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LIFE SCIENCE PAYLOADS PLANNING STUDY

PHASE 2 FINAL REPORT

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

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LIFE SCIENCE PAYLOADS PLANNING STUDY

Final Report

October 1977

MDC-G7234

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W. H. Bush, Jr. (Chief, NASA-JSC Systems Integration and Test Branch)

PREFACE

This document was prepared by the McDonnell Douglas Astronautics Company for the NASA Johnson Space Center, Life Sciences Directorate, under Contract No. NAS9-14589. It presents the Final Report of the Life Science Payloads (LSP) Planning Study.

The LSP Planning Study develops planning data that covers overall acquisition, staging, and integration of elements necessary for Life Science Payloads flown aboard the Space Shuttle. The study also develops information relative to program implementation, mission support, and data disposition for Life Science Payloads.

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ABBREVIATIONS AND ACRONYMS

TERM	EXPLANATION
AFD	Aft Flight Deck
ARC	Ames Research Center, Moffett Field, California
CDMS	Command and Data Management System
CORE	Common Operational Research Equipment
EMI	Electromagnetic Interference
FCT	Flight Control Team
GSFC	Goddard Space Flight Center, Greenbelt, Maryland
JPL	Jet Propulsion Laboratory, Pasadena, California
JSC	Lyndon B. Johnson Space Center, Houston, Texas
KSC	John F. Kennedy Space Center, Florida
L/S	Launch Site or Landing Site
LS	Life Science
LSE	Life Science Experiments
LSEDF	Life Science Experiments Development Facility
LSMA	Life Science Monitoring Area
LSP	Life Science Payloads
MCC	Mission Control Center
MS	Mission Specialist
MSS	Mission Specialist Station
NASA	National Aeronautics and Space Administration
PI	Principal Investigator
POCC	Payload Operations Control Center
PS	Payload Specialist
PSS	Payload Specialist Station
RAU	Remote Acquisition Unit
ROM	Rough Order-of-Magnitude
SMD	Spacelab Mission Development
SMS	Spacelab Mission Simulation
STS	Space Transportation System
VAFB	Vandenberg Air Force Base, Lompoc, California
WTR	Western Test Range

Section 1

INTRODUCTION

1.1 BACKGROUND

The spectrum of Life Science activities in the Space Shuttle era must be carefully planned and economically implemented to effectively fulfill the combined needs of science, manned system development, and programmatics. From a research standpoint, the objectives of the scientific community must be met in terms of investigating life-process phenomena in unique environments. Of equal importance is the considerable manned system development effort that is critically needed to optimize man's utility in space. Finally, and of great importance under today's stringent budgets, is the need for a programmatic approach that will permit maximum flexibility and yield a maximum return on the overall Life Sciences investment. The efforts described in this report were conducted to define plans and implementation methods accommodating these interrelated needs.

This document is the final report for the second phase of the Life Science Payloads (LSP) Planning Study conducted under contract NAS9-14589. The second phase of the study consisted of five specific tasks which are:

- Task 1 - Incorporation of Current Data into Payload Operations Plan
- Task 2 - Survey of LSP Experiments Development Facility and Preparation of Facility Implementation Plan
- Task 3 - Compilation of Existing Life Science Requirements
- Task 4 - Preparation of Spacelab Mission Development Experimenter's Planning Handbook
- Task 5 - Survey of Specimen Accommodation Requirements

This document reports in summary form on the results of these five tasks. Also included are the study approach and guidelines and recommendations and conclusions. A compilation of the total documentation produced in both phases of the LSP study effort is shown in Table 1-1.

TABLE 1-1 LIFE SCIENCE PAYLOADS PLANNING STUDY DOCUMENTATION

DOCUMENT NO.	DATE	TITLE AND CONTENT
PHASE 1 DOCUMENTATION		
MDC G6207	JUNE 1976	VOLUME I, EXECUTIVE SUMMARY - CONTAINS A BRIEF PHASE 1 STUDY PLAN, KEY PHASE 1 STUDY RESULTS, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE EFFORT
MDC G6208	JUNE 1976	VOLUME II, LIFE SCIENCE PAYLOADS OPERATIONS PLAN - PRESENTS THE PHASE 1 LSP IMPLEMENTATION PLAN AND LSP MISSION SUPPORT PLAN. THE PLANS CONTAIN DESCRIPTIONS OF THE KEY ELEMENTS, RESOURCES, AND ORGANIZATIONS FOR THE ACQUISITION, DEVELOPMENT, INTEGRATION, TESTING, OPERATION, AND DATA DISSEMINATION OF LIFE SCIENCE EXPERIMENTS.
MDL G6209	JUNE 1976	VOLUME III, APPENDICES FOR PHASE 1 LIFE SCIENCE PAYLOADS OPERATIONS PLAN - SUPPLEMENTED INFORMATION IS PRESENTED ON THIS DOCUMENT.
MDL G6217	JUNE 1976	VOLUME IV, FINAL REPORT ON STUDY OF VISITING SCIENTISTS PROGRAMS IN MEDICAL AND BIOLOGICAL RESEARCH FACILITIES - THE STUDY APPROACH AND RESULTS ARE PRESENTED FOR THIS PORTION OF THE LSP EFFORT.
PHASE 2 DOCUMENTATION		
MDC G7234 (THIS DOCUMENT)	OCTOBER 1977	LIFE SCIENCE PAYLOADS PLANNING STUDY, FINAL REPORT - PRESENTS SUMMARY OF ALL EFFORT FOR PHASE 2.
MDC G6208 REV 1	OCTOBER 1977	VOLUME II, LIFE SCIENCE PAYLOADS OPERATIONS PLAN - UPDATE OF DOCUMENT PUBLISHED IN PHASE 1 TO INCORPORATE INFORMATION FROM CURRENT SOURCES.
MDC G6579	NOVEMBER 1976	LIFE SCIENCE PAYLOADS PLANNING STUDY, INTEGRATION FACILITY SURVEY, EXECUTIVE SUMMARY - PRESENTS SUMMARY RESULTS OF TASKS TO DEFINE NASA-JSC LSP FACILITY REQUIREMENTS, SURVEY EXISTING FACILITIES, AND PROVIDE RECOMMENDATIONS FOR IMPLEMENTING NEW CAPABILITY.

TABLE 1-1 LIFE SCIENCE PAYLOADS PLANNING STUDY DOCUMENTATION (CONTINUED)

PHASE 2 DOCUMENTATION (CONTINUED)

DOCUMENT NO.	DATE	TITLE AND CONTENT
MDC G6275	NOVEMBER 1976	LIFE SCIENCE PAYLOADS PLANNING STUDY, INTEGRATION FACILITY SURVEY RESULTS - CONTAINS DETAILS OF THE EFFORT DESCRIBED IN MDC G6579, INCLUDING A DESCRIPTION OF APPLICABLE JSC FACILITIES, FACILITY AND EQUIPMENT REQUIREMENTS, MODIFICATION AND EQUIPMENT COSTS, AND IMPLEMENTATION DATA.
MDC G7073	SEPTEMBER 1977	LIFE SCIENCE PAYLOADS PLANNING STUDY, LIFE SCIENCE EXPERIMENTS DEVELOPMENT FACILITY IMPLEMENTATION PLAN - PRESENTS METHODS BY WHICH THE FACILITY AND EQUIPMENT CAPABILITIES NECESSARY FOR PROCESSING LIFE SCIENCE SHUTTLE PAYLOADS MAY BE IMPLEMENTED AT JSC.
MDC G6296	FEBRUARY 1977	LIFE SCIENCE PAYLOADS PLANNING STUDY, LIFE SCIENCE PAYLOADS OPERTIONS REQUIREMENTS - THIS DOCUMENT CONTAINS A COMPILATION OF LSP REQUIREMENTS PREVIOUSLY SET FORTH BY NASA IN-HOUSE AND CONTRACTOR EFFORTS.
MDC G6615	JUNE 1977	LIFE SCIENCE PAYLOADS PLANNING STUDY, LIFE SCIENCE SPACELAB MISSION DEVELOPMENT III EXPERIMENTER'S PLANNING HANDBOOK - PROVIDES POTENTIAL AND ACTUAL EXPERIMENT PRINCIPAL INVESTIGATORS IN THE SPACELAB MISSION DEVELOPMENT TEST PROGRAM WITH GENERAL AND SPECIFIC INFORMATION DESCRIBING THE TEST PROGRAM.
MDC G7084	SEPTEMBER 1977	LIFE SCIENCE PAYLOADS PLANNING STUDY, SPECIMEN ACCOMMODATION SURVEY RESULTS - PRESENTS A DESCRIPTION OF THE ANALYSIS, RESULTS AND RECOMMENDATIONS FROM AN INVESTIGATION OF THE METHODS BY WHICH LIVE SPECIMENS MAY BE ACCOMMODATED ON LIFE SCIENCE PAYLOADS.

The primary objectives of the LSP planning study have been:

A) to develop planning data applicable to the overall acquisition, staging, and integration of LSP program elements

B) to develop program implementation guidelines, mission support information, and documentation of payload characteristics and requirements and

C) to perform analyses of specific problem areas and recommend methods of solution.

The product of the effort directed toward these objectives is presented in this report, and features:

1. Definition of a detailed program for Life Science payload implementation, from experiment solicitation through final data dissemination.
2. A structured program that will interest and attract a large number of investigators from the scientific community.
3. Provisions for phased program development, from initial definition of experiment support requirements, through development of management and support approaches and assessment of payload carrier configurations, to operational support and reporting.
4. Identification and definition of planning, development, and operations phase material in a way that will allow the material to be applied to other space-research disciplines.

Section 2

SUMMARY AND CONCLUSIONS

The LSP Planning Study is a focal point for the development of the Shuttle life science payloads program, and the study has considered inputs from a wide range of sources.

The study has indicated that a productive, cost effective, life science research program in the Shuttle era may be accomplished. However, it has also indicated that detailed planning, experiment selection, and development must be initiated more than three years prior to the launch for a given flight. In order to maintain program responsiveness and to accommodate short lead time experiments, a portion of the weight, volume, utilities and crew time for each flight must be reserved for late assigned experiments until near launch.

An updated LSP Operations Plan has been developed which establishes the methods and procedures required for the overall acquisition, staging, and integration of LSP program elements. The plan addresses all personnel, resource and management needs to implement a payload. Material in the plan originates primarily from inhouse NASA activities and reviews.

Task 2 effort, which surveyed the LSP experiments development facility, showed that current JSC facility accommodations are suitable with relatively minor modifications. Building 36, the Bioengineering and Test Support Facility, is well suited for use as either a shared payload processing facility or as a facility dedicated to operations involving only Life Science payloads. Operations involving receiving and shipping, integration, test and checkout, test monitoring and in-flight science support may be accomplished within the building for either mode of operation. Life Science laboratories, which are currently being centrally located into Building 37, should be capable of supporting the laboratory requirements of the Integration Facility, and crewmember and test subject medical examination support can be provided by existing accommodations in Building 8.

