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BIOMEDICAL PROGRAMS OPERATIONS PLANS

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H. F. Walbrecher

Attachment
/db

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FINAL REPORT

BIOMEDICAL PROGRAMS OPERATIONS PLANS

CONTRACT NAS 9-11037
AUGUST 30, 1974

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER, HOUSTON, TEXAS 77058

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INTRODUCTION

This report summarizes and concludes a series of planning activities researched and developed by the General Electric Company, Houston Operations, for the Johnson Space Center, Life Sciences Directorate under Contract NAS9-11037. This contract has existed since July 1970. Two fundamental research and technology plans were prepared and delivered in June 1971 and February 1972. Respectively, these plans were the Biomedical Research and Technology Plan through 1975 and the Short Range Space Shuttle Research and Technology Implementation Plan. Both plans fell under the technical cognizance of Dr. Wayland E. Hull, Technical Assistant to the Director of Life Sciences. One additional plan was never delivered by direction from the Life Sciences Directorate (LSD), then the Medical Research and Operations Directorate. The undelivered document was the Long Range Earth Orbital Space Station Research and Technology Implementation Plan. Development of this document was discontinued by NASA when the Space Station lost viable program status. Coincidentally, the Life Science Directorate's Skylab Medical Experiments Altitude Test (SMEAT) acquired program status. The General Electric Company was redirected to research SMEAT operational planning requirements, to develop the MR&OD sections of the SMEAT Experiment Operations Plan, to verify the test readiness of the SMEAT medical experiments equipment, and to supervise the operational flow of test acquired data. After contractual redirection, the technical monitor became William H. Bush, Operational Systems and Planning Branch. With the successful completion of SMEAT, the General Electric Company was directed further to establish LSD's Skylab operational planning documentation requirements, to refine the SMEAT operational data flow plan, to assess the effectiveness of LSD's real-time Skylab mission support posture, and from the assessment, to develop recommendations for LSD's Space Shuttle operational guidelines. Dr. William H. Shumate, Neurophysiology Section and senior LSD Skylab medical experiments coordinator, became technical monitor immediately before the Skylab Program entered the flight phase and has remained in this role for the duration of the contract.

This report - the Final Report for NAS9-11037 - shall recapitulate the operational planning evolution from SMEAT through Skylab, the Skylab operational management accomplishments, and provide operational guidelines for Space Shuttle Life Sciences Payloads.

TECHNICAL SUMMARY

I. TECHNICAL SUMMARY

Objectives

The specific objectives of this study were to assess Skylab operations planning, describe the operational posture being planned for the Space Shuttle Program, establish significant operational planning differences between the Skylab Program and the Space Shuttle Program, and to project Life Sciences operational planning guidelines for the Space Shuttle Program from Skylab "lessons learned" and inherent Space Shuttle program characteristics.

Background

The study was conducted in several phases. The first phase was an operational assessment of the Skylab Medical Experiments Altitude Test (SMEAT); the second phase was the planning of Skylab operations documentation; the third phase was a real-time assessment of the Skylab Life Sciences operational posture and collection of Space Shuttle operational planning data; and the fourth phase was to digest the information obtained in phase three and assemble sets of Life Sciences operational planning guidelines. The guidelines have been expressed in terms of operational differences between Skylab and Space Shuttle programs and a tabulated set of Life Sciences experimental opportunities for the Space Shuttle program. Since all the NASA Centers participating in Skylab prepared Skylab Lessons Learned reports, these reports were reviewed and areas applicable to Life Sciences have been extracted and appended to this report.

Phase I Summary

Skylab medical operations planning gained momentum in a disciplined manner at the Johnson Space Center after SMEAT became a viable program. This test became a valuable asset for gathering physiological baseline data, for evaluating medical equipment performance and crew procedures, and for evaluating operational management and operational support concepts and procedures.

Several operational deficiencies were detected after SMEAT entered the chamber test phase. Those unique to the chamber configuration, while rectified, were discounted from further analysis, and specific emphasis was placed on deficiencies which were considerably more universal and could significantly affect Skylab medical ground operations management.

SMEAT uncovered three major problem areas: 1) insufficient pre-chamber planning attention to top-down test management, 2) unresponsive data management, and 3) inadequate peripheral support. These deficiencies manifested themselves three ways: 1) daily results were insufficiently summarized and did not provide adequate management exposure to progressive test status, 2) processing of experimentally acquired data was too slow to permit a near real-time assessment of crew health status, and 3) time difference between laboratory derived and computationally derived data made whole-body physiological assessment difficult at best. Methods used to correct these deficiencies became baseline operational planning approaches for Skylab.

Phase II Summary

There were a certain number of operationally critical and basic differences between SMEAT and Skylab. This listing for SMEAT signifies a difference with Skylab: 1) only Skylab voice communications blackout periods were simulated, 2) biowaste was passed through the chamber daily, 3) blood samples were passed through the chamber after each draw, 4) crew experiments were limited to medical experiments only, 5) no venting was required which could interfere with experiments, 6) trash was passed out the chamber daily and all trash items were inventoried, 7) inoperative major equipment was replaced, 8) the chamber had unique safety factors, 9) food was passed in at fixed intervals, 9) stowage lists were relatively easy to maintain due to the controls instituted for passing items into and out of the chamber, and 10) there was no requirement to deploy a prelaunch or recovery medical team. Due to the deficiencies detected in SMEAT and the operational differences with Skylab, Skylab Life Sciences operational planning tended to over compensate the documentation requirements. There were various drivers causing this condition - all emphasizing goals: 1) a need existed to formalize interorganizational management policies, to communicate these policies throughout the operationally sensitive organizations, and to regulate Skylab preparations in consonance with common objectives, 2) a need existed to define intraorganizational responsibilities and authority for specific Skylab support functions, and 3) a measurement technique was needed to assess operational readiness status for the impending missions. This swing to greater detailed planning was dampened by regular management reviews. A baseline documentation tree evolved which capitalized on in-depth organizational familiarity with Life Sciences mission objectives, Apollo experience, the operational planning accomplishments of adjacent organizations, and the acknowledged awareness of SMEAT accomplishments.

Phase III Summary

Skylab Operational Assessment

The Skylab program was characterized by three separate crew visits. Each visit was functionally partitioned into preflight, flight, and postflight phases. Preflight Life Sciences functions attended to Life Sciences baseline experimental data collection, special physiological conditioning , crew provisioning, and a Flight Crew Health Stabilization Program (FCHSP). After launch and OWS occupancy, there was crew period of adjustment, a structured routine of EVA's, daily activities, daily medical private conferences, closeout of the OWS, and return to earth. During postflight phase and after recovery, the Life Sciences functions attended to an FCHSP consisting of shipborne and JSC situated medical examinations and postflight experimental data collection, crew debriefings and reporting of findings.

Among the preflight activities, the FCHSP attracted the most attention. It has been documented as a specific Skylab Lesson Learned (SLL) and is a high priority activity needing deliberate review. In addition to the microbial control of the crewmen, procedures were rigidly administered to stabilize each crewman for mineral balance studies. Such rigid administration may not be applicable to the Space Shuttle Program.

After docking and OWS occupancy, crew adjustment to the environment took somewhat longer than planned and delayed the start of provocative testing for the cardiovascular and metabolic activity experiments. Consequently, provocative test data describing early physiological conditioning to a null gravity domain are sparse.

Each crew demonstrated a different work capacity; however, flight planning methodology was insensitive to these differences and had to be adjusted in real-time.

The solar observations and earth resources experiments were very sensitive to ground track positions and the day/night cycle. This caused interference with medical experiment schedules which were preplanned to avoid circadian rhythm factors.

Stowage lists were difficult to maintain. Crews had a negative reporting protocol. It was always assumed by the ground that crew stowage was performed in accordance with a prescribed stowage list and consumption of expendables was identical to a consumption plan unless the crew reported differently. Although the crews were very diligent about reporting exceptions, occasional oversights stressed the inventory maintenance system.

Lastly, as missions progressed and experiments surfaced a particular phenomenon, invariably this created a need for additional and supplemental data. As crews advanced on the learning curve, and time became available for additional data collection, use of this time became very competitive among all the scientific disciplines.

The five aforementioned factors had the most dramatic effects on the ground operations. While each one of the factors was managed in real-time and rectified as the events occurred, combinations of the factors occasionally pushed the real-time management process to the ragged edge of effectiveness. The benefits gained from these experiences were that all planning protocols require sufficient latitude to absorb real-time scheduling adjustments; the management structure has to have the authority to respond in real-time mission perturbations; and, the supporting technical resources have to be clearly identified for expedient problem correction.

While the operational plans prepared for Skylab adequately handled the routine mission functions, it was the Life Sciences management network which accommodated the real-time problems and prevented operational slowdowns.

The postflight FCHSP's contained issues consonant with the preflight phase. Recovery and postflight medical examinations and experimental data collection progressed as planned. Postflight reporting of operational and scientific findings had difficulty meeting schedules. While a Skylab Medical Operations Reporting Plan addressed these reports, guidelines established in the plan were difficult to implement. The difficulty arose from interference caused by intermission preparations for the next visit to the degraded vehicle and unscheduled technical reviews. These interferences principally affected those experiments which required laboratory processing of crew returned biosamples and photographic film.

The SL-4 R+10 Day Life Sciences Mission Evaluation Report was dropped as a reporting requirement to Headquarters after SL-3. Also, the formal intermission Life Sciences flight operational readiness review plan was never exercised since no significant operational medical problems had arisen with the crews. Preparations for intermission flight readiness were administered primarily through the Level 1 Configuration Control Board and internal Medical Management Team status reviews.

In general, the postflight reporting schedule tended to overload the ground support resources more than any other activity across the Skylab Program. This activity will require further top-down discipline if these reports are to have timely operational significance.

Collection of Space Shuttle Operational Planning Data

Space Shuttle operational planning data are in a relatively general form and limited to Level I documents and some Level II documents. The preparation of Level III documents is in the formative stage. Much of the material assembled in the main body of this report has been obtained from management reviews and Requests for Proposals (RFP's) issued by NASA Centers.

Phase IV

Space Shuttle Life Sciences Operational Planning Guidelines

Whereas all manned space flight programs through Skylab have been conducted at a total cost to NASA, the Space Shuttle Program is evolving with NASA absorbing the development costs for the Space Shuttle vehicle configuration and assuming an operational role as a 'Host" for "User" organizations. In the operational phase, "Users" will absorb the program costs on a distributive basis. For some conditions, NASA may fill two roles - a Host and a User - and absorb a percentage of the operational costs.

"Users" are organizations destined to have payloads carried to and from earth orbit. They will deliver fully configured payloads or payload components to specified NASA Centers. A fully configured payload, like an earth observation satellite, may be shipped directly to KSC. Component payloads most probably will be sent to specific Payload Integration Centers for flight configuration verification and integration into a carrier for subsequent mating with the Shuttle Orbiter. To ensure proper mating of the payload components with the payload carriers, the payload support systems, and the Shuttle Orbiter, NASA, serving as a Host, will issue accommodations handbooks which describe the program procedures and vehicular interfaces which must be addressed by the User. Failure to follow the Host's guidelines could cause the user to forfeit a flight opportunity.

Serving as a Host Agency, NASA will announce payload traffic opportunities over a long term period - ten years or longer. Payload Integration Centers will be designated. These Centers shall assume total management responsibility of a payload carrier furbished with payload components (i. e., experiments). Additionally, the Payload Integration Center will coordinate all User support requirements between prelaunch payload processing and postflight deployment of specialized flight equipment.

Space Shuttle flights are being planned for seven day Centers. They will be characterized with on-orbit operating autonomy. Mission support will consist principally of long-range planning, ground tracking and centralized control of communications, tracking of scientific progress and accomplishments, rescheduling scientific objectives as data are acquired, crew training, and crew health care.

Initially, payloads are expected to contain mixed scientific investigations. With maturity, traffic models will contain progressively more payloads dedicated to specific scientific disciplines. Accordingly, crewmen who will serve as Payload Specialists will become increasingly more specialized.

Life Sciences experiments are expected to evolve from "passive suitcase carry-ons" to an active flight laboratory concept. An eventual Spacelab is anticipated. This facility will be furbished with standard laboratory configurations to support predominant investigations - vertebrates, invertebrates, plants, etc. The use of supplemental specialized experiment equipment will be discouraged.

In contrast to Skylab, experimenters are expected to have greater "in-line" flight exposure with the Payload Specialists at the Host operations center.

Following payload return, the Host operations center will provide all data prescribed for the experiment, return the experiment, and make available all specific flight equipment necessary to complete the research.

Scientific reporting will be regulated by the User's sponsor. Medical operational reporting will accommodate special routine and non-routine requirements.

Significant Conclusions

A. General Lessons Learned

1. Full configuration payload testing provides considerable operational benefits for the flight crews, the experimenters, and the mission support staff and is recommended as a payload management milestone.

2. For NASA programs when continuity exists from the Definition Phase through the Operational Phase, Life Sciences Operations plans can be limited to routine functions. A mission management staff most expediently accommodates the non-routine perturbations with support from specialists having flight hardware cognizance.

3. For payloads containing mixed disciplinary experiments, short flight span benefits can be maximized with full mission timeline simulations for the payloads. For missions greater than 7 days, experimental effectiveness becomes greater with real-time planning after patterns of experimental information become available.

4. Payload timelines lose usefulness if intolerant to investigative expansions or contractions.

5. Payload timelines have greater value when developed from specific experimental activities rather than general functional objectives.

6. Disciplined procedures ensure precise agreement between the stowage inventories maintained inflight and on the ground.

7. Life Sciences experiments depending upon a circadian rhythm variable should be avoided if mixed interdisciplinary payloads are flown and needs exist for solar and/or terrestrial observations.

8. Unless countermeasures become available, the first three or four flight days tend to be low crew experimental participation days.

9. Crews contribute valuable experimental data if functions extend beyond that of a switch mechanism.

10. Provisions for routine and non-routine dialogue between the inflight experimenters and the Principal Investigators have rewarding benefits.

11. A data management system supporting the scientific disciplines is fundamental to real-time experiments management.

12. Payload planning which recognizes joint experimental data sharing maximizes the benefits of each flight opportunity.

13. Payload planning and timelines should recognize crew requirements for other flight activities consistent with the mission regime.

14. Preplanned alternate experimental investigations permit full flight exploitation and prevent the crews from being caught "cold" with new experimental procedures.

15. The Flight Crew Health Stabilization Program needs to be consistent with the flight program objectives, the crew flight schedules, and the available trained crew population.

16. A clear demarcation is necessary between postflight operational reports and scientific reports.

17. Inflight experiment equipment should be readily calibrated to minimize calibration problems and errors during ground data processing.

18. Complex manual biowaste sampling procedures are flight distractions, compromise sample value, and increase the probability of contamination.

B. <u>Specific Space Shuttle Considerations</u>

1. New management guidelines are necessary to implement the Host/User concept.

2. Development documentation will be a key factor for cost reduction.

3. Early mission costs are expected to be absorbed by NASA until cost-sharing procedures are developed.

4. The conventional Principal Coordinating Scientist concept needs reassessment.

5. As a result of the Skylab student project successes, low cost experiments development is attracting considerable attention.

6. The scientific community will have to be apprised of revisions to the Life Sciences traffic model, the emphasis which will be placed on each flight opportunity, the procedures by which a PI will propose an experiment for a flight assignment, and the criteria to be used for selecting a proposed experiment and assigning it a mission.

7. Experimenters will have total responsibility of their experiment and equipment until launch.

8. Experimenters rather than NASA will provide ground experimental management support during the flight phase.

9. Approved special experiments equipment will be designed by the experimenter to mate with the NASA carrier and the carrier support systems.

10. Since experiment equipment may be tested at more than one NASA Center, the equipment should be compatible with standard test and checkout procedures at the Host sites. Special additional checkout and testing will be the responsibility of the Experimenter.

11. Experimenters will support the training of the Payload Specialists.

12. The use of off-the-shelf laboratory equipment will be encouraged.

13. NASA will not assume responsibility for reporting scientific findings except for those experiments which it sponsors.

II. RECAPITULATION OF THE SKYLAB OPER. PLANNING

II. RECAPITULATION OF THE SMEAT & SKYLAB OPERATIONAL PLANNING EVOLUTION

A. SMEAT Objectives and Operational Planning Background

In February 1971, The Skylab Medical Experiments Altitude Test (SMEAT) became a viable 56-day manned chamber test program. The primary SMEAT objective was to obtain and evaluate baseline data for a typical Skylab mission for those medical experiments which may be altered by the Skylab environment. The secondary objectives were: 1) to evaluate selected experiments hardware, systems, and ancillary equipment, 2) to evaluate mission data reduction and data handling procedures, 3) to evaluate preflight and postflight medical support operations, procedures, and equipment, 4) to evaluate medical inflight experiment operating procedures, and 5) to train Skylab Medical Operations team. Skylab medical experiment equipment items served as SMEAT Program test equipment.

The SMEAT test was conducted in three phases: pre-chamber - the six months prior to altitude test; chamber - the 56-day altitude test, and post chamber - the 18 days immediately following chamber test. The actual chamber test began on 26 July 1972. The test was conducted in a cylindrical, twenty-foot diameter, man-rated, vacuum chamber at the Johnson Space Center. This chamber was configured to resemble the crew quarters designated in the Skylab Orbiting Workshop (OWS). During this test, Skylab mission procedures were used to the fullest extent possible. All communications with astronauts were relayed using the Mission Control Center CAPCOM communication technique. Crew support procedures, such as those for food service and personal hygiene, also were structured in accordance with those of Skylab. Except for the gravity condition, SMEAT was a high fidelity replication of the Skylab physical environment for medical experiments.

The year 1971 was devoted to defining Detailed Test Objectives (DTO's), defining chamber testing procedures, furbishing the chamber, developing crew flight plans and procedures, assembling the data processing system, and acquiring the medical experiments chamber equipment.

In February 1972, just prior to beginning chamber installation of the medical experiments equipment, the General Electric Company was directed to assess LSD's operational readiness posture, the adequacy of the SMEAT test data flow plan, and the completeness of the equipment history documentation accompanying the SMEAT medical equipment. Only the operational readiness assessments and the test data flow plan had continuity through Skylab; therefore, the remaining discussion will emphasize these areas and tangential planning which evolved. The adequacy assessment of medical equipment documentation was closed out with report number TIR 750-M-2002, SMEAT Test Readiness Review Package, May 24, 1972, which was submitted to and approved by the SMEAT Test Readiness Review Board.

The operational readiness assessment originated with a survey of test operational support requirements distributed among the SMEAT Program Plan, the Skylab Mission Support Requirements Plan, the Preliminary SMEAT Operations Plan, the Preliminary Crew Timeline, and the approved SMEAT Medical Detailed Test Objectives (DTO's). The survey revealed a number of key and common operational functions applicable to each DTO for which preparations had to be completed before the chamber test phase began, a need for extended scope and explicitness of the SMEAT Operations Plan, and a need for more disciplined management control procedures.

By June 5, 1972, the operational test preparations were essentially complete and the chamber test phase was ready to begin.

B. Chamber Phase Operational Management

Throughout the chamber test, a Test Operations Management Team (TOMC) composed of key operations personnel, LSD functional management, experimenters, and flight surgeons met daily and reviewed test progress and crew health. While operational procedural deficiencies came to the TOMC's attention, (the identification and correction of which were secondary test objectives), none were more severe than those appearing in data management. Three limitations were immediately distinguishable: 1) no management level summary data were available to monitor the crew's progressive adaptation to the test environment, 2) no experimentally acquired medical data were being utilized to assess the crew's physiological and clinical tolerance to the test domain, and 3) verification of experimental findings was slow and limited the effectiveness of the daily test reviews. To correct these limitations, off-line experiments data processing and biospecimen laboratory analysis were given aggressive attention. As data turnaround times became shorter, experimental findings were summarized on a series of trend charts which included also critical clinical and environmental information. The consolidated trend information provided a convenient crew health status perspective. By the mid-point of SMEAT, these operations became routine activities.

A reporting plan had been prepared to maintain a history of daily test progress, to inform cognizant NASA management components of test progress and medical findings, and to document 7, 14, and 28-day test reviews which were decision milestones for continuing the test. Daily test progress reports were prepared each morning, submitted to TOMC, and distributed as management progress reports. The trend charts were substituted for the periodic 7, 14, and 28-day reports.

After the chamber phase was underway, the crew requested summarized experimental data so they could track their physiological changes during test. Verified numerical experiments data which were distributed by the investigators and plotted routinely on trend charts served the crew's needs. This procedure was continued throughout Skylab.

Operationally, SMEAT was an exercise to definitize Skylab mission support plans; however, physical and operational support difference between SMEAT and Skylab made it difficult to equate the two programs. One fundamental analytical technique was introduced to overcome SMEAT and Skylab differences. This was the operations flow plan which coupled the functional data activities of each medical experiment to each other. The integration of these flow plans into a consolidated plan illuminated their planning value.

C. SKYLAB PLANNING AND DOCUMENTATION

When SMEAT testing ended, the General Electric Company constructed Skylab operations flow plans for crew medical care, medical experiments, and vehicular/crew support systems, (food system, Inflight Medical Support System, etc.). These flow plans were used subsequently to construct the Master Skylab Medical Operations Documentation Plan appearing in Figure II-1. The block diagram, starting on the left side, specifies four (4) fundamental planning documents: 1) an LSD Skylab Operations Plan, 2) a Skylab Medical Flight Operations Plan, 3) a Skylab Medical Experiments Operations Plan, and 4) a Skylab Vehicle Support System Operations Plan. The omission of reference requirements documents is immediately evident; however, the JSC/MSFC Skylab Mission Requirements Document had been deemed sufficiently inclusive and in an acceptable state of preparation to negate the need for a special medical requirements document. The objective was to extract and consolidate relevant mission requirements into the LSD Skylab Operations Plan and to add a general medical management plan which addressed "how" the requirements were to be organizationally implemented. The three (3) remaining and subordinate documents were intended to specify detailed operational methodology.

The Skylab Medical Flight Operations Plan was to be analogous to conventional Apollo Medical Operations Plans and was specified to address the practice of "flight medicine" during the Skylab missions. The Skylab Medical Experiments Plan was to be the operational methodology for conducting Skylab medical experiments and processing the acquired data. The Skylab Vehicle Support Systems Operations Plan was designated to contain LSD's operational management practices for the Inflight Medical Support System, Food and Utensils, Heating Food Tray, CO_2/Dewpoint Monitor, Inflight Blood Collection System, and Utensil Wet Wipes. All remaining topics in the diagram were topical subsets of these three (3) documents. The Skylab Program Office subsequently edited the Mission Requirements Document. The edited revision preserved the flight phase only and was issued in December 1972. Coincidentally, with the distribution of the revised Mission Requirements Document, LSD established a formal Skylab Medical Operation Planning and Review (SMOPAR) panel to review and to coordinate mission preparations within its organization. One of the first recommendations submitted by the

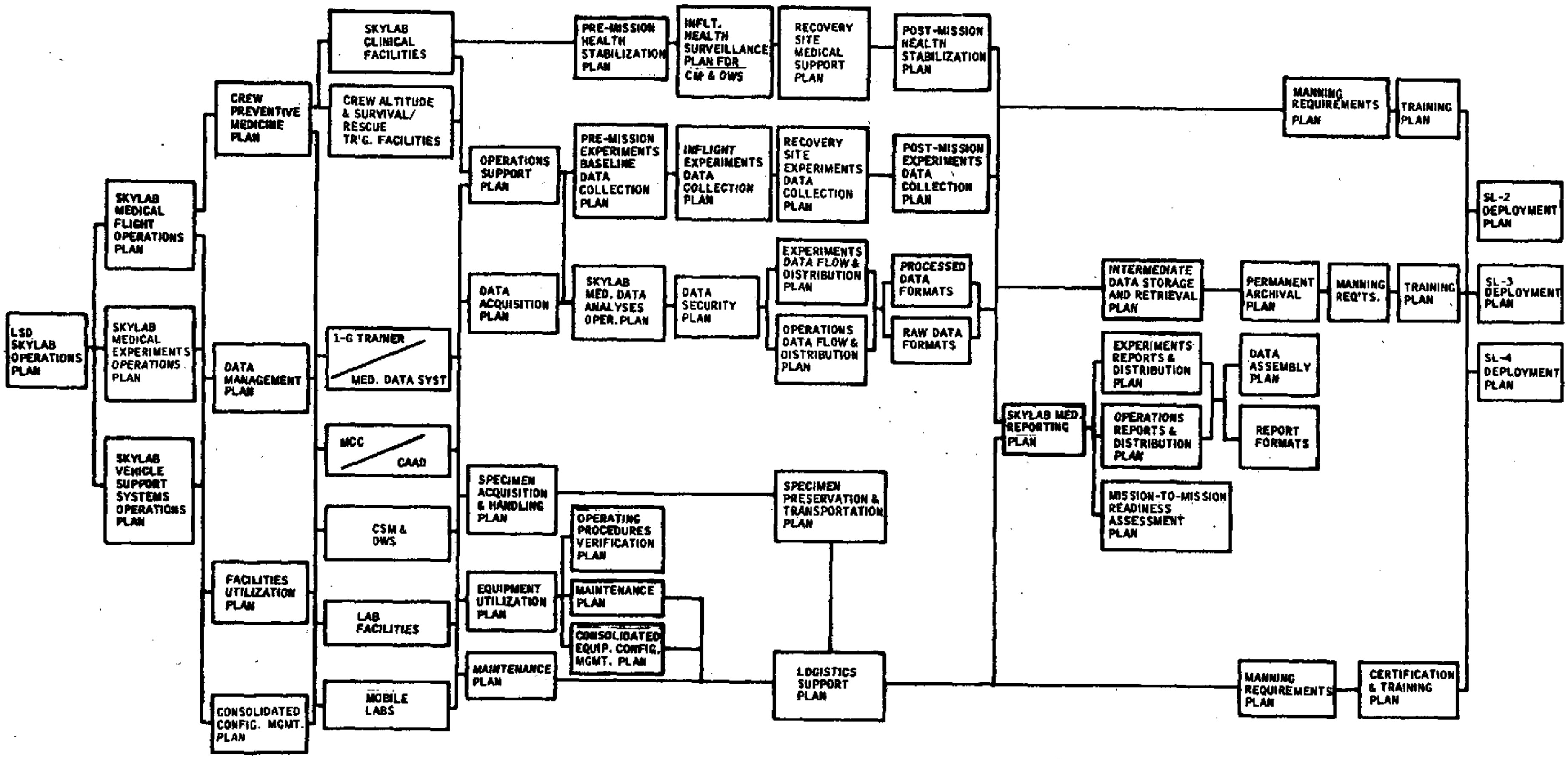

FIGURE II-1
MASTER SKYLAB MEDICAL OPERATIONS DOCUMENTATION PLAN

panel was to abandon the governing LSD Skylab Operations Plan and to prepare a detailed Skylab Medical Requirements Document to re-establish preflight and postflight medical mission requirements. Precious time was inordinately consumed constructing the Skylab Medical Requirements Document. This condition forced a re-evaluation of the Directorate's need for the Skylab Medical Flight Operations Plan, the Skylab Medical Experiments Operations Plan, and the Skylab Vehicle Support Systems Operations Plan. SMOPAR ultimately supported the preparation of seven major plans: 1) a Skylab Medical Operations Plan, 2) a Flight Crew Health Stabilization Plan, 3) a Skylab Medical Operations Reporting Plan, 4) an SML Operations Plan, 5) a Skylab Medical Data and Calibration Management Plan, 6) a special Biochemistry/Clinical Laboratory Operations Support Plan, and 7) a Skylab Biomedical Specimen Recovery Plan. A diagrammatic relationship of LSD's operational documentation structure appears in Figure II-2, LSD Skylab Program Documentation Tree.

In addition to the seven major plans listed above, the General Electric Company was directed to develop and deliver a "Between Mission Reporting Plan". This evolved into a document entitled, "The Procedures for LSD Flight Operations Readiness Reviews". The Flight Operations Readiness Review (FORR) procedures complemented the Skylab Medical Operations Reporting Plan. They set forth methods, techniques, and required accomplishments to assess the Directorate's internal state-of-preparedness for the Skylab mission. Among the prime objectives established for the FORR were those to assess and to establish the Directorate's position and preparedness to act on safety matters concerning crew health and to assess and establish the Directorate's preparedness to support its mission roles.

The SL-3 and SL-4 FORR's were organized somewhat differently from the SL-1/SL-2 FORR. The SL-3 and SL-4 FORR's were designated "intermission FORR's" (IFORR's).

The General Electric Company developed the Skylab Medical Operations Reporting Plan. This documented supported the LSD Data Management System and addressed the formal preparation and distribution of medical reports to be circulated during the Skylab Program Management. The Skylab Medical Operations Reporting Plan was published by NASA as Document No. JSC-07882.

A Summary of Contractual Documents prepared and submitted by the General Electric Company is tabulated in Table II-1.

