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SD 71-217-3

MODULAR

space station

PHASE B EXTENSION

PRELIMINARY SYSTEM DESIGN

Volume III: Experiment Analyses

PREPARED BY PROGRAM ENGINEERING
JANUARY 1972

Space Division
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TECHNICAL REPORT INDEX/ABSTRACT

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MODULAR SPACE STATION PRELIMINARY SYSTEMS DESIGN REPORT, VOLUME III: EXPERIMENT ANALYSES

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ABSTRACT

EXPERIMENT ANALYSIS TASKS PERFORMED DURING NR'S MODULAR SPACE STATION (MSS) PHASE B PROGRAM DEFINITION STUDY ARE DESCRIBED IN THIS VOLUME. IN THESE ANALYSES, NR WAS ASSISTED BY THE SPACE DIVISION OF GENERAL ELECTRIC COMPANY. GE PROVIDED EXPERIMENT REQUIREMENTS DATA AND CONTRIBUTED GUIDELINES AND CRITERIA FOR THE EXPERIMENT SELECTION AND PHASING ACTIVITIES. IN ADDITION, GE CONDUCTED ONE OF THE SUPPLEMENTAL STUDIES REPORTED HEREIN (DATA USER REQUIREMENTS, SUBSECTION 7.1).

NR'S ROLE ENCOMPASSED EXPERIMENT ACCOMMODATION AND SCHEDULING, AND INCLUDED DEFINING AND IMPLEMENTING THE LABORATORY EVOLUTION APPROACH DESCRIBED IN SECTION 3. NR ALSO DEFINED GENERAL-PURPOSE LABORATORY (GPL) REQUIREMENTS AND CONCEPTS AND CONDUCTED THE OTHER SUPPLEMENTAL STUDIES. NR AND GE JOINTLY ANALYZED 1971 BLUE BOOK EXPERIMENT REQUIREMENTS BEFORE THEY WERE INTRODUCED INTO THE MAINSTREAM OF STUDY ACTIVITY.

FOREWORD

This document is one of a series required by Contract NAS9-9953, Exhibit C, Statement of Work for Phase B Extension-Modular Space Station Program Definition. It has been prepared by the Space Division, North American Rockwell Corporation, and is submitted to the National Aeronautics and Space Administration's Manned Spacecraft Center, Houston, Texas, in accordance with the requirements of Data Requirements List (DRL) MSC-T-575, Line Item 68.

Total documentation products of the extension period are listed in the following chart in categories that indicate their purpose and relationship to the program.

ADMINISTRATIVE REPORTS	TECHNICAL REPORTS		STUDY PROGRAMMATIC REPORTS	DOCUMENTATION FOR PHASES C AND D	
				SPECIFICATIONS	PLANNING DATA
EXTENSION PERIOD STUDY PLAN DRL-62 DRD MA-207T SD 71-201	MSS PRELIMINARY SYSTEM DESIGN DRL-68 DRD SE-371T SD 71-217	MSS DRAWINGS DRL-67 DRD SE-370T SD 71-216	EXTENSION PERIOD EXECUTIVE SUMMARY DRL-65 DRD MA-012 SD 71-214	MSS PRELIMINARY PERFORMANCE SPECIFICATIONS DRL-66 DRD SE-369T SD 71-215	MSS PROGRAM MASTER PLAN DRL-76 DRD MA-209T SD 71-225
QUARTERLY PROGRESS REPORTS DRL-64 DRD MA-208T SD 71-213, -235, -576	MSS MASS PROPERTIES DRL-69 DRD SE-372T SD 71-218, -219	MSS MOCKUP REVIEW AND EVALUATION DRL-70 DRD SE-373T SD 71-220			MSS PROGRAM COST AND SCHEDULE ESTIMATES DRL-77 DRD MA-013(REV. A) SD 71-226
FINANCIAL MANAGEMENT REPORTS DRL-63 DRD MF-004	MSS INTEGRATED GROUND OPERATIONS DRL-73 DRD SE-376T SD 71-222	MSS KSC LAUNCH SITE SUPPORT DEFINITION DRL-61 DRD AL-005T SD 71-211			MSS PROGRAM OPERATIONS PLAN DRL-74 DRD SE-377T SD 71-223
	MSS SHUTTLE INTERFACE REQUIREMENTS DRL-71 DRD SE-374T SD 71-221	INFORMATION MANAGEMENT ADVANCED DEVELOPMENT DRL-72 DRD SE-375T SD 72-11			
	MSS SAFETY ANALYSIS DRL-75 DRD SA-032T SD 71-224				

This document is Volume III of the Modular Space Station Preliminary System Design Report, which has been prepared in the following seven volumes:

I	Summary	SD 71-217-1
II	Operations and Crew Analysis	SD 71-217-2
III	Experiment Analyses	SD 71-217-3
IV	Subsystem Analyses	SD 71-217-4
V	Configuration Analyses	SD 71-217-5
VI	Trades and Analyses	SD 71-217-6
VII	Ancillary Studies	SD 71-217-7

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1. INTRODUCTION

Experiment analysis tasks performed during NR's Modular Space Station (MSS) Phase B Program Definition study are described in this volume. In these analyses, NR was assisted by the Space Division of General Electric Company. GE provided experiment requirements data and contributed guidelines and criteria for the experiment selection and phasing activities. In addition, GE conducted one of the supplemental studies reported herein (Data User Requirements, Subsection 7.1).

NR's role encompassed experiment accommodation and scheduling, and included defining and implementing the laboratory evolution approach described in Section 3. NR also defined General-Purpose Laboratory (GPL) requirements and concepts and conducted the other supplemental studies. NR and GE jointly analyzed 1971 Blue Book experiment requirements before they were introduced into the mainstream of study activity.

1.1 OBJECTIVES

The objectives for the MSS experiment analysis tasks were as follows:

1. To translate into engineering terms the experiment requirements expressed in the NASA Blue Book.
2. To assure that the MSS preliminary design reflects the implementation of these requirements in a cost-effective manner.
3. To support the preparation of other program definition products such as the mission sequence plan, the sortie mission analysis, and cost and schedule estimates.
4. To perform a preliminary design of the General-Purpose Laboratory and its equipment.