The Integration Facility should be capable of performing initial receiving and experiment processing activities as early as 1978. A phased build up to full operational capability should be completed by 1981. Until that time, with either payload processing concept, a portion of the space within the Integration Facility will be available for operations other than those directly involved with Life Science payload processing.

Task 3 effort produced the LSP Operations Requirements document which consolidates into a single volume LSP requirements from several previous activities. These activities, which includes NASA internal and contractual studies and results from various NASA working group activities, has produced a substantial amount of information pertaining to the LSP program. Consolidation of this information will provide ready access to previously stated requirements without the time consuming search through information files which has been required in the past. The requirements are presented on standard format worksheets with identification numbers allowing rapid location of the desired requirement.

The LS SMD III Experimenter's Handbook, produced in Task 4, provided a concise, easy to use handbook to convey SMD information to potential Life Science Principal Investigators (PI's) at academic, industrial, health research and NASA centers. The document was a reference source for LSP experimenters participating in the SMD program, and summarized the interface information needed by the PI's as well as outlining the inputs required from them. Information was also included which summarizes the procedures which will be followed in conducting actual Shuttle missions.

Task 5 investigated the methods by which live specimens may be accommodated aboard Life Science Space Shuttle payloads. Emphasis was placed on the identification of practical, cost effective methods of accommodating various categories of research specimens. Every attempt was made to determine accommodation methods which could be efficiently integrated with existing Shuttle and Spacelab systems and which would limit physiological changes and stress in the specimens to a level comparable with that normally encountered in performing similar research in ground based laboratories.

The results identified a serious deficit in Orbiter/Spacelab accommodations required to support Life Science Dedicated Laboratories if the present baseline methods of specimen storage and utilities allocation are maintained. Based on "powered down" specimen holding units for the ascent and descent phases, only a limited quantity of live specimens can be accommodated.

Based on the reference payload accommodation requirement relative to on-pad access, power, cooling and data, the payload accommodations across each major mission phase were deficient (with the exception of prelaunch access) if the live specimens are loaded in the Spacelab holding units for launch. The mission phases encompass prelaunch, ascent, on-orbit, descent and landing and post landing. Although loading and maintaining the specimens in the Spacelab is considered the baseline mode of operation, deficiencies in power range from 26 to 356 percent across the mission phases under the current power allocation. Cooling deficiencies can range from 16 to 355 percent across the mission phases. Special off-loading on the landing strip will be necessary to meet live specimen interactions requirement for those payloads investigating hormone responses to spaceflight. Data handling does not appear to be deficient based on currently defined LS payload requirements.

The prime resolution concept defined for alleviating the accommodation deficiencies to payloads involves: (1) loading the live specimens in the Orbiter mid-deck for launch, ascent and descent/landing, (2) implementing and using the T-0 umbilical, (3) adding a fuel cell power system for on-orbit operation, and (4) off-loading the required specimens at the landing area prior to Orbiter tow.

Alternate concepts were developed should it be mandatory to retain the live specimens in the Spacelab holding units during all mission phases. Essentially, for each mission phase an auxiliary power capability/subsystem and corresponding heat rejection capability were defined.

Section 3

APPROACH AND GUIDELINES

This section presents the approach to the study in the form of a study plan summary, the study guidelines and the key base data consisting of the Life Science Payloads traffic model and representative payloads for planning.

3.1 STUDY PLAN SUMMARY

The second phase of the LSP Planning Study consisted of five specific tasks. Task 1 was accomplished last chronologically and consisted of refining and expanding the Phase 1 Payloads Operations Plan. This was necessary since the LSP program has matured considerably since the first issue of the plan, making available a more definitive definition. Program maturation has occurred through NASA in-house activities, from related NASA sponsored contracts and as a result of tasks 2 through 5 of this LSP Planning Study.

The revised LSP Operations Plan primarily addresses key elements and resources to be utilized for the LSP program, and the organizations and procedures required for planning, acquisition, development, integration, testing, operation and data dissemination activities.

Task 2 provided an LSP Development Facility Survey and Implementation Plan required for accomplishment of the NASA-JSC role in the LSP program. The effort specifically 1) defined top level NASA-JSC Payload Development Facility resource requirements, 2) identified resources currently available, 3) compared the necessary requirements with those available and 4) specified methods and schedules for the implementation of operational era capabilities.

During Task 3, a Life Science Payloads Operations Requirements document was compiled to provide a central reference source to aid inter- and intra-center payload development and design review activities. The objectives of the effort were to document the following types of available information.

- LSP operational requirements
- Interface information for presently identified LSP configurations
- Support requirements for the Life Science Payload Control Center and Mission Control Center
- Habitability requirements for Life Science Payloads

Tabularized standardized formats were used for quick information recording and access.

Task 4 effort developed a Life Science Mission Development Experimenter's Planning Handbook. The result is a concise, easy to use document to provide SMD information to potential life science principal investigators at academic, industrial and health research locations as well as to those at NASA centers. The document is a "stand alone" reference document for LSP requirements which summarizes the interface information needed by the PI's, and outlines the inputs required from them. The document also lists sources of additional information which may be useful to experimenters.

During Task 5, a Life Science specimen accommodations assessment was made. Life science specimens, particularly those with higher order specimens, impose unique requirements on the Shuttle and Spacelab over all mission phases. The "living lab" concept is the basis of most incompatibilities. This task provided an assessment of the driving requirements imposed by live specimens, and selected preferred methods by which these requirements may be met.

3.2 TRAFFIC MODEL

A traffic model describing the types and launch dates for Life Science Payloads is an intrinsic component of payload planning. The LSP traffic model used in this study is given in Figure 3-1. This model is representative and reflects the latest knowledge to be used for planning purposes. This model has been modified periodically as the program matured, however, past and anticipated modifications are not expected to substantially effect LSP program planning and resource requirements.

CALENDAR YEAR	1980	1981	1982	1983	1984*
MINI-LABS	△	△ △	△△	2	2
CARRY-ON LABS	△ △ △	△	+1 COL △	2	2
DEDICATED LABS		△ △	△ △	2	2

* 1985 THROUGH 1991 SAME AS 1984

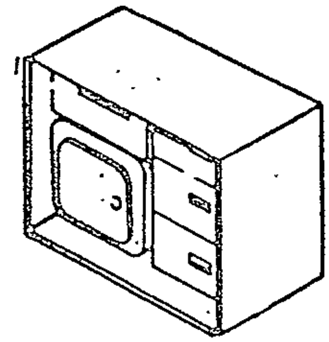
FIGURE 3-1. LIFE SCIENCE PAYLOADS PLANNING STUDY TRAFFIC MODEL

3.3 REPRESENTATIVE PAYLOADS FOR PLANNING

Study activities were based on three general LSP types as indicated in Figure 3-1 of the previous subsection. These payloads enable the conduct of activities required for the successful conduct of Life Science research aboard near-Earth Space Shuttle orbital flights of up to 30 days duration. The three general payload categories are; carry-on labs, mini-labs, and dedicated labs. Figure 3-2 give a sketch of each category lab along with typical characteristics. The lab categories are defined as:

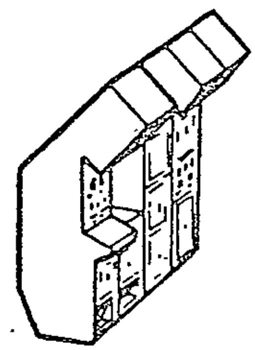
Carry-on Experiment

0 ≤23 Kg (≤50 lbs)
0 Self-contained power, data recording, specimen holding
0 Flown in Orbiter cabin, Pressurized Spacelab, or on Pallet



Mini-lab

0 ≤500 kg (≤1100 lbs)
0 One to four racks
0 Shares Spacelab with experiments from other disciplines
0 Shared Payload Specialists
0 Power, data recording and processing, telemetry available through Spacelab



Dedicated Life Sciences Spacelab

0 ≤3500 kg (≤7700 lbs)
0 All Spacelab utilities dedicated to Life Sciences research
0 Up to four Payload Specialists who are Life Scientists

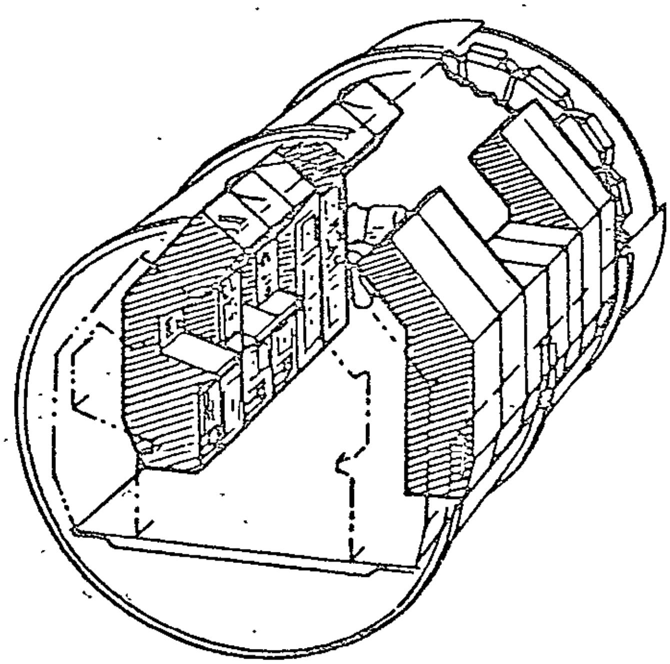


FIGURE 3-2 PRIMARY LIFE SCIENCE PAYLOAD TYPES

- Carry-on Labs - small relatively self-contained groups of equipment generally dedicated to the performance of a single experiment.

- Mini-labs - a grouping of one to four Spacelab racks containing Life Science research equipment and flown aboard missions shared with other disciplines. Mini-labs will usually contain 4 to 5 experiments.

- Dedicated Labs - consist of a Spacelab dedicated totally to Life Science operations. Each dedicated Spacelab contains from 15 to 20 experiments integrated to form an effective payload.

Life Science Payloads, as used in the study, refer to studies in medical, biological, behavioral, life support technology and related fields.

3.4 STUDY GUIDELINES

Planning guidelines have been formulated and evaluated to direct the planning activities toward precise objectives. The majority of these guidelines apply to the STS/Spacelab program in general and many of them are obvious from the overall objectives and needs of the Life Science Payloads Program. The major guidelines are presented below with brief descriptions.

3.4.1 Low Cost

This guideline is especially applicable to the Shuttle launched Life Science Payloads Program due to the relatively low launch costs. Low costs imply cost effectiveness and minimizing the cost for meaningful data return. Low cost does not imply any compromise of crew or support personnel safety.

3.4.2 Flexibility

The program must be structured to accept a wide range of experiment types and designs. It also must be capable of conforming to the individual needs of principal investigators with regard to their degree of involvement in the flight program. Flexibility also implies the ability of the program to adapt to changes in payloads and in schedules. That is, payloads must be capable of being modified at a late date by deletion of certain experiments and acceptance of new ones, and payload processing must have the flexibility required to adjust to revised traffic models.