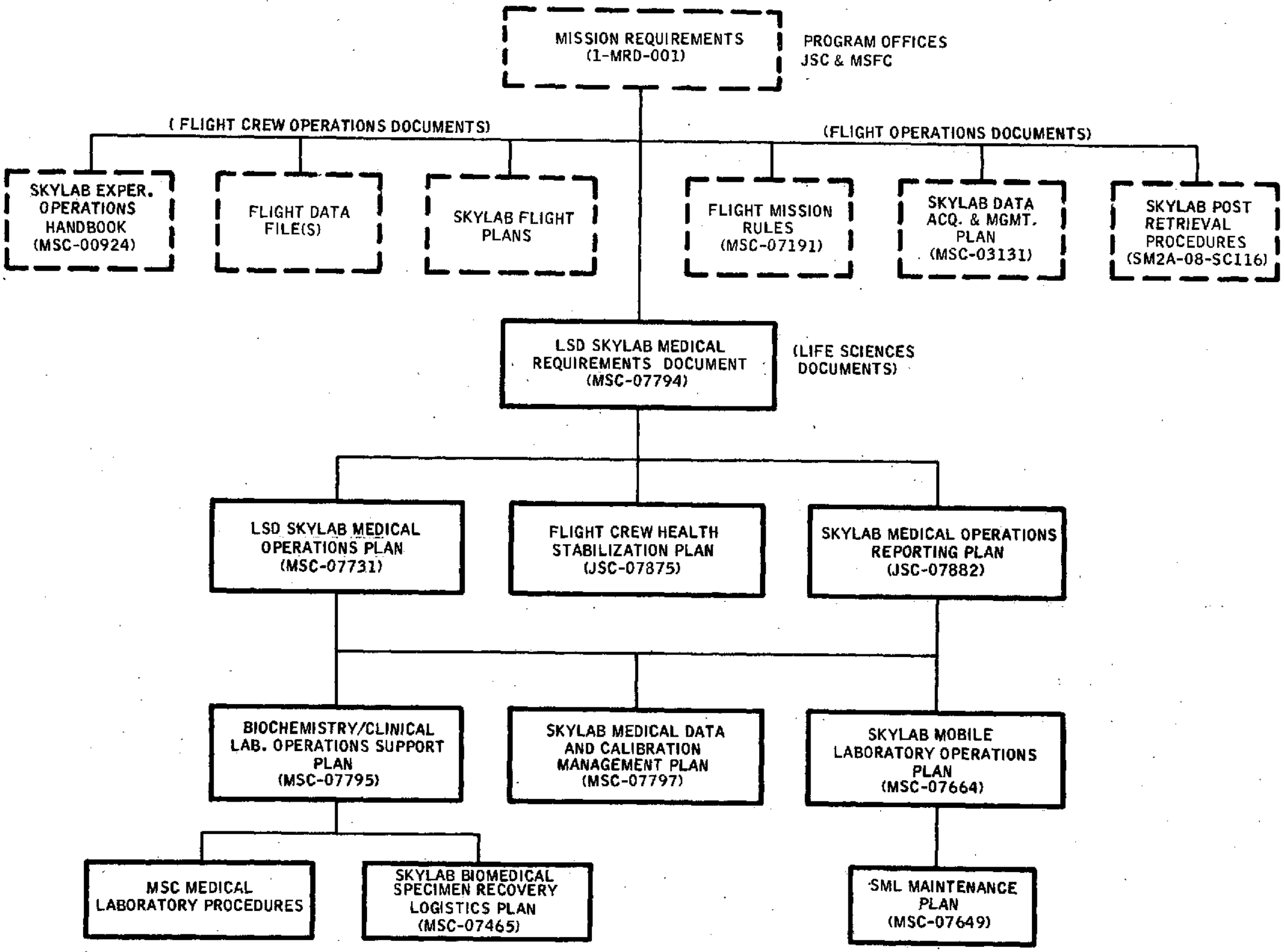

FIGURE II-2
LSD SKYLAB PROGRAM DOCUMENTATION TREE

CONTRACT REQUIREMENT	TITLE OF TRANSMITTED DOCUMENT	REFERENCE
1.. Preliminary Master Documentation Operations Plan	Preliminary Master Operations Documentation Plan	GEH(S)-A-1211
2. Final Master Documentation Operations Plan	LSD Skylab Master Documentation Operations Plan	GE TIR 750-MED-2008
3. Guideline Documents	Skylab Medical Operations Reporting Plan LSD Skylab Documentation Implementation Plan	GE TIR 741-MED-3029 GE TIR 750-MED-2007
4. Assessment Reports	Skylab Operations Documentation Assessment Report	GEH(S)-A-1289 GE TIR 741-MED-3002 GE TIR 741-MED-3015 GE TIR 741-MED-3019 GE TIR 741-MED-3024 GE TIR 741-MED-3028
5. Between Mission Reporting Plan	Procedures for LSD Flight Operations Readiness Reviews	GE TIR 741-MED-3018
6. Skylab Medical Operations Reporting Plan	Same	GE TIR 741-MED-3029
7. Preliminary SL-2 R+10 Day Mission Evaluation Report	Same	GE TIR 741-MED-3034
8. Final SL-2 R+10 Day Interim Crew Health Executive Summary Report	Same	GE TIR 741-MED-3035
9. Preliminary SL-2 R+21 Day Interim Crew Health Executive Summary Report	Same	GE TIR 741-MED-3037

(cont'd following page)

TABLE II-1
SUMMARY OF CONTRACTUAL DOCUMENTATION DELIVERIES

CONTRACT REQUIREMENT	TITLE OF TRANSMITTED DOCUMENT	REFERENCE
10. Preliminary SL-3 R+10 Day Mission Evaluation Report	Procedures for LSD Flight Operations Readiness Reviews	GE TIR 741-MED-3050
11. Final SL-3 R+10 Day Mission Evaluation Report	Same	GE TIR 741-MED-3051
12. SL-3 Preliminary Interim R+33 Day Biomedical Executive Summary Report	Same	GE TIR 741-MED-4001
13. Preliminary SL-4 R+10 Day Mission Evaluation Report	Same	GE TIR 741-MED-4005
14. Final SL-4 R+10 Day Mission Evaluation Report	Same	GE TIR 741-MED-4006
15. SL-4 R+30 Day Preliminary Mission Evaluation Report	SL-4 R+30 Day Preliminary Mission Evaluation Report (Medical Operations)	GE TIR 741-MED-4007
16. Exhibit "E" Final Report	Biomedical Program Study - Final Report	GE TIR 741-MED-4013

TABLE II-1 (Cont'd)
SUMMARY OF CONTRACTUAL DOCUMENTATION DELIVERIES

III. SKYLAB LIFE SCIENCES OPERATIONAL MANAGEMENT

III. SKYLAB LIFE SCIENCES OPERATIONAL MANAGEMENT

A. Operational Objectives

The operational Life Sciences objective was, first and foremost, to do those things necessary to insure the attainment of the Skylab program objectives. These in turn are quoted from the Skylab Operations Directive (Program Directive No. 43C).

(1) Biomedical and Behavioral Performance - determine and evaluate man's physiological responses and aptitudes in space under zero gravity conditions and his post-mission adaptation to the terrestrial environment, through a series of progressively longer missions, and to determine the increments by which mission duration can be increased.

(2) Man-Machine Relationships - to develop and evaluate efficient techniques utilizing man for sensor operation, discrimination, data selection and evaluation, manual control, maintenance and repair, assembly and set-up, and mobility involved in various operations.

(3) Long-Duration Systems Operations - to develop techniques for increasing systems life, for long duration habitability and for long duration mission control. To investigate and develop techniques for inflight test and qualification of advanced subsystems.

(4) Experiments - to conduct solar astronomy and other science, technology and applications experiments involving man when his contribution will improve the quality and/or yield of the results.

B. Skylab Mission Characteristics

The Skylab was placed in a 234 NM orbit around the earth at an inclination of 50° where it functioned throughout three long-duration manned visits and two intervening periods of unmanned operation. A different three-man crew inhabited and operated the orbital assembly during each visit, and performed a number of physical science, biomedical science, earth applications, and space applications experiments.

All of the major experiment hardware and consumables were launched with the unmanned workshop. However, due to contingencies, a desire to upgrade each succeeding mission, and to accommodate additional demonstrations and experiments, a considerable number of items were launched with each crew in the Command Module (CM) and later transferred to the workshop. The three Skylab visit durations were planned and baselined at 28 days, 56 days, and 56 days, respectively. The actual durations were 28.03 days, 59.46 days, and 85.18 days, respectively. The second visit was extended three days beyond baseline to put the recovery location near San Diego, California in order to get the recovery ship docked prior to the second (R+1) day crew medical examination. The last visit was extended to the limit of the expendables, both to perform extra scientific experiments and to learn more about the effects on man caused by longer duration flights. Each successive mission benefited from the knowledge gained on the previous mission. Medically, these benefits permitted the last crew to be as good or better physically at reentry than the two previous crews whose visits were shorter durations.

C. LSD's Operational Responsibilities

The Life Sciences Directorate (LSD) at the Johnson Space Center (JSC) had Skylab responsibility for Crew Health Care, Life Sciences experiments, and related Mission Support.

1. Crew Health Care

This function has been a JSC responsibility since the early phases of the manned space program. Health care involves physical examinations and treatment when required, preflight and postflight crew health stabilization management and real-time inflight health status monitoring.

In support of this role, LSD also had the responsibility for furbishing the OWS with certain health care support items. These included the Inflight Medical Support System (IMSS) and commensurate crew training, the food system, the Operational Bioinstrumentation System (OBS), CO detector tubes, and CO_2/dewpoint monitor. However, these are mainly hardware responsibilities rather than operational responsibilities and will not be discussed further in this report.

2. Experiments

Skylab Objective No. 1, Biomedical and Behavioral Performance, implied that the missions were to be more than endurance contests. The objective specified determining and evaluating man's physiological responses and aptitudes in space under zero gravity conditions. NASA, with the support of the nation's medical community, designed a series of meaningful and comprehensive experiments to fulfill this objective. While LSD had scientific and operational responsibility for Skylab experiments, MSFC was the hardware integration Center. MSFC also supplied much of the SMEAT medical experiment hardware to JSC.

The experiments have been grouped into categories that correspond to major body systems or body functions. The following is a list of seven experimental areas and the experiment components in each area.

A. Nutrition and Musculoskeletal Function Experiments - M070 Series

1. M071, Mineral Balance
2. M073, Bioassay of Body Fluids
3. M074, Specimen Mass Measurement
4. M078, Bone Mineral Measurement

B. Cardiovascular Function Experiments - M090 Series

1. M092, Lower Body Negative Pressure
2. M093, Vectorcardiogram

C. Hematology and Immunology Experiments - M110 Series and S015

1. M111, Cytogenic Studies of Blood
2. M112, Hematology and Immunology
3. M113, Blood Volume and Red Blood Cell Life Span
4. M114, Red Blood Cell Metabolism
5. M115, Special Hematologic Effects
6. S015, Single Human Cells

D. Neurophysiology Experiments - M130 Series

1. M131, Human Vestibular Function
2. M133, Sleep Monitoring

E. Behavioral Effects - M150 Series

1. M151, Time and Motion Study

F. Pulmonary Function and Energy Metabolism - M170 Series

1. M171, Metabolic Activity
2. M172, Body Mass Measurement
3. Mission Support

Mission support which was performed by LSD's flight medicine, research and engineering organizations had the following four distinct categories:

A. Crew Health Monitoring
B. Experiment Coordination
C. Hardware Evaluation and Anomaly Resolution
D. Recovery Team Support

The crew health monitoring was conducted at the Mission Surgeon's console in the Mission Operations Control Room (MOCR). The position was supported by an Aeromedical Technician position in the adjacent Medical Staff Support Room (SSR) and by many of the experimenters who assembled findings while the mission was in progress.

The second category of mission support was experiment coordination performed by the LSD Mission Manager in the Medical SSR. He provided the interface among the MOCR flight controllers, the Principal Investigators (PI's), or Principal Coordinating Scientists (PCS), the project engineers (PE's) in the Mission Evaluation Room (MER), and LSD management. He was the focal point for scheduling medical experiments, for resolving hardware anomalies, stowage problems, medical data processing problems, and for medical data distribution.

The third category of mission support was hardware evaluation and anomaly resolution performed by the LSD Project Engineers in the MER. PE's investigated all anomalies in the medical experiment area and were responsible for recommending "fixes" or "workarounds" whenever LSD hardware was not functioning properly. The PE's also tracked the onboard stowage of medical equipment and advised the crew when the onboard stowage lists conflicted with actual stowage status.

A fourth category of mission support was Recovery Team Support. Each medical recovery team was led by a specific crew surgeon assigned to each crew and was composed of additional flight surgeons, laboratory technicians, experimenters, experiment technicians, project engineers, and laboratory equipment specialists. Medical recovery team equipment was configured in six Skylab Mobile Laboratories (SML) which were transported by a single C5A aircraft to San Diego, California, for loading on the recovery ship. The Prime Recovery Ship (PRS) was provided by the Navy and had onboard Department of Defense (DOD) helicopter crews and a DOD medical team which provided assistance. NASA/DOD coordination and all logistics planning were performed by the Flight Operations and Recovery Branch of the Flight Control Directorate and were not an LSD responsibility. The Recovery Team was deployed approximately a month prior to planned splashdown for the longer missions in order to give the crew the complete recovery protocol (physical exams and postflight experiment runs) in the event of an early mission termination. In case of a mission termination prior to PRS deployment, the SML's were on stand-by status at JSC, ready for loading into a C5A at Ellington Air Force Base and deployment to a number of alternate recovery site locations around the world.

D. LSD's Operational Management Phases

1. Preflight Phase

Preflight medical mission planning was managed through the Skylab Medical Operations Planning and Review (SMOPAR) panel composed of the LSD organizational representatives shown in Table III-1. Generally, the attendance expanded with representatives from Flight Crew Operations Directorate (FCOD) and/or Flight Operations Directorate (FOD) who had cognizance of specific agenda items. These Directorates represented the flight crew and flight control functions, respectively. LSD's Operations Planning Branch served as the secretariat and performed most of the routine functions for the panel. These functions included preparing the meeting agenda, notifying members and attendees, taking minutes, recording, tracking and closing out action items, and setting up a change control system. Under this system, changes to approved (baselined) documents were submitted to the SMOPAR through the Configuration Management Officer on a SMOPAR Change Requirements Directive (SCRD). This procedure was very similar, but less formal than that instituted for flight hardware changes which required approval by the JSC and MSFC Change Control Boards (CCB).

The SMOPAR premission activities included in-depth reviews of all operational aspects of Skylab, including the following activities, most of which resulted in a baseline document.

a) Skylab Medical Requirements (MSC-07794)
b) Preflight and Postflight Crew Health Stabilization Program (JSC-07875)
c) Data Management (MSC-07797)
d) Reporting Plan (JSC-07882)
e) Laboratory Operations (MSC-07795)
f) SML Operations (MSC-07664)
g) Sample Handling (MSC-07465)
h) Mission Requirements
i) Flight Mission Rules
j) Operating Plans (MSC-07731)
k) Crew Training Schedules
l) Crew Baseline Data Schedules

2. Inflight Phase

Because of Skylab missions lengths and the numerous competing scientific objectives, the Skylab Program Director established at the Mission Control Center, the Flight Management Team (FMT) to administrate to policy level decisions during the flight phases. Members included the Skylab Program Manager from both JSC and MSFC and the directors of the key organizations involved in the mission. This group operated as a Level I Configuration Control Board and had authority to approve changes to the mission requirements, mission rules and return stowage requirements.

Other key mission management organizations were extensions of the management organizations used successfully during the Apollo missions. The various mission management groups and their interfaces are shown schematically on Figure III-1, the Skylab Mission Management Organizational Relationships. The key management facility was the Flight Operations Management Room (FOMR) which was staffed by Skylab Program Office representatives from both JSC and MSFC. This group tracked the mission accomplishments and mission problems and when decisions were needed, the FOMR acted directly or submitted recommendations to the Center level Skylab Program Managers for immediate action, and when advisable, FMT action. Serving a staff function to the FOMR was the Science Planning Committee. This group met twice weekly to set experiment schedules and priorities.

The implementation of management decisions involved the Mission Operations Control Room (MOCR) team, the Staff Support Rooms (SSR's), and the Mission Evaluation Room (MER) team, as shown on the diagram. Specifically, medical mission management was effected by the Life Sciences Director supported by the Medical Management Team (MMT). This team was chaired by the Director, or in his absence, a member of the Director's staff, and was composed of both crew health and medical experiment representatives as shown in Table III-1. Decisions by this team, which met almost daily immediately before the FMT meeting, were documented in the minutes of the meetings which had extensive distribution within and outside LSD. Decisions affecting internal administration rarely surfaced beyond the Life Sciences community. Decisions which affected mission management had to be submitted to the FMR. This was done through formal administrative paths and initiated by the medical SSR when the decisions were not time critical. When decisions were time critical, they were taken directly to the FMT by the Director. Policies routed from the MMT and/or FMT were implemented in the Mission Operations Control Room (MOCR) by the Flight Surgeons when they had clinical significance and the Biomed Experiment Officer (BEO) when they had operational experimental significance.

The BEO's were flight controllers, members of the Flight Operations Directorate, immediately subordinate to the Flight Director, and responsible for the flight conduct of the medical experiments. With additional specialists in the adjacent medical Staff Support Room (SSR), the BEO's Biomedical Team managed experiment data collection, data reduction, and delivery of reduced data to the experimenters.

LSD Mission Managers had a console station in the SSR, and interfaced the MOCR and the FOMR with the medical experiments community which consisted of Principal Investigator's (PI's), Principal Coordinating Scientists (PCS), and medical equipment Project Engineers. The LSD Mission Manager also served on the Science Planning Committee to ensure appropriate emphasis was given to medical experiments schedules.

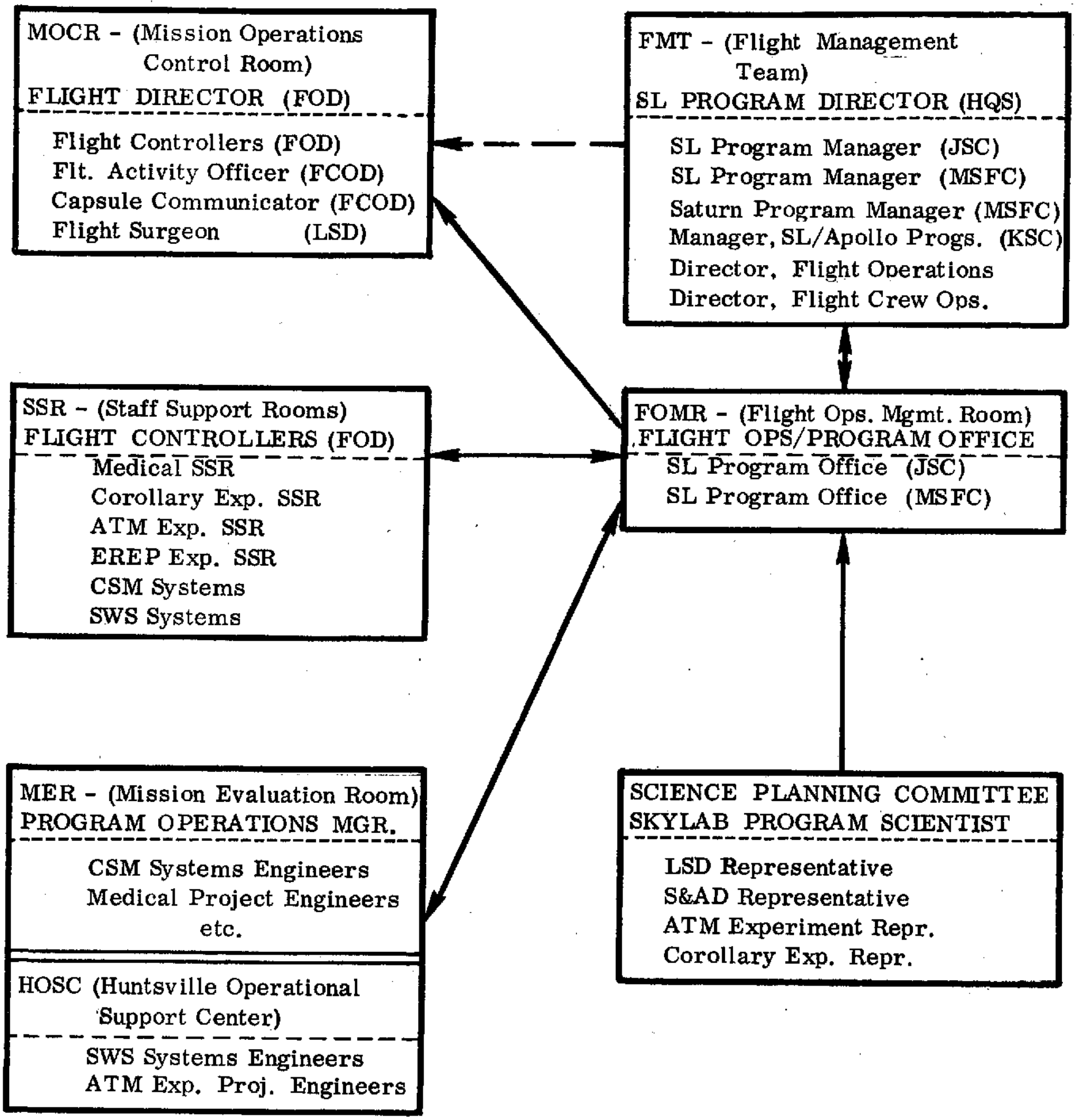

FIGURE III-1

SKYLAB MISSION MANAGEMENT ORGANIZATION AND RELATIONSHIPS

TABLE III-1

LSD OPERATIONAL MANAGEMENT ORGANIZATION FOR SKYLAB

- <u>PREMISSION PHASE</u>

  Skylab Medical Operations Planning and Review (SMOPAR) panel.

  <u>Members:</u>

  Director, LSD
  Deputy Director
  Deputy Director for Medical Operations
  Chief, Biomedical Research Division
  Chief, Health Services Division
  Chief, Bioengineering Systems Division

- <u>MISSION PHASE</u>

  Medical Management Team (MMT)

  <u>Members:</u>

  Same as for SMOPAR panel listed above plus:

  Flight Surgeon(s)
  LSD Mission Manager(s)
  Biomedical Experiment Officer(s)
  Experiment Principal Investigators and
  Principal Coordinating Scientists
  Radiological Health Officer

Experimenters (PI/PCS's) and Project Engineers, whether on-site or off-site, were on-call continuously. The Experimenters had overall accountability for their experiments and provided direct consultative support in matters pertaining to experimental protocol variations, data processing variations, and interpretation of experimental findings. They retained signature authority for closeout actions related to equipment and crew checklist anomalies corrected by cognizant Project Engineers.

Project Engineering assignments were usually coordinated by a representative stationed in the Mission Evaluation Room (MER) which monitored MOCR/SSR and crew air-to-ground communications. Two-way communications between the MER and the MOCR/SSR were conducted over telephone lines.

Finally, the Medical Management Team had the MOCR Flight Surgeons supported by the SSR Aeromedical Technicians. The LSD Flight Surgeons and Aeromedical Technicians, who were functionally subordinate to the Flight Director during their assignments at the Mission Control Center, monitored clinically relevant experiments data and attended to the health care of the flight crews.

Throughout the flight phase, this structure permitted the Life Sciences Director to have total mission visibility and to exercise management interfaces with Skylab Program staff in an upward direction and with the SMEAT trained operations staff located in the Mission Control Center in a downward direction.

3. Postflight Phase

The detailed planning associated with sending a Recovery Team together with transportable mobile laboratories to the Primary Recovery Ship (PRS), began concurrently with each flight phase. The early start was necessary to support an early mission termination as well as a nominal recovery. Recovery preparedness reviews were often agenda items for the daily Medical Management Team meetings and received special independent attention at increasing rates as time drew closer for transferring the Recovery Team to the PRS. Following the deployment of the Medical Recovery Team aboard the PRS, the Crew Surgeon who was the team leader, commenced a series of dry run and wet run simulations to establish efficient crew examination schedules. The Crew Surgeon maintained daily telecom contact with the Director and the Flight Surgeon on duty in the MOCR, provided readiness briefings, and received crew health status reports from the duty Flight Surgeon. On recovery day, quick-look medical reports were telecommed to the Life Sciences Director several hours after recovery, immediately following a complete crew examination, at approximately Recovery plus 10 hours, and every 24 hours thereafter until the eighteen day postflight quarantine period was completed.

E. Review of Skylab Lessons Learned

Since the completion of the Skylab Program, each NASA Center has compiled a Skylab Lessons Learned (SLL) document for their functional areas. These SLL's together with Crew Debriefing Summaries (CDS) have been reviewed in order to project possible implications of these SLL's to the Life Sciences Space Shuttle Program planning. A set of the most pertinent SLL's appear in Appendix A with the originating source specified in the top line of the form. The lower section of the SLL form titled "Application of SLL to Life Sciences Program" was interpreted as part of this final report. LSD action assignments and future policy could be based on the interpretations contained in these SLL's.

It should be noted that the SLL's do not contain specific Skylab medical operations experiences as these lessons learned have not been assembled by the LSD to date. It is, therefore, recommended that lessons learned in this area, e.g., MOCR/SSR operations, SML operations, and FCHSP, etc., be assembled by the LSD from all personnel who participated in the Skylab medical operations. When it is completed, a full set of the SLL's including those reported in this final report will serve as a useful input for the development of Life Sciences Space Shuttle Program and Operations planning.

The SLL's have been interpreted in context with Life Sciences applications and compiled in six disciplinary areas:

I. Life Sciences Experiments/R&D
II. Program Management
III. Mission Planning/Training/Documentation
IV. Operation and Data Management
V. Operation Logistics
VI. Design Interface

Table III-2 projects the SLL's to organizational areas of cognizance within the Life Sciences disciplines. The table illustrates the degree to which the SLL's penetrate all organizational elements.

The far left column on the table contain SLL numbers grouped according to the above disciplines and provide a convenient method of finding specific SLL's in Appendix A, as this number is found on the upper right corner of each SLL.

TABLE III-2
SUMMARY OF THE SKYLAB LESSONS LEARNED
AND ORGANIZATIONAL COGNIZANCE

SLL NO.	SLL TITLE AND CATEGORY	APPLICABLE ORGANIZATION				
		Mgmt. Level I	Mgmt. Level II	Research	Clinical	Eng'g.
I.	LIFE SCIENCES EXPERIMENTS/R&D					
1.	Systematic Space Life Sciences Experiment Program	*	*			
2.	Development of Integrated Medical Data Evaluation System		*			
3.	Experiment for Neuromuscular Reflexes			*		
4.	Experiment for Head Fullness in Zero-G			*		
5.	Experiment for the Effects of Exercise and CVS Integrity			*		
6.	Experiment for Muscular Adaptation in Space			*		
7.	On-Orbit Health Care				*	
8.	Experiment for Skin/Mucous Membrane			*		
9.	Countermeasure(s) for early adaptation				*	
10.	IMSS for all Shuttle Flights	*	*			
11.	Utilization of Two-Way TV for Life Sciences	*	*		*	
12.	Psychophysiological Experiment for 1-g Orientation Effects			*		
13.	Human Errors Analysis of Skylab Missions			*		
14.	Space Shuttle Mass Transfer Simulation	*				
15.	Life Sciences Experiments Alternate Flight Planning		*			
II.	PROGRAM MANAGEMENT					
1.	Operational Support to Experiment Groups			*		
2.	Space Shuttle Life Sciences Experiment Altitude Test	*	*			
3.	Experiment Planning and Development		*			
4.	Life Sciences Experiments Constraint List	*				
5.	Life Sciences Experiment Requirements Document		*			
6.	Life Sciences Experiment Planning		*			
7.	Space Shuttle Medical Documents Requirements		*			
8.	Life Sciences Payload Development Discipline	*				
9.	Interface to Man-Machine Integration Team		*			
10.	GFE Utilization Plan for Life Sciences/Medical Operations					*
11.	Space Shuttle Life Sciences Planning Guidelines		*			
12.	Acceptance Testing of Biomedical Hardware					*
13.	Visual Cues/Design Review Factors		*			
14.	Personal Hygiene Equipment for Shuttle Crew and Passengers	*				
III.	MISSION PLANNING/TRAINING/DOCUMENTATION					
1.	PI-SIM-Training Coordination Plan		*			
2.	Crew Traffic Density Assessment During Mockup Review					*
3.	Ground Medical Support Requirements Definition				*	
4.	Space Shuttle Medical Operations Documents		*			
IV.	OPERATIONS AND DATA MANAGEMENT					
1.	Space Shuttle FCHSP Definition				*	
2.	Postflight Crew Health Monitoring Plan				*	
3.	Life Sciences Crew Training Program		*			
4.	Uniform Test and Checkout Procedures in Various Test Sites		*			
5.	Potable Water Monitoring Plan					*
6.	Private Medical Conference and Crew/P.I. Communication			*	*	
7.	Ground Life Science and Medical Data System Interfaces			*		
8.	Life Sciences Data Management Plan		*			
9.	Life Sciences Data Management System Requirements Definition		*			
10.	Life Sciences Data Quality Monitoring Capability					*
11.	Real-Time/Near-Real-Time Crew Health Evaluation Data System			*	*	
12.	Inflight Data Return Capability	*				
13.	Onboard Life Sciences Data Management Requirements			*		
14.	Life Sciences Data Documentation System		*			
V.	OPERATION LOGISTICS					
1.	Space Shuttle Food System Requirements Definition			*		
2.	Automatic Food, Water Intake, Biowastes Sampling and Preservation	*				
3.	Life Sciences Mission Support Hardware Availability Status Monitoring					*
4.	Experiment Equipment Quantity Requirement Checklist					*
VI.	DESIGN INTERFACE					
1.	Requirements Input to the Shuttle Glass Window Design		*			
2.	Life Sciences Hardware Onboard Calibration Capability			*		*
3.	Crew Safety Warning System	*	*			
4.	Space Shuttle Food Stowage Requirements Definition	*				
5.	Interface with the Habitability Study Team					*
6.	Interface with IVA Safety Design	*				*
7.	Onboard Redundant System Requirements					*
8.	Definition of Manual and Automated Functions	*	*			
9.	LSD's Role in Flammability/Toxicity Hazard and Monitoring Plan		*			

IV. SPACE SHUTTLE OPERATIONAL MANAGEMENT PLAN

IV. SPACE SHUTTLE OPERATIONAL MANAGEMENT PLAN

A. Operational Characteristics

Details of the Space Shuttle System flight hardware, mission characteristics, and payload characteristics appear in Appendix B. These details have been relegated to the Appendix because the System provides the next major set of flight opportunities and deserves considerably more background material than submitted for SMEAT and Skylab.

Salient characteristics of the Space Shuttle program which will control the development of an advanced Life Sciences experiment payload program are listed below:

1. Baseline is a 7-day, low earth orbit mission extending between 28^{0} and 104^{0} inclinations.

2. A capability will exist to extend the missions to 30 days; however, the additional expendables necessary for the longer duration shall be charged to the payload.

3. The operating environment shall consist of a 14.7 psi mixed gas atmosphere for shirtsleeve operations by a four-man crew.

