustic energy into electrical energy. The transducer responds to signals in the frequency range of 36 to 44 KHz. This signal will then be heterodyned with a 40-KHz signal to give an output in the audio range. A number of these barium-titanate transducers will be bonded on the pressure wall of the space vehicle and tested to determine if they can serve as a constant leak monitor. Proper installation of the transducer array will be necessary to ensure triangulation location capability. Portable devices of this kind can also be tested for their ability to identify and locate inboard leaks and as substantiation of the triangulation-location capability of installed units for outboard leaks.

d. Active ultrasonic techniques offer another leak locating technique for detecting micro-leaks from cracks in welds and in the pressure walls. This method has potential for locating dimples and spalls in the pressure wall even though actual leakage did not occur. An electrically excited transducer will start an ultrasonic wave propagating through the structure. Crack detection will be accomplished by detecting echoes reflected from cracks using with the transmitting transducer and its neighbors as receivers.

Table H-1 (page 1 of 3)

SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS INTEGRATED MEDICAL BEHAVIORAL LABORATORY MEASUREMENT SYSTEM (IMBLMS)

Item	Required on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	Space Station					
Integrated Medical Behavioral Laboratory Measurement System (IMBLMS) To include functional equivalent of the following items:	X	X	Provides measurement capability which is functionally equivalent to the capability of the items which follow.	Under development (NASA-MSC) Note: the functional equivalents of items listed below are standard laboratory items. All items are included in current IMBLMS development. Additional developments are noted.	Instruments which perform the measurements listed for each item which follows, and which is compatible with a data management system which will display and/or store the data.		
Audiometer			Tests auditory threshold at various frequencies and speech intelligibility.				
Automated Perimeter			Measures visual field				
Ballistocardiograph			Measures longitudinal body accelerations (ballistocardiogram)				
Blood Gas Analyzer			Measures blood pO_2, pCO_2, and pH				
Blood Pressure Assembly			Measures arterial blood pressure	Under development for Skylab experiment M092: "Inflight LBNP"			
Cardiotachometer			Measures heart rate				
Cell Counter			Counts blood cells automatically				
Chemically Impregnated Paper			Measures urine protein concentration				
Clinical centrifuge			Separate blood plasma from the formed elements				
Compound microscope			Cellular and micro-organism observations				
Problem presentation device			Alphameric display of crew tests				
Dynamometers			Measure muscle size and strength				
Ear canal temperature probe			Measure body core temperature	Under development for Skylab experiment M171 "Metabolic activity"			
Electrocardiograph/ Vectorcardiograph			Measure heart electrical activity	Under development for Skylab experiment M093 "Vectorcardiogram"			

Table H-1 (page 2 of 3)

SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS
INTEGRATED MEDICAL BEHAVIORAL LABORATORY MEASUREMENT SYSTEM (IMBLMS)

Item	Required on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	Space Station					
Electroencephalograph			Measure brain electrical activity	Under development for Skylab candidate experiment M133 "Sleep monitoring"			
Electroanalytical system			Measure pH and ionic concentrations of blood and urine				
Electromyograph			Measures electrical activity of muscle fibres				
Electro-oculograph			Measures electrical activity associated with eye ball movement	Under development for Skylab candidate experiment M133 "Sleep Monitoring"			
Impedance cardiograph			Measure transthoracic impedance change				
Leg plethysmograph			Measure leg circumference	Under development for Skylab experiment M092 "LBNP"			
Mass spectrometer			Measure concentrations of gas and liquid constituents		Increase planned mass range for application in Life Support and Protective Systems research		
Metabolic analyzer			Respiratory system gas measurements	Under development for Skylab experiment M171 "Metabolic activity"			
Phonocardiograph			Measures heart sounds (phonocardiogram)	Developed by NASA for Gemini and Apollo programs			
Pulmonary flowmeter			Measure lung capacity and flow rates				
Pulse wave velocity electronics			Measure pulse wave velocity				
Radiation detector			Measure isotope concentrations in blood components research				
Refractometer			Measure urine specific gravity	IMBLMS development may use different technique			
Spectrophotometer			Measure component concentrations in body fluids				
Task board			Provides tests for task performance	Under development for Skylab experiment M171 "Metabolic activity"			

Table H-1 (page 3 of 3)

SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS
INTEGRATED MEDICAL BEHAVIORAL LABORATORY MEASUREMENT SYSTEM (IMBLMS)