3.4.3 Short Turnaround

The full cycle of past space programs, from experiment selection to post-flight data analysis, has required on the order of four or five years. This long turnaround time is not compatible with a progressive research program, and such a program must be capable of reducing experiment turnaround time to a minimum duration. Although a program of 100 percent quick turnaround experiments is not feasible, a significant number of this type of investigations must be accommodated.

3.4.4 Maximum Use of Existing Equipment

This guideline is consistent with the general philosophy of the program of lost cost, flexibility and short turnaround. Use of existing laboratory and commercial equipment with minimum modifications will contribute to meeting the other program guidelines.

3.4.5 Principal Investigator Accommodation

The heart of the life science program revolves around the attraction and accommodation of life scientist PI's since they are the originators of viable experiments for the program. From this standpoint the program must be especially structured to accommodate the PI.

Section 4

LSP PLANNING STUDY RESULTS

This section briefly presents the results of the five study tasks which were described in subsection 3.1. Detailed results can be found in the reports produced for each task (see Table 1-1). The task results use the traffic model and representative payloads and are responsive to the study plan and study guidelines presented in Section 3.

4.1 LIFE SCIENCE PAYLOADS OPERATIONS PLAN - TASK 1

The LSP Operations Plan presents an initial revision to the Life Science Payloads Operations Plan which was originally published in June 1976. This revision incorporates a substantial amount of data and information which was not available when the initial issue of the document was prepared, including an improved definition of the LSP program concept and approach, current summary descriptions of LSP facilities requirements at ARC, JSC and KSC, and updated payload/vehicle interface data.

The overall LSP Plan presents preferred approaches and procedures for preferred approaches and procedures for Life Science payloads from experiment selection through mission completion. The effort has specifically addressed the acquisition, staging and integration of elements, as well as program implementation, mission support and data disposition for Life Science Payloads. Critical operational areas have been examined to arrive at preferred approaches and procedures. One of the goals of the study has been to structure the results to allow the concepts developed to be applied to other space research disciplines as well as to Life Sciences.

Specific elements of the plan are summarized below.

4.1.1 LSP Program Concept and Approach

The Space Shuttle era will provide the first opportunity to carry out a comprehensive program of Life Sciences experimentation in an orbital environment. The National Aeronautics and Space Administration plans to make the Shuttle the basis of a versatile space Life Sciences laboratory which will be capable of supporting both applied and basic research in the disciplines of biology, biomedicine, behavioral science and life support systems technology. The NASA Life Sciences Program Objectives are (Reference 1):

1. To ensure human health, safety and effective performance in space.
2. To utilize the space environment to further knowledge in medicine and biology.
3. To utilize space technology and the space environment for application to terrestrial medicine and biological problems.
4. To understand the origin and distribution of life in the universe.

Implementation of Life Science Payloads involve numerous activities from experiment selection through development, testing, on-orbit operation and post-landing data dissemination. A summary of end-to-end payload operations is presented in Figure 4-1.

4.1.1.2 Program Organization

The responsibility for planning and management of all NASA space sciences activities is assigned to the Associate Administrator/Office of Space Sciences (AA/OSS). Within this Office is the Director for Life Sciences who, through the NASA Headquarters and Center organizations reporting to him, is responsible for the direction of the total Life Science program. (See Figure 4-2). It is also the responsibility of the Director for Life Sciences to coordinate with the European Space Agency (ESA) Life Science program to ensure that joint scientific objectives are met.

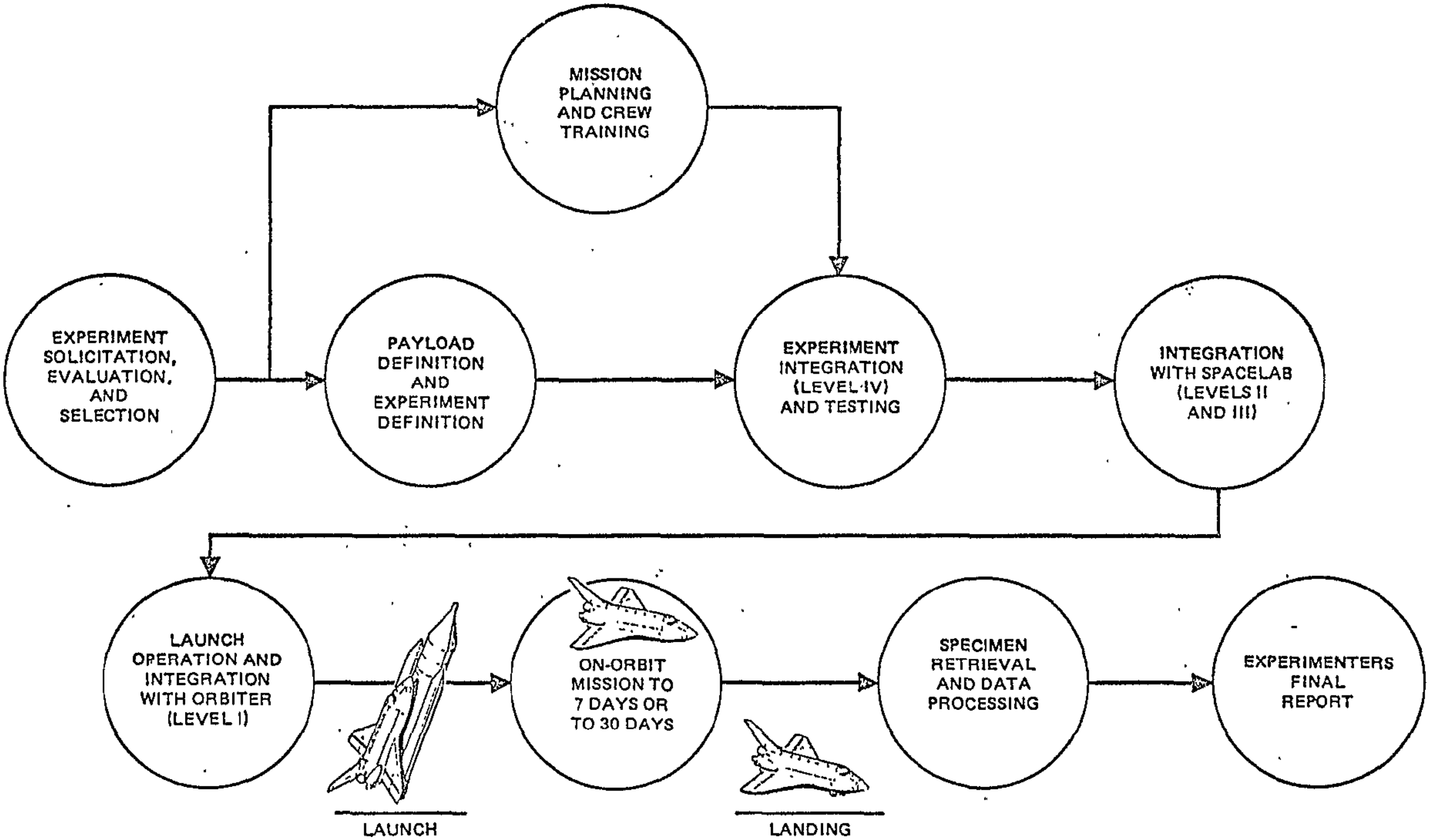


FIGURE 4-1 SUMMARY OF END-TO-END PAYLOAD ACTIVITIES

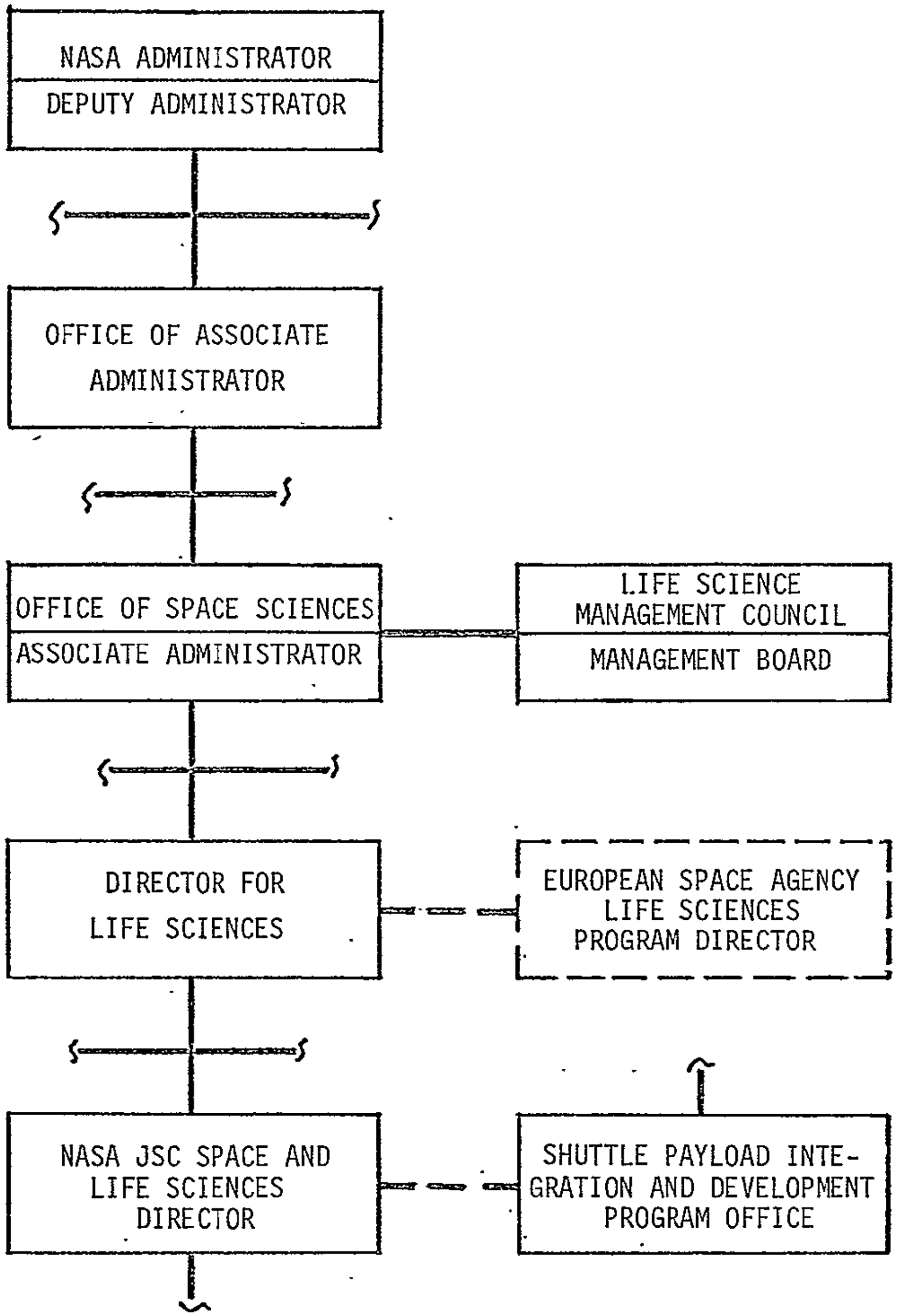


FIGURE 4-2 TOP LEVEL NASA ORGANIZATION RESPONSIBLE FOR LIFE SCIENCE PAYLOAD ACTIVITIES

Life Science payload activities are implemented through efforts conducted under the direction of the Integrated Life Science Shuttle Experiments Project and the Common Operational Research Equipment (CORE) Project. The primary goal of the CORE Project is to assemble an inventory of flight qualified general purpose laboratory equipment which Life Science investigators may use for their experiment programs conducted in space.