4. Load factors will not exceed 3-g's along the x and z axes.

5. Payloads will contain mixed scientific disciplines initially and graduate to dedicated disciplines as the Space Shuttle program progresses.

6. Payloads will be configured as Sortie Labs, Carry-on experiments, Pallets, Free Flyer Satellites, Tugs, and payloads with kick stages (Definitions appear later in this section).

7. Spacelabs launched as manned, Shuttle attached sortie labs will be configured most probably with general laboratory equipment. The general laboratory configuration will be baselined by the "Host" organization for the experimenters who will be considered "Users".

All other payloads will be automated. If these automated payloads are to remain attached to the Shuttle Orbiter, crew functions can be expected to be limited to turn-on/turn-off procedures.

8. Payload costs from preflight through postflight will be prorated among all experiments assigned to a Space Shuttle mission.

9. Specialized experiment equipment will be discouraged.

10. Organizations outside NASA will be encouraged to sponsor flight experiments.

B. Life Science Research Goals and Objectives

Based on experience gained in previous programs, Space Shuttle program Life Science goals and objectives will include the following three broad areas of investigation as discussed in the Preliminary Summarized NASA/ESRO Payload Descriptions, Sortie Payloads, MSFC, October 1973:

1. Biomedicine: A variety of man-related studies on man or on animal model systems where required for safety, etc., to understand:

a. Mechanisms of man's responses to space flight and capabilities to adapt to space environments.

b. Man as an element of flight systems whose performance critically affects total system performance and whose safety is of primary concern. Technology of the total man-machine interface is to be validated and improved.

2. Space Biology: Research on a wide variety of biological materials ranging from cells of whole organisms in order to understand:

a. The role of gravity in life processes on earth and in space.

b. The nature and influence of biological rhythm on organisms on earth.

c. The biological implications of high-Z energetic particles.

d. Potential applications of biological knowledge gained in space to solutions of problems on earth for the benefit of mankind.

3. Advanced Technology: Variety of research, including, but not limited to:

a. Development of regenerative life support systems and advanced protective devices.

b. Measurement of man's performance in EVA and development of supportive equipment.

c. Demonstration and flight evaluation of teleoperator technology.

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
<u>NASA</u>																				
Astronomy	2	2	2	1	2	4	2	5	2	4	5	4	7	6	7	5	6	5	6	77
Physics	2	1	2	1	2	1	2	2	3	1	2	3	1	2	3	4	3	4	4	43
Planetary	1	1	2	2	2	2	5	2	7	-	3	4	5	5	2	-	2	2	2	49
Lunar	-	-	-	-	-	-	1	-	-	-	-	1	-	1	1	1	1	1	1	8
Life Sciences (LS-1)*	-	-	-	-	1	-	1	2	2	2	2	2	2	2	2	2	2	2	2	26
Earth Observations	1	2	-	2	3	3	3	3	4	3	3	2	4	2	6	2	4	2	4	53
Earth and Ocean Physics	-	1	-	1	1	-	2	2	4	2	-	-	1	4	-	-	-	4	-	22
Communications and Navigation	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Space Processing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Technology	-	-	-	-	-	-	-	1	-	1	-	1	-	1	-	1	-	1	-	6
Total	6	8	7	7	11	10	16	17	22	13	15	17	20	23	21	15	18	21	19	286
Non-NASA/Non-DOD																				
Communications and Navigation	5	9	8	6	6	9	4	6	6	5	8	6	6	6	3	9	5	9	4	120
Earth Observations	1	1	2	2	3	4	3	2	4	4	2	2	3	3	3	7	4	5	4	59
Earth and Ocean Physics	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	-	3	-	9
Total	6	10	10	8	9	13	7	8	10	9	10	8	9	12	6	19	9	17	8	188
GRAND TOTAL	12	18	17	15	20	23	23	25	32	22	25	25	29	35	27	34	27	38	27	474

*See Table III-3 for definition

TABLE IV-1
1973-1991 AUTOMATED PAYLOAD SUMMARY

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
NASA													
Astronomy	1	2	3	4	5	7	7	6	6	6	5	6	58
Physics	1	2	3	3	5	5	6	5	6	5	6	5	52
Earth Observations	2	2	2	2	2	2	2	2	2	2	2	2	24
Space Processing	1	2	4	4	4	4	4	4	4	4	4	4	43
Earth and Ocean Physics	2	2	2	2	2	2	2	2	2	2	2	2	24
Communication & Navigation	-	1	1	1	1	1	1	1	1	1	1	1	11
Life Sciences (LS-2)*	2	2	2	2	2	2	2	2	3	3	3	3	28
Space Technology	2	4	4	4	4	4	4	4	4	4	4	4	46
Total	11	17	21	22	25	27	28	26	28	27	27	27	286
Non-NASA/Non-DOD													
Space Manufacturing	-	-	-	-	-	1	2	1	2	1	2	1	10
Foreign Sortie	2	3	3	4	3	4	3	4	3	4	3	4	40
Total	2	3	3	4	3	5	5	5	5	5	5	5	50
Grand Total	13	20	24	26	28	32	33	31	33	32	32	32	336

*See Table III-3 for definition.

TABLE IV-2
1980-1991 SORTIE PAYLOAD SUMMARY

PAYLOAD CODE	PAYLOAD	WEIGHT kg (lb)	DIMENSIONS (Length/Diameter) m (ft)	DESTINATION (Incl./Apo./Per.) km (n.mi.)
	Automated Spacecraft			
LS-1	Life Sciences Research Module	Will provide a means of conducting life science experiments in the weightless environment. Will study the operational capabilities and process parameters of life support and protective systems equipment.		
		180 (400)	2/1 (6.8/3)	28.5°/Low Earth Orbit
	Sortie Payloads			
LS-2	Laboratory and Carry-On Payloads	Will perform research in wide range of experiment areas (bio-engineering, space medicine, bio-research, space systems research) from molecular level studies to biological systems analysis to investigation of total organisms. Emphasis on man-related space flight problems. Will evaluate experimental tele-operator systems as precursors to operational systems as well as development of apparatus technology and operational concepts for efficient utilization of man in space.		
		17 000 (37 500) (Includes Expendables	17.8/4.3 (58.4/14)	28.5°/Low Earth Orbit

TABLE IV-3

LIFE SCIENCES PAYLOAD CLASSIFICATIONS

C. Operational Management Goals

Payload traffic tabulations appear in Tables IV-1 and IV-2. These tables have been taken from the 1973 NASA Payload Model, Space Opportunities, 1973-1991, October 1973, (Ref. 8) and summarize the launch opportunities planned for all scientific disciplines. Life Sciences space flight research will be conducted in automated spacecraft, which can be left in orbit for long periods of time or in Orbiter attached laboratories and carry-on payloads. Disciplined scientists will operate the laboratories and provide sophisticated observation and manipulation of the experiments.

The automated payload modes have remote, if any, crew experimental involvement. The experiment equipment can be placed in orbit as a free flyer or it can be delivered to orbit, remain attached to the vehicle, and returned to earth at the completion of the Shuttle's orbital staytime. When the payload is a free flyer, it may be left in orbit and retrieved by a later Shuttle visit.

The Sortie mode relates to direct crew involvement. In this mode, the experiment equipment remains attached to the Shuttle Orbiter, and experiments are managed and/or conducted by the disciplined specialist during the Orbiter's orbital stay time.

Table IV-3, Life Science Payload Classifications, (Reference 8), summarizes payload characteristics.

Since the payload traffic models and the operational utilization of these payloads are being defined, evolutionary variations of the payload modes can be expected to occur for specific scientific demands. These variations will address principally orbital attitudes and inclinations which may be particularly beneficial to the experimental program, or which may be adjusted to meet mission management constraints.

Crew Health Management

Traditions which have been the hallmark of prior program successes will undoubtedly give way to a new generation of crew health management. The changes arise not because the traditional methods are antiquated, but because considerable space flight knowledge has been gained which offsets these traditions. Considering the payload traffic models estimated through the 1991 era and the baseline Space Shuttle System launch plan for the Kennedy Space Center, launches at seven-day intervals are foreseeable well within the decade. The Space Shuttle System is expected to be employed in a manner analogous to airline operations; flight crews will fly patterned schedules.

This necessitates a reassessment of the traditional pre-, in-, and postflight medical programs. The degree to which these programs will be altered are subject to detailed review. Operations conducted in Skylab and medical data obtained from this program suggest that inflight health monitoring protocols will require a reassessment also. If such monitoring remains an absolute safety consideration, effectivity may be limited to environmentally unstable flight phases and specific crew functions - launch to orbit insertion, EVA, and deorbit to landing - unless crew related physiological experiments are dedicated to the mission.

An operational flight medicine posture has been proposed that would have the ground serve as backup support for contingent medical events. Implications imposed by this posture are interesting. To implement the backup capability, historical data are mandatory. Data acquisition must be deliberately disciplined. Therefore, to exercise a backup role, a regular interface must be maintained with the mission. If this is the case, the backup role refers to the delivery of aid, not necessarily to the collection of surveillance data. The methods used for collecting medical data influence the definition and development of the clinical surveillance program.

Illness and injury are mission hazards. Criteria for returning a crew must be established; however, every attempt should be made for early diagnosis to protect group health, initiate therapy, and minimize early crew return.

It should be noted that a 14.7 psia atmospheric pressure will require provisions for a prebreathing protocol if EVA is to be conducted with Apollo type garments.

Principal environmental factors remain weightlessness, radiation, ambient atmosphere, and thermal considerations which are critical with regard to fire, explosion, and decompression effects as well as atmospheric contamination. While body systems are especially sensitive to these environmental factors, so too, are many of the vehicle hardware and software systems. The sensitivity thresholds of the body system may be limiting operational factors.

Inflight crew activity schedules demand careful attention. Evidence exists that early mission work schedule and diet adjustments reduce the symptomatology coincident with the early phase of zero-g adaptation.

Experiment Payloads

Definitions

The final definition of payload types is still being considered; however, for this discussion payloads are grouped accordingly: 1) Sortie Labs, 2) palletized experiments, 3) maintenance and servicing modules, 4) large space telescopes, 5) low altitude satellites, 6) high altitude satellites and expendable payloads, and 7) space tugs.

Sortie Labs may be defined as Shuttle attached Spacelab payloads requiring manned experiments involvement.

Palletized experiments are an assembly of individual, automated experiments mounted on a common carrier frame. The experiments may or may not be dedicated to a single scientific area, and all or some of the automated experiments may or may not be retained with the Shuttle Orbiter's payload pay for earth return.

Maintenance and service modules are a class of payloads which contain equipment that can be used to service an orbiting observatory or automated experiments flying free of the Shuttle.

Large space telescopes represent a class of payloads which remain attached to the Shuttle, but are maneuvered in the Shuttle payload bay and pointed to the target.

Low altitude satellites are a class of automated payloads, generally dedicated to a specific scientific discipline, and placed into orbit directly by the Shuttle.

High altitude satellites are automated payloads released into orbit by the Shuttle and boosted by a dedicated third stage into a high altitude orbit or into a planetary intercept trajectory. The third stage will be reusable for refining orbits, lowering orbits for recapture by the Shuttle, or for orbiting a planetary target.

Space tug payloads are essentially vehicles ferried into orbit by the Shuttle and used to place automated payloads into a special orbit, to service satellites in high parking orbits, or to modify their configurations, and to retrieve orbiting payloads for servicing or earth return.

Payload Operations Management Concept

Operations management for the Shuttle payloads is being planned to stress the owner/operator - host site concept; a concept similar to airline operation.

The overriding principle of the owner/operator portion of the concept is the responsibility of the basic hardware owner through all program phases. The basic owner/operator is responsible for his hardware and all attendant tests and operations; however, the basic owner/operator falls under the direction or influence of payload carrier owner who integrates the basic hardware into the next higher assembly. For example, prior to installation of a basic group of hardware into a payload carrier - such as a Sortie Lab, Pallet, etc., the experimenter as a basic owner/operator, has complete responsibility for his equipment; after installation aboard the carrier, although the owner of the next higher assembly schedules and controls combined systems tests and schedules, the basic payload owner is required to verify his hardware performance. The carrier owner certifies integrated compatibility with the Space Shuttle owner. The experimenter's hardware/software is not "turned over" to the payload carrier owner or to the Space Shuttle host site.

The same principle applies to the payload carrier owner when the carrier is mated with the Shuttle Orbiter. The payload carrier owner retains responsibility for his hardware and software systems, but comes under the control of the Shuttle Orbiter owner/operator for combined systems tests, scheduling, and access to the equipment.

The "host" portion of the concept is that the owner of a site and/or facility is a host to the next lower order payload level hardware. If Kennedy Space Center is to integrate a payload carrier to the Shuttle Orbiter, it will be a host site for the basic experiments. Also, a private industrial site and/or facility may be a host site without NASA surveillance until payload and Shuttle Orbiter mating.

Each host will impose a set of mandatory criteria and restrictions on the next lower order owner/operator who is considered a "user". These criteria and restrictions are anticipated to be the host's accommodation requirements, and define the capabilities and limitations/constraints of the host's interfaces that the user must match. These requirements are intended to be the official source of information to assist the next lower order owner/operator's payload preparations by acquainting him with at least the following capabilities:

1. Payload interface design requirements/constraints to enable compatibility between the user's and host's equipment. These interfaces extend to GSE and facility accommodations.

2. Host site management and required documentation.

3. Operations policies and schedules, showing the user how his participation integrates with the overall operation.

4. Facilities available which provide guidance in obtaining any unique facilities required for any specific payload.

5. Available host support services.

6. Safety requirements.

Implementation of the policies under this concept promote the following effects:

1. Minimize organizational interfaces.

2. Decouple Shuttle from payload development and processing

3. Reduce hardware turnovers from one organization to the next, thereby eliminating the exchange of formalized test requirements, procedures, training, etc., that normally accompanies each turnover.

4. Reduce documentation to only that required to assure schedule, safety, disciplined operations, and compatibility.

5. Have direct payload owner/operator involvement.

Mission Support

General

The mission support roles, as employed during the Mercury-Skylab era, are destined to be modified. Greater operating autonomy will be delegated to the flight vehicles. Ground mission monitoring will be limited to key parameters which will permit the economical and vital assessments of operational status, and lend themselves to rapid and accurate "take-over" of the mission functions necessary to recover from "contingency/emergency" conditions.

The Skylab communications coverage served notice that without the addition of more acquisition sites and/or the introduction of a communication satellite system, orbiting vehicles at a 270 n. m. altitude cannot expect more than approximately 40 percent contact with the ground as a daily average (Space Shuttle and Spacelab Discussions, Volume E, Mission Operations, Johnson Space Center, October 11-12, 1973, JSC-08500). Such intermittent orbital coverage interferes with ground operational and experiments real-time monitoring and establishes the need for onboard data recording and periodic data retrieval from the recorders by the ground stations. Often in Skylab, a large percentage of the medical experiments were conducted during a loss of signal (LOS) and very little opportunity existed for real-time operational assessment. Although the Spaceflight Tracking and Data Network systems performed as designed, the long periods where no communications were possible between stations demonstrated a need for an alternate communications management posture. Continuous expansions of the Spaceflight Tracking and Data Network is a questionable economical course of action although it would significantly simplify flight operations and enhance real-time scientific data return. Inflight operational autonomy offers an economical program alternative.

Skylab crew technical debriefings reinforced a need for the flight crews to plan their daily activities. Historically, the ground transmitted daily flight plans to the crews; however, they were prepared without an in-depth appreciation of the exact day-to-day conditions which prevailed aboard the vehicle. The crews, no two of which had identical performance profiles, had a general difficulty accommodating these flight plans, stretching the crew's work-day when they were in a "catch-up" situation. The crews have suggested greater planning autonomy in the future. This coincides with Space Shuttle operational objectives.

To effect great inflight autonomy, what ground management and control functions will be retained?

After confidence is gained with the Shuttle systems, the operational ground/vehicle interfaces can be expected to emphasize critical flight phasing operations. These operations will be limited to monitoring crew-initiated computer maneuvers and piloting functions necessary for landing. The "mission support" function may be considered analogous to aircraft enroute and terminal traffic control.

Mission support will consist principally of long-range planning and mission management, ground tracking and centralized control of communications, tracking of scientific progress and accomplishments, rescheduling scientific objectives as data are acquired, crew training, and crew health care. Mission command and control will be a secondary mission support role.

Command and control may be assumed to be analogous to a Command Post operation. Authority and capability to decentralize or centralize the operating posture will exist to accommodate the immediate or anticipated needs. Decentralized command and control is expected to be the normal mode. All elements of flight operations will exercise their delegated autonomy. In the event of contingency or emergency, the alternate operating mode will be a centralized posture to coordinate and integrate all functions necessitating this posture.

As tabulated in Space Shuttle and Spacelab Discussions, Volume E, Mission Operations, October 11-12, 1973, JSC, real-time mission operations positions are being addressed in five areas: 1) Flight Director, 2) Science and Technology Coordination, 3) Operations Procedures and Flight Planning, 4) Communications and Data Control, and 5) Principal Investigator/Technical Representative. Traditional positions have given way to the autonomous functions of the space flight element and have been relegated to multi-purpose on-call support. Mission support room locations for these functions remain an unknown factor. It is apparent the role of the Flight Surgeon has been relegated from an "in-line" function to an "off-line" function if it is to appear as "Mission Control Center" position. Therefore, present plans call for flight crew health care as a status monitoring function at best without a direct interface with the orbiting crew.

The role of the experimenter has been elevated to an "in-line" function. It is presumed that the position would be occupied by a Life Science representative comparable to a Skylab "LSD Mission Manager" when dedicated Life Sciences payloads are flown. The "in-line" experimenter position would be supported by the scientific disciplines being flown - much in the same manner as Skylab.

Life Sciences Operational Management

Life Sciences Shuttle operational management will undoubtedly be more decentralized than Skylab. Organizationally, management will be structured to meet the launch schedule demands. This implies a greater delegation of responsibility to a middle management structure.

With program maturity, operational flight medicine is expected to become a relatively stable and routine function. In contrast, payload development and mission integration will be considerably more dynamic. Payloads will be in various development stages continuously. Top management will focus attention on pre- and postflight mission payload administration.

Life Sciences Operational Administration

The operational administrative functions will address: 1) operational planning for mission assignment dates, resource integration, and payload servicing, 2) payload logistics support, 3) coordination of crew operations, 4) terminal operations integration, 5) data management, 6) simulation and training, and 7) verification of crew procedures and experiment hardware/software performance.

During the conduct of the administrative roles, operational flight medicine will be performed as an independent site function. Payload operational administration will begin with experiment selections and Shuttle launch assignments. Principal Investigators will be assigned administrative project support for integrating their experiments into the payload configuration and into the stream of premission operational activities necessary to develop an experiment flight readiness posture. After a Principal Investigator (PI) commits his experiment to flight, the host Operations Center will provide to the experimenter the use of local facilities for flight following, and data acquisition and processing in accordance with preplanned agreements. These accommodations by the host Operations Center will include provisions for real-time monitoring of the flight experiment, the coincident voice communications, when appropriate, real-time data displays, special data processing, organizing quick-look data, troubleshooting the experiment, and assisting with real-time flight planning. Should the PI prefer the use of other facilities, interfaces can be arranged at a cost to the PI for obtaining rapid access to mission status, experiment status, and formatted telemetry data.

Following payload return, the host Operations Center will provide all data prescribed for the experiment. The Center will return the experiment to the PI and make available specific flight equipment necessary to complete the research.

V. COMPARISON OF THE OPERATIONAL CHARACTERISTICS

V. COMPARISON OF OPERATIONAL CHARACTERISTICS FOR SKYLAB AND SPACE SHUTTLE

A. Major System and Operational Comparisons

As part of this study, a series of tables have been prepared and submitted as Appendix C, which compares the operational characteristics of the two space programs. These have been separated into different categories so that the full impact in any one area will be more apparent. The categories chosen include:

Mission Characteristics
Environmental Factors
Crew Health Considerations
Mission Operations
Payload Operations Management

Most of the parameters compared between Shuttle and Skylab have differences. The differences are accepted and impact is explored with accompanying descriptive material.

B. Comparison of Life Sciences Experiment Operational Management Functions

A set of tables have been prepared similar to the ones in the previous section, but relating specifically to the operational management of Life Sciences experiments. These are presented in Appendix D. The previous section, (Appendix C) compares Skylab and Shuttle mission and payload operations in a general context that could be applicable to any operation, while this section goes into much finer detail of management that applies to an organization that sponsors the type of experiments and payloads presently visualized in the life science area. It should be realized that the Shuttle experiments operational management has not been defined to the detail presented in this section. This is, instead, a concept advanced here in order to stimulate thinking, discussion, and eventually, implementation. The concepts are compatible with available Shuttle documentation, specifically, References 1 through 7. Some of the Shuttle details are listed as "unknown", and should be resolved in the immediate future.

These comparisons are grouped by mission phase, namely, the premission phase, the inflight phase, and the postflight phase, since the required functions are so completely different from one phase to the next.

Some generalizations can be made from a review of these tables which support ideas presented previously in this report. One is the lack of need for many centralized activities for Shuttle as shown in a réduction in experiment configuration control management, experiment failure reporting systems, experiment status reviews, and daily team meetings during the missions. Also to be noted is that there are certain functions that NASA/JSC needs to do only if the experiment is NASA/JSC sponsored.

C. Comparison of Operational Documentation Requirements

The documentation that has evolved during the space programs from Mercury through Skylab will undoubtedly be different for the Space Shuttle. The Life Sciences Skylab operations documentation was discussed in Section II of this report and diagrammed in Figures II-1 and II-2. The tables in Appendix E show how the Shuttle documentation is expected to differ from Skylab. These tables are chiefly concerned with the Level 3 documentation to meet Space Shuttle obligations and responsibilities in the crew health and biomedical experiments operations.

VI. HISTORICAL CONCERNS IN SPACE LIFE SCIENCES,

VI. HISTORICAL CONCERNS IN SPACE LIFE SCIENCES AND PROSPECTS FOR THE SPACE SHUTTLE ERA

The aerospace life sciences community has recognized potential concerns for manned space flight. These historical concerns have been classified between biomedicine and the biosciences. Biomedicine consists of areas of space medicine, psycho/behavioral science, man-machine integration, life support and protective systems, The biosciences include primate, small vertebrate, invertebrate, plants, and cytological and molecular biology and exobiology.

Areas of concern have been expressed in various publications during the past decade. For example, MSC/MR&OD document, "A Biomedical Program for Extended Space Missions," Volume I, May 1969, identifies forty-four (44) areas of concern with respect to past flight evidence, current status of understanding, and future approach to acquire greater knowledge.

Other examples of representative concerns are documented in technical publications issued by the aerospace community:

A. Medical Aspects of an Orbiting Research Laboratory, Space Medical Advisory Group Study, NASA SP-86, 1966, Washington, D. C.

B. Experiment Program for Extended Earth Orbital Mission, Volume II, Aerospace Medicine, and Volume III, Biosciences, OMSF, NASA ("Yellow Book").

C. Preliminary Edition of Reference Earth Orbital Research and Applications Investigation, Volume VIII, Life Sciences, BHG 7150. 1, January 15, 1971 ("Blue Book")

NASA SP-86, contains recommended inflight experiments, associated ground-based R&D, and estimations of priorities for the 1966 era.

The NASA "Yellow Book" contains a comprehensive list of "component experiments" under the heading of aerospace medicine. This listing includes medicine and behavior, man-system integration, and life support and protective systems, as well as clinical medicine and pharmacology in space. This listing has been established as the fundamental structure for all other documented Life Sciences research recommendations.

The NASA "Blue Book" describes Life Sciences experiments grouped as "Functional Program Elements (FPE)". Such a grouping facilitates the determination of laboratory hardware configurations which can service sets of allied disciplines.

Appendix F contains a condensation of concerns expressed in NASA SP-86, the "Yellow Book", and the "Blue Book". Since each document had different classification systems, Appendix F tabulates the concerns against subject matter and parenthetically lists the respective paragraph or FPE numbers. The "Yellow Book" was selected as the basic organizational guide.

The tabulations have been edited with experiments accomplished during the three Skylab visits and notes appear at the far right of the chart which address specific future investigative attention as foreseen by the General Electric Company.

VII. REFERENCES

VII. REFERENCES

1. Space Shuttle Program Requirements Document - Level I - Office of Manned Space Flight.

2. Space Shuttle Level II Program Definition and Requirements JSC-07700 - Volume I through Volume XVI (not all available).

3. Space Shuttle and Spacelab Discussions - October 11-12, 1973, Vol. E, Mission Operations - JSC-08500.

4. Space Shuttle and Spacelab Discussions - March 21-22, 1974, JSC-09001

5. Space Shuttle System Definition Handbook - Space Division Rockwell International - SD 72-SH-0068

6. Orbiter Definition Handbook (Preliminary Design Review Configuration) Space Division - Rockwell International - SD 72-SH-0071 B (February 4, 1974).

7. Launch Site Accommodations Handbook for Shuttle Payload - February 1, 1974 (KSC-Draft)

8. The 1973 NASA Payload Model Space Opportunities 1973-1991 - NASA Headquarters (October 1973).

APPENDIX A

APPENDIX A

APPLICATION OF THE SKYLAB LESSONS LEARNED TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

TABLE A-1

SUMMARY OF THE SKYLAB LESSONS LEARNED
AND ORGANIZATIONAL COGNIZANCE

SLL NO.	SLL TITLE AND CATEGORY	APPLICABLE ORGANIZATION				
		Mgmt. Level I	Mgmt. Level II	Research	Clinical	Eng'g.
I.	LIFE SCIENCES EXPERIMENTS/R&D					
	1. Systematic Space Life Sciences Experiment Program	*	*			
	2. Development of Integrated Medical Data Evaluation System		*			
	3. Experiment for Neuromuscular Reflexes			*		
	4. Experiment for Head Fullness in Zero-G			*		
	5. Experiment for the Effects of Exercise and CVS Integrity			*		
	6. Experiment for Muscular Adaptation in Space			*		
	7. On-Orbit Health Care				*	
	8. Experiment for Skin/Mucous Membrane			*		
	9. Countermeasure(s) for early adaptation				*	
	10. IMSS for all Shuttle Flights	*	*			
	11. Utilization of Two-Way TV for Life Sciences	*	*		*	
	12. Psychophysiological Experiment for 1-g Orientation Effects			*		
	13. Human Errors Analysis of Skylab Missions			*		
	14. Space Shuttle Mass Transfer Simulation	*				
	15. Life Sciences Experiments Alternate Flight Planning		*			
II.	PROGRAM MANAGEMENT					
	1. Operational Support to Experiment Groups			*		
	2. Space Shuttle Life Sciences Experiment Altitude Test	*	*			
	3. Experiment Planning and Development		*			
	4. Life Sciences Experiments Constraint List	*				
	5. Life Sciences Experiment Requirements Document		*			
	6. Life Sciences Experiment Planning		*			
	7. Space Shuttle Medical Documents Requirements		*			
	8. Life Sciences Payload Development Discipline	*				
	9. Interface to Man-Machine Integration Team		*			
	10. GFE Utilization Plan for Life Sciences/Medical Operations					*
	11. Space Shuttle Life Sciences Planning Guidelines		*			
	12. Acceptance Testing of Biomedical Hardware					*
	13. Visual Cues/Design Review Factors		*			
	14. Personal Hygiene Equipment for Shuttle Crew and Passengers	*				
III.	MISSION PLANNING/TRAINING/DOCUMENTATION					
	1. PI-SIM-Training Coordination Plan		*			
	2. Crew Traffic Density Assessment During Mockup Review					*
	3. Ground Medical Support Requirements Definition				*	
	4. Space Shuttle Medical Operations Documents		*			
IV.	OPERATIONS AND DATA MANAGEMENT					
	1. Space Shuttle FCHSP Definition				*	
	2. Postflight Crew Health Monitoring Plan				*	
	3. Life Sciences Crew Training Program		*			
	4. Uniform Test and Checkout Procedures in Various Test Sites		*			
	5. Potable Water Monitoring Plan					*
	6. Private Medical Conference and Crew/P.I. Communication			*	*	
	7. Ground Life Science and Medical Data System Interfaces			*		
	8. Life Sciences Data Management Plan		*			
	9. Life Sciences Data Management System Requirements Definition		*			
	10. Life Sciences Data Quality Monitoring Capability					*
	11. Real-Time/Near-Real-Time Crew Health Evaluation Data System			*	*	
	12. Inflight Data Return Capability	*				
	13. Onboard Life Sciences Data Management Requirements			*		
	14. Life Sciences Data Documentation System		*			
V.	OPERATION LOGISTICS					
	1. Space Shuttle Food System Requirements Definition			*		
	2. Automatic Food, Water Intake, Biowastes Sampling and Preservation	*				
	3. Life Sciences Mission Support Hardware Availability Status Monitoring					*
	4. Experiment Equipment Quantity Requirement Checklist					*
VI.	DESIGN INTERFACE					
	1. Requirements Input to the Shuttle Glass Window Design		*			
	2. Life Sciences Hardware Onboard Calibration Capability			*		*
	3. Crew Safety Warning System	*	*			
	4. Space Shuttle Food Stowage Requirements Definition	*				
	5. Interface with the Habitability Study Team					*
	6. Interface with IVA Safety Design	*				*
	7. Onboard Redundant System Requirements					*
	8. Definition of Manual and Automated Functions	*	*			
	9. LSD's Role in Flammability/Toxicity Hazard and Monitoring Plan		*			

APPENDIX A-1

SKYLAB LESSONS LEARNED -

LIFE SCIENCES EXPERIMENTS R&D

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Systematic Space Life Sciences Experiment Program	HQ - MMS 1, MLA 3, December 4, 1973	I-1

The Skylab Lessons Learned (SLL):

Selection of experiment proposals with outstanding scientific merit, flight compatibility and cost effectiveness requires complete description and definition of experiment proposals at the time of experiment selection. This, in turn, requires that sufficient leadtime be given prospective investigators to allow definition studies and documentation before experiment selection. Future programs should carefully plan and manage the experiment development effort.