1.2 OVERALL APPROACH

Two phases of analysis were required by the introduction of the revised NASA Blue Book (NHB 7150.1), which became available in February 1971. The effort required to assimilate the data it contains was completed in May 1971. Since by this time the contract schedule required significant progress in the definition of the MSS concept, several analyses were performed using experiment requirements data from the 1969 Blue Book. For example, MSS subsystem support requirements for experiments were established using these data. Later, an analysis of 1971 Blue Book data was performed to establish the validity of these requirements. In all cases, it was determined that no significant revision of MSS experiment support capabilities was required. However, in a few cases, it was necessary to devise alternate techniques to accommodate experiment requirements. The major activities of the MSS experiment analysis are illustrated in Figure 1-1.

The requirements analysis activity consisted of compiling (and revising, where necessary, with NASA concurrence) Blue Book experiment requirements into a format that could be used by subsystem engineers, designers, and operations analysts. The experiment selection and phasing analysis produced a time-phased set of on-orbit experiment performance capabilities

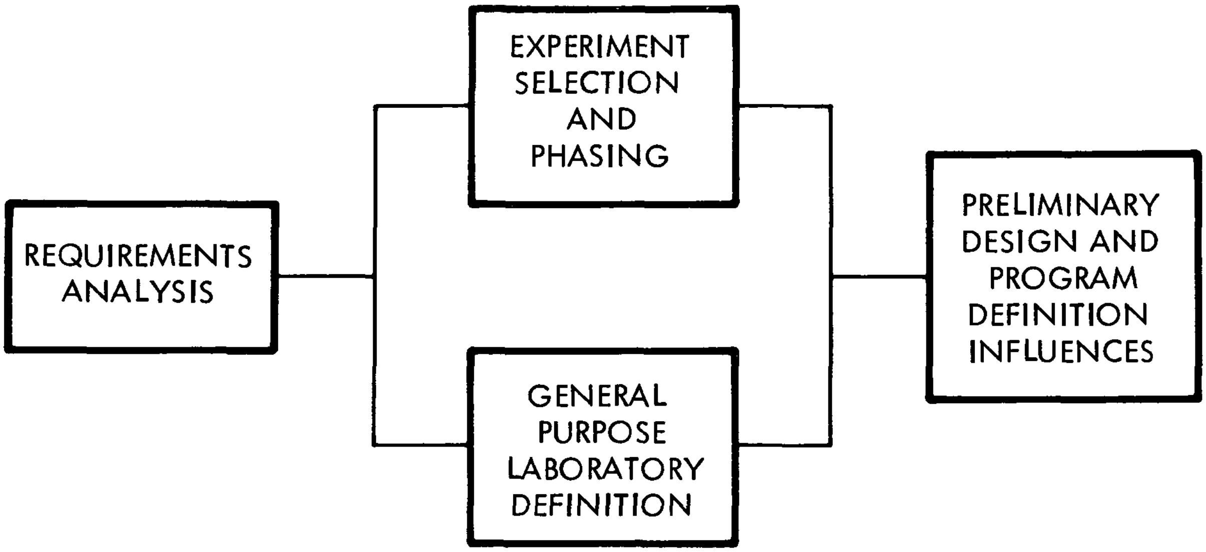


Figure 1-1. MSS Experiment Analysis

(and their associated support requirements) consistent with the evolving nature of the space station program. In parallel with this, a General-Purpose Laboratory was defined that provides general support to experiments and areas for the installation of experiment equipment. Finally, all of these activities were focused into the identification of "final" requirements to be implemented in preliminary design and program definition (mission sequence plan, costs, and schedules) activities.

In addition, supplemental studies were performed when NR required additional insight into specific aspects of the experiments and their implementation, such as data analysis and sensor fields of view.

Because the modular space station evolves in capability from its initial phase to its growth phase, an evolutionary approach was adopted for experiment requirements. The approach used by NR in defining evolving experiment laboratories is summarized later in this section and discussed in detail in Section 3. This approach was adopted as an alternative to reducing the variety of experiment activities that could be accommodated on the initial space station. This laboratory-evolution approach to experiment accommodation and the definition of requirements and concepts for a General-Purpose Laboratory mark the most significant differences between the experiment analysis activity and previous efforts.

1.3 SOURCE DATA

The primary source document for MSS experiment analyses is NASA document NHB 7150.1, Preliminary Edition of Reference Earth Orbital Research and Applications Investigations (Blue Book). The Blue Book is organized by discipline into eight volumes, as follows:

Volume I	Summary
Volume II	Astronomy
Volume III	Physics
Volume IV	Earth Observations
Volume V	Communications/Navigation
Volume VI	Materials Science and Manufacturing
Volume VII	Technology
Volume VIII	Life Sciences

Each of these volumes is divided into one or more sections, each describing a functional program element (FPE). An FPE consists of a group of research and applications investigations (experiments) related by common objectives and/or by common requirements. In the Blue Book, each FPE is defined physically, with descriptions of typical equipment that would be provided in a laboratory designed to accomplish designated FPE goals and objectives. Descriptions are then provided for a set of experiments that typically would be conducted in such a laboratory using the equipment provided.

1.4 SUMMARY

This section summarizes each of the major sections in this volume. The summary follows the organization of the volume, with preliminary analyses discussed first, followed by separate sections on each major analysis conducted after the introduction of 1971 Blue Book data. The last section, 7, summarizes the results of supplemental studies.

1.4.1 PRELIMINARY ANALYSIS SUMMARY (Section 2)

This phase of the study began with the results of the Modular Space Station Phase A study and concluded with the introduction of the 1971 Blue Book into the mainstream study effort. The major tasks conducted during this phase were the program emphasis sensitivity analysis and the analysis of the 1971 Blue Book data. Preliminary GPL requirements were also defined during this phase, but the discussion of the GPL has been confined to Section 3 and is not included in Section 2.