Experiment/payload definition, development, checkout, integration, flight support and post-flight analysis activities will be conducted under the ILSSE Project. JSC has been designated as the lead center for the ILSSE and CORE Projects, and the Life Sciences Experiments Program Manager at JSC will coordinate the efforts of all NASA centers involved in these projects. Other directorates at JSC, ARC and KSC will provide support as appropriate.

4.1.1.3 Overall Management Functions

The overall management function is to:

1. direct effort,
2. monitor progress and status,
3. allocate resources,
4. establish lower level organizations, responsibilities, and operating policies, and
5. submit up-to-date status reports to upper management.

Management direction controls technical status and performance, schedule, and cost. These are dependent factors, and when one of them is affected by management direction, the other two factors are impacted. Therefore, management direction must occur with care and a full understanding of the impact of all decisions. A management function is to direct the program to maintain proper balance between the three factors. One important way of providing management with impact information is through change control which assesses the impacts of proposed redirection. This gives management the necessary insight to allow correct decisions on program redirection to be made.

The overall management functions occur at several levels. Funds, resources, and schedule commitments must be made at multiple levels, the highest within the Life Science Experiments Program being the Program Manager level. Based on projections of the needs of individual LS payload development centers and the launch site (project level), project funds and resources will be allocated and master schedules will be produced. The Life Science Experiments Program Manager's Office will then manage the program from a macroscopic standpoint.

Similar management functions will occur at the project level. For instance, the ARC and JSC Project Managers will allocate funds and resources and perform scheduling for each activity for which they are responsible.

4.1.1.4 Operations Overview

The activity cycle for early Life Science flights will span approximately five years from release of the AO through postflight report distribution, as indicated in Figure 4-3. The duration of this cycle will be compressed as experience is gained, and it is expected that a cycle time of approximately two years will be reached before the mid-1980's.

Carry-on and Mini-lab payloads will have somewhat different task flows than Dedicated Labs. Both Carry-on and Mini-labs are shared payloads and thus final integration of the experiment elements may occur at a site other than JSC. In the case of Mini-labs this will normally be at the lead payload center for the particular flight. The Carry-on Labs are less complex, and will usually proceed directly to the launch site for integration. Also Carry-on Labs will not normally contain specimens, so specimen related tasks may not be required.

4.1.2 Mission Planning and Preparation

The information contained in this section describes the key mission planning and preparation operations and includes:

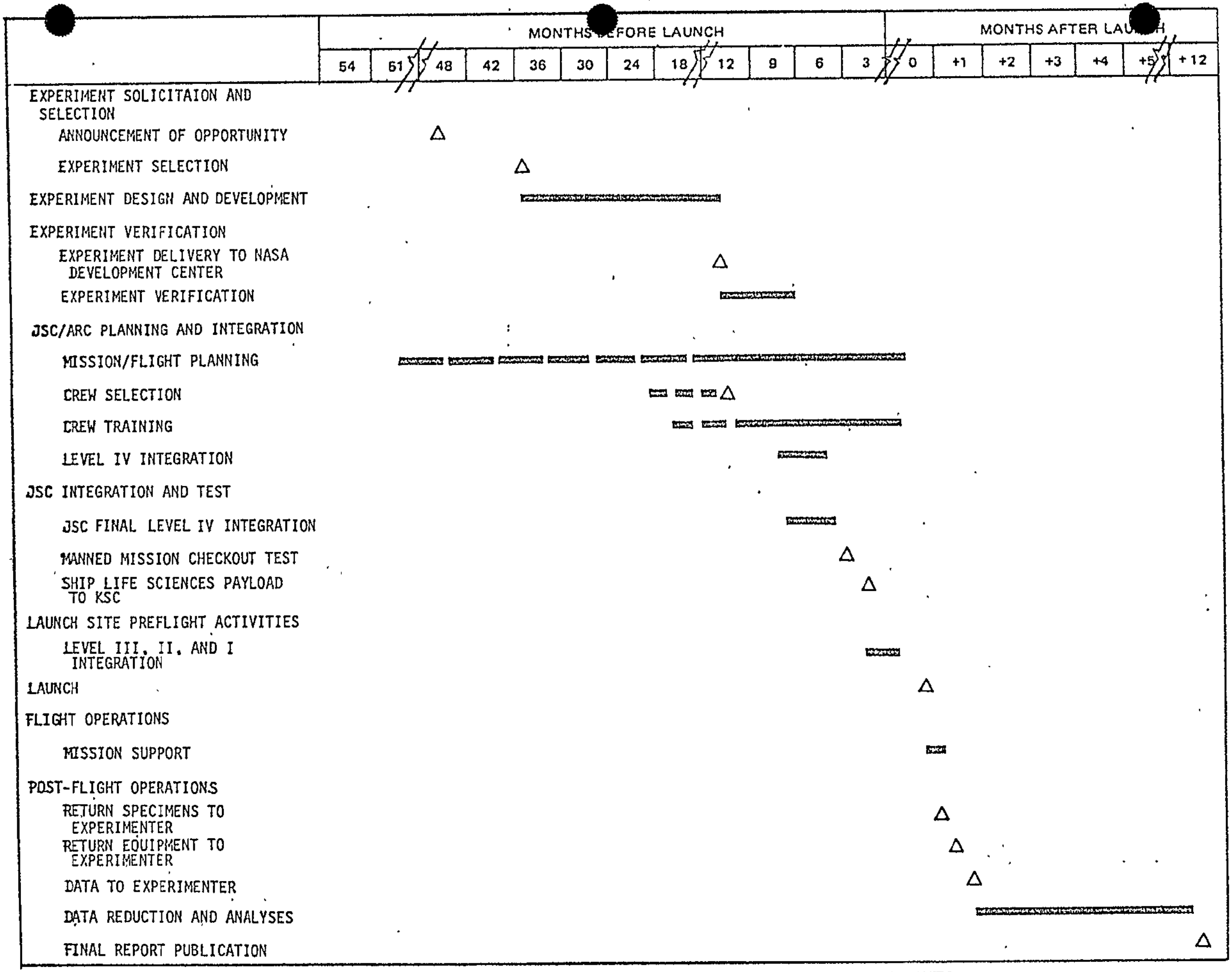


FIGURE 4-3 LIFE SCIENCE PAYLOADS CYCLE- SCHEDULE OF ACTIVITIES FOR EARLY FLIGHTS

A) mission planning
B) flight planning
C) flight crew selection
D) integrated payload systems tests, and
E) review activities.

The material presented in this document is for the most part general in scope. As payload and payload carrier designs mature, the information will be expanded and updated and a family of detailed support plans, keyed to specific Life Science flights, will be evolved.

4.1.2.1 Mission Planning

Life Science personnel will initiate the mission planning activity by determining the top level tasks to be performed on a series of STS flights. The array of mission types planned will allow program objectives to be met in an efficient manner by allowing the timely assignment of similar experiments to common flights (Reference 1). The STS User Handbook (Reference 2), supplemented by communications with NASA-JSC STS Operations personnel, will be the primary STS information source for this activity (Reference 3). A set of forms, headed by STS Form 100 (Reference 2), will then be filled out by Program-level Life Science personnel. Such information as general payload description, mission goals, flight requirements, constraints, priorities, and the desired flight duration and launch date will be listed on the forms.

The completed forms will be identified as a preliminary Mission Plan and will be sent to NASA Headquarters Office of Planning and Program Integration (Code 0) (Reference 3). This process is shown in block diagram form in Figure 4-4.

On acceptance of the Mission Plan by the STS organization, a series of analyses are undertaken to verify the compatibility of the services desired with the STS capabilities. This planning effort, identified as mission