Otherwise, excellent proposals in preliminary definition stages may be rejected due to lack of sufficient preparation time, while less meritorious, but thoroughly described proposals may be selected by default.

Application of SLL to Life Sciences Program:

1. Plan a Life Sciences program to take advantage of Space Shuttle flight opportunities.
2. Express NASA's long range life sciences interests to the scientific community.
3. Advise the scientific community about procedures for submitting experimental proposals.
4. Inform scientific community regarding experiment selection criteria.

References:

1. NASA/OMSF "Yellow Book": Experiment Program for Extended Earth Orbital Mission, 1969.
2. NASA "Blue Book": Reference Earth Orbital Research & Appl. Invest., Vol. III, 1971.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Development of Integrated Medical Data Evaluation System	MSFC - 3.5.6.	I-2

The Skylab Lessons Learned (SLL):

Joint Observation Programs:

Until fairly late in the development of Skylab, the five ATM Principal Investigators (PI's) planned to operate their experiments according to their own individual observing program. This approach had the following shortcomings:

1) Non-optimum use of allocated ATM flight plan time.
2) Very difficult if not impossible to correlate data between experiments.
3) Inability to use all ATM film.
4) Each individual observation program was written without proper consideration for the objective of other observing programs.
5) PI's discovered that many scientific gaps would exist in the data if this approach was used.

At that time, they began working toward a joint observing program with the following objectives:

6) Define a set of problems to be solved at ATM as an observatory, not as six individual experiments.
7) Write the joint observing program such that all experiments are working on the same problem at the same time.
8) Define the joint observation programs so that the maximum utilization of ground-based observatories can be made.
9) In constructing the joint programs, provide maximum capability for the PI to make real-time changes in order to optimize his data return.

Application of SLL to Life Sciences Program:

1. Although data sharing was not a planned procedure for Skylab Medical Experiments, analogous situations with this SLL were recognized. Item 2, correlation of data between experiments, was difficult since analogous with Item 4 and 5, none of the inflight medically obtained data indicated either crew health degradation or provided definite predictive parameters.
2. This SLL applied to the Space Shuttle Life Sciences Experiments Program has implications of being potentially the most important lesson learned from the Skylab and suggests consideration for a systematic Joint Evaluation Program.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment for Neuromuscular Reflexes	Crew Debriefing Summary (CDS)	I-3

The Skylab Lessons Learned (SLL):

Neural Reflexes:

SPT reported that all crewmen's reflexes were hyperactive. (SL 1/2, 7.8.)

Application of SLL to Life Sciences Program:

1. In Skylab, crew's body posture and other anthropometric changes appear to indicate a general muscular reorientation takes place in transition from 1-g to zero-g. Clinical observation of this hyper-reactivity of neural reflex is confirmable by more precise quantitative experiments on man or animals.
2. Standardization of measuring methods with foreign experimenters, e.g., USSR, will be desirable.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment for Head Fullness in Zero-G	CDS	I-4

The Skylab Lessons Learned (SLL):

Sensation of Head Fullness:

All crewmen noticed some head stuffiness in orbit, but it was apparently not due to mucous. Blood vessels in head and neck are always full; however, stuffiness may have been due to the presence of larger than normal quantities of blood (SL 1/2, 7.1).

Personal exercise reduces sensation of head fullness for a period of one to two hours; so does eating. Chewing and the act of defecation immediately fills upper torso with blood. (SL/4, CDR)

Application of SLL to Life Sciences Program:

1. Crew's subjective comments and debriefing material deserve a comprehensive analysis in the light of space medical interests. These also generate new questions to their mechanism which would be candidate experiment areas to be explored.
2. Experiments which delineate relationships of blood distribution changes affecting the sensation of head fullness in reference to resting condition, exercise, eating, and other activities are applicable. Measurement methodology and devices, such as inflight rheoencephalography, to correlate various changes are explorable opportunities.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment for the Effects of Exercise and CVS Integrity	CDS	I-5

The Skylab Lessons Learned (SLL):

Inflight Exercise:

1. CDR reported that he was able to condition himself while in orbit and reported feeling better and better with more and more exercise. (SL 1/2, 7.5).
2. The Mark I exerciser is good, but doesn't get all the muscles. Those muscles that are not used deteriorate rapidly (buttocks, lower back). (SL/3, 7.6).
3. PLT had a low period while over-exercising for a few days. He says you must not overdo the exercise. There probably is a practical limit. It's a different level than on the ground - each crewman has to seek his own level. (SL/3, 7.6).
4. SPT did not use the arm exercise portion of the ergometer (the others did). No one used the chest board. (SL/3, 7.18.a)

Application of SLL to Life Sciences Program:

1. Relationships and effects of various exercise to the cardiovascular system in 1-g and zero-g bear experimental investigation.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment for Muscular Adaptation in Space	CDS	I-6

The Skylab Lessons Learned (SLL):

Use of Muscles in Space and Ground:

1. Stomach muscles are used almost continuously. Unused muscles tend to get very soft. (SL 1/2, 7.7)
2. The CDR's waist size was so small that sometimes a 50mm of Hg vacuum could not be obtained in the LBNPD. Relocation of internal organs in zero-g was probably a contributory factor. The CDR reported that his waist size just before leaving the OWS was 28-1/2 and was 29-3/4 immediately following recovery. (SL 1/2, 7.14).
3. Riding the ergometer in orbit is more like running on earth due to the body motions involved. (SL 1/2, 7.9).
4. The bike really didn't simulate running. Running causes exhaustion, while the bike never did. (SL/3, 7.18.b)
5. SPT felt they could have stayed up there indefinitely, but they would have needed changes in dietary practices and exercise, and variations in types of work activities. (SL/3, 7.13)
6. SPT and CDR had sore joints following their jogging exercises back here on earth. PLT did not experience this. (SL/3, 7.19.c.)

(cont'd following page)

Application of SLL to Life Sciences Program:

1. A comprehensive experiment can be planned and implemented to explain the following questions:
   a. For controlled body movements, which muscle groups perform differently in zero-g and 1-g (metabolically, chemically, mechanically, neurally, etc.)?
   b. What basic changes occur in the muscular tissue after transition from 1-g to zero-g and vice versa?
   c. How does "muscle pumping" affect the peripheral blood dynamics during exercise in zero-g?

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment for Muscular Adaptation, in Space	CDS	I-6

The Skylab Lessons Learned (SLL):

Use of Muscles in Space and Ground:

7. PLT's feet and heels have been a little sore, and sitting down is somewhat uncomfortable. (SL/3, 7.19.d.)

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
On Orbit Health Care	JSC	I-7

The Skylab Lessons Learned (SLL):

In-orbit crew stay time:

Psychological and physiological conditions of the flight crew resulting from the 84-day visit indicated no constraints for longer duration flights. For example, the food and sleep requirements were about the same as on the ground, but to maintain reasonable physical conditions of the muscles, 1 to 1-1/2 hours of deliberate daily exercise was established by the crews for the second and third visits.

Application of SLL to Life Sciences Program:

1. It is premature to assume that crew health problems will not occur during 7-30 day Space Shuttle flights, although Skylab was flown successfully for longer periods.
2. One to one and a half hours daily exercise was considered maximum for the in-orbit stay time of Skylab.
3. See SLL: Experiment for the Effects of Exercise and CVS Integrity, SLL No. I-5.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment for Skin/Mucous Membrane	CDS	I-8

The Skylab Lessons Learned (SLL):

Skin/mucous membrane responses to spaceflight:

1. Toenails and fingernails didn't grow too well, and later they cracked and split. Could be due to the dry air. CDR had quite a few hangnails at the end of the mission. (SL/3, 7.10)
2. No one developed any body odor until after mission day 40. It could be related to the quantity of salt taken in (CDR. (SL/3, 7.14).
3. The crew did not generate as much saliva on orbit as they did on the ground. (SL/3, 7.18.c.)

"Tingling Sensation":

1. At about MD 10 all crewmen noticed a tingling in the bottoms of their feet when some pressure was applied. The sensation seemed to be spreading slowly and did not clear up until R+1. (SL 1/2, 7.4)
2. The SL-3 crew has not experienced the tingling sensation in the feet reported by the SL-2 crew. (SL/3, 7.19.e.)
3. Similar sensations were reported during the LBNP experiment run (SL/3)

Application of SLL to Life Sciences Program:

1. In Skylab, areas of excretion and skin/mucous membrane were not fully investigated. As the above crew comments suggest, subtle changes are taking place in skin/mucous membrane functions during exposure to the weightlessness. It is recommended that manned or animal experiments which delineate the mechanisms of these phenomena experienced by the crew should be included in the Space Shuttle Life Sciences Experiments Program.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Countermeasure(s) for early adaptation	CDS	I-9

The Skylab Lessons Learned (SLL):

Man's Initial Vestibular Adaptation to Space Flight:

1. During oculogyral illusion tests SPT and PLT both reported some oscillatory target motions at the lower acceleration levels. (SL 1/2, 7.16.a)
2. There were no after affects from the motion sensitivity tests. Recovery was much better in orbit than on the ground. (SL 1/2, 7.16.b.)
3. Crew reported establishing their own frames of reference as required for the task at hand. They had no frame of reference with the lights off. All sensations of motion are visual. Crew was unable to detect vehicle attitude changes other than visually. (SL 1/2, 7.16.c.)
4. Crew maintained a sense of up and down, usually coincident with 1-g trainer orientation. (SL 1/2, 7.17)
5. The SL-2 and SL-3 crews had no problems with angular accelerations. It is suspected the sickness felt by the SL-3 crew may have been due to the otolith function. Conditioning in the T-38 and centrifuge prior to launch may have prevented this problem. It is also suspected that going directly into a large volume (OWS) and performing heavy work right away may have contributed to the queasiness. (SL/3, 7.4)

(Cont'd following page)

Application of SLL to Life Sciences Program:

1. From an operational point of view, the above findings impose a requirement to find countermeasure(s) to eliminate low crew work capacities in the first 3-5 days in space. The approach extends beyond the vestibular and cardiovascular disciplines and includes other aspects, e.g., crew selection, preflight habituation, preflight simulation, food system, and flight planning, etc.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Countermeasure(s) for early adaptation	CDS	I-9

The Skylab Lessons Learned (SLL):

Man's Initial Vestibular Adaptation to Space Flight: (Cont'd from previous page)

6. PLT did not notice a definite change in adaptation from l-g to zero-g, although he did feel poorly if he didn't get enough sleep. Should definitely get the required amount of sleep. (SL/3, 7.7)
7. SPT felt bad only the first 3 or 4 days. His good feelings and highs were associated with working experiments successfully. (SL/3, 7.8)
8. Scopolamine/dexedrine definitely helps curb motion sensitivity. However, until mission day 3 the crew was not aware that they were allowed more than one a day. (SL/3, 7.5)

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
IMSS for all Shuttle Flights	HQ - JSC MLO - K 11/26/73	I-10

The Skylab Lessons Learned (SLL):

1. Crew Efficiency Profile (HQ/MLO): Crew efficiency early in the mission seems to be governed by vestibular reaction to zero gravity and learning the knack of operating in zero gravity. The vestibular reaction may be minimized by conditioning and drugs. The amount of learning may be minimized by improved design for zero gravity operations.

Lesson Learned was:

Crew efficiency seems to increase from a rather low level during the first week and reaches a highly satisfactory plateau by the second or third week.

2. Period of Initial Adaptation to Space Environment (JSC-K): Crew adaptation to unrestricted movement in a large volume spacecraft requires 4-5 days. During this adaptation period, varying degrees of stomach awareness and decreased crew efficiency should be expected. A light schedule should be planned for this period, and the crew should not be scheduled beyond their capabilities to do useful work. Acceleration of crew activity was not possible until the crew adaptation period was past.

Application of SLL to Life Sciences Program:

1. Should the same adaptation period occur in the Space Shuttle missions, a 7-day flight with manual experiments could be compromised. It appears appropriate to develop predictive crew and passenger selection criteria for identifying candidates who exhibit an early zero-g sickness syndrome. Otherwise, develop reliable countermeasures to provide highest crew efficiency in the first 7 days of flight. (See SLL I-9).
2. In case of indisposed crew during the first 5 days, IMSS data and/or medical experiments to understand the mechanisms of early adaptation can be planned as an alternate flight objective.

SLL Title:	SLL Source & No.	SLL No.
Utilization of Two-Way TV for Life Sciences	HQ - MLA 103 & 111 December 10, 1973	I-11

The Skylab Lessons Learned (SLL):

Television Planning:

Early identification of television goals and tighter control of requirements and their implementations; television was a late-comer to Skylab, other than the establishment of a basic technical capability. An early understanding of what the Agency management wanted from television would have been very helpful. Television goals and objectives, the emphasis to be placed upon television, and the assignment of functions and responsibilities should be established early in the program, and clearly communicated within the program. This would include early coverage within top-level program documentation.

Video Uplink Capability:

The capability to uplink video was not provided in Skylab; however, there were numerous times in the mission when it would have been very valuable.

A capability to uplink and playback video within the spacecraft should be provided. This would enable the crew to observe repair procedure worked out on the ground and to see details of hardware they may have to repair in orbit. Scientific information such as solar activity drawings or earth observations data could also be uplinked.

Application of SLL to Life Sciences Program:

1. Define medical requirements for possible application of television for the Space Shuttle missions in the following areas:

   a. Crew performance evaluation via video tape and real-time for critical crew functions.

   b. IMSS procedural and performance evaluation.

   c. Remote medical diagnosis. Utilization of video uplink in areas of providing medical diagnostic and therapeutic information beyond the IMSS checklist can be planned and evaluated for mock-illness cases.

   d. Life sciences demonstrations transmitted from the Spacelab for education and publicity.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Psychophysiological Experiment for 1-g Orientation Effects	JSC	I-12

The Skylab Lessons Learned (SLL):

Design "eye" and "reach" envelopes:

The Skylab ATM console became much more "available" in zero-g to the crewman than during seated 1-g training sessions. Most Skylab crewmembers used foot restraints only when working at the ATM console.

If zero-g operation of a console or control panel is to be with foot restraint only, the design eye point should be an area with its center higher than the accepted 1-g counterpart. Likewise, reach envelopes for zero-g work stations should be expanded from the 1-g seated standard to a foot restrained zero-g standard.

Application of SLL to Life Sciences Program:

More research and pertinent data for the psychophysiological effects of deviation from the 1-g orientation are warranted to establish optimum design criteria on this subject.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Human Errors Analysis of Skylab Missions	MSFC - 3.4.2	I-13

The Skylab Lessons Learned (SLL):

Human Errors:

Minimize opportunity for human error by designing parts that cannot be installed backward, etc. Critical parts should be inspectable (physically or functionally, as required) after installation in the final launch and flight configuration. Establish mandatory inspection points early.

Application of SLL to Life Sciences Program:

1. This SLL is an opportunity to assemble data on the occurrence of human errors during the Skylab missions, to hypothesize causes for each class of error, and to develop countermeasures to minimize their probability of occurrence.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Mass Transfer Simulation	JSC	I-14

The Skylab Lessons Learned (SLL):

Mass handling and transfer in the spacecraft:

1. Large masses are easily manageable in zero-g.
2. Individual techniques varied between crewmen for moving items about the vehicle, but all adapted well and were quite successful.
3. The real problem is in handling multiple small items without a container to "fence them in." The limiting factor on handling large masses is the cross sectional area, which tends to block the crewman's view of the transfer path and the terminal site if more than 20 x 25 inches. Energy inputs used to initiate transfer must be removed at termination, and care must be taken not to "overdo it".

Application of SLL to Life Sciences Program:

1. Mass handling and transfer performance was studied by the Time and Motion experiment (M151) in the Skylab. The cross sectional area addressed in SLL may not be pertinent for the Space Shuttle. A further study in a Shuttle mockup may be needed.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Experiments Alternate Flight Planning	HQ - MMS 1 November 26, 1973	I-15

The Skylab Lessons Learned (SLL):

Flight Planning for Long Duration Missions:

Most of Skylab's detailed timelines became obsolete shortly after docking due to variables such as weather and preference of crew and equipment. However, the data bank available from detailed preflight planning allowed rescheduling of tasks in increments suitable to the new mission conditions. This short cycle real-time planning (approximatel y 48 hours) involved specialists from the necessary disciplines and was done as a matter of routine. Lessons learned were:

(1) Detailed preflight planning of long duration missions is necessary to size the quantity of expected activity, estimate the resource margins, and identify real-time decisions that may be needed.

(2) The actual conduct of long duration missions is best served by short cycle real-time flight planning that responds to variables as they actually occur.

Application of SLL to Life Sciences Program:

1. It is highly probable that a criterion for experiment selection on Space Shuttle will be task time. Awareness of task times is particularly important for real-time planning of payloads having mixed scientific disciplines and task time management of dedicated payloads.

APPENDIX A-II

SKYLAB LESSONS LEARNED -

PROGRAM MANAGEMENT

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Operational Support to Life Sciences Experiment Groups	JSC	II-1

The Skylab Lessons Learned (SLL):

Operational Support to Experiment Groups:

The basic operational design, tentative crew procedures and the compatibility with mission operations of several Skylab experiments definitely suffered from a lack of crew operations inputs early in the development cycle. As a result, hardware redesign, procedural work-arounds and/or continual procedures and timeline changes were required. It was frustrating to the experimenter and crews and posed a significant problem to procedures and flight planning specialists.

An operations representative knowledgeable about crew operations requirements and capabilities should be designated to work with potential experiment suppliers as soon as an experiment is seriously considered for assignment to a manned space flight system. Experiment developers should be encouraged to learn what can and cannot be done by flight crews before they proceed with their hardware design. For future manned space missions,establish early contacts and information exchange between experiment developers and crew operations specialists.

Application of SLL to Life Sciences Program:

1. Experiment coordinators for the above should be assigned early in the program development phase.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Life Sciences Experiment Altitude Test	JSC, HQ - MMS-8	II-2

The Skylab Lessons Learned (SLL):

Manned Altitude Testing of Experiment and Spacecraft Systems:

The Skylab medical experiments altitude test (SMEAT) exercised flight configuration equipment under conditions similar to those planned for flight. Several hundred anomalies were recorded and resolved long before Skylab was launched. Many corrections in nomenclature, markings, equipment handling, food and beverage quantities, waste management system, urine and fecal collection equipment, vacuum cleaner equipment resulted from SMEAT. Manned altitude chamber tests which simulate critical mission sequences should be conducted on equipment sensitive to operation at reduced pressure. Short duration crew reviews such as crew station, transfer, stowage, CCFF, etc. do not enable the crew and the crew representatives to identify all discrepancies in experiment and crew equipment design, stowage and usage. SMEAT also provided an excellent test of crew procedures and many changes were made in the flight crew checklists. The SMEAT effort resulted in the preliminary training and organization problem areas (data handling, personnel training, reporting systems, etc.) that had to be resolved before the Skylab missions commenced.

SLL Reference:
Skylab Medical Experiments Altitude Test (SMEAT), NASA TWX-58115

Application of SLL to Life Sciences Program:

1. Space Shuttle Life Sciences Concept Verification Test (CVT) program may be considered as a prelude to a high fidelity Space Shuttle Life Sciences payload test.
2. Payload development planning should consider a full range of test programs and key milestone dates.
3. A "full-up" test should include flight and ground support configurations.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Experiment Planning and Development	HQ - MLA 20 December 10, 1973	II-3

The Skylab Lessons Learned (SLL):

PI and his organization should be given prime contract (and responsibility) for development of experiment flight hardware. Certain experiment hardware that was procured from industrial contractors had cost increases that it is believed would have been eliminated if the PI had maintained control of the hardware development. The PI and his organization were more aware of many subtle points that would have to be taken into consideration during development. The PI had also worked with similar type sensors for many years. The industrial contractor more often than not assembled a team that had not done work in the particular area so a "learning curve" was involved. Serious consideration should be given to making sure the PI is tied in very tightly with the industrial contracts. It was difficult for the PI to know what was going on or to affect the design.

Application of SLL to Life Sciences Program:

Space Shuttle experiments management policies tend to be emphasizing the SLL concept. Experimenters will be responsible for all aspects of their experiments. NASA will manage the integration of an experiment to the experiment carrier.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Experiments Constraint List	HQ - MLA 5 & 10A November 23, 1973	II-4

The Skylab Lessons Learned (SLL):

Impact of Operations Requirements on Experiment Design:

In establishing the functional requirements and design features of experiment hardware and the spacecraft facilities needed for experiment support, there should be explicit identification and assessment of the impact these requirements and features will have on the operations in orbit. Design and cost trade-offs should be made with full understanding of the impact they will have on the productivity of the mission, particularly with regard to "the use of crew time", the interference of one experiment with another, and the systems factors (e.g., pointing, power, thermal) which may constrain experiment operation. The Scientific Airlock was designed to service a number of experiments, and its flexibility was very valuable in being able to accommodate new experiments. There was only one airlock on each side resulting in conflicts between experiments and in unproductive use of crew time in changing from one experiment to another. Addition of a second airlock on each side would allow simultaneous operation and greater flexibility in experiment scheduling.

Application of SLL to Life Sciences Program:

1. Experimental operating constraints should be carefully evaluated during demonstration and readiness testing.
2. A constraint list should be prepared and transmitted to the Space Shuttle Program Office early so that they can be given sufficient attention during flight planning, crew training, and mission simulations.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Experiment Requirements Document	HQ - MLE 16 December 5, 1973	II-5

The Skylab Lessons Learned (SLL):

When experiments for specific missions or space programs are developed by a wide spectrum of the technical community, such as principal investigators from aerospace companies, universities, space centers, and even foreign countries, it is highly desirable that a single general document or specification be used as a guide in the preparation of more specific specification to establish and maintain a uniformity of requirements. The use of an experiment general specification or experiments requirement document as a guide for the preparation of specific or detailed experiment specifications is highly desirable to make certain that requirements and functions are adequately specified.

SLL Reference:

Skylab Experiments General Specification (Headquarters)
Experiments Hardware General Requirements (JSC)

Application of SLL to Life Sciences Program:

In Skylab, some of the specifications useful to the experimenter and hardware designers such as launch and flight environment were documented in the Skylab Cluster Requirements Specification. For the Space Shuttle, a general experiment accommodation handbook, perhaps with a separate appendix for each payload type would be beneficial.

If a payload type is destined to be a Life Sciences payload, a specific Life Sciences engineering accommodations document is deemed applicable.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Life Sciences Experiment Planning	SLL Source & No. JSC	SLL No. II-6

The Skylab Lessons Learned (SLL):

Mission Requirements Definition:

The numerous late changes in Skylab mission requirements caused severe impact to the development of crew timelines and resulted in real-time operations that were not as efficient as they could have been. Real-time flight planning was complicated by the specification of functional objectives which were not discrete activities or series of activities in the mission.

Late mission requirements changes occur frequently in the manned space program. Response to mission requirements changes could be handled much more efficiently if mission objectives were defined in terms of events which could be discretely scheduled. Scheduling constraints and requirements could be defined more readily to the flight planners, accurate timeline generation would be facilitated, and determination of mission accomplishments would be much simpler.

Application of SLL to Life Sciences Program:

This SLL is particularly important for payloads containing mixed scientific disciplines. An experiment can be scheduled by its constituent parts rather than be treated as a complete entity and lends itself to more efficient "bookkeeping".

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Medical Documents Requirements	JSC	II-7

The Skylab Lessons Learned (SLL):

Requirements Documents Applications:

The initial applications of the Skylab Experiment General Requirements Document and the Ancillary Hardware Requirements Document were more rigorous and more far-reaching than needed in many cases. Excessive documentation resulted. The earliest environmental requirements for GFE and experiments were obtained from the AAP cluster requirements specification. The EVA thermal environment was not included as part of the cluster requirement specification and a special set of conditions peculiar to the operating requirements of the extravehicular equipment had to be generated. A special document, CSD-S-033, "Design Environments for CSD Provided Hardware" was generated from the cluster requirements specification, other engineering sources and analysis. This document tailored the general requirements to the specific class of hardware furnished by JSC. The broad application of generalized requirements and general environmental specifications to the different types of hardware can result in design impact to accommodate a specification condition which may not apply to the system under design. Excessive documentation effort and costs can be avoided by appropriate tailoring of requirements early in the program.

Application of SLL to Life Sciences Program:

1. Define and establish the most appropriate documentation plan for the Space Shuttle Life Sciences Operations during the experiments concept definition phase.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Payload Development Discipline	MSFC - 2.5.3	II-8

The Skylab Lessons Learned (SLL):

Design Reviews:

Skylab experience has demonstrated that an effective design review must emphasize the hardware, but should also include the review of inflight repair possibilities, single failure points, test plans, and available test results, such as component test data. The reviews must be scheduled in a timely manner with data packages being reviewed by the pertinent disciplines prior to the actual review. Action items from the reviews were documented on Review Item Discrepancy (RID) forms. Post review followup and ultimate disposition of all RID's was formalized and reported regularly. High fidelity mockups have proven to be very useful for these reviews, and the importance of early availability of interface control documentation was clearly shown.

Application of SLL to Life Sciences Program:

This SLL suggests the need for specific payload integration centers which exercise full management discipline for a payload configuration.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Interface to Man-Machine Integration Team	SLL Source & No. JSC	SLL No. II-9

The Skylab Lessons Learned (SLL):

Man-Machine Engineering Design Adequacy Assessment Team:

No concerted effort had been undertaken in manned spaceflight programs prior to Skylab to systematically document the design adequacy of the man-machine interface. Such an effort has now been established and its worth is beginning to show up in terms of Shuttle design implications. This discipline should become a standard element of the manned spaceflight organization.

A man-machine engineering oriented team should be established at JSC to offer preflight design input data, gather man-machine interface data during flight, and analyze the results postflight for all missions in an effort to maintain a continuing flow of applicable flight experience into the bank of design oriented man-machine engineering data.

Application of SLL to Life Sciences Program:

1. Although most of the man-machine interface tasks may have been done by the E&D Directorate, the man-machine integration is an important portion of Life Sciences and representation on the Space Shuttle man-machine interface team if such a team is to be organized is desirable..
2. The Skylab crew debriefings contain numerous "human factors" which have Shuttle design implications. Many items lend themselves to laboratory investigations before design specifications are approved.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
GFE Utilization Plan for Life Sciences/ Medical Operations	HQ - MLE 128 November 27, 1973	II-10

The Skylab Lessons Learned (SLL):

Maximum Utilization of Center Test Facilities:

Skylab has been particularly aware of utilizing active Government testing facilities wherever possible for their GFE. For example, (1) the utilization of the "JSC Thermal Vacuum Facility to test and verify the MSFC built ATM; (2) the modification and utilization of existing JSC vibration facilities rather than building a special contractor vibration and acoustics test facility for Skylab". In this case, strong action by Headquarters over a several month period was required to force the decision to upgrade JSC facilities and have MSFC and their contractors use that facility. There should be strong program office direction and action to ensure maximum utilization of existing center test facilities.

SLL Reference:

NASA GFE/Facility Accommodation Documents

Application of SLL to Life Sciences Program:

Identify test sites and GFE utilization plan for the maximum overall cost effectiveness of conducting required tests and training.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Acceptance Testing of Biomedical Hardware	JSC	II-12

The Skylab Lessons Learned (SLL):

Acceptance Testing of Biomedical Hardware:

Early qualification and acceptance testing of the M171 metabolic analyzer was inadequate because no manned tests were included. The MA functioned adequately with a mechanical pump, but it did not perform adequately using a human subject during rest and exercise. Specifically the electronic trigger design for the spirometers functioned well with a sine-wave mechanical pump, but false-triggered when subjected to human respiratory patterns.

All biomedical hardware should be tested in accordance with its designated experiment requirements.

Application of SLL to Life Sciences Program:

Qualification and acceptance testing should not be limited to compliance with end-item specifications, but should include a user integrated performance demonstration to ensure compliance with the operational objectives.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Life Sciences Planning Guidelines	HQ - MLA 12 December 10, 1973	II-11

The Skylab Lessons Learned (SLL):

The Skylab Student Project should be examined as an example of how to develop low cost experiment hardware. The Skylab student experiments were added to the program quite late. It was generally thought that only one or two, or at the most six or seven, of the twenty-five national winners could be accommodated inflight. Nineteen were finally performed. This was made possible by the establishment of firm technical and programmatic guidelines, an understanding among all participating organizations, and a strong motivation on the part of all the key participants to develop as many flight worthy low cost experiments as possible in the time frame required. The development of experiment hardware and procedures required should be conducted within the normal framework in regards to review of requirements, determination of analyses and tests required, etc., however, a widely accepted, management philosophy must exist which says that all things normally done within that framework shall be scrutinized. All things proposed to be done, or proposed not to be done, should be addressed specifically. This philosophy has to be understood by all organizations involved in establishing, reviewing and implementing requirements placed upon the experiment or its development.

Application of SLL to Life Sciences Program:

Student experiments demonstrated than an "accommodations handbook" technique has considerable cost savings advantages and deserves refinement for the Life Science Experiments program plan.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Visual Cues/Design Review Factors	JSC	II-13

The Skylab Lessons Learned (SLL):

Visual Gravity Vector:

The architecture of the Skylab OWS was gravity oriented. This orientation permitted ease of ground testing and crew training. In flight, this convention provided the crew with a familiar coordinate system permitting easy orientation, location recognition, and equipment identification. The majority of crewmembers favored this architectural arrangement.

In weightless conditions, architectural adherence to an "up-and-down" convention was found to be desirable as a convenience but not as a constraint.

Utilization of Space Inhabitable Compartments:
It was expected that habitable compartment volume would be more efficiently utilized in zero gravity space stations, because the space above one's head, which is poorly utilized in earth-based compartments, would be more fully utilized in zero gravity. Possibly because of the particular architectural arrangement of the Skylab crew quarters, the crews were not inclined to use the space above tables, consoles, etc., or anywhere above their shoulder level when operating on the lower deck of the OWS. Utilization of space in the smaller habitable compartments was very similar to utilization in earth gravity. Overhead space was not particularly useful in orbit in spite of the increased ease of access.