The program emphasis sensitivity study had as its objective the determination of the sensitivity of the modular space station concept (subsystems, configuration, etc.) to changes in the type of experiment program conducted. Three experiment program types were formulated. These programs were defined as follows:

Program A	Emphasizes early socioeconomic benefit (applications)
Program B	Emphasizes early high-priority science
Program C	Emphasizes most significant activity from both applications and scientific disciplines ("balanced" program)

Three program schedules were prepared (one for each program type), and station resource requirement profiles were prepared. In addition, system requirements such as attitude stabilization and permissible contamination levels were estimated. The major conclusion resulting from a comparison of these programs was that the station concept is relatively insensitive to experiment program emphasis. Thus, no further sensitivity analyses were performed, and it was decided to proceed with a single experiment program when the 1971 Blue Book data were incorporated. With NASA concurrence, a balanced program was selected.

Before 1971 Blue Book data could be introduced into the study, it was necessary to gain an understanding of its impact on the mainstream effort that had already taken place. Would subsystem concepts require major revision? How many RAM's would be required? Questions such as these had to be answered before an approach could be formulated to accomplish the desired objective, which was total replacement of 1969 Blue Book data by 1971 Blue Book data. An initial quick-look comparison was conducted and presented to NASA in late February 1971. This comparison uncovered several potential major impacts on previous study efforts. A detailed analysis of these potential impacts resulted in definitions of solutions that maintained the validity of most previous study results. These solutions were coordinated with NASA in early May 1971.

1.4.2 LABORATORY DEFINITIONS AND REQUIREMENTS SUMMARY (Section 3)

In NR's approach, MSS laboratories were defined that evolve in capability through two or more discrete levels. One laboratory was defined for each FPE, except in the life sciences discipline, where four FPE's (LS-2, 3, 4, 5) were accommodated by one laboratory. This resulted from the high level of commonality that exists among the equipment items required to perform the typical experiments of those FPE's.

From the total set of objectives assigned to each FPE in the Blue Book, subsets were selected for accomplishment at each capability level. From the total set of FPE experiments included in the Blue Book, a subset was selected that is consistent with each subset of objectives. The equipment items that are required to perform the selected experiments were then identified.

A set of integrated requirements was defined for each laboratory at each implementation level. These requirements reflect the influence of both the evolution in laboratory capability and the results of the requirements impact analysis.

The laboratory definitions and requirements that resulted from this analysis were used as inputs to the experiment scheduling activity.

Each of the experiment laboratories (at each level) is described in Section 3 in terms of objectives, selected experiments, equipment, operational concept, and support requirements. In general, Level I laboratories are aimed at accommodating shuttle sortie missions. Levels II and III laboratories are accommodated on the modular space station GPL or in attached or detached (free-flying) RAM's.

In order to complete the definition of MSS experiment support capabilities, a General-Purpose Laboratory was defined. This laboratory provides equipment that performs a variety of functions common to several FPE's. Included in the GPL are equipment items that provide the capability to perform, for example, data analysis, photographic processing, mechanical, electrical, and optical maintenance, and selected physical science and life science functions. In addition, the nadir-oriented and zenith-oriented airlocks are included in the GPL, as is all MSS volume provided for the accommodation of experiment-peculiar (i.e., Government-furnished) equipment.

The GPL was defined by first identifying its functional requirements, then defining the equipment required to perform these functions. Volume requirements for the GPL were determined, and conceptual sketches and a preliminary performance specification prepared. These analyses and products are described in Section 3.

1.4.3 EXPERIMENT MODE OF ACCOMMODATION SUMMARY (Section 4)

This analysis resulted in the assignment of recommended accommodation modes for each experiment defined in the 1971 Blue Book. These recommendations were used in establishing the accommodation mode for each experiment laboratory. Modes considered were as follows:

- GPL - General-Purpose Laboratory (corresponds to integral mode of previous studies)
- FF RAM - free-flying research and applications module (corresponds to detached mode of previous studies)
- Attached RAM - RAM that operates while docked to the MSS (corresponds to attached mode of previous studies)

The number of experiments considered (145) made a qualitative analysis necessary. The factors that led to each recommended mode are presented herein. Of the 145 experiments, 34 were recommended for the FF RAM mode, driven by contamination control, stabilization, and acceleration control requirements. Of the remainder, 29 were recommended for the attached RAM mode. For those recommended for GPL accommodation, airlock requirements were identified.

1.4.4 EXPERIMENT SELECTION AND PHASING ANALYSIS SUMMARY (Section 5)

The objective of this analysis was to provide guidelines for the preparation of the reference experiment program described in Section 6. Since not all experiment laboratories can be accommodated within the five-year initial MSS time frame (even after capability evolution is introduced), it was necessary to order the laboratories based on priority. These laboratory priorities were established by first classifying the typical experiments in the 1971 Blue Book according to (1) the nature of the objectives accomplished (i. e., whether of an applied or nonapplied nature), and (2) the intrinsic value of the experiments in satisfying important disciplinary goals. These experiment classifications and their resultant priorities are presented in Section 5, as are additional constraints that should be obeyed in the scheduling process.

High-priority experiments include those in earth observations, solar astronomy, and biomedical research. Experiments in advanced technology were generally given a low priority as a result of the particular program emphasis selected (i. e., "balanced socioeconomic benefit and scientific return").

1.4.5 EXPERIMENT SCHEDULING SUMMARY (Section 6)

Section 6 is a summary of the more detailed discussion of experiment scheduling contained in Volume II, Operations and Crew Analysis, SD 71-217-2. The major inputs to the scheduling activity were the experiment priorities and scheduling constraints (Section 5) and the laboratory requirements (Section 3) as well as scheduling ground rules based on MSS capabilities. Of the latter, the most significant was the manpower limitation of 35 man-hours per day for the initial MSS.

Based on the priorities and constraints provided for experiments, a preferred sequence of laboratories was prepared. Then, applying ground rules such as the manpower limit, a laboratory schedule was prepared. The resultant Reference Experiment Program (REP) has a duration of slightly more than 15 years. In general, this program accomplished one cycle of each laboratory at each level, with cycle durations specified in Section 3. A preliminary REP that provided the number of cycles required to accomplish fully Blue Book goals and objectives required 35 years.

The REP implements the laboratory evolution approach, with Level II labs replaced by Level III labs after growth station IOC. A cost comparison with an all-level III program shows that the evolutionary approach defers peak annual funding for experiments by five years (well beyond the station funding peak). Since the experiment funding peak is $500 million per year, this accomplishes a significant smoothing of program cost requirements.