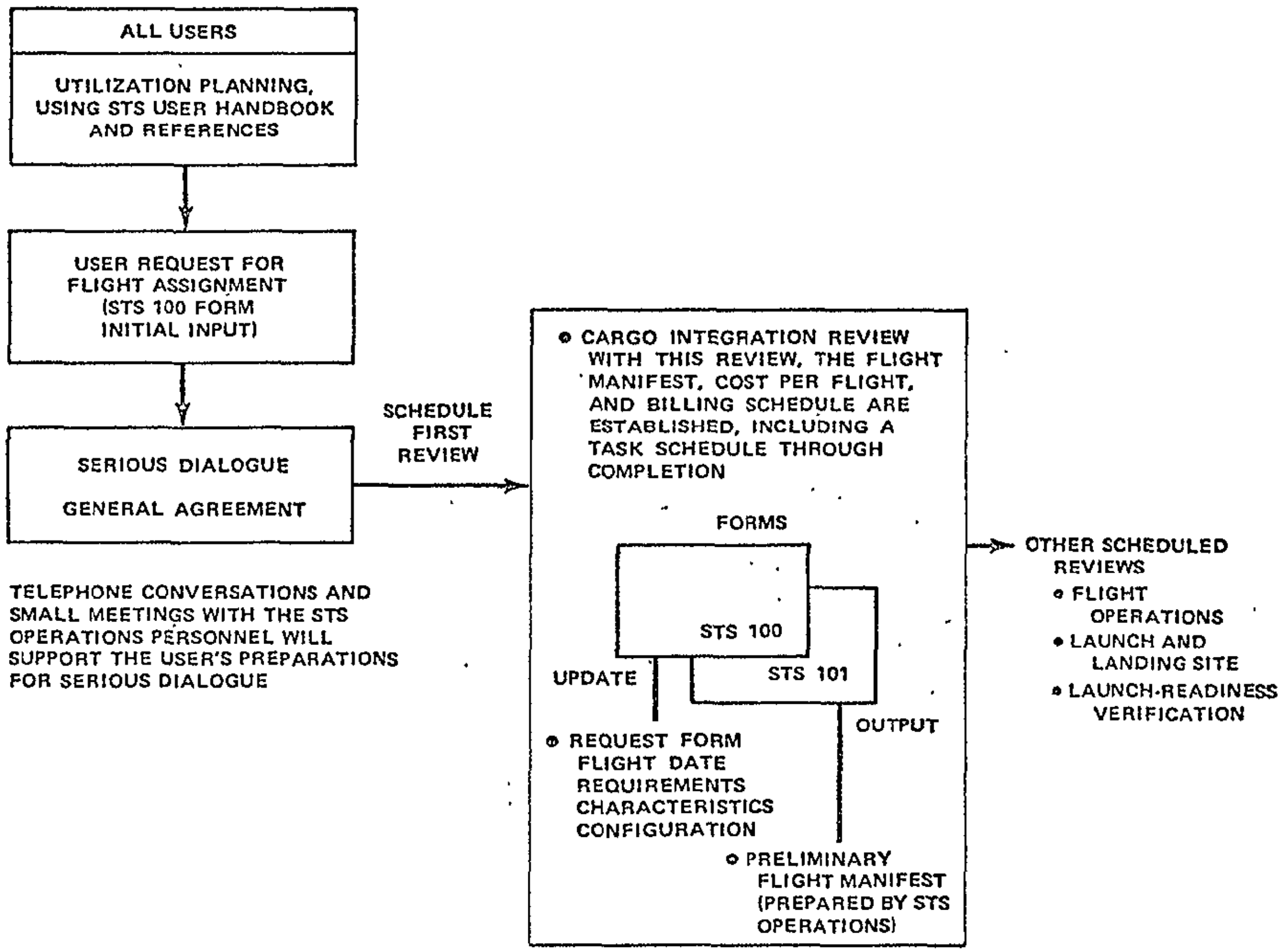


FIGURE 4-4 INITIAL MISSION PLANNING COORDINATION ACTIVITIES

suitability analysis, occurs on a schedule which is dependent on mission complexity. Routine or repetitive missions may be analyzed as late as one year prior to launch. Output of these analyses will include a tentative launch date (or interval), cost, crew size, payload size and weight, STS flight kit requirements, delivery dates, and top level training requirements (Reference 3). In order to maintain program flexibility, a percentage of the payload weight, volume, power, thermal control, consumables, and crew time will be reserved for late-arriving experiments. "Strawmen" experiments may be included in the planning cycle to fill these reserved resource blocks.

4.1.2.2 Flight Planning

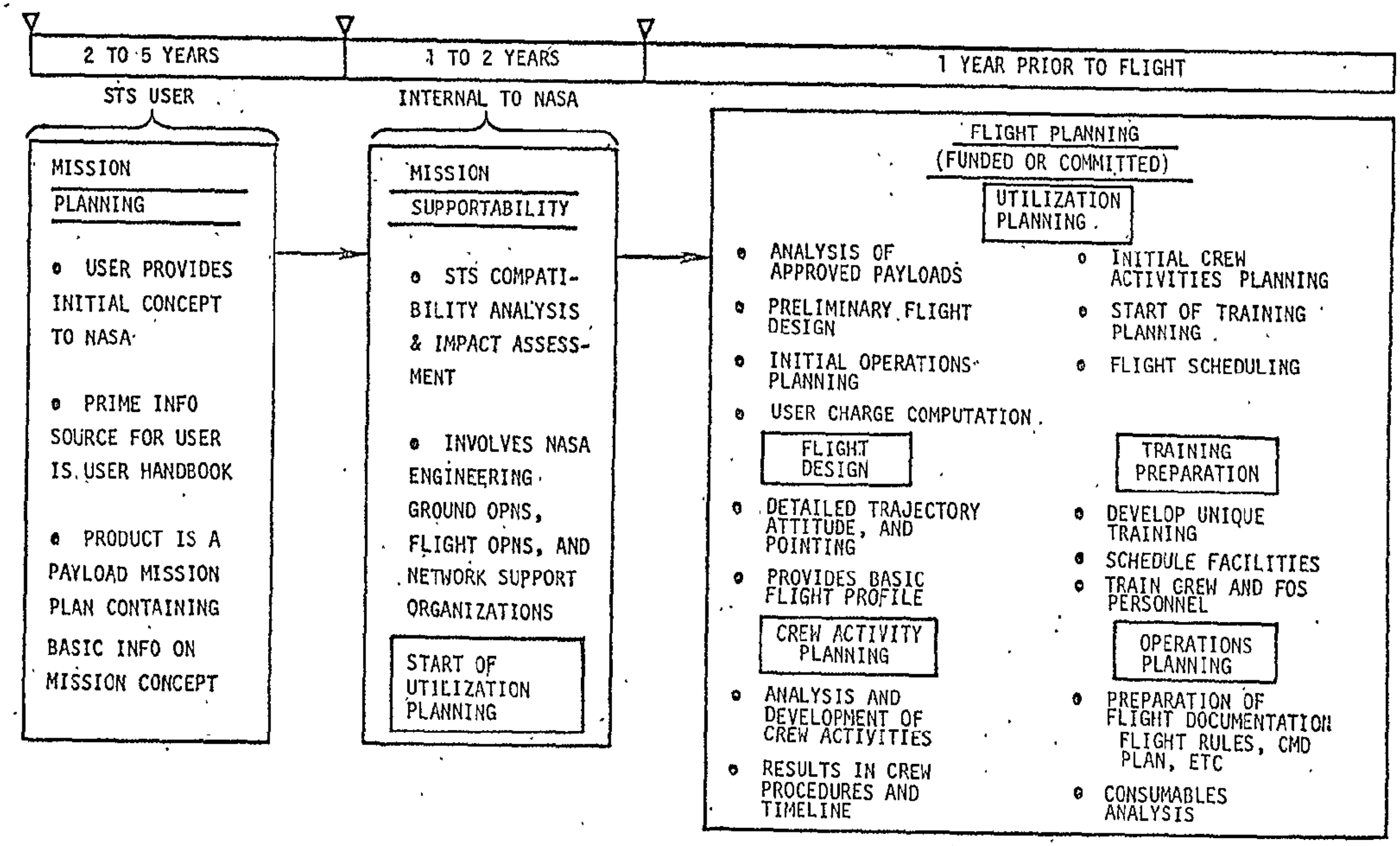
Flight planning for STS flights consists of five interrelated elements: utilization planning, flight design, crew activity planning, training preparation and operations planning. The functions performed under each of these elements and their interfaces with the mission planning and mission supportability activities are shown in Figure 4-5.

4.1.2.3 Flight Crew Selections

The flight crew for an Orbiter with a Life Science Payload will consist of a Commander, Pilot, Mission Specialist, and one to four Payload Specialists. (The maximum crew size is 7; early missions designed to verify Orbiter performance will be flown with only a Commander and Pilot.) It is anticipated that the Commander and Pilot for a particular flight will be assigned by the JSC Astronaut Office using criteria other than payload requirements as the primary standard of selection. The Astronaut Office will also assign Mission Specialists, but it is expected that Mission Specialists trained in the primary discipline of the payload will be supplied whenever practical. Primary and alternate functions of the flight crew are indicated in Figure 4-6.

4.1.2.4 Preflight Systems Tests

The overall objective of preflight checkout and verification tests is to verify before launch that proper preparations have been made for the planned flight. Within this overall objective, a number of subsidiary objectives are accomplished by the tests. These include:



(1) "MISSION" IS DEFINED AS A SET OF INVESTIGATIONS OR SPACE OPERATIONS TO ACHIEVE PROGRAM GOALS. IN CONTRAST TO A "FLIGHT" WHICH IS A SINGLE SHUTTLE ROUND TRIP, A MISSION MAY ENTAIL PART OF A FLIGHT OR MAY REQUIRE SEVERAL FLIGHTS TO ACCOMPLISH ITS GOALS.

(2) PROVISIONS WILL BE MADE FOR ACCEPTING "QUICK REACTION" PAYLOADS INTO THE PLANNING SYSTEM AT POINTS LATER THAN 1 YEAR PRIOR TO LAUNCH. FLIGHTS OF THIS TYPE WOULD REQUIRE ONLY A SIMPLIFIED CREW INTERFACE AND COULD BE "PREPLANNED."

FIGURE 4-5 PREFLIGHT PLANNING INTERFACES

ORIGINAL PAGE IS OF POOR QUALITY

PRIMARY FUNCTION
OPTION WITH CROSS-TRAINING
LIMITED DUTY BASIS

	CDR	PILOT	MISSION SPEC	PAYLOAD SPEC
ORBITER FLIGHT OPERATIONS • VEHICLE FLIGHT CONTROL • GUIDANCE, NAVIGATION • VEHICLE SYSTEMS MANAGEMENT • MONITOR, CONTROL FLIGHT SAFETY ITEMS • RENDEZVOUS AND DOCKING • MANIPULATOR OPERATIONS • CONSUMABLES MANAGEMENT • ACTIVITY SCHEDULING – ASSISTANCE • MONITOR PAYLOAD CAUTION AND WARNING • ELECTRICAL POWER MANAGEMENT • ENVIRONMENTAL CONTROL	PRIMARY FUNCTION	PRIMARY FUNCTION	LIMITED DUTY BASIS	
PAYLOAD OPERATIONS MANAGEMENT • ORBITER/PAYLOAD SUBSYSTEM CHECKOUT, OPERATION • MONITOR PAYLOAD CAUTION AND WARNING • MANAGE PAYLOAD SUPPORT COMMUNICATIONS • ASSIST IN EXPERIMENT OPERATIONS AND MAINTENANCE • CONSUMABLES MANAGEMENT • ACTIVITY SCHEDULING – PRIMARY • PRIME FOR EVA OPERATIONS	OPTION WITH CROSS-TRAINING	OPTION WITH CROSS-TRAINING	PRIMARY FUNCTION	

PAYLOAD OPERATIONS
• PERFORM EXPERIMENTS INITIATION, OPERATION, MONITORING
• EXPERIMENT DATA MANAGEMENT
• PERFORM PAYLOAD MAINTENANCE
• INTERFACE WITH GROUND EXPERIMENTERS AS REQUIRED
• ACTIVITY SCHEDULING – ASSISTANCE
• PAYLOAD HOUSEKEEPING OPERATIONS
  • PAYLOAD SYSTEMS MONITORING
  • CONSUMABLES MANAGEMENT
	LIMITED DUTY BASIS	LIMITED DUTY BASIS	LIMITED DUTY BASIS	PRIMARY FUNCTION

FIGURE 4-6 CREW FLEXIBILITY

- Verification of payload-related procedures
- Verification of stowage lists
- Refinement of timelines
- Training
- Verification of data management procedures
- Overall flight support

Although large-scale integrated simulations are able to best model the actual conditions encountered in orbit, valuable data may also be obtained from smaller-scale tests. These will involve experiment payloads at various levels of integration and tests using high fidelity mockups such as the SMD facility.

4.1.2.5 Pre-Flight Review Activities

A sequence of review activities will be conducted prior to the payload/ Orbiter integration activities for each Life Science Shuttle flight. The purpose of these reviews will be to ensure that proper preparations have been made to attain the flight objectives, and to promote crew and equipment safety throughout the preflight, flight, and postflight periods. Review activities will include (1) a cargo safety certification, (2) a payload preshipment review, and (3) a flight readiness review.