Item	Required on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	Space Station					
Transcutaneous doppler flowmeter			Measure pulse wave contour				
Venous pressure manometer			Measure peripheral venous blood pressure				
Vision monitor			Provide variety of vision tests				
IMBLMS peripheral equipment To include the following items:	X	X	Laboratory equipment associated with or in support of the research measurements performed with the above items				
Bicycle ergometer			Provide calibrated work load	Under development for Skylab experiment M171 "Metabolic Activity"			
Body Mass Measurement Device			Measure body mass	Under development for Skylab experiment M172 "Body Mass Measurement"			
Lower body negative pressure device			Apply negative pressure to lower body	Under development for Skylab experiment M092 "Inflight lower body negative pressure"			
Rotating litter chair			Provide rotation and tilt for vestibular research	Under development for Skylab experiment M131 "Human Vestibular Function"			
Freezer (-20°C)			Store urine samples and plant samples (Space Biology)		Increase capacity to handle storage of plant samples		
Freezer (-70°C)			Store blood samples				
Incubator			Provide environment for microbial culturing				
Refrigerator			Storage of micro-organisms and other samples		Increase capacity to accommodate Drosophila and Arabidopsis samples		
Slide staining equipment			Microscope slide preparation				

Table H-2 (page 1 of 3)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – LABORATORY EQUIPMENT

Item	Reqd on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	SS					
Anesthetizer	x	x	Anesthetizes Drosophila prior to handling	Current method employs ether	Nonflammable anesthetizing agent compatible with research activity	6 mo	$ 30K
Autoclave	x	x	Sterilizes small equipment and disposal of bacteriological cultures	Standard laboratory item; e.g., Castle Model 7	Steam generator requires modification for operation in weightlessness. Trays must restrain objects	1 yr	$ 30K
Biocentrifuge		x	Provides a variable-g force for plant and animal research	None	Study, design, fabrication, and test Provide up to 1-g force for plants and animals with at least 7½-ft radius centrifuge Include atmosphere supply to subject enclosures Accommodate maximum practical number of enclosures by means of multiple arms Consider attachment and removal of enclosures without stopping rotation	3 yr	$ 800K
Chemical Oxygen Demand (COD) Analyzer	x	x	Measures COD of water samples	None	––	––	––
Colony Counter	x	x	Automatically counts the number of microorganism colonies on culture plates	None	Instrument to scan (e.g. optical) a culture plate and provide an electrical readout of number of colonies present in the range 30 – 300	1 yr	$ 150K
Electromechanical Delay Electronics	x	x	Measures time between ECG R wave and PCG A-V valve wave	Currently performed experimentally in laboratories with small general-purpose computer	Electronics to perform measurement and provide readout or incorporate in IMBLMS computer	6 mo	$ 60K
EVA and IVA Lights	x	x	Illuminates crew subject during maintenance and cargo handling experiments	Illumination developed for Skylab experiment M151	Safe and portable light sources with provision for mounting in a variety of positions and locations	6 mo	$ 50K

Table H-2 (page 2 of 3)

SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – LABORATORY EQUIPMENT

Item	Reqd on Skylab B	Reqd on SS	Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
Gas Chromatograph	x	x	Measures concentration of constituents of gases and liquids	Several available for Earth laboratories; e.g., Beckman Model GC-2A	Review available designs to ensure compatibility with spacecraft equipment specifications	6 mo	$ 30K
He/CO Gas Source	x	x	Provides helium and carbon monoxide mixture required for determination of lung diffusion capacity	Standard laboratory item	Review container design to ensure compatibility with spacecraft equipment requirements	3 mo	$ 30K
High-temperature Sterilizer	x	x	Sterilizes small equipment; e.g., microscope slides and culture inoculating needles	Current laboratory practice uses the flame of a Bunsen burner	A means of rapidly raising the temperature of instruments to sterilize them with the same effectiveness as the Bunsen burner flame	1 yr	$ 100K
Human research centrifuge		x	Space medicine research	Development study for NASA by General Dynamics Corp., San Diego	• Design, fabrication and test of flight unit • Provide variable "G" forces up to 1G • Radius arm at least 10 ft • Accommodate one instrumented area in variable position	3 yr	$ 1.5n
Media Preparation Containers	x	x	Preparation of microorganism culture media	Dehydrated media requires elaborate preparation Prepared plates have short storage life	Methods of extending the storage life of prepared media, or, a simplified process by which de-hydrated media may be used in weightlessness	2 yr	$ 250K
Fluid transfer equipment	x	x	Handling of fluid samples	NASA-MSFC development project	Provide for handling and measurement of small quantities of various fluids	2 yr	$ 250K
Seed handling equipment	x	x	Handling of minute seeds of Arabidopsis plant	Seeds selected with forceps and dropped into growth tubes	Restraint of stock of seeds and method of placing them into narrow growth tubes	1 yr	$ 30K
Total organic carbon (TOC) analyzer	x	x	Measure TOC content of water samples	New development (Perkin-Elmer) now in use in MDAC 90 day Space Station simulator run	Size and weight reduction and design compatible with spacecraft equipment requirements	2 yr	$ 300K