1.4.6 SUPPLEMENTAL EXPERIMENTS STUDIES SUMMARY (Section 7)

Several studies were performed in order to gain additional insight into specific areas of experiment requirements. The most significant of these, data user requirements, multispectral scanner mechanization, experiment field-of-view requirements, and airlock requirements, are presented in Section 7 and summarized here.

The data user requirements study resulted in a detailed estimate of the types of data that would be generated from typical experiments in the earth observations discipline, the typical sensor equipment involved, and the operations of the typical data transmission processes. The study results also include data requirements of the on-board user, i.e., aboard the MSS. Also noted is the crewman's involvement in data acquisition and data transmission operations and procedures. Finally, the ground user data requirements are analyzed, with data displays and data processing requirements identified. Typical ultimate users are also indicated.

In the multispectral scanner mechanization study, an alternate means was devised to accommodate high data-rate sensors such as the multispectral scanner of the earth observations discipline. Several alternate data acquisition/storage processing modes are described, showing the interactions among the space station information subsystem, the multispectral scanner, and the on-board investigator.

In the experiments field-of-view requirements study, the earth observations discipline was investigated in more detail. The field-of-view requirements of the various earth observations sensors were analyzed in order to gain insight into potential arrangements and deployment requirements. Sketches were prepared showing relative location of the sensors to achieve full field-of-view requirements.

The airlock requirements study resulted in the definition of the airlock size for modular space station preliminary design. There are two airlocks, one nadir-oriented and one zenith-oriented (when the station maintains the local vertical flight mode), sized to permit installation and deployment of experiment equipment.

2. PRELIMINARY ANALYSIS

This section contains brief discussions of two tasks that were performed before the introduction of 1971 Blue Book data into the mainstream study effort. These two tasks are the program emphasis sensitivity analysis and the 1971 Blue Book data analysis.

2.1 PROGRAM EMPHASIS SENSITIVITY ANALYSIS

The objective of this analysis was to determine the sensitivity of the MSS concept to changes in experiment program emphasis. The study used experiment requirements data from the 1969 Blue Book, but the major conclusion of the study—that the station concept is insensitive to program emphasis—is valid for 1971 Blue Book requirements as well. Since the requirements data are outdated, they are not presented in detail; this discussion concentrates on methodology and results.

The sensitivity analysis approach is illustrated in Figure 2-1. Three experiment program types were postulated. These were defined as follows:

> Program A - gives high priority to investigations leading to early socioeconomic benefits (for example, earth observations, biomedical research, materials science)
>
> Program B - gives high priority to investigations that are scientific in nature (for example, solar and stellar astronomy, animal and plant biology, high-energy astronomy)
>
> Program C - emphasizes the most important investigations from all disciplines (basic and applied science, with both earth observations and astronomy conducted early)

An experiment scheduling rationale was devised that resulted in three experiment schedules (one for each program type). The resource requirements (logistics, electrical power, etc.) of these programs were evaluated, as were design requirements (such as General-Purpose Laboratory floor space) and operational requirements (e.g., contamination control, attitude modes, and stabilization). These requirements were then compared to see if there were any significant differences among the three program types in terms of impact on the MSS concept.

The experiment scheduling approach employed in this study is illustrated in Figure 2-2. Each of the experiments was placed in one of four primary benefit categories: Category I for experiments emphasizing direct socioeconomic benefits; Category II for experiments providing primarily scientific benefits, which are earth- or applications-oriented; Category III for high-priority scientific experiments, which are basic rather than applied and Category IV for experiments providing general knowledge for such things as advanced subsystem development.

In parallel, each experiment was evaluated for its basic "worth." The worth rating indicated the relative importance, on a scale of 1 through 5, of the experiment in accomplishing significant goals within its discipline.

A set of selection priorities was then established for each program type. For example, since Program A gives high priority to experiments providing socioeconomic benefits, Category I experiments with high-worth ratings (5) have the highest priority. Category III worth-5 experiments have the highest priority in Program B, and in Program C worth-5 experiments have high priority regardless of benefit category.

The experiment benefit category and worth data were fed through the program priority filter, and experiment priorities for the three program types were defined. Experiment priority is thus an indication of the relative importance of each experiment within each program.

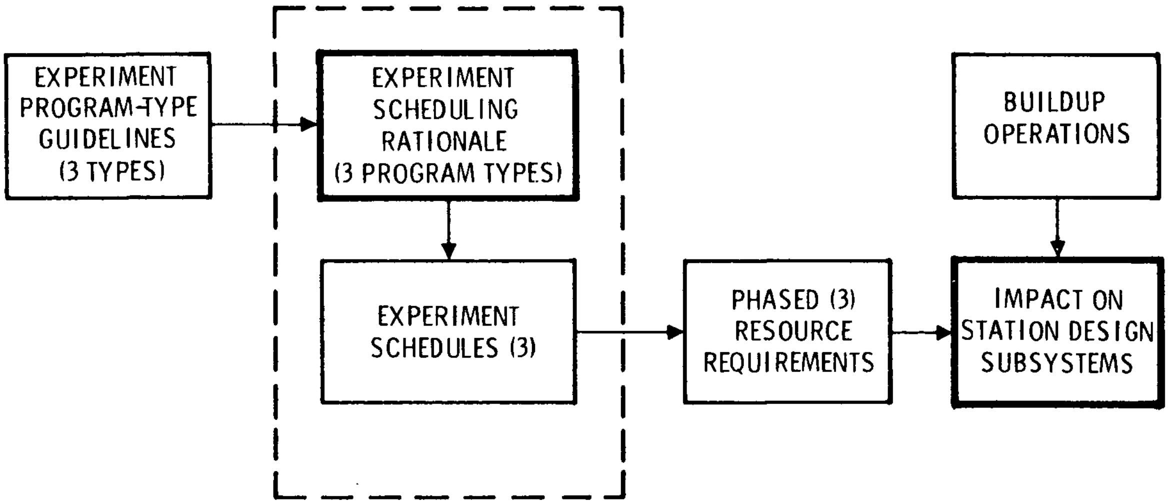
Before these experiment implementation priorities could be translated into program schedules, experiment phasing interrelationships and constraints had to be defined. These constraints were established by considering such factors as:

1. Precursor Nature of the Experiment. Precursors are those experiments that should be conducted before another experiment in order to enhance the results of the supported experiment. Examples include contamination and spacecraft environment evaluation as well as crew performance evaluation.