4.1.3 LSP Facilities

NASA facilities for the development, integration, crew training, operational support, and experiment/payload data processing support for Life Science payloads are required at ARC, JSC and KSC (Figure 4-7). Additional development/support areas may be located at PI facilities and contractor sites. Little commonality exists among the Life Science facilities at the different locations, as the operations to be performed at each of the sites differ substantially. Not every facility requires the capability to perform all operations, and activities have been consolidated and assigned to ARC, JSC or KSC to reduce costs wherever possible.

ACTIVITY	JSC	ARC	KSC
EXPERIMENT DEVELOPMENT AND VERIFICATION			
RECEIVING AND INSPECTION	X(1)	X	
EXPERIMENT DEVELOPMENT/FABRICATION	PI/CONTRACTOR LOCATIONS		
EXPERIMENT TEST	X	X	
EXPERIMENT INTEGRATION			
RECEIVING AND INSPECTION	X	X	X
CORE AND EXPERIMENT STORAGE	X	X	X
PAYLOAD INTEGRATION	X	X	X
CHECKOUT TEST	X	X	X
MOCKUP AREA	X	X	
PERFORMANCE MONITORING	X	X	X
CLEAN ROOM AREA	X	X	
PAYLOAD TRAINING			
TRAINING AREAS	X	X	
SCIENTIFIC AND TECHNICAL SUPPORT			
LIFE SCIENCES LABORATORIES	X	X	X
SPECIMEN HOLDING/HANDLING	X	X	X
SCIENCE MONITORING	X	X	X
PI REMOTE LOCATIONS	PI HOME INSTITUTIONS		
DATA PROCESSING			
COMPUTER SUPPORT	X	X	
DATA DISPLAY	X	X	X
DATA STORAGE/ARCHIVAL	X	X	

NOTE: (1) "X" Denotes Facility Normally Required.
Requirements May Vary for Individual Experiments/Payloads

FIGURE 4-7 SUMMARY OF LSP FACILITY LOCATIONS

4.1.4 Communications and Data Management

The communications and data management interfaces provide the means to transfer data between on-orbit experiment operations and ground-based support teams in the MCC, POCC, SMA, SORC, and elsewhere. Interfaces include those for the acquisition of digital, analog, video, and voice signals as well as interfaces for issuance of digital control signals in a variety of forms. The communications and data management networks which may be synthesized from various configuration of the system components offer a wide range of capabilities. The data options selected for a particular payload by the Life Science Experiment Program Office will be based on integrated experiment requirements and must be negotiated in the preflight planning phase with the STS operator.

4.1.5 Training

Training requirements for Life Science Payloads flights may be divided into Shuttle/Spacelab-related training and payload/experiment-related training. Most Shuttle and Spacelab systems training will be administered by non-payload NASA organizations.

The NASA-JSC STS Training Control Board will be responsible for STS-related training (Reference 6). Examples of STS-related training include Orbiter accommodations, life support systems, hatches, caution and warning systems and habitability, and emergency and contingency procedures.

The Life Science Experiments Program Office will have the overall responsibility for ensuring that the flight and ground crews are sufficiently trained in payload and experiment operations to (1) properly conduct all scheduled experiment-related operations, from prelaunch through postlanding, (2) obtain the desired scientific data from the experiments, (3) obtain increased data return in the event of advantageous unforseen opportunities, and (4) work around experiment contingencies. The Life Science Experiments Program Office will also see that sufficient experiment carrier vehicle information is imparted to experiment PI's to help them properly design, fabricate, test, and operate their experiments and to obtain the desired experimental data.

Several important lessons were learned from the SMS I and II and SMD III tests which are recommended for implementation into the mature Life Sciences Experiments Program. These are listed below:

A) PI-Provided Training - The principal investigators are in a unique position to efficiently provide crew training due to their in-depth understanding of the experiments. Having the PI's pass on the detailed techniques and operational procedures of their experiments directly to the crew eliminates special training personnel and can also reduce the training documentation required. However, assistance must be provided to PI's regarding course content, training schedule coordination, training aids and training documentation, and training verification.

B) Parallel Flight Control Team and Flight Crew Science Training - Auditing of selected sessions of PI-administered flight crew training by Shuttle and payload flight control teams develops improved understanding of in-flight operations, reduces integrated training requirements, and leads to improved real-time anomaly resolution.

C) Utilization of Flight Equipment for Crew Training - The use of actual flight experiment hardware whenever possible for crew training reduces costs, improves the fidelity of the training, and allows verification of documented experiment procedures.

4.1.6 LSP Personnel

A wide variety of personnel capabilities are required for Life Science Experiments Program implementation including management, engineering, and scientific specialties. Management determines overall program direction of resources, establishes policies, determines responsibilities, and monitors progress. Engineering specialists perform specific engineering tasks such as payload development and testing. Scientific specialists provide scientific guidance to other individuals on the program including PI assistance and coordination. PI's and NASA staff scientists form the backbone of the program in that they provide the Life Science experiments and provide scientific guidance for implementation and operation of the experiments.

4.2 LSP INTEGRATION FACILITY SURVEY AND IMPLEMENTATION PLAN - TASK 2

The Life Science Payload Integration Facility Survey was conducted to determine accommodations needed and those presently available for the development, test, integration, checkout, and flight support of Life Science Carry-on Labs, Minilabs (shared Spacelab payloads), and Dedicated Labs (Spacelab payloads in which all experiments aboard are in the discipline of Life Science). A summary of required NASA-JSC integration facility activities is presented in Figure 4-8.

Primary emphasis was placed on those integration and flight support activities to be conducted in NASA-JSC Building 36. However, additional JSC facilities identified as capable of providing direct support to Life Science Payload activities were also examined and documented.

4.2.1 Integration Facility Processing Requirements

Initial efforts of the LSP Integration Facility survey were conducted to determine the top level operations which must be conducted in the JSC Life Science Payload processing area. As a result, twelve major subfacilities composed of 30 lower level processing areas were identified. An assessment of the major facility characteristics and requirements of each of the 30 processing areas was made.

Summation of the individual processing area requirements indicated that primary integration and checkout activities would require 1,385 m^2 (14,900 ft^2) of which about 700 m^2 (7,500 ft^2) should be environmentally controlled to the class 100K cleanliness level. An overall area of slightly over 2,040 m^2 (22,000 ft^2) was projected for support laboratory activities of

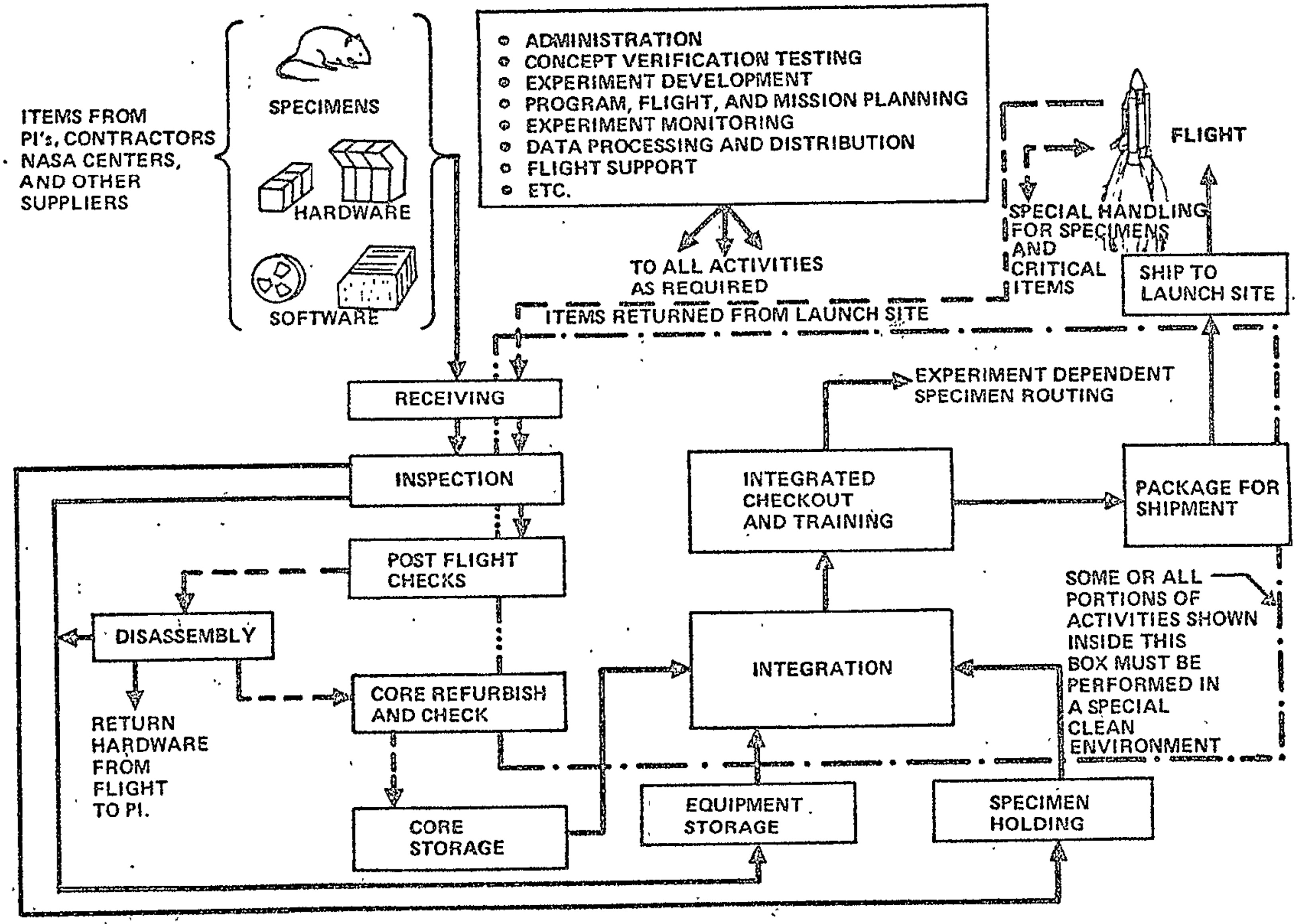


FIGURE 4-8 TOP LEVEL JSC LIFE SCIENCE EXPERIMENTS DEVELOPMENT FACILITY ACTIVITIES

the integration facility, and 420 m^2 (4,500 ft^2) were estimated as required for outside dock and storage activities. A total of 5,072 m^2 (54,600 ft^2) was estimated to be required for all Integration Facility activities.

In addition to facility space requirements, the support equipment requirements were also evaluated in the same survey phase. GSE items presently on NASA/ESA GSE listings (References 5 and 6) were reviewed for applicability to the Integration Facility operations, and 25 items whose capabilities corresponded with those necessary for LSP activities were identified. An additional list of 39 items was also prepared which specified items providing flight hardware support that NASA/ESA GSE items were not cost effectively capable of providing. Other support equipment required for use in the Integration Facility was also defined on an area by area basis. Preliminary rough order-of-magnitude (ROM) costs were estimated for these support equipment items and for the GSE items.