Application of SLL to Life Sciences Program:

Perceptual cues provide operational safety and minimize human error. Attention to these factors appears to be Life Sciences items at design reviews.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Personal Hygiene Equipment for Shuttle Crew and Passengers	JSC	II-14

The Skylab Lessons Learned (SLL):

Personal Hygiene Equipment:

Various Skylab crewmen complained that the personal hygiene items did not meet their accustomed standards, and consequently they avoided some items such as the shower soap, toothpaste, shampoo, razors. The shower soap left some crewmen with a "stinging" sensation, hence they quit using it. The shampoo had a distinctly unpleasant odor, hence was avoided. The toothpaste was not ingestible and the inconvenience of zero-g spitting caused some crewmen to use it sparingly. The safety razors clogged badly with no way to employ the 1-g "slosh in the water" convention in the zero-g environment. The quantity of soap supplied onboard Skylab was established based on a usage rate of 1 bar/man/2 weeks plus 5 bars per month for housekeeping and cleaning tasks, yielding a total of 55 bars. The SL-2 crew used only 1 bar of soap for the entire mission as opposed to the 11 allocated for use. A re-evaluation of the quantity of soap to be flown should be made based on the SL-3 and -4 data.

A wider range of hygiene and grooming equipment and expendables should be provided, probably as a personalized kit for each crewman.

Application of SLL to Life Sciences Program:

A Life Sciences personal hygiene requirements document appears appropriate before resolving end-item specifications. Consideration may be given to qualification and acceptance testing from a Life Sciences perspective.

APPENDIX A-III

SKYLAB LESSONS LEARNED

MISSION PLANNING/TRAINING/DOCUMENTATION

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
PI-SIM-Training Coordination Plan	JSC	III-1

The Skylab Lessons Learned (SLL):

Experiments Inputs Needed for Simulator Design:

Throughout the production of solar image, corona and radiation simulations ,for the Apollo Telescope Mount displays of the Skylab simulator, a team consisting of the principal investigators and their colleagues advised the simulation engineers on the solar image renditions. The good communications provided the feedback necessary to assure the high fidelity rendition of image simulations required for valid training.

During the development of experiment simulations for crew training, there must be good communications between the experiment experts and the simulation engineers.

Application of SLL to Life Sciences Program:

1. This SLL is applicable to the Life Sciences Experiments development in the Space Shuttle and crew training. Since the type of experiments in each Space Shuttle Life Sciences mission may be different, a long-term PI coordination and crew training plan should be established consistent with the Program timelines.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Crew Traffic Density Assessment During Mockup	SLL Source & No. JSC	SLL No. III-2

The Skylab Lessons Learned (SLL):

Control Console Protection:

The airlock module/MDA area of Skylab was a high-use passageway, yet the major spacecraft ECS and EPS controls and displays were located there. Instances of inadvertent switch or circuit breaker actuation occurred frequently because of either being bumped inadvertently or because the crew used existing panel guards as "fingerhold" mobility or restraint aids.

Control consoles should not normally be located along major IVA crew traffic routes. When control panels are located in high traffic areas, bump-proof switch guards should be incorporated to preclude inadvertent switch actuations.

Application of SLL to Life Sciences Program:

1. Implementation of this SLL is not a function of LSD.
2. Traffic density is a useful parameter to configure payloads and evaluate configurations during payload mockup design compatibility tests.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Ground Medical Support Requirements Definition	CDS	III-3

The Skylab Lessons Learned (SLL):

Post-Recovery Crew Subjective Sensations:

1. First indications of any vestibular problems occurred on the water during recovery although PLT got out of couch for awhile when CM was on recovery chutes. (SL 1/2, 7.18)
2. CDR was very careful in explaining postflight vertigo symptoms. None of the crewmen ever had uncontrollable motion sensations. Symptoms were more like vertigo encountered while flying. Illusions of excess motion always stopped when head motions were stopped. (SL 1/2, 7.19)
3. Postflight sensory awareness became normal after about 2 days and motor reflexes became normal after about 4 days. Ship's motion superimposed on equilibrium readjustment may tend to delay recovery. (SL 1/2, 7.20)
4. Crew speculated that condition degrades with time after splashdown for several hours. Complete readjustment to 1-g takes some time. (SL 1/2, 7.21)
5. Balance was always lost laterally (left/right) rather than frontwards/backwards. (SL/3, 7.3)

(continued next page)

Application of SLL to Life Sciences Program:

1. The SLL indicates that medical support can be expected at the Space Shuttle landing site(s).
2. It appears that considerable ground medical support operations planning will be required. Ground medical support operation requirements planning appears quite opportune for early program phases.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Ground Medical Support Requirements Definition	SLL Source & No. CDS	SLL No. III-3

The Skylab Lessons Learned (SLL):

Post-Recovery Crew Subjective Sensations: (cont'd from previous page)

6. Crew had regained almost normal equilibrium by the third or fourth day after recovery, and were completely normal in about a week. (SL/3, 7.19a)

7. A tired feeling after activity on earth continues (2 weeks after splashdown) to some extent. (SL/3, 7.19.b.)

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Medical Operations Documents	HQ - MMS 2, MLO 7 December 4, 1973	III-4

The Skylab Lessons Learned (SLL):

Need to Review Documentation Requirements Carefully:

Documentation can get "out of hand" if not closely controlled and confined to that which is necessary - not desired. There is a need for each responsible element of a manned space flight program to conscientiously review and eliminate non-essential documentation. In order to meet the future flight program objectives, namely, the reduction in cost and not frighten away potential investigators, the reduction of mandatory documentation to a minimum essential must be accomplished.

Application of SLL to Life Sciences Program:

1. Evaluate all the Skylab mission medical documentation for their usefulness.
2. Define essential and minimum number of Space Shuttle Medical documents and the documentation plan consistent with the Space Shuttle Program and Operation plans.

APPENDIX A-IV

SKYLAB LESSONS LEARNED

OPERATIONS AND DATA MANAGEMENT

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle FCHSP Definition	HQ - MMS 6 December 4, 1973	IV-1

The Skylab Lessons Learned (SLL):

Flight Crew Health Stabilization Programs (FCHSP) should be retained:

Flight Crew Health Stabilization Programs should be continued, having proven effective in eliminating concerns of possible crew morbidity and even incapacitation from communicable disease, during flights and post-recovery evaluations. The monetary, time and inconvenience costs of these programs are minor compared to those which would be incurred ultimately by the launch delays, backup crew preparation, inflight crew degradation, etc. resulting from communicable disease in the absence of such programs.

Application of SLL to Life Sciences Program:

1. Assemble and evaluate the data of past FCHSP in respect to manhours, monetary cost, inconvenience and effectiveness. Merits of an Apollo/Skylab type Flight Crew Health Stabilization Program (FCHSP) for the Space Shuttle Missions need review. If a less severe policy contains the benefits commensurate with the Space Shuttle program objectives, this policy should be defined to establish a clear set of planning guidelines. Such guidelines could be drivers for passenger selection if such an operational posture is to be implemented by NASA.
2. Define and establish practical and effective FCHSP requirements for the Space Shuttle.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Postflight Crew Health Monitoring Plan	HQ - MMS 7 December 4, 1973	IV-2

The Skylab Lessons Learned (SLL):

Postflight Crew Activities:

Following the return of the SL-2 crew and their debriefing comments, it became apparent that the postflight period needed to be more stringently structured in order to assure the maximum protection of the crew from a health standpoint and to insure the optimum return to their preflight physiological status. The recommendations from the SL-2 crew were incorporated in the postflight schedule of activities for the SL-3 crew wherein inviolate periods were designated for rest, exercise, eating, and sleep under the general surveillance of the Medical Support Team and specifically, the Crew Flight Surgeon. How much of the earlier return of the SL-3 crew to their preflight physiological status comparative to SL-2 crew can be attributed to the improved postflight schedule cannot be quantified, but there certainly was a contribution of this program to the SL-3 crew's more rapid recovery. There is a need to carefully plan and program the time and activities of crews returning from manned space flight missions of Skylab durations.

Application of SLL to Life Sciences Program:

1. The postflight crew activity policy should be documented early and detailed postflight crew activity plans should be documented several months prior to any mission.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Crew Training Program	HQ - MLO 4 November 26, 1973	IV-3

The Skylab Lessons Learned (SLL):

Crew Specialization:

With one exception, manned space flights prior to Skylab employed crewmen selected and trained primarily for operational expertise. The Skylab hardware mission profile was able to tolerate crewmen with more modest operational backgrounds while also providing an opportunity for extensive use of specializations in medicine and science.

Skylab has successfully employed crewmen selected primarily for their scientific or medical expertise with operational training as a supplement. These specialists have greatly enhanced the effectiveness of onboard equipment for their discipline while also adequately performing operational tasks. This blend of specialization and cross training appears to produce high quality data while still allowing flexibility in crew scheduling.

Application of SLL to Life Sciences Program:

The above SLL is also valid for the Space Shuttle Life Sciences payload specialists. The turn-around cycle for the Space Shuttle Life Sciences flight opportunities program should provide ample leadtime for establishing and maintaining an appropriate crew training program.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Uniform Test and Checkout Procedures in Various Test Sites	JSC	IV-4

The Skylab Lessons Learned (SLL):

Uniformity of test and checkout procedures for various sites:

Procedures for performing identical tests at different locations should be made uniform to avoid different sequences.

Application of SLL to Life Sciences Program:

1. Identify medical support equipment and payload tests and checkout required in various sites.

2. Establish uniform test and checkout procedures at all sites involved with handling Life Sciences related flight equipment.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Potable Water Monitoring Plan	MSFC - 3.1.7 & 3.1.8	IV-5

The Skylab Lessons Learned (SLL):

Iodine Absorption from Water System:

During tests of the water system deionization hardware, a serious problem discovered was that the organic resin in the deionization container removed the iodine from the water passed through the container. As a minimum for biocidal action 0.5 mg/l of iodine is required and anything over 6.0 mg/l is a taste problem. The volume of the deionization resin was 220 cubic inches and the flow rate of the water was very low, i.e., 24 pounds per day in three 8-pound slugs (one for each meal). The water sitting stagnant in the container between meals would lose iodine to the resin. Therefore, when water was discharged from the container the iodine content would be below the 0.5 mg/l acceptable minimum. The problem was solved reducing the resin volume to 66 cubic inches.

Ions in Water Supply System:

Three metallic ions were of concern in the water supply: chromium (Cr), nickel (Ni) and iron (Fe). The maximum allowable ionic content of the water is 0.05 mg/l for Cr and Ni and 0.30 for Fe. Nickel was not a problem in that the resin in the deionization container removed the Ni ions. The Cr and Fe, however, started at approximately 40 to 45 days to break through the resin and exceeded the above specifications ion levels. The Cr and Fe passed through the

(continued following page)

Application of SLL to Life Sciences Program:

Operationally, Life Sciences should maintain a close coordination in areas of specifications, crew procedures, ground support test procedures, and reporting to insure crew health and safety.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Potable Water Monitoring Plan	SLL Source & No. MSFC - 3.1.7 & 3.1.8	SLL No. IV-5

The Skylab Lessons Learned (SLL):

Ions in Water Supply System: (continued from previous page)

resin and mainly as particulates and not ions. Therefore, future water systems should incorporate a particulate filter in the line and the filter should be designed to allow easy replacement.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Private Medical Conference and Crew/P.I. Communication	HQ - MLA 8 December 10, 1973	IV-6

The Skylab Lessons Learned (SLL):

Crew/P.I. Communications:

On the Skylab missions, direct contact between the crew and P.I.'s was used to good effect in the day-to-day planning of flight control operations. It was done from the beginning in the medical experiments, as part of the daily private medical conferences. On the second and third missions, weekly planning sessions were held in which the crew conversed successively with representatives from each of the experiment disciplines on the mission.

Direct communications between the flight crew and selected Principal Investigators representatives are:

a) a productive means to refine onboard experiment operations and

b) a feasible and acceptable element in the framework of disciplined flight planning control.

Future programs with larger crews should consider multiplex channels allowing several conversations to proceed simultaneously.

Application of SLL to Life Sciences Program:

1. In Skylab, medical experiments were not discussed in the private medical conference.

2. Crew/Experiment PI communications is a planned operational posture for Space Shuttle. Procedures will have to be developed to implement this posture for the Life Sciences payloads.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Ground Life Science and Medical Data System Interfaces	MSFC - 2.4.2.c.	IV-7

The Skylab Lessons Learned (SLL):

Data Management:

In developing and implementing future ground data systems where multi-NASA centers are involved, a total integration function is desirable. The responsibility and authority should be assigned to a single entity and it in turn should be responsible for task assignments, requirements integration, resources commitment and definition, scheduling, statusing, reporting and implementation. To accomplish this function, data management planning should have Level 1 configuration control.

Application of SLL to Life Sciences Program:

Interfaces with the Space Shuttle program ground data system will require definition as a step toward the development of a Life Sciences data management plan.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Data Management Plan	MSFC - 2.4.2.a.	IV-8

The Skylab Lessons Learned (SLL):

Data Management:

Future spacecraft instrumentation and information (data) systems design considerations should include the impact on ground data handling systems.

The Skylab onboard data system configuration was a combination of previously-qualified flight systems with limited data management capabilities. The inability to perform onboard data processing required that additional processing of data be performed by the ground network remote sites in order to accommodate data flow rates with the existing network capabilities.

A total integrated design effort should consider sensors with data compression capabilities, onboard processing systems that will only transmit key parameters and analyzed results, information systems with decision making capabilities as to what constitutes valid data for transmission, and onboard data compression techniques.

Application of SLL to Life Sciences Program:

This is a followup to the prior SLL. A Life Sciences data management plan is necessary to allocate flight and ground processing functions and to delineate methodology to be used for postflight integration and distribution of the acquired data.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Data Management System Requirements Definition	MSFC - 2.4.2.f.	IV-9

The Skylab Lessons Learned (SLL):

Data Management:

At the time of the initial Skylab launch, the data system readiness was not equivalent to that of the flight hardware and software. To assure readiness, the development and operational aspects of ground data systems should be placed under some program level type of control, such as Interface Control Documents (ICD's).

This function should make provision for:

1) Standard operating procedures throughout the total data system,
2) Assignment of data teams knowledgeable in the user's requirements, data structure and processing systems
3) Certification of personnel through in-depth training
4) Specific definition of requirements to properly size the implementing system
5) Specific timelines for requirements definition, generation and submission
6) Data flow test program
7) Data quality monitoring program
8) Specific timelines for hardware and software development and implementation.
9) Data system configuration management
10) Overall data system development and operation activities scheduling, statusing and reporting.

Application of SLL to Life Sciences Program:

As an outgrowth of the Life Science Data Management plan, a data acquisition and processing requirements document will be necessary to ensure integration with the Space Shuttle Data System.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Data Quality Monitoring Capability	MSFC - 2.4.2.e.	IV-10

The Skylab Lessons Learned (SLL):

Data Management:

Due to inherent and imposed data distortions, a Data Quality Monitoring (DQM) program should be provided to identify the data quality to users. DQM program capability should be provided at each point in the data flow stream that imposes some form of data handling (e.g., transmission and reception systems, line capability switching, data formatting, data compression, production processing, etc.). The program should specify special data tags, computer programs, data sampling and validation techniques, and data enhancement capability.

Application of SLL to Life Sciences Program:

In Skylab, it was said that the raw data of major cardiovascular experiments such as systolic and diastolic blood pressures available to the MDRS at the SSR after the experiment run had errors of up to ± 15 mmHg. Since the availability of data to the surgeon was time-dependent, he had to use such data in real-time and near-real-time as the only available data regardless of data accuracy. Real-time data quality, especially for the manned medical experiments, deserves special attention.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Real-Time/Near-Real-Time Crew Health Evaluation Data System	HQ - MLO 5 November 25, 1973	IV-11

The Skylab Lessons Learned (SLL):

Data Transmission:

The following categories of data transmission appear to have room for extensive improvement:

1. Data Format: Data should not be collected in formats that require major intermediate processing before being compatible with the user. Rapid analysis and feedback are essential to efficient real-time flight planning. Since data standardization is also desirable, it may be feasible to develop a limited selection of standard data options that can satisfy nearly all user requirements.

2. Voice Communications: Provide multiple simultaneous voice loops including private communications. Single channel voice through a single ground spokesman is an unnecessary impediment to real-time management of simultaneous onboard activities. Private conversations have proven effective for medical consultation and morale; but with single channel, they prevent progress on all other fronts.

3. Visual Data: High quality real-time TV may reduce or eliminate transporting of film and allow rapid feedback into real-time flight management. Multiple TV sources, some of which are ground controlled, would also enhance data gathering.

Application of SLL to Life Sciences Program:

1. The above is applicable to both Life Sciences experiment data system and inflight crew health evaluation system of the Space Shuttle. In Skylab, the crew health assessment was made by clinical judgement via crew voice communication and rudimentary utilization of critical experiment data.

2. Real-time and near-real-time crew health assessment data processing techniques will benefit the mission-to-mission postflight medical care program if the ground medical staff can anticipate specific medical support requirements. Also, such techniques will help modify experimental protocols if data indicate trends away from expectations.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Inflight Data Return Capability	HQ - MLA 14 December 10, 1973	IV-12

The Skylab Lessons Learned (SLL):

Inflight Data Return Capability:

In the case of the Skylab medical experiments, it was necessary to have certain of the data available for determining crew health. ATM telemetered certain data which greatly aided the PI's inflight planning. It must be noted that many Skylab experiments use film and in that case results are not available until after the mission.

Experiment designs should allow for data return during the mission to the extent feasible to allow for real-time modification to the operating procedure during the mission.

Application of SLL to Life Sciences Program:

Probability of being confronted with unexpected experiment findings is high in the Life Sciences as in the other sciences; inflight data return and capability of real-time modification to the Life Sciences experiment procedures during the Space Shuttle Mission may be essential for a successful mission.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Onboard Life Sciences Data Management Requirements	JSC	IV-13

The Skylab Lessons Learned (SLL):

Onboard Spacecraft Experiment Data Readout:

Some experiment data collected on SL/2 and SL/3 was unusable because of equipment malfunction, errors in calibration, or improper set up. Experiment test data on the ground could be compared to sample onboard data for gross determination of acceptability. Onboard experiment data readout and assessment capability should be designed into all future manned spacecraft. This would allow the crewman to assess the experiment performance and thus optimize experiment data taking as well as crew operational time.

Application of SLL to Life Sciences Program:

1. This SLL is applicable to all biomedical and biological experiments in the Space Shuttle.

2. Requirements need to be defined for integrating the Payload Specialist into experimental program so that maximal advantage may be obtained from this crewman's attendance.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Data Documentation	MSFC - 2.4.2.b.	IV-14

The Skylab Lessons Learned (SLL):

Data Management:

For Skylab, the planning and implementation of data systems were accomplished assuming nominal operations. It was within this assumption that both flight operations and scientific data were combined into one major system. The system that resulted is not totally adaptable to handling continuous scientific data as well as contingency operations data.

Future ground data systems should provide capabilities for independent processing and handling of data for flight operations and scientific functions. The output from these systems, though flexible to accommodate the user's processing capabilities, should be standardized to minimize the various types available. A data user's handbook listing the outputs and constraints is recommended to be provided to users prior to requirements definition.

Application of SLL to Life Sciences Program:

As the Shuttle Data System matures, a Life Sciences Operational Accommodations Handbook should contain data system descriptions so that the users can plan their interfaces and anticipate the form in which the experiments data will be assembled.

APPENDIX A-V

SKYLAB LESSONS LEARNED

OPERATION LOGISTICS

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Food System Requirements Definition	JSC	V-1

The Skylab Lessons Learned (SLL):

Food System Design:

The following three items are recommended in the design of food systems where long term space flight is involved.

1. Menu standardization: Response, simplicity, cost, and amount of documentation can be optimized if standard menus are implemented in the food system which would have all crewmen eating the same basic meal at the same time.

2. Pantry type food storage versus meal sequence food storage: Particularly for long term flight, a pantry style food storage system is recommended. This type of system stores all identical foods in the same location and a meal is prepared by selecting the desired foods from the storage area in much the same manner as a home pantry. (This arrangement allows flexibility and provides for changing eating habits, desires, and for changes in mission duration, timelines, etc.)

3. Operational system versus experiment support: The Skylab food system served two purposes: (1) It was the operational system for supplying the crewmembers nourishment; as well as, (2) being a large element of the M070, Mineral Balance Medical Experiment series. It is recommended, if feasible, that the operational food system be isolated and controlled

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Application of SLL to Life Sciences Program:

A recommendation made in the Space Rescue Symposium, 5th International, IAA, Vienna, Austria, October 1972 was that the Shuttle pilot and co-pilot eat meals from different menus in order to avoid a simultaneous occurrence of incapacitation by food poisoning. An extensive survey of airline-type food system and recommendations accumulating in literature may assist the planning.

SLL Title: Space Shuttle Food System Requirements Definition	SLL Source & No. JSC	SLL No. V-1

The Skylab Lessons Learned (SLL):

Food System Design: (Continued from previous page)

separately from the experiment food or formulation that would be used in connection with any nutrition or medical experiments.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Automatic Food, Water Intake, Biowastes Sampling and Preservation	JSC - K	V-2

The Skylab Lessons Learned (SLL):

Waste Management System Design Features:

The airflow system for collecting feces worked well for Skylab and this concept is recommended for future spacecraft. Higher airflow than that used on the Skylab system would be desirable. The seat should be fabricated of a softer material, and the outside diameter should be widened to provide a better airflow seal. The Lap belt and handholds were absolutely required. The airflow system for collecting urine worked well for Skylab, and this concept is recommended for future spacecraft. The collection system should provide a volume of at least 4000 ml per man/per day. Urine separator should not be as noisy as the one used on Skylab. The waste management compartment should be located sufficiently far from the sleep compartment. The urine collector should be refrigerated and stored to prevent odor buildup or stored in a sealed condition. The same blower design was used for the fecal collector, the shower, and the vacuum cleaner on the Skylab. The in-orbit hand washer consisting of a water dispenser and cloth squeezer was satisfactory. An enclosed design permitting the crewman to actually wash with the water would be desirable.

Application of SLL to Life Sciences Program:

1. If the waste management system is to be used for collecting biowaste samples, requirements need to be defined for urine and fecal sampling, measurement of volume/mass and sample preservation to make minimum impact on crew time, procedures, and contamination before the operating configuration is finally approved.

2. An automatic measuring sampling, recording, and preservation of the food and water intakes and biowastes could increase the medical data available from all flights with no interference to the crew time. Such a system is within current state-of-the-art technology.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Mission Support Hardware Availability Status Monitoring	MSFC - 2.7.3	V-3

The Skylab Lessons Learned (SLL):

Mission Support Hardware:

Test hardware, breadboards, mockups, etc., along with hardware specialists should be maintained and available for mission problem resolution assistance.

Use of backup hardware, breadboards, mockups, and hardware specialists became very valuable in malfunction problem solving. This was demonstrated numerous times in order to evaluate off-nominal conditions, determine the nature of a failure mode and to evaluate potential corrective actions.

Application of SLL to Life Sciences Program:

This SLL suggests a traditional hardware procurement with a complete facsimile of the flight equipment on the ground. The SLL needs to be investigated to determine the most cost effective approach which will provide operational benefits without undue cost burdens.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Experiment Equipment Quantity Requirement Checklist	SLL Source & No. JSC	SLL No. V-4

The Skylab Lessons Learned (SLL):

Determination of equipment quantities:

On Skylab, technical monitors and suppliers did not have sufficient information to determine accurate equipment quantities. For example, how many CO monitors, or TV cameras or clothing modules, etc., were to be required to support all ground and flight activity. The project office devised a combination events chart and requirements checklist which assured that enough items would be available and minimized production of unnecessary items. The key factors affecting quantity are breadboard, mockup, prototype, qualification, production for flight, flight backup, trainers, and spare parts. Timing is also important in sequencing usage to reduce total quantities required. Individual hardware suppliers should not independently establish hardware quantities required for program activities. The program organization must establish a consistent approach in determining quantities of equipment required to support a program. A combination events chart and requirements checklist was a useful tool for quantity determination.

Application of SLL to Life Sciences Program:

1. This SLL applies to all Life Sciences experiments hardware. Data needs to be assembled pertinent to defining the quantities of equipments required to support all ground and flight activity. This information has to be available to the experimenters and hardware developers.
2. Combination events chart and requirements checklist may be developed early as a planning aid.

APPENDIX A-VI

SKYLAB LESSONS LEARNED

DESIGN INTERFACE

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Requirements Input to the Shuttle Glass Window Design	JSC	VI-1

The Skylab Lessons Learned (SLL):

Spacecraft Glass Window Design:

Glass strength degrades with time because of a combination of stresses in certain environments, of which moisture is recognized as the most detrimental. Some flaws are always created during the manufacturing process, but are generally not detectable by any known method other than proof testing based on fracture mechanics analyses. This method was used to evaluate both the Command and Lunar Module windows. Structural design requirements must consider the possible degradation effects of exposure to a space radiation into the crew habitation area affecting the crew's health or actuating UV fire sensors. Fracture mechanics should be used as the principal method to evaluate spacecraft glass structural designs and to specify the proof tests required to verify the safety of the design. Proof tests should be conducted in an inert environment, particularly one free from moisture, to ensure that the glass flaws do not grow during the proof testing. Test evaluation criteria must also include IR and UV radiation considerations. The pressure seal backup capability for single pane windows should be verified as adequate for crew protection in the event of rapid decompression due to window failure.

SLL Reference:
Apollo Experience Report-Spacecraft Structural Windows, NASA TN D-7439

Application of SLL to Life Sciences Program:

The Life Sciences interface with this SLL exists in the following areas:

a. Crew safety devices, and countermeasures in case of acute decompression due to the glass window fracture.

b. IR and UV radiation effects to the crew health.

c. Adequacy of the visibility and visual field for the remote controlled payload operation.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Life Sciences Hardware Onboard Calibration Capability	MSFC - 3.1.23.	VI-2

The Skylab Lessons Learned (SLL):

Onboard Calibration:

Design onboard calibration capability into experiments or other equipment requiring calibration.

Application of SLL to Life Sciences Program:

Onboard Life Sciences experiment hardware should have this capability (Skylab had some calibrating capability).

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Crew Safety Warning System	HQ - MLE 90 November 26, 1973	VI-3

The Skylab Lessons Learned (SLL):

Inhibiting Devices - Master Alarm System:

Master alarms were triggered in flight from extraneous causes. It was necessary to suppress the alarm to permit normal operations to proceed. One example was a fire alarm which was initiated by radiation experienced in the South Atlantic Anomaly Zone.

Inhibiting devices should be placed on individual caution and warning alarm systems. It is necessary to suppress "flase" alarms which occur in flight.

SLL Reference:

(1) Skylab 1/Skylab 3 Summary Report - Sept. 26, 1973, Problem Tracking List MSFC Problem 24.
(2) Skylab JSC FRR Handout - April 13, 1973

Application of SLL to Life Sciences Program:

Not a Life Sciences function to establish policy. The General Experiment Spec. (Ref. SLL #MLE 16) should specify caution and warning (C&W) functions which are to be built into the experiment hardware.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Space Shuttle Food Stowage Requirements Definition	JSC	VI-4

The Skylab Lessons Learned (SLL):

Food System Storage Lockers:

The storage volume for the food system in the spacecraft was defined early in the program cycle allowing the food lockers to be built with poor tolerance control which resulted in eleven different sizes for the eleven different lockers. Maximum tolerance buildup in each direction could exceed 1/2". The loaded food restraint assemblies were to fit all lockers. These restraint assemblies were quite massive and once in orbit were required to be removed by the crew. The use of shims (wedges) was unsuitable because of the odd shapes of the lockers which would not allow shims and/or the inserts to be removed after inserting the food restraint assemblies in the lockers. As a result, internal damping techniques inside the cannisters, cans and restraint assemblies were employed to provide the vibration isolation required to protect the food. Extra development and testing were required to qualify the system.

Realistic dimensional tolerances should be standardized on large volume food system storage lockers to minimize interface problems, shimming and test requirements.

Application of SLL to Life Sciences Program:

This SLL has particular importance since the storage lockers will contain items during Shuttle ascent, descent, and landing.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Interface with the Habitability Study Team	JSC	VI-5

The Skylab Lessons Learned (SLL):

Habitable Environment:

The Skylab "comfort box" was acceptable. Temperature was comfortable, humidity was a bit low. Chapped lips, dry skin, and nasal discomfort were attributed to the low humidity by Skylab crews. Portable fans helped to relieve heat layers created by exercise, etc. and not dispersed by convection. Separate thermal controls for the WMC would have allowed more comfortable bathing.

Acoustic environment was pleasant and odors were virtually nonexistent. Portable fans are desirable. Individual thermal controls for sleep and waste management compartments would also be desirable.

Application of SLL to Life Sciences Program:

Life Sciences needs close coordination with the habitability study team with respect to experiments planning and operational performance.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Interface with IVA Safety Design	JSC	VI-6

The Skylab Lessons Learned (SLL):

IVA Mobility in Spacecraft:

The PLT's position at the wardroom table was located such that in order to exit the wardroom he had to translate over the table or have another crewman move from his position to allow passage. Passage over the table was also a hazard from the "foot-in-the-food tray" point of view. Skylab crewmen contacted OWS dome sufficiently en route to the dome hatch to leave dents in the ceiling. The crewmembers often bruised their legs as a result of multiple hatch negotiations and immediate attitude reorientations during the day. (Based purely upon laws of mechanics, translation normal to the principal body axis would be undesirable). In the small cluttered compartments the crew moved around in the erect position. Since only the "floor" offered foot restraint, and since often there was insufficient space to stretch out "horizontally", the crew probably had little choce, IVA architectural layout should insure that normal translation routes do not interfere with the working, eating, sleeping, or relaxing crewmen. The "critical" point along a crewman's translation patch is where he either changes direction or negotiates an opening (hatch, etc.) Attitude excursions are inherent at these junctures and the lower extremities are constantly "dinged" on thresholds & hardware protruding around doorways. A buffer zone of "bump protection" should be employed adjacent to all openings, and the immediate areas should be kept clear of protruding hardware.