2. Concurrency Requirements. Certain experiments should be conducted concurrently with others because of equipment commonality or related objectives.

3. Availability Dates. The earliest projected launch dates for an experiment must be considered as a major constraint.

Combining experiment priorities with experiment phasing interrelationships and constraint results in preferred experiment sequences for each



OBJECTIVE:
DETERMINE SENSITIVITY OF STATION DESIGN & SUBSYSTEMS TO CHANGES IN EXPERIMENT PROGRAM EMPHASIS.

Figure 2-1. Sensitivity Analysis

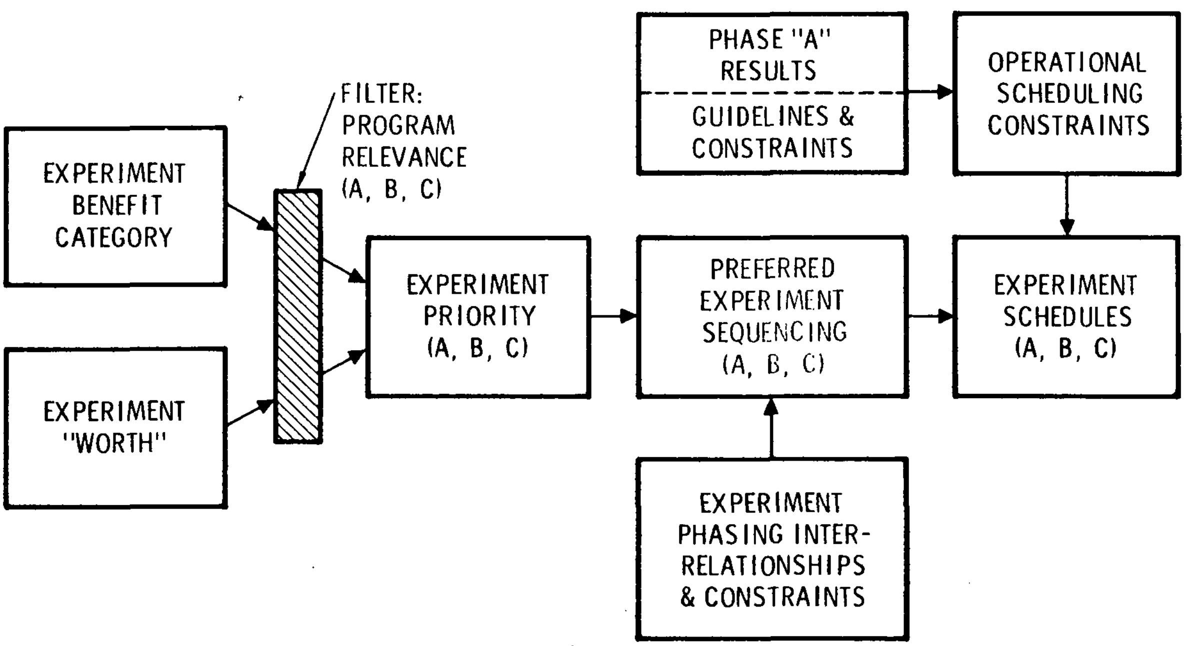


Figure 2-2. Experiment Scheduling Rationale (Sensitivity Analysis)

program. Combining these sequences with programmatic scheduling constraints resulted in the three program schedules. Programmatic scheduling constraints used in the analysis were as follows:

1. Available crew man-hours for experiments

   Initial MSS: 35 man-hours per day
   Growth MSS: 80 man-hours per day

2. Number of RAM's simultaneously supported by the MSS

   Initial MSS: 2 attached or detached
   Growth MSS: 3 attached and 3 detached

From the schedules, resource profiles were determined. An example is shown in Figure 2-3. Here average power requirements for the three programs are shown as a function of program year. It can be seen that the highest values for each program are very similar, as are the shapes of the curves. Thus, there are no significant differences among the programs in terms of electrical power requirements. Similar profiles were prepared for data, logistics, and laboratory floor space. In addition, demands on the MSS for contamination control and stabilization were evaluated. The results of these comparisons are summarized in Figure 2-4.

Stabilization and contamination control requirements are similar for all three programs because, whereas in Program A (socioeconomic benefit) earth surveys are scheduled early, Program B (scientific benefits) has astronomy observations in the attached mode scheduled early. Program C (balanced) has both earth observations and astronomy scheduled relatively early.

Other influences which, in retrospect, led to few significant differences among programs included the scheduling constraints which tended to require certain precursor experiments early, regardless of program emphasis. In addition, earth observations experiments, which are both high electrical power consumers and large data generators, tended to appear early in all programs due to their dual role in providing socioeconomic benefits and scientific return (the latter in, for example, atmospheric physics and geology).

GPL floor space requirements also did not vary significantly from program type to program type. The range of values was 800 to 1000 square feet (for the initial MSS). The reason for this small variation is that the GPL was designed to be relatively insensitive to program emphasis by stressing commonality in the selection of functions to be accommodated. The variation, then, arises only in the free floor space devoted to experimenter-provided equipment, not in the basic support equipment.

In conclusion, it appears that, at the system level, the MSS should be basically the same regardless of the type of program it supports. There is no particular advantage in deferring capabilities of the basic station (but there are program cost advantages in deferring certain costly experiments—see Section 6), since a lower capability level would degrade all experiment program types equally.