4.2.2 Survey of Existing JSC Facilities

A review was conducted to document the capabilities of existing JSC facilities and equipment having possible applicability to LSP processing. This effort defined the presently available nucleus about which LSP operations may be most economically implemented. The review documented the arrangement, floor space, door sizes, utility services, and existing support equipment available.

Building 36, considered the most favorable location for the majority of LSP processing operations, received the survey emphasis; however, two other buildings at JSC, identified as having applicable unique capabilities, were also examined. These additional sites included:

a) Building 8, found to have medical examination capabilities which will be useful in collecting baseline data from crewmembers and other test subjects.

b) Building 37, presently being reconfigured to provide a common site for most Life Sciences scientific laboratories. This capability will be required to support tests and analyses required by experiments during integration/test activities as well as during pre- and post-flight activities.

4.2.3 Development of Facility Concepts

Two plans were developed by which LSP Integration Facility activities may be cost effectively implemented at JSC. The first of the two designs is for an Integration Facility in which the Bioengineering and Test Support Facility (Building 36) is shared between Life Sciences and other disciplines. In this concept the Building 36 space assigned to LSP operations will approximate that presently assigned to Life Sciences. Floor space for PI and contractor office areas, equipment storage, and additional required functions must be made available in other JSC facilities.

The second design illustrates a configuration in which as many LSP functions as possible are co-located in Building 36. This concept will result in reduced transit time between activity sites for personnel, reduced equipment movement, and improved communications. However, it does require that Building 36 be dedicated only to operations associated with Life Science Payloads.

4.2.4 Recommended Facility Concepts and Implementation Approach

Current JSC facility accommodations are suitable for use as a Life Science Payloads Integration Facility with relatively minor modifications. Building 36, the Bioengineering and Test Support Facility, is well suited for use as either a shared payload processing facility or as a facility dedicated to operations involving only Life Science payloads. Operations involving receiving and shipping, integration, test and checkout, test monitoring and in-flight science support may be accomplished within the building for either mode of operation. Life Science laboratories, which are currently being centrally located into Building 37, should be capable of supporting the laboratory requirements of the Integration Facility, and crewmember and test subject medical examination support can be provided by existing accommodations in Building 8.

The dedicated Integration Facility concept was found to be capable of providing slightly more cost effective payload processing and of providing more flexibility in scheduling of operations when Life Science needs were considered independently from the requirements of other JSC disciplines. However, an overview of JSC center-wide payload processing requirements with an evaluation of the various possible tradeoff decisions should be conducted to indicate the most cost effective overall Integration Facility approach. Final selection of the shared or dedicated mode of operations should be made based on visibility of the total long range payload processing requirements to be conducted by all disciplines at JSC, and on projected resource availability at the center during the entire STS era. An effort of this magnitude was outside the scope of the contractual tasks described in this report.

It is recommended that the activities discussed below be accomplished to most effectively bring the Experiments Development Facility to operational status.

1) Conduct Make/Buy Analysis of GSE

   Investigations should be made and negotiations conducted with appropriate NASA/ESA contractor parties to determine cost and delivery dates for GSE items in the current Spacelab program inventory. Make/Buy decisions should then be made, based on development facility requirements and performance, cost and schedule data.

2) Perform Detail Requirements Definition and Conceptual Design Activities

   In-depth requirements definition and conceptual design activities should be initiated immediately to allow procurement of facility equipment to be initiated in early 1978.

3) Prepare Detailed ITE Usage Plans

Additional detailed studies of the use of ITE for cargo transport to the launch site should be conducted. These investigations should consider such areas as route selection of obstruction avoidance, state and local permit requirements, transport time estimates, support vehicle and personnel requirements, and ITE availability schedules.

4) Prepare Detailed Processing Plans

Event sequences to be accomplished in the various facility processing areas should be developed, and schedules for the accomplishment of these activities for early Life Science launches defined.

Particular emphasis should be placed on the development of plans for processing the Spacelab 1 payload and in coordinating these processing activities with in-progress facility modification and activation work.

These planning activities should be structured to develop methods to optimize the use of the existing and currently planned facilities and equipment and to smooth peaks and low points in facility activity levels.

4.3 LSP OPERATIONS REQUIREMENTS DOCUMENT - TASK 3

A substantial amount of information pertaining to the planned Space Shuttle Life Science Payloads (LSP) program has been prepared over the past four years as a result of NASA internal and contractual studies, and also as a result of various NASA working group activities. During Task 3 the output from these previous activities were consolidated in a single reference volume. Consolidation of this information will provide ready access to previously stated requirements without the time consuming search through information files which has been required in the past. Consolidation will also allow consistent Life Sciences responses regarding LSP Shuttle Spacelab payload requirements to inquiries made by NASA and ESA sources, contractors, and experiment PI's.

The requirements were presented on standardized worksheet formats similar to those which have been used in other NASA requirements documentation. The basic categories of requirements described on the worksheets include:

a) currently defined Life Science Payloads operational requirements,
b) currently documented interface information for several presently identified Life Science Payload configurations,
c) Life Science related Payload Control Center and Mission Control Center support requirements,
d) Life Science Payloads habitability requirements.

The requirement sheets have been arranged in an effort to provide rapid access to desired information. Each requirement worksheet has an identification number for identifying requirements according to category. Summary flow diagrams depicting operations flows are also provided to aid in locating desired requirements. Table 4-1 gives an example of a requirements worksheet.

4.4 LIFE SCIENCE SPACELAB MISSION DEVELOPMENT III EXPERIMENTER'S HANDBOOK - TASK 4

Preparation for implementation of Life Science Payloads has begun at NASA-JSC. The focal point of the effort conducted to date has been a series of Spacelab Mission Development (SMD) tests which have been conducted through May 1977. Three such tests, called Spacelab Mission Simulations, have been performed to date, the third, SMD III, was recently completed and the Experimenter's Handbook prepared in Task 4 was designed for this third test. These tests are being used to develop the management, engineering, and operational capability for handling Life Sciences Payloads, including experiment solicitation, evaluation and testing under simulated flight conditions. The SMD tests will benefit NASA through the development and verification of program resources, operational methods, and interfaces, and will aid experimenters by providing a test bed for the checkout of experiment apparatus, protocols, software, and procedures.

TABLE 4-1

LIFE SCIENCE PAYLOADS OPERATIONS REQUIREMENTS STATEMENT

Category: Specimen Operations   No.2.1.1.1(b)   Rev.: NEW

Mission Period: [ ] preflight   [ ] in-flight   [x] postflight

Date: 19 August 76   Requirements Level: [ ] II   [x] III

Title: ASCENT/DESCENT TV REQUIREMENTS

Originator: G. Wells

Originator's Organization: MDAC-H

Operational Task: Ascent/Descent Monitoring

Vehicle/System: Spacelab/CDMS

Reference Documentation for Requirement: Impact Statement attached to Memo DE5/6-76/5, dated 3 June 76 from G. McCollum to PM01/W. A. Emanuel, MSFC.

Requirement Description: Low frame rate TV will be required during ascent/descent. Real time transmission of this data to the ground has not been identified as a requirement.

Impact Source: Same

Impact If Requirement Not Implemented: Failure to provide the necessary ascent/descent services will have a severe detrimental effect to the planned Life Sciences payload program.

Coordination/Approval:

	initial	date		initial	date
DB			Steering Committee		
DE			SSPO		
			SPIDPO		

The SMD III Experimenter's Handbook provided a concise, easy to use handbook to convey SMD information to potential Life Science Principal Investigators (PI's) at academic, industrial, health research and NASA centers. The document was intended to be a reference source for LSP experimenters participating in the SMD program, and summarized the interface information needed by the PI's as well as outlining the inputs required from them (see Figure 4-9). Information is also included which summarizes the procedures which will be followed in conducting actual Shuttle missions.

4.5 SPECIMEN ACCOMMODATION SURVEY - TASK 5

This task investigated methods by which live specimens may be accommodated aboard Life Science Space Shuttle payloads. Emphasis was placed on the identification of practical, cost effective methods of accommodating various categories of research specimens. Every attempt was made to determine accommodation methods which could be efficiently integrated with existing Shuttle and Spacelab systems and which would limit physiological changes and stress in the specimens to a level comparable with that normally encountered in performing similar research in ground based laboratories.

The primary objectives of the work were:

- to determine and summarize the driving requirements for the care and housing of the live specimens types most utilized by experimenters,
- to review previously suggested payload models and select a realistic composite reference payload for the determination of specimen accommodation requirements,
- to develop candidate concepts to meet the specimen accommodation requirements of the reference payload,
- to select the preferred accommodation methods by means of trade studies and supporting analyses, based on available Shuttle and Orbiter capabilities.