Application of SLL to Life Sciences Program:

IVA architectural layout of the Life Sciences payloads is necessary to eliminate crew injuries and to optimize the efficiency of the work station operation.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title: Onboard Redundant System Requirements	SLL Source & No. JSC	SLL No. VI-7

The Skylab Lessons Learned (SLL):

Redundant systems should allow concurrent operation if desired:

Redundant systems, and in some cases, redundant components, should be designed to be capable of operating at the same time. This approach would allow use of two systems or components if one were to be marginally acceptable. The lack of this capability caused difficulty in operating several Skylab systems after failures or anomalies occurred in orbit.

Application of SLL to Life Sciences Program:

The concept of redundancy is applicbable to design of the Spacelab, Life Sciences experiments and crew health monitoring.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
Definition of Manual and Automated Functions	JSC - F	VI-8

The Skylab Lessons Learned (SLL):

Improve Utilization of On-Orbit Crew Time Through Ground Control:

In Skylab, experiments such as the ATM S055 and the ATM pointing control were accomplished through ground commands during unmanned periods and while the flight crew were not in attendance. Ground control was also used successfully for solar array electrical power generating system, data and video recorder tape management, and control moment gyro momentum management.

Ground controlled or automatically sequenced equipment and experiments allows activities to occur during crew rest and sleep periods. Ground control should be used for repetitive or time consuming functions which do not require onboard crew judgment. Future programs should review all functions desired during crew sleep, eat and unmanned periods for possible accomplishment by ground controlled functions.

Application of SLL to Life Sciences Program:

1. Review and evaluate medical and experimental operational requirements and define corresponding functions in the following categories:
   a) Functions which cannot be automated
   b) Functions which can be manual during crew attendance and automated when crew not in attendance to relieve activity burden.
   c) Functions which can be completely automated.
2. During the process of allocating functions, care must be taken to integrate the crews in the experimental domain, using their reasoning capabilities, and avoiding roles analogous to elemental transducers.

APPLICATION OF THE SKYLAB LESSONS LEARNED (SLL) TO THE SPACE SHUTTLE LIFE SCIENCES PROGRAM

SLL Title:	SLL Source & No.	SLL No.
LSD's Role in Flammability/Toxicity Hazard and Monitoring Plan	HA - MLQ 1 November 27, 1973	VI-9

The Skylab Lessons Learned (SLL):

Control of Materials Whose Use Contribute to the Flammability/Toxicity Hazard

Procedures for material certification and assessment for flight safety should be finalized early in the program. Evaluation should consider worse case condition. As applied to Shuttle, failures of ECS which result in 0_2 enriched environment should be considered.

All interior paints presently known require high temperature bake to meet toxicity requirements.

Care should be taken in selecting elastomeric closed cell foam for stowage container packing if spacecraft undergoes pressure excursions.

SLL Reference:

1. Skylab Materials Control Program - Skylab Program Directive 13
2. OMSF Material Evaluation Criteria, NHB 8060.1

Application of SLL to Life Sciences Program:

Potential Life Sciences roles in the following areas of Flight Safety and materials control appear productive:

a) Establishment of limits for the detection of atmospheric contamination, permissible concentration of volatiles, radioisotopes, etc.

b) Flight safety countermeasures, crew procedures, including escape and rescue.

c) Requirements for sustaining the life of incapacitated crew and passengers.

APPENDIX B

APPENDIX B

THE SPACE SHUTTLE SYSTEM

APPENDIX B

THE SPACE SHUTTLE SYSTEM

Information contained in the following paragraphs; A. Operational Characteristics, B. Mission Characteristics, and C. Payload Characteristics, have been extracted from the Space Shuttle Program Requirements Document, Level 1, Office of Manned Space Flight, May 4, 1973, Revision No. 5 (later amendments), and Space Shuttle Definition Handbooks published by Space Division, Rockwell International.

A. Operational Characteristics

The Space Shuttle System flight hardware consists of a reusable Orbiter Vehicle including installed main engines, an expendable External Tank (ET), and reusable Solid Recoverable Boosters (SRB) which burn in parallel with the main engines. The Orbiter Vehicle shall be capable of cross range maneuvering during entry, aerodynamic flight, and horizontal landing. The design objective for the Orbiter Vehicle is a minimal useful life of 10 years with low cost refurbishment and maintenance for as many as 500 reuses.

The Orbiter Vehicle's payload bay geometry shall have a clear volume of 15-foot diameter by 60 foot length. The Space Shuttle System shall accommodate payload masses ranging between 0 and 65,000 pounds in all flight phases with a limitation of 32,000 pounds maximum landing payload weight.

The Orbiter Vehicle's cabin, which will provide a shirtsleeve, 14.7 psi, mixed gas atmospheric environment, accommodates a crew of four, consisting of a commander, pilot, a mission specialist and a payload specialist. The Orbiter shall be provisioned for support of these personnel for a 7-day mission (28 man-days). The design shall provide the capability to accommodate two additional specialists and provisioning up to 42 total man-days with no orbiter system change. The two additional specialists and all special accommodations for them including their seats, intercoms, and life support consumables will be charged against the payload. For shorter duration missions, the cabin should, with minor interior changes, accommodate a total of 10 personnel, including the crew of four. All passenger provisions, exceeding 42 man-days, other than orbiter structural provisioning shall be provided in kit form chargeable to payload and/or with payload provided storage of expendables.

The Orbiter Vehicle shall be capable of direct voice command, telemetry, and video communications with the ground and with an eventual interface to a communications satellite system. There shall be provision for secured voice and data communications equipment.

The Orbiter Vehicle docking subsystem shall be compatible with requirements of International Docking Agreements established for future space vehicle systems.

B. MISSION CHARACTERISTICS

The Space Shuttle System shall be designed to accomplish a wide variety of missions. These missions will involve direct delivery of payloads to specified low earth orbits; placement of payloads and transfer stages in parking orbits for subsequent transfer to other orbits; rendezvous and station keeping with detached payloads for on-orbit checkout; return of payloads to earth from a specified orbit; placement of payloads with kick stages in earth orbit for subsequent injection into interplanetary trajectories; and provisions for routine and special support to space activities, such as sortie missions, rescue, repair, maintenance, servicing, assembly, disassembly and docking.

1. Reference Missions

The reference missions for the Space Shuttle System are described below. For performance comparisons, Mission 1 will be launched from Kennedy Space Center (KSC) into a 50 by 100 n. m. insertion orbit and Mission 3 will be launched into approximately the same insertion orbit from the Vandenberg AFB, but at an inclination that will put it in close to a polar orbit.

a. Mission 1. Mission 1 is a payload delivery mission to a 100 n. m. circular orbit at 28^{o} inclination. The mission will be launched due east and requires a payload launch capability of 65,000 pounds and return payload of 32,000 pounds. The boost phase shall provide insertion into a minimum 50 n. m. altitude and a minimum 100 n. m. apogee altitude. The purpose of this mission will be assumed to be placement and/or retrieval of a satellite. The orbiter vehicle on-orbit translational delta V requirements are 650 ft/sec from the orbital maneuver subsystem (OMS) and 100 ft/sec from the RCS.

b. Mission 2. Mission 2 is a 7-day combination revisit to an orbiting element and spacelab mission, where the orbiting element is in a 270 n. m. circular orbit at 55^{o} inclination. The payload capability will be based on existing performance requirements as defined for Missions 1, 3a, and 3b. The on-orbit delta V requirements in excess of a 50 x 100 n. mi reference orbit are 1250 fps from the Orbital Maneuver System (OMS) and 120 fps from the RCS.

c. Mission 3. Mission 3 (a) is a payload delivery mission to an orbit at 104° inclination and return to the launch site in a single revolution. The boost phase shall provide insertion into an elliptical orbit with a minimum of 50 n. m. altitude and a minimum apogee of 100 n. m. The payload requirement is 32,000 pounds with a return payload of 2,500 pounds. The Orbiter's on-orbit translation delta V requirements are 250 fps from the OMS and 100 fps from the RCS. Mission 3 (b) is a payload retrieval mission similar to 3(a), but with a launch payload payload of 2,500 pounds and a return payload of 25,000 pounds. The delta V requirement is 425 fps from the OMS and 190 fps from the RCS.

2. Launch Azimuth

The Space Shuttle System shall have a variable azimuth launch capability to satisfy the acceptable launch-to-insertion azimuths from both the KSC and Vandenberg AFB launch sites.

3. Crossrange

The Orbiter Vehicle shall have the aerodynamic crossrange capability to return to the launch site at the end of one revolution for all inclinations within the Space Shuttle System capability. Crossrange is to be achieved during entry, which is defined as beginning at 400,000 feet altitude and ending at 50,000 feet altitude.

4. Return Payload

The Orbiter Vehicle shall have the capability to land the design return payload of 32,000 pounds with nominal wind and load factors and up to 65,000 pounds return payloads under emergency landing condition constraints.

5. Load Factors

The Space Shuttle System launch trajectory resultant load factors shall not exceed 3-g's in the x-axis and resultant entry trajectory load factors shall not exceed 3-g's in the z-axis for the Orbiter Vehicle. These limits do not apply to abort modes. The product of g-forces and time shall not be detrimental to the crew/passengers.

6. Turnaround

The Space Shuttle System flight hardware turnaround time from landing/touchdown at the launch facility to launch shall not exceed 160 working hours for any class mission. This operational capability can be achieved through an evolutionary approach. The Solid Recoverable Boosters (SRB) inventory and turnaround times will support this total system requirement.

7. Launch from Standby

The Space Shuttle System design shall provide the capability to be launched from a standby status within two hours, and hold in a standby status for twenty-four hours. Standby status is defined as ready for launch except main propellant fill, crew ingress and final systems verification.

8. Rescue

To fulfill the space rescue role, the Space Shuttle System shall have the capability to launch within twenty-four hours after the vehicle is mated and ready for transfer to the pad. The Orbiter Vehicle shall be capable of being docked using an active docking module brought up in the rescue vehicle. The Orbiter Vehicle shall be capable of supporting the survival of a 4-man crew for 96 hours after an in-orbit contingency. Support for additional personnel must be provided in payload.

9. Abort

The Space Shuttle System shall provide a safe mission termination capability through all mission phases.

10. Mission Duration

Mission duration of seven days shall be used to size the Orbiter for self-sustaining lifetime (from liftoff to landing) for a crew of four. The Orbiter design shall not preclude the capability to extend the orbital stay time up to a total of thirty days by adding expendables. For missions in excess of seven days, the weight and volume of the added expendables and tankage shall be charged against the payload.

C. Payload Characteristics

Payloads are construed as the collective grouping of space hardware items such as Spacelab, Carry-on experiments, Pallets, Free Flyer Satellites, Tugs, and payloads with kick stages equipment into appropriate composite flight packages. Figure B-1 illustrates candidate payloads and orbiter accommodations chargeable to the payloads. The marriage between Life Sciences research objectives and specific payload accommodation is being definitized - preliminary planning has addressed Space Laboratories, palletized experiments and, when applicable, carry-on "suitcase" experiments for launch of opportunity. Whereas Spacelab may be dedicated to a disciplinary area; i.e., astronomy, solar physics, space processing, life sciences, etc., both pallets and Spacelabs may carry multi-disciplined experiments. Also a

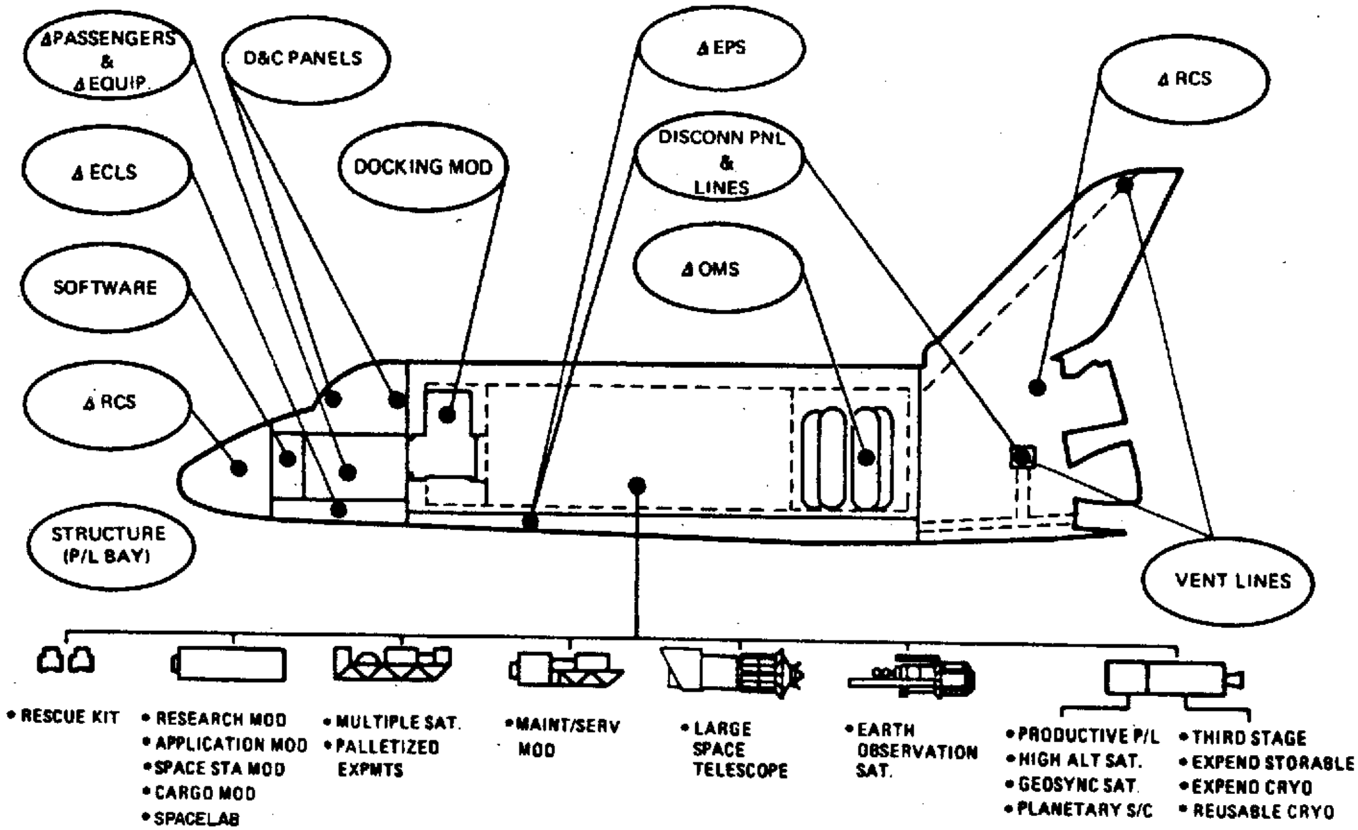

FIGURE B-1
CANDIDATE PAYLOADS FOR SHUTTLE ORBITER

mission may carry mixed disciplined and configured payloads. Carry-on experiments, not portrayed in the illustration, are understood to be rudimentary experiments, requiring little or no crew attention, and totally self-contained. Combinations of payload types; i. e., spacelab and pallet, should not be discounted.

In the interest of maintaining minimal orbiter/payload interfaces, payloads will be capable, where possible, of functional checkout before installation in the orbiter, and to standard interface concepts developed between payloads and Orbiter.

1. Checkout

Payload performance testing and payload system checkout will be required prior to installation into the Orbiter. Payload checkout while on the launch pad will be minimized to essential safety critical monitoring, and physical access to the payload will be limited to critical functions only. On-orbit status checks of the payload will be provided via the Orbiter and prior to payload activation and/or deactivation when applicable.

2. Data Management

The Orbiter shall provide standard displays and controls for operating payload systems and monitoring the safety status of the payload. The payload shall provide to the Orbiter, at the interface, such information concerning the status or condition of the payload as is necessary to insure safe vehicle operationa. Digital, discrete, and analog signals shall be conditioned by the payload and supplied to the Orbiter Vehicle for transmittal. Such equipment and capability shall be chargeable to the payload. Payload unique control and display accommodation with the Orbiter cabin shall be chargeable to the payload. A minimum standard interface shall be provided to exchange data for safety and payload status checks, and vehicle and operational parameters, such as navigation, guidance and control. Additional support may be feasible during certain operational modes.

3. Payload Communication

The Orbiter shall provide direct and relay telemetry, command, and two-way voice capability with attached payloads and with released payloads. The Orbiter shall be capable of receiving and displaying payload data including video information, and the RF downlink shall provide for relay of these limited payload data to the ground for both attached payloads and for released payloads.

4. Payload Safety

Payload elements shall have self-contained protective devices or provisions against payload-generated hazards while the payload is attached to the Orbiter. Hazards generated by the Orbiter payload interactions during load, transport, deploy and recovery activities shall be identified and mutually resolved by the Shuttle and payload program offices.

5. Contamination

The Orbiter Vehicle shall be designed to minimize the generation, introduction and accumulation of contaminants within the cabin, payload bay, and around attached payload modules. Payload and Orbiter RCS thruster exhaust shall not impinge or be reflected on deployed payloads or into the open payload bay. The total level of contamination within the payload bay from all sources shall be controlled to minimize the effects on payloads during all phases of Shuttle operations.

6. Power

The Orbiter electrical power system shall provide for a payload electrical energy allowance of not less than 50 KWH in the form of redundant 28v DC power to the payloads. Energy in excess of 50 KWH will be mission dependent and may be provided by additional Orbiter consumables charged to the payload or by independent payload systems. Power supplied by the Orbiter for payload consumption will be limited to 5 KW average and 8 KW peak.

7. Attitude Control

Stability and attitude control requirements beyond those of the basic Orbiter Vehicle shall be provided by the payload system. The Orbiter Vehicle shall be capable of pointing at any ground, celestial, or orbital object within $\pm$ 0.5 degrees. The Orbiter shall also be capable of accepting compatible commands from a payload-supplied and payload-mounted sensor for positioning.

8. Rendezvous and Docking

The Orbiter Vehicle shall have an onboard capability to rendezvous and dock with in in-plane cooperative target or a passive stabilized orbiting element displaced up to 300 n. m. For Orbiter Vehicle preplanned docking missions, the docking mechanism will be installed in the payload bay. The weight of the docking mechanism and associated attachment fittings shall be chargeable to the payload.

9. Payload Attachment - (Also Servicing/Power/Data Panels)

The Orbiter shall provide standard discrete attachment points for mounting payloads. These attachment points shall be located along the payload by to accommodate different payload lengths and to allow for random order retrieval of multiple payloads.

10. Payload Deployment and Retrieval Mechanism

The Orbiter shall provide a payload deployment and retrieval mechanism which shall be stowed outside the 60-foot length by 15-foot diameter payload volume. This mechanism shall deploy the payload clear of the Orbiter mold line. Release of the payload from the deployment mechanism shall leave the payload and the Orbiter with only small residual attitude drift rates. Spin-up capability, if required, will be accomplished by the payload.

For retrieval, the deployment/retrieval mechanism shall interface with payloads designed for retrieval and, after attachment of the mechanism to the payload, shall align the payload in the payload bay to accommodate secure stowage of the payload. Additionally, the payload deployment and retrieval mechanism shall be capable of supporting the payload in the deployed position under the attitude stabilization and docking loads.

11. Payload Bay Vents

Provisions for venting the payload bay shall be provided by the Orbiter. This vent system shall minimize the impact of venting upon the attitude control system.

12. Payload Bay Access

The Orbiter and launch facility will permit access to the payload bay for payload installation, service, and removal in the Orbiter flight preparation area and on the launch pad. Access for personnel and cargo to the payload bay will also be available through the hatch, which interfaces the Orbiter crew compartment with the payload bay. Ground access to the payload bay will be limited to the period up to two hours before launch.

APPENDIX C

APPENDIX C

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE (GENERAL CATEGORIES)

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR MISSION CHARACTERISTICS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Mission Autonomy	Minor degree	High degree	1) Skylab crews found that ground control of all mission details was not desirable and that the crew could accomplish more with some flexibility in the flight plan. Shuttle planning is directed to give the crew more autonomy. 2) The concept of payload specialists assigned to the crew should give them the expertise to exercise this autonomy efficiently.
Crew Size	3 - Commander, Scientist Pilot, and Pilot	4 (reference) - Commander Pilot, Payload Specialist, Mission Specialist	Shuttle can carry more than the basic crew if needed for specific payloads (up to 7 with Spacelab mission).
Mission Length	28 days 59 days 85 days	7 days, with growth to 30 days	
Orbital Characteristics	Fixed orbit (50° inclination, 210 nautical miles circular orbit)	Variable inclination and orbital altitude	
Launch Site	Kennedy Space Center only.	Kennedy Space Center (NASA) and Vandenberg Air Force Base	
Recovery	Command Module only - water landing	Earth landing strip fixed recovery sites identical with launch sites.	Skylab recovery ships, mobile medical laboratories, and elaborate logistics provisions will not be needed for Shuttle.
Abort Effect	Probable loss of revisit capability	Safe mission termination through all mission phases; recovery of orbiter and payload for later reuse.	
Payload Characteristics	Multi-disciplined	Principally payloads dedicated to a single disciplinary area; moderate amount of mixture of disciplines is feasible.	Considerable planning integration to obtain all objectives scheduled for the Skylab Program.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR MISSION CHARACTERISTICS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Data Management	Dependent on telemetry and ground processing. - Delayed feedback to the orbiting vehicle, if any. (predominantly open loop).	Autonomous within flight vehicle throughout flight phase	Shuttle experiment results should be enhanced by onboard data management capability
Experiment Return	Very limited capability (weight and volume limitations).	Normal mode of operation is to return the payload (except for satellites and deep space probes.)	This simplifies many experiments by reducing photography and crew observations. Also helps in anomaly resolution if any occur so that future experiments can be improved.
Mission Evolution	Limited	Unlimited	Skylab revisits were limited to two only and mission changes were limited due to weight and volume payload capability of the revisit Command Modules. Shuttle program can be continually revised so that later missions can profit by every lesson learned on earlier missions.
Payload Ownership	Mostly government (NASA plus some DOD, university and foreign)	Can be owned by industry, universities or other institutions, both U.S. and foreign.	Ownership by other than NASA is feasible due to the concept of the payload and also the concept of multiple independent experiments on one payload pallet. Shuttle payload costs should be greatly reduced due to the re-usability of both the orbiter and the payloads.
Safety Standards	Manned Space Flight Certification	Space Shuttle System: Manned Space Flight Certification Standard - Payloads: Commercial Industry and airline standards	Experiment costs should be reduced with the utilization of Shuttle standards.
Microbial Contamination	Rigid Inflight Hygienic Procedures	• Moderate procedures; • Controlled by mission-to-mission refurbishment	This should enable Shuttle crews to have more time for productive work or rest.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR MISSION CHARACTERISTICS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Rendezvous and Docking	Absolutely necessary for crew transfer from Command Module to Workshop	Variable constraint; dependent on type of mission flown. - No planned crew transfer unless a rescue operating mode is designated.	
Deployment and Retrieval of Unattached Payloads	None	Objectives for special missions	
Venting Effects	Impacted operation of attitude control system	Minimal impact, if any	Mission dependent. Shuttle vents all the time unless stored.
Load Factors	Launch stress only for experiments in the Orbital Workshop.	Not to exceed 3-g's.	
Communications	Less than 20% average coverage per day	Same without communications satellite (except for polar orbits). Greater than 90% average daily coverage with communications satellite 2-way air/ground TV.	No Tracking and Data Relay Satellite antenna - 15% One Tracking and Data Relay Satellite antenna - 40 to 60% Two Tracking and Data Relay Satellite antennae - 85 to 100%
Payload Constraints	Fixed to launch configuration with minor alterations via visit-to-visit resupply. - Mostly internal with passively mounted external experiments. - Considerable crew involvement.	Fixed for each mission - Variable from mission-to-mission - Attached or free flying capability - • Manual • Automated - Active - Passive • Combined operating modes for attached payloads	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR ENVIRONMENTAL FACTORS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Atmospheric Composition	70% O_2 30% N_2 $<$ 5 mm Hg CO_2	80% N_2 20% O_2 $<$ 7.6 mm Hg CO_2	5.0 mm nominal
Atmospheric Pressure	5.0 psia	14.7 psia	
Operating Environment	Shirtsleeve	Shirtsleeve	
EVA Prebreathing	Not necessary	Will be necessary	Shuttle cabin will be 14.7 psia with 80% N_2. Skylab workshop and Apollo CM was at 5.0 psia.
Flammability	Extensive material screening	Extensive material screening	Shuttle atmosphere with 80% N_2 plus zero-g effects makes flame propagation less of a problem than normal earth environment.
Outgassing	Material testing	Material testing	Shuttle atmosphere will be the same as on earth so there will be much less tendency for outgassing of nonmetallic materials.
Liquid Waste Disposal	Vented overboard via trash compartment	To be determined	
Solid Waste Disposal	Left in orbit (except for M071 dried samples).	To be determined	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR MISSION OPERATIONS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Experimenter Support	"Off-Line"	"In-Line"	Experimenters to have an in-line mission role during flight following either a direct interface with the Flight Director or through a Principal Investigator technical interface.
Support to Experimenter	Involvement through NASA Principal Coordinating Scientist (PCS)	Continuous direct involvement with payload integration center	In Skylab, NASA was responsible for providing experiment hardware and software support; in Shuttle these functions shall reside with the individual experimenters.
Logistics Support	NASA	Mixed	NASA will provide logistics support to the experiment carrier interface. Logistics from the interface to the experiment will be experimenters' responsibility.
Experiments Planning	Experimenter with Operations Center	Experimenter direct with payload	Experimenter to establish protocol and crew procedures for experiment and to provide support to the payload center for coordinating these functions in the mission plan.
Experiments Training	NASA PCS Coordination	Flight Operations Management	Training interface with crew coordinated by payload center.
Mission Data Support	NASA PCS Coordination	Direct interface between experimenter and flight operations management	Coordination with flight operations to establish the formats in which experiments data will be submitted to experimenter.
Flight Experiments Anomaly Corrective Action Support	NASA PCS's and Project Engineers	Experiment and Support Staff	
Mission Management and Control:			
- Ascent Phase			
• Payload Monitoring	Ground	Onboard - Prime Ground - Backup	
- On-Orbit Phase:			
• Payload Monitoring Prior to Activation	Ground	Onboard - Prime Ground - Backup	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR MISSION OPERATIONS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
- On-Orbit Phase: (cont'd)			
• Activation, Checkout, and Deployment	Onboard	Onboard - Prime Ground - Backup	(Limited by Station Contact)
• Subsystems Operations in Support of Payloads	Onboard and Ground	(Spacelab Support) Onboard - Prime Ground - Backup	
• Payload Performance Monitoring	Mixed	(Spacelab-Mixed)	Responsibilities vary for payload; preferred mode is onboard prime.
• Payload Subsystems and Experiment Operations	Onboard	Onboard - Prime Ground - Backup	Ground will have real-time command capability - application sensitive to experiment complexities, man/machine interactions, degree of automation, etc.
• Free Flyer Payload (while in vicinity of host vehicle)	Not applicable	Ground - Prime Onboard - Limited	Orbiter will have limited status monitoring while near vicinity of free flyer; possibly limited commands (engine safe command, attitude control deactivation)
• Attached Payload Operations (no manned experiments involvement)	Onboard	Mixed - Onboard and Ground Control	Requirements may vary between payloads.
• Consumables Management	Ground	Onboard - Prime Ground - Monitor	Ground has monitoring and prediction capability (automated and manual). Strongly related to activity scheduling function.
• Activity Scheduling	Ground	Mixed Preferably onboard management	Varies with payload complexity and degree of ground interfaces (coordination of network, Experimenter support, etc.).
• Radiation Monitoring/Prediction	Ground	Onboard - Prime Ground - Monitor	Ground to have premission and real-time monitoring and projection capability - manage major decisions.
• Communications Scheduling and management	Ground	• Voice - Onboard-Prime - Ground - Monitor • Data - Ground-Prime - Onboard-Backup	Total daily orbital coverage dependent upon orbital altitude and addition of communication satellite(s). Telemetry data recording to be an automatic onboard function with manual override. Ground will command data dumps per flight plan, or upon onboard request.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR MISSION OPERATIONS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
- On-Orbit Phase: (cont'd)			
• Data Management (Payload Data)	Mixed	Mixed	Onboard personnel will have capability for automatic and manual control of editing and recording of experiments data. Ground will schedule sites and network for orbiter support and format data for Experimenter.
• General Concept	Ground had continuous command and control	Ground to have executive level control - inflight mission support to be analogous to aircraft enroute and terminal traffic control	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR PAYLOAD OPERATIONS MANAGEMENT

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Experiments Concept	Independent experiments	• General laboratory • "Suitcase" carry-on • Automated • Passive	Orbiter experiments bay to have fixed interfaces for fit and functions
Operations Policies	Host Site	Host Site	With experiment owner participation during operations
Payload Characteristics	Multi-disciplined	Approximately 50% single discipline and 50% mixed	Mission dependent
Experiment Development	NASA	Experimenters	Dependent on funding source
Flight Constraints	Manned space flight certification standards	Industrial standards and NASA flight safety standards	
Ultimate NASA Role	Total responsibility	Host responsibility	All experiment costs chargeable to experimenter and payload center allocatable to these areas.
Experiment Selection and Payload Development Integration	NASA Program Offices	To be established	Experiment assignment of each flight will be based on a long-range Experiment Implementation Planning Committee which will consist of NASA national and/or international scientists.
NASA Relationship to Experimenter for Collected and Processed Data	Owner and Host	Host only	In Skylab, NASA retained one copy of all data obtained during mission phases. Unless special agreements are reached with NASA, NASA distributes all data to experimenters. When NASA retains data, experiment costs may be fully chargeable to NASA or shared between NASA and experimenter.
Payload Contingency on Ground	Delay Flight Schedule	Remove or fly degraded schedule	Contingency payloads available for flight if payload needs to be removed.
Laboratory Ownership	NASA	NASA, with assignment to payload centers	Ownership may be only for period of usage - then recycled to perhaps another discipline.
Special Flight Equipment Ownership	NASA	Experimenter	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR PAYLOAD OPERATIONS MANAGEMENT

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Baseline Equipment and Payload Carrier Checkout Equipment Ownership	NASA	NASA-Host Site	
Special Checkout Equipment and Special Software	NASA	Experimenter	
Opportunity for a Major Experimenter to fly with his experiment	No	Yes	
Flight Hardware Interface Verification Testing	NASA	NASA-Host Site	For payload to orbiter interface and payload module to payload module interfaces only.
Flight Hardware Performance Testing			
• General Lab	NASA	NASA	For safety related items and common equipment items.
• Special Hardware	NASA	Experimenter and Payload Center	
Management of Reports of Experiment Findings	NASA	Experimenter and experimenter sponsor	
Support Services	Central NASA control	NASA-Host Site	As required, charged to payload owner
Support Facilities	Host Site	Host Site	As required, charged to payload owner

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR CREW HEALTH CONSIDERATIONS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Clinical Health Status Monitoring during pre- and postflight phase	Rigidly disciplined for fixed pre- and postflight periods	Periodic and routine throughout a crewman's flight status assignment.	Considerable numbers of candidate crews and passengers pool must be monitored for their crew health status. Their health status will have to be matched with their training and mission objectives of particular mission.
Work/Rest Cycle Constraints	Yes	Yes	Autonomy on Shuttle permits crew flexibility.
Biorhythm Adjustments	Necessary	Minimal	Skylab recovery constraints, extensive deactivation timeline, and long medical protocol after recovery forced sleep period shift (and then a subsequent readjustment).
Scientist Physiological Training	N/A	Yes	
Astronaut Physiological Training	Yes	Yes	
Inflight Diagnostic and Therapeutic Resources	Extensive - all crewmen	One or two selected crewmen for each mission.	
Inflight Physical Conditioning	Extensive	• Moderate for short duration missions • Extensive for longer duration missions	
Baseline Physiological Data Collection	Extensive	Extensive only for life sciences mission.	Possibly only for crewmen who would be subjects for medical experiments in twice-a-year Spacelab missions.
Crew Health Assessments	Prime objective, but data system was principally for experiments	Limited	
Crew Clinical Training	Extensive course for all crew-members	Only a few selected crews will be trained.	Short missions such as are planned for Shuttle may reduce possibility of serious medical problems, but possibility of accidents and hazards may be higher in the Shuttle due to multiple crews and repeated use of the same vehicle.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR CREW HEALTH CONSIDERATIONS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Crew Health Stabilization	Mandatory	To be determined	
Diets	Rigidly regulated (experiment requirement)	Principally pantry style; moderate menu constraints	
Clinical Health Status Monitoring During Flight Phases	Mandatory	Most probably limited to transitional flight phase; all other on a standby basis unless a specific experiment is involved.	
Criteria for Each Mission Termination	Real-time decisions	Real-time decisions	
Operational Hazards	• Fire • Radiation • Depressurization • Toxicity • Disease and Injury	Same plus landing hazards	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR CREW HEALTH CONSIDERATIONS

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Crew Health Stabilization	Mandatory	Highly desirable, but its value should be re-evaluated and possibly modified	A contagious disease on a Skylab mission would have compromised the crew health objectives of that visit and also any subsequent visits since the OWS/AL/MDA modules could not be decontaminated.
Diets	Rigidly regulated (experiment requirement)	Principally pantry style; moderate menu constraints	
Clinical Health Status Monitoring During Flight Phases	Mandatory	Most probably limited to transitional flight phase; all other on a standby basis unless a specific experiment is involved.	Shuttle crew health status monitoring applies to not only twice a year Spacelab missions, but all other missions.
Criteria for Each Mission Termination	Real-Time decisions	Real-Time decisions	
Operational Hazards	o Fire o Radiation o Depressurization o Toxicity o Disease and Injury	Same	
Work/Rest Cycle Constraints	Yes	Yes	Autonomy on Shuttle permits crew flexibility.
Biorhythm Adjustments	Necessary	Minimal	Skylab recovery constraints, extensive deactivation timeline, and long medical protocol after recovery forced sleep period shift (and then a subsequent readjustment).