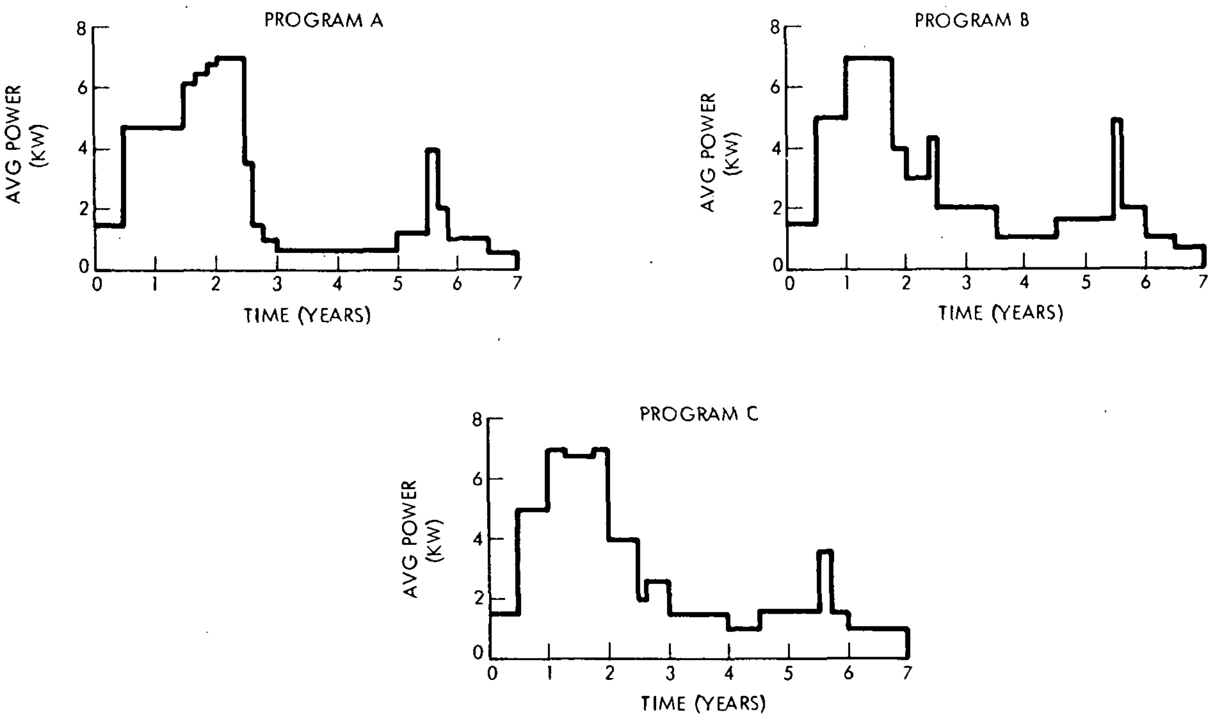


Figure 2-3. Electrical Power Requirements (Experiments Only)

IMPACT AREA	PROGRAM A	PROGRAM B	PROGRAM C
ELECTRICAL POWER DEMAND	6.8 KW	6.9 KW	6.8 KW
STABILITY	NO SIGNIFICANT DIFFERENCES		
LOGISTICS	9300 LB/MO	9600 LB/MO	8700 LB/MO
CONTAMINATION	NO SIGNIFICANT DIFFERENCES		
DATA	4.7 MBPS	4.7 MBPS	4.7 MBPS

PRELIMINARY CONCLUSION:

STATION DESIGN & SUBSYSTEMS CONCEPTS RELATIVELY INSENSITIVE TO EXPERIMENT PROGRAM EMPHASIS.

Figure 2-4. Sensitivity Analysis (Impact-Assessment Summary)

2.2 1971 BLUE BOOK DATA ANALYSIS

The approach used in this analysis is illustrated in Figure 2-5. The MSS capability model defined during the Phase A definition study was compared to requirements resulting from a preliminary review of the 1971 Blue Book. Any 1971 Blue Book requirement that could not be accommodated by this previously defined capability model was examined in more detail. The objective of this analysis was to see if some simple procedure (such as time-sharing) could resolve the incompatibility. If this was not possible, two alternatives were considered. As shown, these were (1) revise the MSS capability, or (2) devise an alternate means of implementing the experiment.

In general, it was not considered desirable to revise MSS capability upward due to the increase in MSS cost estimates this would cause. However, alternate implementation schemes had to satisfy the requirement that they cause no significant reduction in experiment accomplishment.