Table H-2 (page 3 of 3)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – LABORATORY EQUIPMENT

Item	Reqd on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	SS					
Video tape recorder	x	x	Video and audio recording of selected crew activities	Variety of commercial units available	System to provide synchronized recording of audio and video at a variety of frame rates: operation with remote cameras and microphones	1 yr	$ 250K
X-ray bone densitometer	x	x	Measure bone density	Many available commercial models in required range, e.g., dental X-ray units	Review of available designs to ensure compatibility with research application and spacecraft equipment specifications	1 yr	$ 150K
Storage of unfertilized frog egg	x	x	Experiment 3-101; Frog egg fertilization and morphogenisis	Normal storage time for untreated eggs is 14 – 15 hrs. Treated eggs may be stored for up to 32 hours	Storage time limitation forces early experiment activation. Experiment success may be compromised by launch delay (e.g. Biosatellite II) or activation delay. Technique to ensure successful storage for up to 72 hrs would increase probability of success	2 yr	$ 100K
Nutrient source capable of long term storage for developing frog embryos	x	x	Experiment 3-101: Frog egg fertilization and morphogenisis	Available nutrients have a shelf life of approximately 100 days	Nutrient source which may be stored for greater than 100 days will permit continuation of research for duration of one crew cycle (nom. 90 days)	3 yr	$ 150K

Table H-3 (page 1 of 2)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – EXPERIMENT SUBJECT SUPPORT MODULES

Item	Reqd on Skylab B	Reqd on SS	Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
Arabidopsis module	x		Accommodate Arabidopsis plants for experiment 3-104	Current research program under Dr. Brown at University of Pennsylvania	Module design, fabrication and test to accommodate 10 seedling tubes in a 14.7 psia, 2 gas (O_2, N_2) atmosphere. Include atmosphere control, illumination control, time-lapse photography, access and such instrumentation as the P.I. will require	2 yr	$ 250K
Cucumber module	x		Accommodate cucumber plants for experiment 3-105	Current research program under Dr. Siegel at University of Hawaii	Module design, fabrication and test to accommodate 10 to 60 plants (to be harvested as required) in a 14.7 psia 2 gas (O_2, N_2) atmosphere. Include atmosphere control illumination control access and required instrumentation	2 yr	$ 250K
Drosophila module	x	x	Accommodate Drosophila subjects for experiment 3-106	Derivative of module developed for Biosatellite II (Drs. Browning and Oster)	Module design, fabrication and test to accommodate up to 1000 flies in containers of 5 male and 5 females in each in a 14.7 psia, 2 gas (O_2, N_2) atmosphere. Provide atmosphere and illumination control, access, sample return and instrumentation.	3 yr	$ 350K
E. coli module	x	x	Accommodate bacteria for experiment 3-107	Current research at NASA, LRC under Dr. J. Wilkin Reference module developed for Biosatellite II program	Module design fabrication and test to accommodate bacteria in accordance with requirements of P.I. Include time-lapse photography, access and instrumentation.	1½ yr	$ 200K
Frog egg module	x	x	Accommodate frog eggs for experiment 3-101	Current research at NASA, ARC under Dr. Tremor	Module design, fabrication and test to accommodate at least 300 frog eggs and sperm in 20-30 water filled capsules. Provide automatic sperm-egg mixing, preservation, time-lapse photography and return of specimens.	2 yr	$ 300K
Mouse module	x		Accommodate mice for experiment 3-102	Current research and development at University of Southern California under Dr. P. Meehan	Module design, fabrication and test to provide for breeding of initial 8 mice into a colony of 100 in a 14.7 psia, 2 gas (O_2, N_2) atmosphere. Provide atmosphere and illumination control, automatic feeding and waste management, TV monitoring and instrumentation.	2 yr	$ 450K