APPENDIX D

APPENDIX D

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR LIFE SCIENCES EXPERIMENT MANAGEMENT

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR LIFE SCIENCES EXPERIMENT MANAGEMENT

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
PREMISSION EXPERIMENTS MANAGEMENT			
1. Experiment Req'mts. Document Mgmt.	Yes	Unknown	Under review
2. Experiment Implementation Plan Management	Yes	Unknown	Under review
3. Manned Spaceflight Experiment Board Reviews	Yes	Yes	
4. Contract End-Item Specifications Management	Yes	No	Host Accommodations Handbook
5. Principal Coordinating Scientist (PCS) Selection	Yes	Unknown	Under review
6. Project Engineering Assignments	Yes	No	Project engineering per se to be Experimenters' responsibility.
7. Payload Integration Manager Selection	Yes	Yes	
8. Design Reviews Management	Yes	Yes	Payload Design Reviews will be interface and performance safety reviews by the host sites.
9. Phased Program Management	Yes	Not universal	Only for those experiments sponsored and funded agencies using this method of management.
10. Technical Integration and Control Plans Management	Yes	No	Host accommodation handbook
11. Configuration and Change Control Management	Yes	Limit to interface, weight, and safety integration management	Degree to which this function is implemented controlled by accommodation handbooks for each host site.
12. Failure Reporting System Management	Yes	No	Experimenters responsible for their equipment - except for safety critical items.
13. Experiment Status Reviews	Yes	No	Status reviews to be held for payload integration only by host sites.
14. Operations Planning Panels	Yes	Not in traditional terms	Host site accommodations handbook attends to traditional planning - Shuttle operations planning attends to payload program rather than individual payloads.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR LIFE SCIENCES EXPERIMENT MANAGEMENT

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
15. Quality Control Management	Yes	By payload owner except for safety critical items by each host site.	
16. Traceability Management	Yes	By payload owner	
17. Flight Readiness Reviews	Yes	Yes	To include sign-off by experimenters - failure to sign-off causes experiment to be removed, but experimenter has to accept all subsequent cost if no substitute experiment available.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR LIFE SCIENCES EXPERIMENT MANAGEMENT

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
INFLIGHT EXPERIMENTS MANAGEMENT			
1. Daily Medical Team Meetings	Yes	No	Experiment to have "in-line" role with flight operations.
2. Periodic reviews of findings	Yes	No	
3. Daily representation at Flight Management Reviews	Yes	No	Experiment representative required if experiment plan needs to be altered.
4. Science Planning Meetings	Yes	No	Science planning to be crew activity as a function of flight plan; planning support for modifying experiment plans to be a real-time flight management responsibility.
5. Real-time addition of experiments	Yes	No	
6. Centralized 24-hour mission management	Yes	Unknown	
7. Mission Support Room Project Management	Yes	No	
8. Real-Time Data Distribution	Yes	Yes	

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR LIFE SCIENCES EXPERIMENT MANAGEMENT

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
POSTFLIGHT EXPERIMENT MANAGEMENT			
1. Owner Payload Recovery Management	No	Yes	Host Site's accommodation's handbook.
2. Experimenter Hardware/Software Recovery Management	No	Yes	Host Site's accommodation's handbook.
3. Payload Carrier Refurbishment Management	No	Yes	
4. Operational Equipment Experiment Closeout Management	Yes	Yes	As applied to closeout testing agreements.
5. Centralized Management of Experimental Findings	Yes	No	
6. NASA Support Services for Experimental Data Analysis	For NASA PI's	For NASA PI's	NASA services to other PI's will be in accordance with premission agreements.
7. Closeout Cost Management	Yes	Yes	Shuttle cost management and billing remains to be defined.

APPENDIX E

APPENDIX E

COMPARATIVE LIFE SCIENCES OPERATIONAL DOCUMENTATION BETWEEN SKYLAB AND SHUTTLE

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE FOR LIFE SCIENCES OPERATIONS DOCUMENTATION

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
Level 1, Headquarters Program Requirements Documents	Yes	Yes	
Level 2, Center Level Program Definition, Requirements, and Specifications	Yes	Yes	Mission operations documentation will attend to each type of payload carrier: spacelab, pallet, etc.
Level 3, Center Level Supporting documents including functional operations documents. (only LSD functional documents are listed).			
1. Medical Requirements Document	Consolidated Mission Clinical/ Experiment requirements	Independent clinical and experimental requirements	Clinical requirements are expected to remain stable from mission-to-mission Experimental scope will change from mission-to-mission
2. Medical Operations Plan	Same as above for Operations Plans	o Flight operations medical plan o Spacelab pallet, etc., experiment operations plans	Experiment operations plans will be prepared for each combination of experiments designated for each type of payload carrier.
3. Flight Crew Health Stabilization Plan	Yes	Unknown	
4. Skylab Medical Operations Reporting Plan	Yes	No	To be included in the operations plans under heading #2.
5. Biochemical/Clinical Lab Operations Support Plan	Yes	No	This becomes an experiment responsibility if he so has the need.
6. Skylab Medical Data and Calibration Management Plan	Yes	No	See accommodations handbook - heading #10 below.
7. Mobile Laboratory Operations Plans	Yes	No	Shuttle Orbiter will land at launch site - host site will provide medical facilities.
8. Mobile Laboratory Maintenance Plan	Yes	No	Same as above.
9. Biomedical Specimen Recovery Logistics Plan	Yes	Yes	Rather than being a NASA plan, it will be an experimenter's plan so that he can interface with host site.

COMPARATIVE OPERATIONAL CHARACTERISTICS BETWEEN SKYLAB AND SHUTTLE
FOR LIFE SCIENCES OPERATIONS DOCUMENTATION

PARAMETER	SKYLAB	SHUTTLE	COMMENT/RATIONALE
10. Accommodations Handbooks	No	Yes	These handbooks will be available from each host site interfacing with the experimenter. It will explain host site operating policies, equipment interfaces, available facilities, support services, etc., and advise the user of his responsibilities to the host.

APPENDIX F

APPENDIX F

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS FOR THE SPACE SHUTTLE ERA

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -1

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	1.0 BIOMEDICAL (HUMAN AND ANIMAL) 1.1 Neurophysiology				• Life Sciences hypotheses/ questions, future approach, and systematic experiment planning logic
IME 1.2 Effects of a Rotating Environment on Man in Space Flight (Priority 1) IME 1.3 Effects of Weightlessness and Sub-gravity states on the function of Otolith apparatus and the semi-circular canals (Priority 1)	1.1.1 Vestibular Functions 1.1.1.1 Head Movement Effects During Rotation 1.1.1.2 Otolith and Semi-circular Canal Sensitivity	1.4.1.1 Human Vestibular Functions 2.4.3.4 Effects of changes in gravity on the Otolith (Rat) 2.4.3.1 Vestibular Research in Space (Goldfish) 2.4.3.2 Vestibular apparatus development (rats) 2.4.3.5 Neural and behavioral development in inbred mice 1.4.1.2 EEG Neurological Exp. 2.4.3.6 Force of Isometric Contraction of Non-vestibular/Vestibular Muscle in Low Gravity Env. (Rat)	• M131 - Human Vestibular Function - Oculogyral Illusion (OGI) - Motion Sensitivity (MS) - Spatial Localization (M131-2) • SD 10 Fish Otolith • Preflight Vestibular Habituation • Stand test with eye closed	• Neurological Evaluation: to determine neurological changes accompanying adaptation to space environment (man) • Brain responses to rotation: to examine electrophysiological response of cortex to rotation in the absence of tonic otolith influences (man) • Vestibular sensitivity in man: to determine vestibular sensitivity in man during exposure to zero-g (man) • Vestibular function: to determine how separate vestibular receptors relate to one another in zero-g (Vertebrates:frogs)	• Countermeasure(s) to eliminate crews low work capacity in the first 5-7 days of Shuttle missions due to motion sickness and other initial adaptation to weightlessness
SFEP 9 Experiment with various combinations of Non-24-Hrs-W-R-S cycles in the weightless environment	1.1.1.3 Altered day-night cycle effects (rats and cats) 1.1.1.4 Vestibular electrical activity (rats and cats)	2.4.3.3 Neural Correlates of Function of Mammarian Vestibular System (Mice)			
IME 1.1 EEG changes during arousal and drowsing (Priority 2)	1.1.2 Sleep	1.4.1.3 Sleep Monitoring	• M133 - Sleep Monitoring		

IME: Inflight Medical Experiment SFEP: Space Flight Exp. prior to Orbital Research Lab SD: Science Demonstration

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -2

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
IME 1.7 Evaluation of Spontaneous Activity (Initiative), GSR and EEG as Indicators of Vigilance (Priority 1)	1.1.3 Alertness	2.4.2.6 CNS function in hibernating or hypothermic mammals in weightlessness (Marmot Hamster)			
	1.1.4 Biorhythms	1.4.1.2 Circadian Rhythms	• S071/S072 Circadian Rhythm of Pocket Mice and Vinegar Gnat (Incomplete)		• Circadian Rhythm experiments
		2.4.2.5 Circadian Rhythms (Mice)			• Change of ovarian cycle and functions in space
		2.4.1.5 Periodicity of Growth and Conidial information in Fungi			
		2.4.2.3 Weightlessness, Growth and Rhythm			
			• Achilles Tendon Reflex Measurement		

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -3

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	1.2 Cardiovascular Functions 1.2.1 CV Deconditioning				
IME 2.8 Changes in Circulatory Response to Exercise with Duration of Exposure to Weightless State. (Priority 1)	1.2.1.1 Circulatory Response to Exercise	1.4.10.1 Exercise conditioning	• Inflight Ergometer, Treadmill, Mark I, II, & III Exercise Daily • Muscle Girth (prior to and after exercise)	• Myocardial function during exercise stress: to determine the detailed dynamics of myocardial function during supine ergometry in zero-g environment.	• Mechanisms of the sensation of head fullness disappearing after the exercise and eating experienced in the Skylab.
IME 2.1 Changes in Blood Volume and Central Venous Pressure (Priority 1)	1.2.1.2 Volume effects on arterial pressure control system	1.4.2.3 Arterial pressure control system			• Is there an optimum daily exercise load for each individual as Skylab crew speculated? If so, what is the empirical index of this "optimum exercise load"?
IME 2.5 Changes in Efficacy of Arterial Pressure Control System by Shifts of Blood Distribution .(Priority 1)	1.2.3 Homeostatic Mechanisms 1.2.3.3 Blood volume and distribution	1.4.7.1 Blood volume and RBC life span	• M113 - Blood volume and red cell life span (Pre and Postflight only)		• Visualization/quantification of blood redistribution in various body organs after transition from 1-g to zero-g and vice versa.
IME 2.9 Sensitivity of Carotid Sinus Arterial Pressure Control Loop	1.2.3.1 Carotid Sinus Sensitivity 1.2.3.4 Carotid baroreceptor electrical activity (primate)				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -4

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
IME 2.5 Changes in Peripheral Arteriolar Reactivity (Priority 1)	1.2.3.2 Peripheral arterial reactivity	1.4.2.6 Peripheral Arterial Reactivity	• Special Cardiovascular Test #1: Muscle Pump Effectiveness • IR Body Photography		
IME 2.3 Changes in Peripheral Venous Compliance and Pressure During Weightless State (Priority 1)	1.2.1.3 Peripheral Venous Compliance		• Special Cardiovascular Test #2: Limb Blood Flow/Venous Compliance in Leg • Echocardiography • Balistocardiogram (Pre- and Postflight)		
IME 2.4 Evaluate Significance of BCG and/or Kinetocardiogram for estimation of Cardiac Dynamics (Priority 1)	1.2.1.4 Cardiac Dynamics 1.2.1.6 Cardiac Output (Swine)	1.4.2.5 Cardiac Dynamics - BCG 1.4.2.2 Vectorcardiogram	• M093 - Vectorcardiogram • Cardiac Size/Cardio-Thoracic Ratio (X-Ray) (Pre-and Postflight)	• LS 1-9 Monitor Retinal Electrophysiology: to determine the feasibility of monitoring the electroretinogram (ERG) during space flight (Man)	
IME 1.4 Intraocular Blood Pressure Under Condition of Prolonged Whole Body Weightlessness (Priority 1)	1.2.1.5 Intraocular Arterial Blood Pressure	1.4.2.4 Intraocular Blood Pressure		• Monitor Intraocular Pressure: to determine feasibility of measuring intraocular pressure with state-of-the-art instrumentation (Man)	
IME 2.10 Susceptibility of CVS of a Hydrostatically Simulated Upright Position - LBNP (Priority 1)	1.2.2 Deconditioning Countermeasures 1.2.2.1 Lower Body Negative Pressure Device (LBNPD)	1.4.2.1 Use of LBNP	• M092 - Inflight LBNP • Leg Blood Pressure Measurement on Alternate M092 runs • M092 Facial Photographs during LBNP • Use of Orthostatic Countermeasure Garment by crews in re-entry and post-recovery periods.		• Value of Inflight LBNP responses data as cardiovascular deconditioning index and prediction of post-recovery crew responses. • Cardiovascular deconditioning measurement methods other than LBNP.
IME 2.7 Predictive Tests to Assess Ability of Vasomotor System to Readjust to Reentry Stress (Priority 1)	1.2.2.3 Occlusive Cuffs 1.2.2.4 Response to Shock Therapy (Dog or Swine)				

LS: Demonstration No. as designated in JSC Test I, Jan. 16, 1974

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS OF THE SPACE SHUTTLE ERA -5

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
IME 2.2 Assessment of Body Mass in Real-Time (Priority to be determined)		1.4.6.2 Body Mass Measuring	• M172 - Body Mass Measurement • Stereophotogrammetry • Center of Mass Measurement		
GBE 11 Study of Effects of Centrifuge Simulation of Flight Launch Profile on ADH Activity and Other Urinary Secretion Control Factors	1.2.2.2 Onboard Centrifuge	7.4.4.1 Locomotion and Balancing Capability in Roto-Gravitation 2.4.2.2 Necessity of Gravity for Normal Growth of Turtles		• Effects of Artificial Gravity: to investigate the vestibular system requirements for low level artificial gravity (Vertebrates: frogs)	
	1.2.4 Total System 1.2.4.1 Long Duration Weightlessness (Primate Experiments)	4.4.1.1 Effects of Zero Gravity on Life Processes of Small Organisms 2.4.1.1 Orbital Subhuman Primate (Macaca Nemestrina) 4.4.1.6 Functional Developmental Stability of Vertebrate Embryos			• Miniature onboard artificial gravity device, animal responses, to delineate effects of artificial gravity in space against deconditioning.
IME 2.11 Effects of Weightlessness on Pulmonary Mechanics (Priority 1)	1.3 Respiration 1.3.1 Ventilatory Mechanics 1.3.1.1 Pulmonary Mechanics		• Vital Capacity Measurements (as part of M171)	• LS 1-1 Lung Physiology in zero-g conditions: to provide in-depth data on physiological changes and adaptations resulting from zero-g environments (Man)	
IME 2.12 Effects of Weightlessness on Control of Respiration (Priority 1)	1.3.1.2 Respiratory Control				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -6

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
IME 2.13 Changes in Blood Gas Exchange	1.3.2 Pulmonary Efficiency 1.3.2.1 Blood Gas Exchange	7.1.4 Gas and Energy Exchange in Tissue			
IME 2.14 Changes in Self-cleansing Action of Lung with Duration of Exposure to the Weightless State (Priority 2)	1.3.2.2 Lung Cleansing (Rats)			• Particulate deposition in the respiratory tract during weightlessness: to measure the deposition of insoluble particulates in the human respiratory tract during weightlessness (Man)	
GBE 1 Mechanisms of Atelectasis and the Associated Pulmonary A-V Shunt During Exposure to Acceleration	1.3.2.3 Induced Pulmonary Infections (Mice) 1.3.2.4 Recovery from Non-infections Lung Trauma (Albino Rats) 1.3.2.5 Gas Exchange and Blood Flow Distribution in Lungs				
GBE 2 Relationship of the Susceptibility to the Pulmonary Derangements to the Pressure and Composition of the Gas Mixture Being Breathed.	1.3.3 Atmospheric Composition 1.3.3.1.1 Composition		• Atmospheric Total Pressure and 0_2 Partial Pressure Monitoring	• LS 1-6 Atmospheric Analysis	

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS OF THE SPACE SHUTTLE ERA -7

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
GBE 6 Potential Incidence of Dysbarism Following Either Premeditated Operational or Emergency Decompressions to the 3.5 psi (Absolute) Pressure Suit Atmosphere GBE 7 Relationship of Incidence of Dysbarism vs. Time of Equilibration at Operationally Important Atmospheres to Make Dysbarism Incident Probability Zero. GBE 8 Develop Means of Efficient Countermeasure of Simple Recompression to the Original IV Atmosphere from Decompression GBE 9 Detailed Atmosphere Pressure and Composition History of any Mission/Vehicle to Establish the Dysbarism Hazard for a Given Mission.	1.3.3.1.2 Dysbarism				• Spacecraft system and personalized countermeasure technology for a possible rapid decompression of the Space Shuttle ("Life Cocoon"/JSC/CSD) • Onboard medical care capability of dysbarism and acute anoxia

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -8

<u>NASA SP-86</u> MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	<u>NASA "YELLOW BOOK"</u> EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - <u>RESEARCH AREAS AND COMPONENT EXPERIMENT</u> - SEPT. 1969 -	<u>NASA "BLUE BOOK"</u> REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	<u>SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES</u> - 1973-1974	<u>SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS</u> WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	<u>OTHER RECOMMENDED R&D AREAS</u> APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
<u>R&D 18</u> Develop Self-contained Emergency Breathing Apparatus as Protection Against Atmospheric Contaminants	<u>1.3.3.1.3</u> Contaminants	<u>1.4.11.1</u> Airborne/Contaminant	• Atmosphere Volatile Concentrator		• Measurement of Atmospheric Trace Contaminants
<u>R&D 25</u> Means of Equipments of Inflight Detection of Atmospheric Contaminants			• CO Measurements		
<u>GBE 3</u> Time-concentration Relationships Which May Effect RBC Life Span Shortening With The Range of Individual/Differences in Susceptibility	<u>1.3.3.1.4</u> Oxygen Toxicity <u>1.3.3.1.5</u> Carbon Dioxide <u>1.3.3.1.6</u> Effects of Weightlessness		• CO_2 Monitoring		
<u>GBE 4</u> Develop an In-Vitro Predictive Test of RBC Life Span Susceptibility	<u>1.3.3.2</u> Advanced Aerosol Particle Analyzer		• T003 Inflight Aerosol Analyzer		
	<u>1.4</u> Gastrointestinal <u>1.4.1</u> GI Functions and Mobility <u>1.4.1.1</u> Mobility and pH	<u>1.4.4.3</u> GI Mobility and pH			• Gastrointestinal Radiosonde to Measure pH, intraluminar pressure, etc.

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SFEP 1 Animal Flight Tests on the Effect of Weightlessness on Peristalsis and Muscle Deterioration	1.4.1.2 Intestinal Absorption				• Intestinal absorption in 1-g and zero-g.
SFEP 3 Determine ADH Activity During Manned Space Flight by Means of Urinary Assay Concomitant with Fluid Requirement, Blood Volume and CV Effects of Weightless Flight	1.4.2 General Renal Function 1.4.2.1 Indices of Renal Function 1.4.2.2 Renal Stone Formation (Rats) 1.4.2.3 Renal Infection (Rats)	1.4.3.2 Indices of Renal Function 1.4.3.1 Renal Blood Flow 1.4.3.3 Renal Calculus Formation in Rats 1.4.3.4 Renal Infection in Rats	• Daily Crew Reports of Water Intake and Urine Output	• LS 1-12 Renal Concentration	• Automated Food and Water Intake, and urine output measurements, sampling, and preservation system
R&D 7 Develop Improved Urine and Fecal Collection Devices to Improve both Metabolic Balance Study and Pilot's Sanitation		1.4.5.2 Specimen Mass Measuring	• M074 - Specimen Mass Measurement Device (SMMD) • M073 Urine Sampling		
IME 3.1 Effects of Prolonged Space Flight on Various Metabolic Functions (Priority 1)	1.5 Metabolism and Nutrition 1.5.1 General Metabolism 1.5.1.1 Energy Metabolism	1.4.6.1 Metabolic Activity 2.4.2.1 Role of Gravity in Life Processes of Mammals (Rat, Mouse, Hamster)	• M171 - Metabolic Activity • EVA Heart Rates and Metabolic Rates Computation	• Gravity and Bioenergetics (Metabolism) (Rat) (Radioisotope)	

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GBE 13 Metabolic Studies to Determine the Caloric Cost of Activity	1.5.2 Specific Metabolism 1.5.2.1 CHO and Fat Metabolism 1.5.2.2 Protein Metabolism		• Food Intake Measurements including Minerals, Vitamins, through preflight, during, and postflight (F-21 to R+18)		
GBE 12 Reconditioning of Crewmembers to a Low Caloric Intake and Normalization of Body Fat Store.					
IME 3.4 Effects of Prolonged Space Flight on Fluid and Electrolytes Metabolism (Priority 1)	1.5.2.3 Body Fluid Composition	1.4.4.2 Biochemistry of Body Fluids	• Insensible H_2O Loss		• Inflight Sweat Sampling Method and Onboard Chemistry Analysis Device
IME 3.2 Effects of Prolonged Space Flight on Mineral Metabolism and Bone Densitometry (Priority 1)	1.5.2.4 Mineral Metabolism	1.4.4.1 Mineral Balance 4.4.1.7 Effects of zero-g and Hormones on Bone Culture Mineral Metabolism 2.4.1.3 Effects of Reduced Gravity on Bioelectric Potential/and Bone Metabolism (Rat)	• M071 - Mineral Balance • M078 - Bone Mineral Measurement (Pre and Postflight only)		

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GBE 10 Calcium Metabolism at Various Phases of Training Under Various Preflight Conditions for Baseline Levels of Each Potential Astronaut.					
	1.5.3 Cellular Metabolism	1.4.7.2 Red Blood Cell Metabolism	• M114 - Red Blood Cell Metabolism		
	1.5.4 Muscle and Bone Metabolism	2.4.2.7 Role of Gravity in Avian Bone Metabolism (Quail)		• Pituitary Function, Plasma Enzymes and Bone Metabolism in zero-g (Rat) (Radioisotope)	• Study of functional, structural, and chemical changes of cardiac and skeletal muscles in weightlessness and return to 1-g.
	1.5.5 Nutrition				
R&D 4 Nutrition Acceptability and Palatability for Extended Periods of Such Potential Foods as Algae, Reconstituted Liquid or Semi-liquid Diets of Natural Products					

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IME 3.3 Determination of Bone Demineralization During Prolonged Space Flight (Priority 1)	1.6 Musculoskeletal 1.6.1 Skeletal Decalcification	4.4.1.4 Effects of zero-g to Bone Tissue Cultures 4.4.1.8 Effects of zero-g on Calcium Metabolism of Human Cell Tissue Culture			
	1.6.1.1 Bone Density	1.4.5.1 Bone Densitometry	• M078 - Bone Densitometry		
	1.6.1.2 Fracture Healing (Guinea Pigs)	1.4.10.1 Wound Healing (Animal)		• Cellular Aspects of Wound Healing: to determine the effects of reduced gravity on wound healing (Rats or Rabbits)	
	1.6.1.3 Calcium Mobilization (Chickens)	2.4.1.6 Tissue growth and repair in Weightlessness (Rat)		• Quantitation of Calcium dynamics in zero-g. (Chicken) (Radioisotope)	
	1.6.2 Work Capability, Exercise, and Deconditioning	2.4.2.4 Effect of Weightlessness on Chickens			
	1.6.2.1 Muscle Status (Muscle Mass and Strength)		• Anthropometric Measure of Limb, Girth, and Height • Muscle Strength Tests (Flexors and Extensors)		• Effectiveness of electric stimuli as a countermeasure to muscular deconditioning (USSR)
	1.6.2.2 Induction of Pressure Atrophy (Guinea Pigs)				
	1.6.3 Deconditioning Index				
	1.6.3.1 Electromyographic Evaluation	1.4.5.3 Deconditioning Indices EMG	• EMG (Pre and Postflight)		• Deconditioning Indices of EMG

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IME 3.6 Effects of Prolonged Space Flight on Neuro-endocrine Function (Priority 1)	1.7 Endocrinology 1.7.1 Stress Effects 1.7.1.1 Endocrine Assays	1.4.9.1 Endocrine Assays	• M073 - Bioassay of Body Fluids (Pre and Postflight)		
IME 3.5 Effects of Prolonged Space Flight on Physiologic Temperature Regulation (Priority 1)	1.7.1.2 Thermal Regulation 1.7.1.3 Adrenal and Parathyroid, Histopathology and Function (Albino Rats) 1.7.1.4 Gonad Histopathological Evaluation (Albino Rats)	1.4.9.2 Thermoregulation 2.4.1.5 Tissue and Cell Morphology with and Without Endocrine Gland Ablations 1.4.9.3 Gonad Histopathological (Animals)			• General Adaptation Syndrome (GAS) indices as deconditioning indices for space flight (USSR)
GBE 25 Study Simulation of Prolonged Confinement to Obtain Background Information on Prospective Crewmembers	1.7.2 Remedial and Prophylactic Measures		• Inflight IMSS Blood Draw - Hemoglobin and Urine Specific Gravity Measurements		• Space Shuttle Onboard medical care capability requirements
R&D 24 Study the Effect of Transfusion of Plasma and Blood on Man Under Zero-g Conditions					• Effectiveness of whole blood transfusion and parenteral fluid therapy in weightlessness.
GBE 26 Weightless Simulation Studies to Identify the Most Important Physiological Parameters Indicating Loss of Fitness					

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SFEP 11 Test those items Noted in the Clinical Test Battery for Surveillance of Astronaut and Environmental Actual Future Space Flight					
IME 4.1 Dynamics of Hemic Cell Proliferation Distribution and Destruction (Priority 2, Probably First Feasible in Extended Apollo)	1.8 Hematology 1.8.1 Blood 1.8.1.1 Chromatin Evaluation (Leukocyte Replication)	4.4.1.3 Effects of zero-g on Morphogenesis and Embryoesis in Cultured Somatic Cells 4.4.2.1 Chromosomes and Nucleic Acid Synthesis of Human Tissue Culture 1.4.8.2 Cytogenic Studies of Blood	• M111 - Cytogenic Studies of the Blood • S015 - Effect of Zero Gravity on Single Human Cells		
				• Inflight Embryo Development Evaluation Study: to determine effect of space flight on vertebrate embryo (fish): verify under simulated space flight conditions inflight fertilization and fixation techniques (Fish embryo and sperm)	

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IME 4.2 Cytogenic Studies of the Human Hemic Cells (Priority 2 Pre-and Postflight More than Several Days Duration)	1.8.2 Blood Cell Dynamics				
	1.8.2.1 Erythrocytes	1.4.7.3 Special Hematologic Effects	• M115 - Special Hematologic Effects (Pre- and Postflight test only)	• Hemolytic Rate of Rat RBC in zero-g. (Radioisotope)	
	1.8.2.2 Leukocytes				
IME 4.4 Selected Parameters of Leukocyte Functions in Space Environment (Priority 2 or 3 Flight Longer than 1 Week with Multiple Crews)	1.8.2.3 Platelets				
	1.8.2.4 WBC Mobilization after Chemical Challenge (Albino Mice)			• Cytoplasmic Functions in Ameba and Tissue Culture: to study the Effects of zero-g on cytoplasmic functions in animal cells (Micro-organisms and tissue cultures)	
	1.8.2.5 Maximum Rate of RBC Production (Albino Rats or Mice)				
	1.8.2.6 Wound Healing (Swine		• NOTE: Crew comments: wound healing, hair and nail growing in space appear to be slower.		• Effects of space flight to Erythropoiesis and Bone Marrow (Histology, vertebrate)
IME 4.5 Selected Parameters of Blood Coagulation and Hemostatic Function (Priority 2 or 3 - Pre- and Postflight)	1.8.3 Coagulation System Integrity	1.4.7.4 Blood Coagulation			• Study of changes of skin functions and growth of nail and hair in weightlessness.
	1.8.3.1 Hemostasis				• Change of blood coagulation system integrity in space.