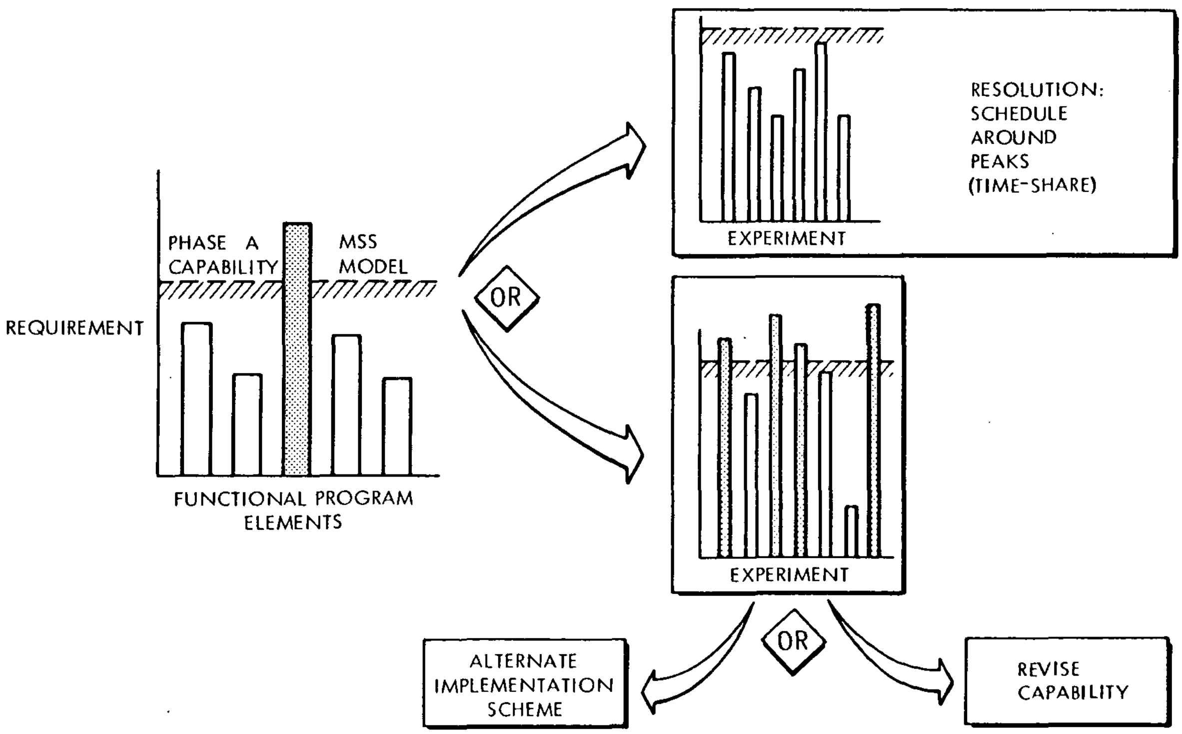


Figure 2-5. Blue Book Data Analysis

An overview of 1971 Blue Book requirements by discipline is shown in Figure 2-6. The discipline letter code along the abscissa of each graph is defined as follows:

A - Astronomy
P - Physics
ES - Earth Observations
C/N - Communications/Navigation
MS - Materials Science and Manufacturing
T - Technology
LS - Life Sciences

The requirements shown are the totals for all the FPE's within the disciplines shown, except for pointing stability where the worst-case requirements are shown, since for this parameter, time-sharing is not a feasible alternative. Crew time requirements for earth observations are not explicitly stated in the 1971 Blue Book and are thus not shown. They were estimated in later analyses (Section 3).

Requirements which, at this level, exceed MSS capabilities are indicated with arrows. Note that some disciplines contain only one FPE (namely earth observations, communications/navigation, and material science).

Each type of requirement shown in Figure 2-6 is discussed in the following paragraphs.

2.2.1 ELECTRICAL POWER

The electrical power requirements for the individual technology FPE's are shown in Figure 2-7A. One FPE, T.4 (advanced spacecraft systems test) exceeds the initial MSS capability of 4.5 kilowatts. A plot of the power requirements of the 12 experiments within this FPE reveals that no single experiment exceeds the 4.5-kilowatt level (Figure 2-7B). Thus, time-sharing solves this potential problem.

In a similar manner, power peaks in materials science can be scheduled—the maximum experiment requirement in this discipline is 3.2 kilowatts.

2.2.2 WEIGHT

If the capability of the shuttle to bring a payload to the space station orbit is exceeded, weight is a driver. This capability is 20,000 pounds, total, but from this 8000 pounds must be subtracted to account for cargo module or RAM structure and subsystems.