Table H-3 (page 2 of 2)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – EXPERIMENT SUBJECT SUPPORT MODULES

Item	Reqd on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	SS					
Restrained primate module	x		Accommodate one Rhesus monkey for experiment 3-103	• Current research at UCLA under Dr. R. Adey • Biosatellite III • Current research at UCB under Dr. N. Pace	Modify Biosatellite III capsule for installation in Skylab. Provide for return of subject.	1½ yr	$ 450K
Unrestrained primate module	x		Accommodate 2 Rhesus monkeys for experiment 1-130	Current NASA "Orbiting Primate Experiment" (OPE) development	Atmosphere supply (O_2 and N_2) may be removed from current design and provision made to utilize spacecraft supply. Atmosphere control and all other capabilities retained.	--	--

Table H-4 (page 1 of 3)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – LIFE SUPPORT SYSTEM TEST ASSEMBLIES ON ADVANCED SKYLAB

Item	Reqd on Skylab B	Reqd on SS	Application	Current Status and Availability	Development Required	Estimated Time (yr)	Estimated* Cost
Nucleate boiling module	x		Experiment 4-101	Conceptual design study by General Dynamics Corp. under NASA, LRC contract. (Reference 11)	Design, fabrication and test of prototype and flight test units	1-½	$ 300K
Flow regime characteristics module	x		Experiment 4-102	Conceptual design study by General Dynamics Corp. under NASA, LRC contract. (Reference 11)	Design, fabrication and test of prototype and flight test units	1-½	$ 300K
Convective heat transfer module	x		Experiment 4-103	Conceptual design study by General Dynamics Corp. under NASA, LRC contract. (Reference 11)	Design, fabrication and test of prototype and flight test units	1-½	$ 300K
Cryogenic fluid management module	x		Experiment 4-104	--	--	2	$ 500K
Water electrolysis system	x		Experiment 4-105	Pre-prototype system has been developed by the NASA and is under test on the NASA "90-day Space Station Simulator run" at MDAC	Design, fabrication and test of flight test units which will be compatible with the operational oxygen regenerator subsystem on advanced Skylab missions	2	$ 900K
Diffusion convection module	x		Experiment 4-106	Conceptual design study by General Dynamics Corp. under NASA, LRC contract. (Reference 11)	Design, fabrication and test of prototype and flight test units	1-½	$ 300K
Inertial separation module	x		Experiment 4-107	Conceptual design study by General Dynamics Corp. under NASA, LRC contract. (Reference 11)	Design, fabrication and test of prototype and flight test units	1-½	$ 300K
Film stability and transport module	x		Experiment 4-108	Conceptual design study by General Dynamics Corp. under NASA, LRC contract. (Reference 11)	Design, fabrication and test of prototype and flight test units	1-½	$ 400K

*Estimated cost of assembly development only; does not include associated R&D effort.

Table H-4 (page 2 of 3)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – LIFE SUPPORT SYSTEM TEST ASSEMBLIES ON ADVANCED SKYLAB

Item	Reqd on Skylab B	Reqd on SS	Application	Current Status and Availability	Development Required	Estimated Time (yr)	Estimated* Cost
H_2-depolarized electrochemical cell CO_2 collector	x		Experiment 4-109	Under development by TRW, Inc.	Design, fabrication and test of prototypes and flight test units. Flight test unit to be compatible with operational CO_2 concentrator subsystem on advanced Skylab missions.	2	$ 800K
Advance microbial control and monitoring equipment	x		Experiment 4-110	Gas chromatographic method available in laboratory model. ATP and FMN bioluminescence and phosphorescence method in early development	Design, fabrication and test of prototypes of units employing candidate methods, and of flight test units employing selected methods	3	$ 700K
Comfort zone evaluator	x		Experiment 4-111	– –	– –	2-½	$ 800K
Water condenser/ separator unit	x		Experiment 4-112	A hydrophobic/hydrophilic separator developed by LMSD for NASA was tested in NASA "90-day space station simulator run."	Design fabrication and test of flight test units. Flight test unit to be compatible with oxygen regenerator and urine recovery subsystems on advanced Skylab mission.	2	$ 400K
Spillage handling and recovery equipment	x		Experiment 4-113	None	Study of problem and approaches to solution. Design fabrication and test of prototypes of candidate approaches, and of flight test units of selected approaches.	2	$ 250K
Reverse osmosis water recovery-system	x		To be tested in experiment 4-114	System under development by NASA, MSC	Design, fabrication and test of prototypes and of flight test units. Flight test unit must be compatible with urine recovery subsystem on advanced Skylab missions.	2	$ 700K
Vacuum drying waste management system	x		To be tested in experiment 4-115	Prototypes under development by General Electric Co. for NASA. One prototype tested in "90-day run."	Design, fabrication and test of flight test units. Flight test units will operate in conjunction with operational waste management subsystem on advanced Skylab missions.	2	$ 600K
RITE waste management system	x		To be tested in experiment 4-116	Under development by General Electric Co. for the NASA.	Design, fabrication and test of prototypes and flight test units. Flight test unit will operate in conjunction with operational waste management subsystem on advanced Skylab missions	2-½	$ 1,500K