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	1.9 Microbiology and Immunology				
	1.9.1 Microbiology	4.4.3.2 Effects of space environment on insect viruses and virus infected insects		• LS 1-11 • Effect of Space flight on the replication of adenovirus: to determine the effect of zero-g on replication of adenovirus and Microbial Ecological Monitoring System (MEMS) operation under space flight conditions (tissue culture)	
	1.9.1.1 Microbial Evaluation of Environment/Surface	4.4.3.3 Hypogravity on Host/Parasite Relationships in Bacteria			
	1.9.1.2 Microbial Profiles of Crewmembers	1.4.8.3 Microbial Profiles of Crewmembers (See 1.4.11.1)	• Inflight Microbiology (Crew & Environmental)		
	1.9.1.3 Air Sampling for Micro-organisms(see 3.11.1.2 T003)	2.4.1.4 Immune Responses of Animals (Squirrel and Hamster)	• T003 - Inflight Aerosol Analysis	• Microbial Load Monitor: to determine usability of Microbial Load Monitor (MLM) inflight, capability of providing diagnostic coverage, and utility in measuring microbial load on surfaces and in specimens (Microbial specimens with man)	
IME 4.3 Survey of Immunoglobin, Complement, and Antibodies in the Sera of Selected Astronauts (Priority 3 for Flights Longer than 30 Days with Multiple Crews)	1.9.2 Immunology 1.9.2.1 Immunological Survey of Crewmembers	1.4.8.1 Human Immunity in Vitro Effects	• M112 - Man's Immunity in Vitro Aspects	• LS 1-4 Viral Replication	
GBE 21 Study Untoward Reactions to All of the Medication Included in the Medical Chest for all Crewmembers	1.11 Space Pharmacology		• Sensors and Drugs Sensitivity Tests		• Change of drug effects to man inflight and postflight
GBE 22 Maintain a Careful Check on the Experience with Illness and Drugs in Space Flight	1.11.1 Drug Effects and Stability 1.11.2 Pharmacological Manipulation of Sleep, Behavior and Biorhythms. 1.11.3 Dose Level				• Drug effects and stability in space

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R&D 26 Develop Methods Enabling Prompt Detection of Solar Flares and Means of Transmitting this Information from Ground-Based Stations to Spacecraft	1.12 Radiobiology 1.12.1 Molecular and Cellular Changes 1.12.2 Mammalian Systems Changes 1.12.3 Combined Effects of Radiation and Other Stresses	4.4.2.3 Effects of Space Environment on Rate of Mutation of Radiation Resistant Microorganisms 4.4.2.2 Molecular Reactions of Biological Interest 1.4.11.2 Ionizing Radiation (High Z Particle) 4.4.1.2 Effects of Weightlessness, Space Vacuum and Radiation on Soil Sample Integrity and Viability during Long-term Storage and Preservation	• D008 - Radiation in Spacecraft • Radiation Health Monitoring (Daily, Cummulative, REM on Skin, Eye and Bone Marrow, in both Actual and Predictive) • Visual Flash Light Phenomena Debriefing (SL-1/2 & SL/3) Inflight Observation (SL/4)		• Effects of Visual Flash Light Phenomena to Central Nervous System, Histopathology
GBE 24 Evaluate Methods of Medical Safety Monitoring During Parabolic Flight to Determine Feasibility of Its Use in Zero Gravity	1.13 Clinical Medicine 1.13.1 (Physician-Attended Onboard Diagnostic and Therapeutic Capability) 1.13.2 (Onboard Minor Surgery Procedures and Equipments)		• Private Medical Conference (Crew-Ground Crew Surgeon) • NOTE: Inflight IMSS, Blood Draw and Urine specific gravity measurements procedures took 2 hours or longer than planned 45 minutes in weightlessness.	• LS 1-8 Inflight Biochemical and Clinical Diagnostic Data Acquisition and Delivery System: to demonstrate feasibility and practicality of inflight biomedical analysis and medical monitoring (Human Specimens) • LS 1-2 Surgery on mammals in zero-g: to determine feasibility of performing diagnostic and therapeutic work in zero-g to determine adequacy of IMSS for accomplishing first objective (Dogs)	• Space Medical Clinic concept definition (a Payload) which accommodates sickbay, rescue and escape (Medical Module) • Validation of onboard basic diagnostic and therapeutic procedures and hardware (as biomedicine experiments) • Application of Television - Remote medical diagnosis technology - Space Life Sciences Seminar

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	1.14 Bioinstrumentation				
	1.14.1 Implant Telemetry - Animal				
	1.14.2 External Instrumentation (i.e., Oculometer)				• Personal biotelemetry system for multiple crew safety and locations monitoring
R&D 15 Develop Instruments and/or Test Procedures to make Inflight Measurements of Cerebral Deficit or Deterioration which are Directly Compatible to Ground-Based Measurements	1.14.3 Dosimetry				
	2.0 Man-Systems Integration				
	2.1 Space System Human Factors			• LS 1-7 Man-system integration	

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IME 1.11 Human Performance as a Function of the Work-Rest-Sleep Cycle. (Priority 2) (See SFEP 9)	2.1.1 Work Performance Studies 2.1.1.1.1 Measures of Work Performance (Restraints and Fine Force Generation)		• M151 - Time and Motion Study		• Methods and devices to assess performance proficiency
R&D 14 Expand Psychological Test Battery to Include Tests and Techniques and Develop a Standard Procedure of Tests for Valid Evaluation	2.1.1.1.2 Restraint and Gross Force Generation	7.4.2.3 Locomotion and Restraint Capability			
R&D 17 Evaluate Current Methods of Psychomotor Test for their Reliability and Repeatability	2.1.1.2 Performance Efficiency (Psychomotor Functions)	7.4.1.3 Effects of Space Flight Environment on Psychomotor Functions	• ED 41 Maze		• Space Shuttle psychomotor tests package
IME 1.5 Harmonic and Other Analyses of Voice Characteristics for Possible Indications of Anxiety, Depression, Hostility, and Other Emotional Reactions (Priority 1)					
	2.1.1.3 Work-Rest Cycle		• Circadian Rhythm Input Shift Inflight		

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GBE 20 Perform Habitability Experiment to Answer the Psychological Effects of Spatial Confinement with Social Restriction, Restricted Exercise, and Crowding	2.1.2 Habitability		• M487 - Habitability/Crew Quarters		
	2.1.2.1 Artificial Gravity	7.4.4.2 Fine Psychomotor Capability in Roto-Gravitation			
		7.4.4.3 Cargo Handling and Gross Psychomotor Capabilities in Roto-Gravitation			
GBE 14 Trial and Long-Term Occupation of Fixed-Base Simulators Employing Variations in Lighting and Color	2.1.2.2 Volume and Layout 2.1.2.3 Interior Design Illumination, Decor and Changes	7.4.3.1 Interior Configurations, Environment, and Decor			
IME 1.10 Effects of Spatial Confinement Variables on Group Performance in Weightlessness (Priority 1)	2.1.2.4 Crew Internal Mobility (Flexible Airlock)		• D021 - Expandable Airlock Technology (Cancelled)		
R&D 12 Investigate Optimal Clothing Fabrics for Space Existence	2.1.2.5 Simulated Day-Night Cycle 2.1.2.7 Clothing Comfort				
GBE 19 Conduct Simulation of Specified Mission Manned with Astronauts or Astronaut-like Crewmembers for Duration Equal to Mission Time to Measure Human Reliability and Group Dynamics	2.1.2.8 Off-Duty Recreational Facilities 2.1.3 Small Group Dynamics and Selection 2.1.3.1 Crew Composition (Interpersonal Factors)	7.4.3.2 Off-Duty Activities and Facilities 7.4.1.4 Effects of Space Flight Environments on Individual and Group Dynamics	• SMEAT (Skylab Medical Experiments Altitude Test)		

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R&D 23 Conduct Constant Surveillance for More Sensitive and More Predictive Methods to be Incorporated into Crew Selection Procedures	2.1.3.2 Crew Selection				• Space Shuttle crews and passengers selection criteria
	2.1.3.3 Off-Duty Time Recreation				• Crew and Passenger Training Program
GBE 23 Continue Surveillance of Methods Used for Flight Crew Crew Medical Selection for Improvement	2.1.3.4 Advanced Methods of Training				• Definition of most common injuries and illnesses occurring in Space Shuttle Crew Population groups
	2.1.4 Information Display and Processing	7.4.2.4 System Controller Capabilities			• Onboard medical display requirements - Orbiter - Spacelab
	2.1.4.1 Processing of Complex Information				• Integrated medical experiments data evaluation system
	2.1.4.2 Information Retrieval				• Multi-crewmen and Passengers Health Monitoring System
					• Space Norm Data Bank/Space Human Standards Data Bank and Information Retrieval System

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
GBE 16 Simulation of Rendezvous Maneuver	2.1.5 Manual Control Research 2.1.5.1 Influence of Motion on Simulation				• Remote manipulation of Shuttle Payload and crew performance (Tele-operation and Crew Performance)
R&D 13 Investigate Effects of Angular Acceleration on Visual Acuity	2.1.5.2 Manual Navigation Guidance and Control				
SFEP 5 Practice of Rendezvous and Docking	2.1.5.3 Manual Backup to Automatic Control System 2.1.5.4 Human Transfer Function (T-007)				
SFEP 4 Experimental EVA Recognition	2.2 Extravehicular Technology 2.2.1 EVA Performance				
SFEP 7 Measure Attenuation of Light Achieved by the Use of Shielding Materials	2.2.1.1 Performance During EVA Maintenance and Assembly	6.4.10 Protective Clothing and Advanced Spacesuit Assemblies			
	2.2.1.3 Development of EVA Assembly, M&R Capability	7.4.2.2 Assembly, Deployment, M&R Capabilities			
	2.2.1.4 Unpowered Locomotion in zero-g	(See: 7.4.2.3)			

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	2.2.2 Translation Aids				
	2.2.2.1 Integrated Maneuvering LSS		• M509 - Astronaut Maneuvering Equipment (AME)		
	2.2.2.2 Handling Qualities of Maneuvering Systems (Personal Translation)				
	2.2.2.3 Self-stabilization and Attitude Control Techniques				
	2.2.2.4 Advanced Control Concepts for EVA Stabilization and Locomotion				
	2.2.2.5 Foot Controlled Maneuvering Units		• T020 - Foot Controlled Maneuvering Unit(FCMU)		
	2.2.2.6 OMPRA				
	2.2.2.7 Astronaut and Cargo Transfer Aids	7.4.2.1 Cargo-Handling Capabilities			
	2.2.3 Crew Systems Interface				
	2.2.3.1 Cargo Transfer Devices				
	2.2.3.2 Astronaut Mobility Through Airlocks and Passageways				
	2.2.3.3 EVA Display and Control Systems				
	2.3 Maintenance and Maintainability				
	2.3.1 In-Space Maintenance				
	2.3.1.1 Suit Effect on Astronaut Motor Performance				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS OF THE SPACE SHUTTLE ERA -24

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	2.3.1.2 Suit Mobility 2.3.1.3 Suited Crewman Performance Criteria Handbook 2.3.2 System Design for Maintainability 2.3.2.1 Human Engineering Criteria for M&R (Accessibility) 2.3.2.2 Integrated Maintainability Criteria 2.3.2.3 Checkout and Fault Isolation Design Requirements 2.3.3 Crew Assistance Systems 2.3.3.1 Space Tools - Power Manual, Special (M&R in zero-g) 2.3.3.2 Worksite Technology Restraint Systems, Fasteners, Bonding Techniques 2.3.3.3 Manipulation Design		• M509 - Gravity Substitute Workbench (Cancelled)		

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
IME 1.6 Emotional Changes During Prolonged Space Flight (Priority 1) - Minimum 30 Days Mission (See IME 1.5)	2.4 Behavior 2.4.1 Confinement and Isolation 2.4.1.1 Astronaut Response to Environment (Intrapersonal Factors)		• Private Voice Communication of Crew and Family Inflight • Preflight Crew Psychological Consultation/Evaluation		• Clinical and Psycho/Behavioral Test Battery for Space Shuttle Crew
IME 1.8 Effect of Frustrating Situations on Subsequent Psychological Performance During Prolonged Space Flight (Priority 1)	2.4.2 Man-Machine Behavior				
IME 1.9 Behavior and Performance Levels During Periods of Mental Stress and Relative Relaxation (Priority 2)	2.4.4 Skill Retention	7.4.3.3 Skill Retention and Assessment			
SFEP 6 Measure Flux of Light Energy at Various Wave Lengths	2.4.5 Visual Skill (Visual Function) 2.4.5.1 Visual Target Acquisition		• Visual Functions Tests (Pre- and Postflight)	• Visual Function Tester: to determine the feasibility of measuring binocular vision during space flight (Man)	
SFEP 8 Determine Interaction Between Vision and Weightlessness	2.4.5.2 Color Detection in Small Targets 2.4.5.3 Improved Retinal Image Stabilization Techniques			• Retinal Sensitivity: to determine feasibility of measuring retinal sensitivity in space environment (Man)	

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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	2.4.5.4 Visual Prediction				
	2.4.5.5 Contrast Sensitivity				
	2.4.5.6 High Luminance Effects				
	2.4.5.7 Size and Distance Interrelation				
	2.4.5.8 Space Perception (Communication and Recording)				
	2.4.5.9 Oculometry for Human Engineering				
	2.4.5.10 Visual Aids				
	2.4.5.11 Extraterrestrial Scientific Visual Observations				
GBE 18 Select Tests to Measure Cerebral Functioning Evaluation Program on Test or Techniques, Utilize any Space and Time Facilities in Other Earlier Manned Experiments and Develop Flight-type Instrumentation	2.4.6 Other Sensations and Perceptions	7.4.1.2 Effects of Space Flight Environment on Cognitive Processes	• ED52 - Web Formation (Spider)		
	2.4.6.1 Kinesthetic Function				
	2.4.6.2 Orientation - Temporal and Spatial (Orientation Senses)				
	2.4.6.3 Chemical Sense Function		• Taste Thresholds		
	2.4.6.4 Somesthetic Function				
	2.4.6.5 Intellectual				
	2.4.6.5.1 Intellectual Function				
	2.4.6.5.2 Higher Mental Function				
	2.4.6.6. Auditory Function		• Audiometry Tests (Pre- and Postflight)		

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EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS OF THE SPACE SHUTTLE ERA -27

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	3.0 Life Support and Protective System				
R&D 8 Recycling of Water, with Purification to Acceptable Standards of Potability for Human Use	3.1 Water Management				
	3.1.1 Water Reclamation				
	3.1.1.1 Water Recovery Methods and Components	6.4.[illegible] Water Recovery Methods and Components			
	3.1.1.2 Water Recovery System Pretreatment Mixing				
	3.1.2 Potability Monitor		• Potable Water Monitoring - DTO 20.16 Return Water Sample - DTO 20.17 Iodine Monitoring		
	3.1.2.1 Flight-type Potability Monitoring System				
	3.1.3 Thermal Control				
	3.3.3.1 Condensing Heat Transfer and Condensation Rate in Heat Exchanger				
R&D 7 Develop Improved Urine and Fecal Collection Device to Improve Both Metabolic Balance Study and Pilot's Sanitation	3.2 Waste Management	6.4.2 Waste Management Methods and Components			
	3.2.1 Collection				
	3.2.1.1 Transport of Solids by Gas Drag				
	3.2.1.2 Transport of Liquids by Gas Drag				
	3.2.1.3 Manual Transport of Solids				
	3.2.1.4 Collector Tests (Waste Management-Feces and Urine Collection)				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS OF THE SPACE SHUTTLE ERA -28

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	3.2.2 Processing				
	3.2.3 Sampling				
	3.3 Thermal Control	6.4.3 Advanced Cooling System, Methods and Components			
	3.3.1 Heat Transfer-Cooling				
	3.3.3.1 Advanced Cooling Methods and Components				
	3.3.1.2 Gas-to-Solid Heat Transfer in Cabin Air Cooling				
	3.3.2 Heat Transfer-Heating				
	3.3.2.1 Integration of Radioisotope Power and EC/LS				
	3.3.2.2 Heat Source Comparison (Integrated Thermal Control System Utilizing Waste Heat & Electrical Energy)				
	3.3.2.3 Solid-to-Gas Heat Transfer in Cabin Air Heating				
	3.3.2.4 Effectiveness of Thermal Insulation and Surface Coating		• D024 - Thermal Control Coating		
	3.3.2.5 Convective Heat Transfer in zero-g				
	3.3.2.6 Measurement of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry				
	3.3.2.7 Nucleate Boiling Mechanism (pool boiling in long-term zero-g)				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	3.3.2.8 Parameters Affecting Comfort Level (Effect of Wall Temp., Ventilation Rate, Cabin Pressure, Gas Composition, and Crew Clothing Comfort Level)		• M487 - Habitability/Crew Quarters		
	3.3.3 Atmosphere Circulation				
	3.3.3.1 Cabin Air Distribution and Control				
	3.3.4 Thermal Storage Systems				
R&D 9 Develop Techniques and Materials for Body Cleansing in Space	3.4 Personal Hygiene and Sanitation				
	3.4.1 Body Cleansing				
R&D 10 Develop Techniques and Equipment for Shaving, Haircutting, and Nail Paring in Space	3.4.1.1 Evaluation of Equipment (Equipment and Procedures for Personal Hygiene)				
	3.4.2 Whole Body Washing	6.4.4 Zero-g Whole Body Shower	• Skylab Whole Body Shower System		
R&D 11 Develop Techniques and Equipment for Laundering of Clothes in Space	3.4.3 Technology for Clothing Maintenance and Cleansing				
	3.4.4 Oral Hygiene		• Oral Examination and Saliva Sampling (Pre- and Post-flight)		
	3.4.5 Hair Removal				
	3.5 Atmosphere Supply, Control and O_2 Regeneration	6.4.5 Advanced Two-Gas Atmosphere Supply and Control Subsystems			
R&D 21 Develop Sealants for Both Capsule Perforation and EVA Suit Perforation	3.5.1 Nitrogen and Oxygen Supply and Recovery	6.4.6 Atmosphere Supply Methods and Components			
	3.5.1.1.1 Test of Storage Technology (Atmosphere Supply Methods and Components)	6.4.7 O_2 Regeneration Methods and Components			

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	3.5.1.1.2 Atmosphere Supply Methods & Components (Chemical Storage and Supply)				
	3.5.1.1.3 Atmosphere Supply Methods & Components (Refrigeration/Reliquefaction)				
	3.5.1.2 O_2 Generation from Water (Electrolysis Methods & Components)				
	3.5.1.3 O_2 Recovery from CO_2 (O_2 Recovery Methods and Components)				
	3.5.1.4 Airlock Gas Conservation				
	3.5.1.5 Density Profiles of Liquid at and Near the Critical State				
	3.5.1.6 Capillary Studies				
	3.5.1.7 Kinetics and Dynamics of Gas Bubbles				
	3.5.1.8 Gas-Free Liquid Maintenance				
	3.5.1.9 Interface Phenomena in Liquid-Gas Separation (Static and Motion Tests of Interface Phenomena)				
	3.5.1.10 Supply Gauging (Adv. Fluid Mgt. & Gauging Subsystem)				
	3.5.2 Trace Contaminant Control	6.4.9 Advanced Trace Contaminants Control and Monitoring Subsystem			

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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	3.5.2.1 Absorption of Gases by Liquids at zero-g				
	3.5.3 Humidity Control				
	3.5.3.1 Water Condenser-Separator Methods and Components				
	3.5.4 Two Gas Control				
	3.5.4.1 Advanced Two-Gas Atmosphere Supply and Control Subsystem				
	3.5.5 CO_2 Control				
	3.5.6 Microbiological Control and Monitoring				
	3.6 Carbon Dioxide Removal				
	3.6.1.1 CO_2 Collection Methods and Components	6.4.8 CO_2 Collection Methods and Components			
	3.6.1.2 Advanced Integrated Atmosphere Purification and Thermal Control Subsystems				
	3.7 Trace Contaminants Control				
	3.7.1.1 Biological Control and Monitoring of Life Support Subsystems				
	3.7.1.2 Integrated Trace Contaminant Control and Monitoring Subsystems				
	3.8 Astronaut Protective Systems				
	3.8.1 Intravehicular Space Suit/Clothing				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	3.8.2 Extravehicular Space Suit				
	3.8.2.1 Protective Clothing and Adv. Space Suit Assemblies	6.4.10 Protective Clothing and Adv. Space Suit Assemblies			
	3.8.3 Portable Life Support System (PLSS)				
	3.8.3.1 EVA Suit and Biopack	6.4.11 EVA Suit and Biopack			
	3.9 Subsystem Integration				
	3.10 Closed Spacecraft System Problems				
	3.10.1 Life Support				
	3.10.1.1 Advanced Integrated LSS II				
	3.10.1.2 Advanced Integrated LSS II				
	3.10.1.3 Animal Research Facility LSS				
	3.10.2 Solid and Liquid Control				
	3.10.2.1 Vapor Purge of Liquid Systems in zero-g				
	3.10.2.2 Retention, Techniques for Liquid and Solids During Equipment Servicing, R&M				
	3.10.2.3 Solid and Liquid Spillage Recovery and/or Cleanup				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
R&D 1 Extent of Risk of Fire with Various Combinations of Inert Gas with 0_2 in the Pressure Range of 3.5 to 14.7 psi	3.10.3 Fire Prevention 3.10.3.1 Combustion Mixing and Heat Transfer 3.10.3.2 Flame Propagation (Solids and Fluids Combustion)		• Inflight Test of Skylab Fire Extinguisher • M479 - Zero Gravity Flammability		
R&D 2 Critical Tests to Validate the Gravity Dependent Factors in Fire	3.11 Sensors and Instrumentation 3.11.2 Fire Prevention				
R&D 3 Studies of Materials with Primary Interest in Vapors and Flammability	3.11.2.1 Fire Sensing (Fire Prevention and Sensing in zero-g on Reduced Gravity) 3.11.2.2 (Combustion Reproduct Sensing)				
R&D 19 Develop Miniaturized Hand-operated Ejection Fire Extinguisher	3.11.1 Cabin Atmosphere Sensors 3.11.1.1 Leak Detection				
R&D 20 Space-based Study of Fire and Its Propagation at Zero Gravity	3.11.1.2 Aerosol Particle Analyzer (T-003) 3.11.1.3 (Oxygen and Nitrogen Sensors)				
R&D 27 Develop a Prompt Fire Warning System	3.11.1.4 (Contaminant Sensors)				

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R&D 5 Possibility of Extending a Natural Diet by Means of a Concentrated, High Density, Synthetic Diet R&D 6 Continue Work in Food Packaging to Enable Accurate Measurement of Intake of Food Constituents	3.12 Food Management 3.12.1 Food Storage and Flight Preparation 3.12.1.1 Food Storage and Flight Preparation 3.12.2 Nutrition 3.12.3 Packaging		• M487 - Habitability • Skylab Food System and Nutrition Monitoring		• Zero-g Food Regeneration/ Production Technology for Long-Term Manned Missions

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	SPACE BIOLOGY FPE I - PRIMATE (BIO A) Physiology of Chimpanzees in Orbit Hemodynamic and Metabolic Effects of Weightlessness on Monkeys			• Effect of Zero-g and Return to 1-g on Central Vestibular Activity and Sensitivity (Squirr (Squirrel, Monkey: Saimiri Scinrens) • Metabolic and Cardiovascular Studies in Orbit (Pig-tailed Monkey: M. nemestrina)	
	FPE II - MICROBIOLOGY (BIO C) The Role of Gravity in General Cellular Function		• S015 - Zero Gravity:Single Human Cells		
	The Role of Gravity in Maintaining Genetic Stability in Free Cells				
	The Role of Gravity in Tissue Function				
	The Role of Gravity in Maintenance of Normal Development in the Animal Embryo				
	The Role of Gravity in Host Parasite Relationships				

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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	The Role of Geophysical Environmental Factors in Control of Biorhythms in Microorganisms				
	The Role of Gravity in Interactions at the Molecular Level of Cellular Metabolism		• ED32 - In Vitro Immunology		
	FPE III - SMALL VERTEBRATES (BIO D) The Role of Gravity in Immune Responses of Mammals				
	The Role of Gravity in the Function of the Mammalian Organism Through Its Life Cycle			• Physiologic Cost of Repeated Shuttle Sorties	
	The Role of Gravity in Hibernation				
	The Influence of Geophysical Factors on Biorhythms in Vertebrates			• Photoperiod Effects on CNS and Physiological Biorhythms in zero-g.	
	The Influence of Gravity on Behavior in Mammals				
	The Role of Gravity in Cardiovascular Function				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS AND PROSPECTS OF THE SPACE SHUTTLE ERA -37

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	The Role of Gravity in Growth and Metabolism in Reptiles				
	The Role of Gravity in Embryogenesis and Development in Amphibia			• LS 1-10 Inflight Embryo Development	
	FPE IV - PLANT SPECIMENS (B10 E)				
	Plant Responses From 0 to 1-g			• LS 1-3 Soybean Nodulation: to determine gravity dependence of nodulation of legume roots by rhizobium (Soybean seedlings)	
	Pea Seedling Growth in Orbit		• ED 61/ED62 Plant Growth • ED 63: Cytoplasmic Streaming	• Plant growth and function in a space flight environment: to acquire experience and data to develop plant selection, growth growth, and data systems for space flight applications (plant)	
	Plant Morphogenesis Under Weightlessness			• Transport of Photosynthate in Pea Seedlings: to determine gravity dependence of downward transport of photosynthate. (Pea seedlings).	
	Dorsiventrality in Gametophytes			• Electrophysiology of the Venus Flytrap: to explore use of Venus Flytrap as a model for studying effects of space environment on nerve function (Venus Flytrap)	

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NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	The Role of Auxin Medicated Reactions in the Developing of Wheat Seedling During Weightlessness			• Metabolism and Energetics in Hypogravity in a Higher Plant (Marigold) (Radioisotope)	
	The Role of Gravitational Stress in Land Plant Evolution: The Gravitational Factor in Lignification			• Pine Lignification: to determine influence of space flight environment on lignification in differentiating pine stem cells (Pine Seedlings)	
	Effect of Geophysical Factors on Circadian Rhythms in Plants			• Pea Phototropism: to determine relative strengths of phototropism and geotropism in plants (Pea Seedlings)	
	FPE V - INVERTEBRATES (BIO F)				
	The Role of Gravity in the Function of the Invertebrate Organism Throughout Its Life Cycle		• Gypsy Moths • ED 52: Web Formation	• LS 1-5 Cytoplasmic Functions	
	The Role of Gravity in Morphogenesis				
	The Role of Gravity in Invertebrate Metabolism				

EVOLUTION OF LIFE SCIENCES EXPERIMENTS/CONCERNS
AND PROSPECTS OF THE SPACE SHUTTLE ERA -39

NASA SP-86 MEDICAL ASPECTS OF AN ORBITING RESEARCH LABORATORY, SPAMAG STUDY 1966	NASA "YELLOW BOOK" EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS, OMSF - AEROSPACE MEDICINE - RESEARCH AREAS AND COMPONENT EXPERIMENT - SEPT. 1969 -	NASA "BLUE BOOK" REFERENCE EARTH ORBITAL RESEARCH & APPLICATIONS INVESTIGATION, VOL. III LIFE SCIENCES JANUARY 1971	SKYLAB LIFE SCIENCES EXPERIMENTS/SPECIAL TESTS/NOTES - 1973-1974	SPACE SHUTTLE POTENTIAL LIFE SCIENCES EXPERIMENTS WHICH HAVE BEEN PROPOSED AS OF JANUARY 1974	OTHER RECOMMENDED R&D AREAS APPLICABLE TO SPACE SHUTTLE LIFE SCIENCES
	The Role of Gravity in Aging in Invertebrates				
	The Role of Gravity in Genetic Phenomena in Invertebrates				
	Biorhythmicity in Invertebrates				
	The Role of Gravity in Influencing Behavior in Invertebrates				
	FPE VI - BIOTECHNOLOGY LABORATORY				