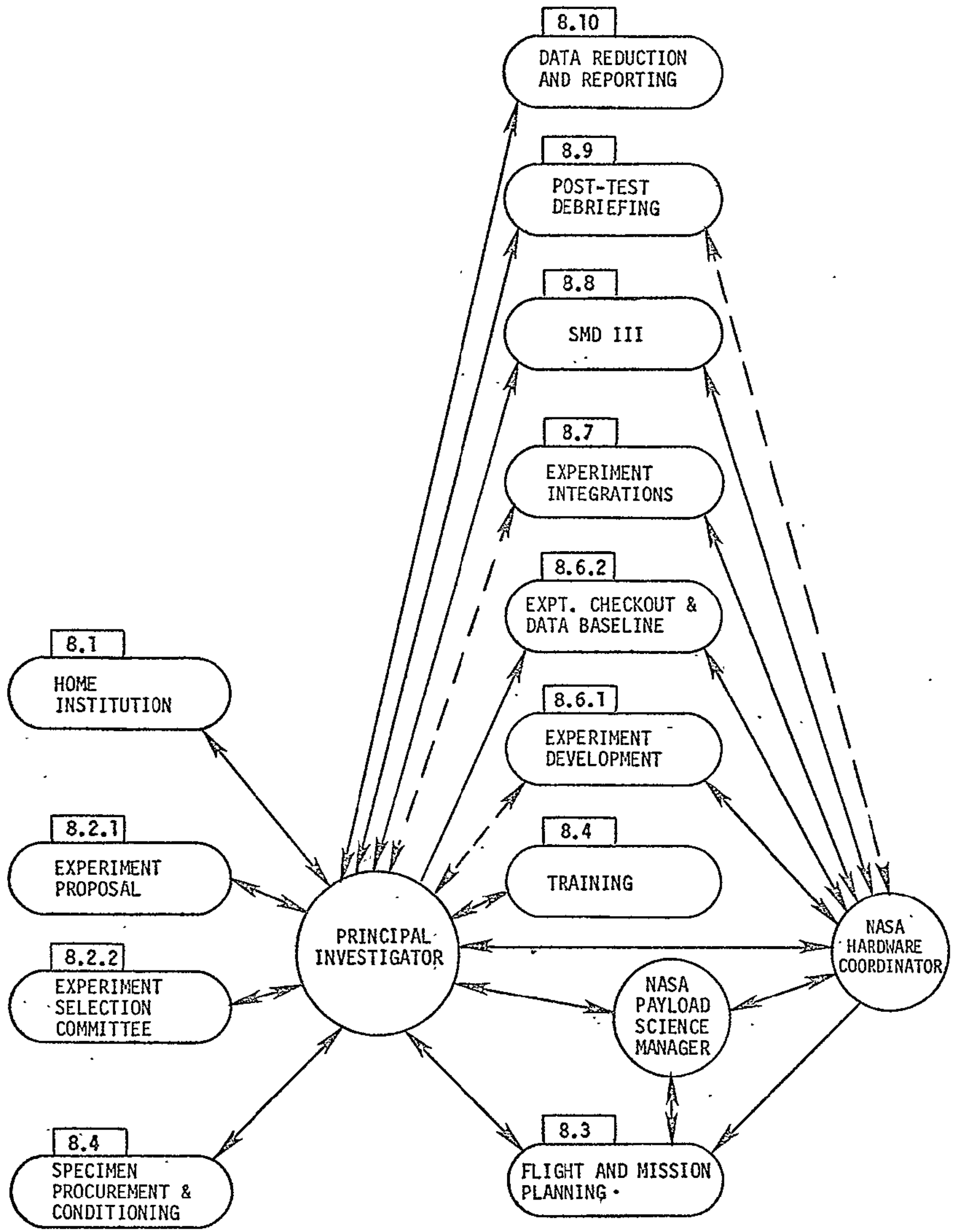


FIGURE 4-9 PI WORKING INTERFACES

The specimen accommodation survey described in this report addresses the provision of live specimens aboard Life Science Carry-on, Minilab, and Dedicated Lab Shuttle or Shuttle/Spacelab payloads. The investigations and analyses described cover the time period from installation of the specimens in the flight vehicle until the specimens are off-loaded on completion of the flight. These times may not coincide for all experiments, specimen types, or for various accommodation options involving a particular specimen. Survey emphasis was placed on the determination of preferred specimen loading, access, and unloading methods, the determination of methods to provide necessary power and cooling for Life Science Spacelab payloads, and the identification of methods by which the data handling needs of Life Science payloads may be provided.

The results of this study identify a serious deficit in Orbiter/Spacelab accommodations required to support Life Science Dedicated Laboratories if the present baseline methods of specimen storage and utilities allocation are maintained. As an example, 1350 watts maximum continuous electrical power is available to the Spacelab during Orbiter ascent and descent: the Spacelab requires 620 watts for mission independent equipment (EPDS, ECS) and 199 watts for the EPDS inverters; minimum experiment equipment including refrigerators/freezers in a powered down mode require 67 watts--leaving 464 watts of power to support the live specimens aboard the Spacelab. Based on "powered down" specimen holding units for the ascent and descent phases, only a limited quantity of live specimens can be accommodated. Representative specimen complements may include:

(a) Two primate units (1 primate per unit) and one each plant, cells/tissues, and invertebrate holding units, or
(b) One rodent unit (36 rats) and one each plant, cells/tissues, and invertebrate holding units, or
(c) One primate unit, 16 rodents and one each plant, cells/tissues, and invertebrate holding units (assumes rodent holding units of 16-rat capacity are available).

Other specimen combinations can be accommodated; however, all possible combinations using only 464 watts of power represent a dedicated Life Sciences mission with limited scientific return potential.

During flights with payloads using the aft flight deck (AFD) capability (up to 350 watts), the available power to the specimen holding units during ascent/descent could be reduced to114 watts.

The type and quantity of specimens selected to formulate the hypothetical reference payload for general LS operations planning represents a realistic complement of experiments that are sufficiently demanding on Orbiter/Spacelab payload supporting resources to provide a quasi upper boundary within which most future LS payloads could be accommodated. A maximum capacity LS laboratory scientific payload complement was not an objective of the study.

Based on the reference payload accommodation requirement relative to on-pad access, power, cooling and data, the payload accommodations across each major mission phase were deficient (with the exception of prelaunch access) if the live specimens are loaded in the Spacelab holding units for launch. The mission phases encompass prelaunch, ascent, on-orbit, descent and landing and post landing. Although loading and maintaining the specimens in the Spacelab is considered the baseline mode of operation, deficiencies in power range from 26 to 356 percent across the mission phases under the current power allocation. Cooling deficiencies can range from 16 to 355 percent across the mission phases. Special off-loading on the landing strip will be necessary to meet live specimen interactions requirement for those payloads investigating hormone responses to spaceflight. Data handling does not appear to be deficient based on currently defined LS payload requirements.

Alternatives for alleviating the accommodation deficiencies to payloads involves: (1) loading the live specimens in the Orbiter mid-deck for launch, ascent and descent/landing, (2) implementing and using the T-0 umbilical, (3) adding a fuel cell power system for on-orbit operation, and (4) off-loading the required specimens at the landing area prior to Orbiter tow.

Alternate concepts were developed should it be mandatory to retain the live specimens in the Spacelab holding units during all mission phases. Since additional power, cooling and GSE will be required, significant cost impact to the payload will be imposed for implementation of the alleviation methods. Essentially, for each mission phase an auxiliary power capability/subsystem and corresponding heat rejection capability were defined. The power subsystems included the T-0 umbilical for prelaunch, a storage battery kit for ascent and descent, an additional fuel cell unit for on-orbit operations, and removing the live specimens at the landing strip immediately after rollout. Cooling subsystems recommended to handle the additional heat developed by the power subsystem include increasing the Orbiter flash evaporator capability and adding a payload radiator kit.

Section 5

RECOMMENDATIONS

The in-depth LSP planning activities and critical special emphasis tasks accomplished during the study have identified several key recommendations which are key to LSP program readiness. These include the areas of 1) updating and expansion of LSP planning activities, 2) implementation of LSP Development Facility, 3) updating and revision of LSP Operations Requirements, 4) revision of SMD Experimenter's Handbook and integration into LSP Experimenter's Handbook and 5) implementation of LSP specimen accommodations.

5.1 UPDATING AND EXPANSION OF LSP PLANNING ACTIVITIES

The LSP Planning Study is one of numerous activities currently being carried out by NASA to prepare for the LSP Program in the Shuttle era. The LSP Planning Study relied heavily on the results of these related activities because it encompasses nearly all aspects of the LSP Program. Because of the dependent relationship of these various program activities, several iterations are necessary to arrive at the final program content.

The plans reported on in this document are second iteration plans based on an LSP operational program which is still somewhat in a state of flux. Many program aspects have not yet been finalized and NASA activities are underway to firm these aspects. It is of paramount importance to continually update and expand the LSP Operations Plan as additional information becomes available. The updated plans will give NASA the most realistic vision of the program for planning purposes and will also provide needed information to other LSP program elements to ensure compatibility.

5.2 IMPLEMENTATION OF LSP DEVELOPMENT FACILITY

The following recommendations for implementation are made as a result of the facility survey:

(a) The JSC Life Sciences Directorate should take necessary steps to insure that the required facility areas as indicated in this survey are made available for LSP processing in the Space Shuttle era.

(b) The selected Integration Facility design should be submitted to JSC Facilities Engineering personnel or to an Architectural and Engineering (A&E) consultant for more detailed facility modification design, costing and schedule information.

(c) Additional survey effort should be expended to determine the parametric impacts on Integration Facility requirements resulting from an altered Life Science traffic model.

(d) The top level subfacility requirements identified by this survey should be expanded to include an additional level of detail for all subfacilities. Particular emphasis is needed to define the Spacelab and Orbiter structural configurations and subsystems necessary to imitate the functions of flight hardware during test, training, interface verification and checkout.

(e) A make/buy cost effectiveness analysis should be performed for each item of NASA/ESA GSE applicable to Integration Facility activities. The specific capabilities of NASA/ESA GSE items should be compared to more detailed Integration Facility requirements than was possible within the scope of this survey. Particular emphasis should be placed on the characteristics of in-building transporters, dollies, and flight hardware handling equipment. For GSE components where a "make" decision is reached, preliminary design of long lead time and high complexity items should be initiated. Preliminary procurement actions should be initiated for "buy" category GSE.

5.3 UPDATING AND REVISION OF LSP OPERATIONS REQUIREMENTS

The purpose of Task 3 effort was to compile requirements from existing documentation without including requirements which require accommodations outside of the current Shuttle and Spacelab baselines. As these requirements are examined by NASA scientists and engineers, deletions and revisions to the LSP requirements are anticipated. Continuous revision and updating of the LSP Operations Requirements document is necessary so the document can effectively aid NASA inter- and intra-center payload development and design review activities.

5.4 REVISION OF SMD EXPERIMENTER'S HANDBOOK AND INTEGRATION INTO EXPERIMENTER'S HANDBOOK

The SMD III Experimenter's Handbook was designed primarily to direct potential PI's for the SMD III test. The format of this document was chosen to be conveniently converted into a User's Guide for the STS era. It would inform the PI in all major interfacing elements of the program. Examples include flight accommodation by STS and Spacelab, organizational interfaces, available facilities and resources, program procedures, experiment design requirements and reference documents. Much of the information included in the SMD User's Guide would be included in the STS User's Guide. The User's Guide would be structured to be largely applicable to other scientific disciplines, as well as to life sciences. One way of accomplishing this is to format the guide so that sections applicable to specific scientific disciplines could be removed and modified for the applicable discipline. Many sections will be general in nature and apply equally to any discipline.

5.5 IMPLEMENTATION OF LSP SPECIMEN ACCOMMODATIONS

The following recommendations are based on STS subsystems, Spacelab and LS payload information available in mid-1977 upon which the reference (strawman) LS payload/laboratory was developed.

- The NASA Life Sciences should consult with other payload disciplines to identify payload accommodation deficiencies and together take the necessary steps to ensure sufficient "utilities" are provided to conduct the quantity and quality of scientific experiments that will attract Shuttle users.

- Life Science experiments to be flown on early STS flights should be carefully selected to fall within the power and cooling limitations described in this report unless ancillary subsystems are provided.

- Storing live specimens in special transporters for early LS dedicated Spacelab missions should be considered in order to accommodate a complement of specimens attractive to potential STS users from both the scientific and economic aspects.

- Development of Spacelab mission dependent, CORE and unique LS experiment support equipment should strongly emphasize low power consumption designs. On-orbit experiment operations and procedures should also stress power conservation.

- The Shuttle payload disciplines should be strongly represented in all projects and meetings addressing Orbiter and/or Spacelab power allocation to payloads. The payload power allocation has been significantly reduced over the past 2 years.

- An auxiliary power and cooling module with corresponding heat rejection for mounting in the payload bay (or extendible) should be provided as a CORE item. The capacity should be 4 kilowatts minimum to satisfy present and future payload requirements.

- Ground support equipment (GSE) should be developed to allow removal of LS live specimens at the landing area for immediate transport to a ground laboratory.

- Additional study should be conducted as LS payload requirements are better defined and CORE designed in order to determine impacts on specimen quantities that can be carried, and to scope ancillary power and cooling subsystem requirements.

Section 6

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