*Estimated cost of assembly development only; does not include associated R&O effort.

Table H-4 (page 3 of 3)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – LIFE SUPPORT SYSTEM TEST ASSEMBLIES ON ADVANCED SKYLAB

Item	Reqd on		Application	Current Status and Availability	Development Required	Estimated Time (yr)	Estimated* Cost
	Skylab B	SS					
Protective clothing and IVA suit assemblies	x		To be tested in experiment 4-118	Designs under study by NASA, ARC and MSC	Design, fabrication and test of prototype and flight test units	2	$ 700K
Space suit and biopack	x		To be tested in experiment 4-119	Designs under study by NASA, ARC and MSC	Design, fabrication and test of prototype and flight test units	2	$ 600K
Leak detection equipment	x		To be tested in experiment 4-121	Several designs under study by NASA, MSFC	Design, fabrication and test of prototype and flight test units	3	$ 600K

*Estimated cost of assembly development only; does not include associated R&D effort.

Table H-5 (page 1 of 2)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS – EXPERIMENT SUBJECT SUPPORT FACILITIES

Item	Reqd on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	SS					
Animal research support facility		x	Research with animals for Biomedicine and Space Biology	• Nothing available or in study for total facility The following programs or studies are applicable to components of the facility • Biosatellite III (ARC) • Orbiting Primate Experiment (LRC) • Automated Primate Research Laboratory (OART) • Mouse facility development, USC (OART) • "Study of an Animal Research Facility..." MDAC Report DAC 58039 (Ref. 14)	• Study and design of an animal research facility which is adjacent to but isolated from the other portion of the Biotechnology Laboratory • Include large vertebrate housing facility and possibly invertebrate housing facility • Include laboratory facilities unique to animal research and those required for work with animals removed from enclosures • Provide for convenient access to biocentrifuge • Provide for maximum utilization of IMBLMS data system and other laboratory analytic facilities consistent with isolation requirements • Provide for protection of research subjects from infection by crew, or spacecraft atmosphere • Isolate facility from noise and other disturbances	2½ yr	–
Large vertebrate housing facility		x	Accommodate large vertebrates such as dogs and monkeys	None. (See table 5-28 for reference programs)	• Design, fabrication and test of prototype and flight units • Facility to be incorporated in Animal Research Support Facility portion of Biotechnology Laboratory	3 yr	$ 900K
Small vertebrate housing facility		x	Accommodate small vertebrates such as rats and mice	None. (See Table 5-28 for reference programs)	• Design, fabrication and test of prototype and flight units. • Facility to be incorporated in Animal Research Support Facility portion of Biotechnology Laboratory.	3 yr	$ 800K
Invertebrate housing facility		x	Accommodate invertebrates such as flies, beetles, spiders, etc.	None	• Design, fabrication and test of prototype and flight units	2½ yr	$ 700K

Table H-5 (page 2 of 2)
SUPPORTING RESEARCH AND TECHNOLOGY REQUIREMENTS –
EXPERIMENT SUBJECT SUPPORT FACILITIES

Item	Reqd on		Application	Current Status and Availability	Development Required	Estimated Time	Estimated Cost
	Skylab B	SS					
Plant facility		x	Provide a controlled environment for an assembly of plant enclosures	None	• Design, fabrication and test of prototype and flight units	2 yr	$ 700K
Microbial facility		x	Provide an enclosed environmentally controlled facility to support microbial research activities	None. (See Table 5-28 for reference)	• Design, fabrication and test of prototype and flight units	2½ yr	$ 700K