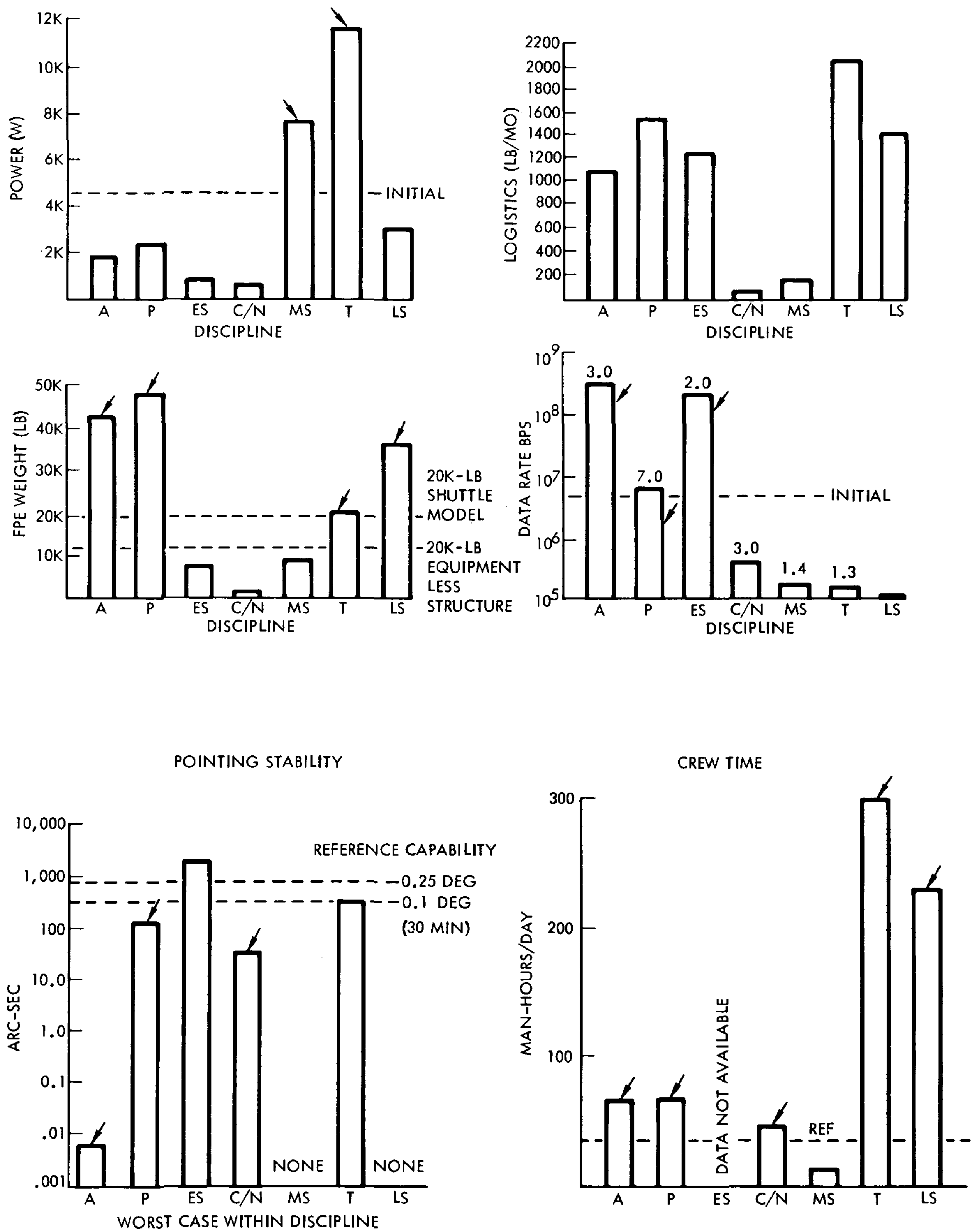


Figure 2-6. Requirement Drivers by Discipline

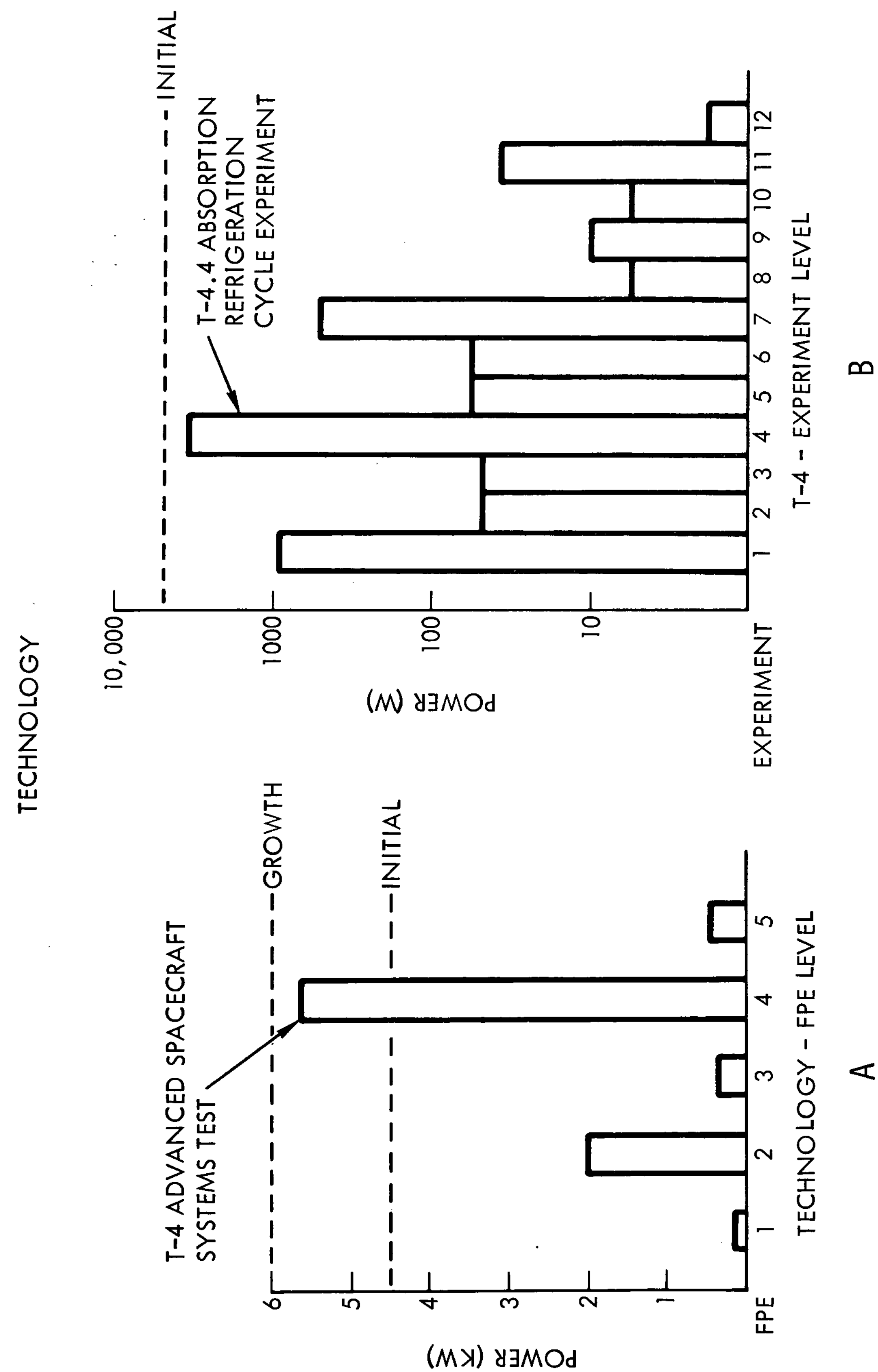


Figure 2-7. Electrical Power Driver

At the FPE level, astronomy and technology each have one FPE that exceeds the capability model (Figure 2-8). Since both of these FPE's are to be housed in free-flying RAM's, it was assumed that later definitions of either the RAM or the experiment equipment would bring the weights within limits.

The situation in physics is different. Figure 2-9 reveals that the weight of the Cosmic Ray Physics Lab (FPE P-3) greatly exceeds shuttle capability. This is due to the total absorption device (TAD) that is required for three of the five defined experiments. This device must be assembed in orbit and will require multiple launches.

Since no life sciences FPE exceeds 8000 pounds, there is no major driver within this discipline.

2.2.3 LOGISTICS

No monthly logistics requirement exceeds (or even approaches) the shuttle capability of 12,000 pounds. Thus, there are no drivers in this requirement category.

2.2.4 DATA RATE

This parameter was treated as a special case in order to reduce, if possible, the capability level that resulted from the MSS Phase A study. This capability (for experiments) was 6×10^6 bits per second of digital data. It was desired to reduce this to approximately 2×10^6 bits per second in order to avoid high-cost technology. Therefore, all experiment data-rate requirements were studied to see if this were feasible without compromising experiment achievement.

Five of the six astronomy FPE's have data acquisition rates that greatly exceed even the 6×10^6 bits per second level (Figure 2-10A). Typically, at the experiment level, these produce the results shown in Figure 2-10B—all of the experiments in FPE A-3, advanced solar astronomy, exceed 6×10^6 bits per second. Thus, Mr. P. Schwindt, of MSFC, was contacted (with NASA approval) to determine the feasibility of an alternate implementation scheme. With his concurrence, it was assumed for the purpose of this study that internal data processing equipment will be provided along with the astronomy laboratories, which reduces the rate into the MSS information subsystem (ISS) to no more than 4×10^4 bits per second. In addition, film may be used to record the data. It was agreed that these techniques would not degrade experiment performance. However, more frequent revisits of detached astronomy RAM's will be required if film is used instead of electronic data transmission.

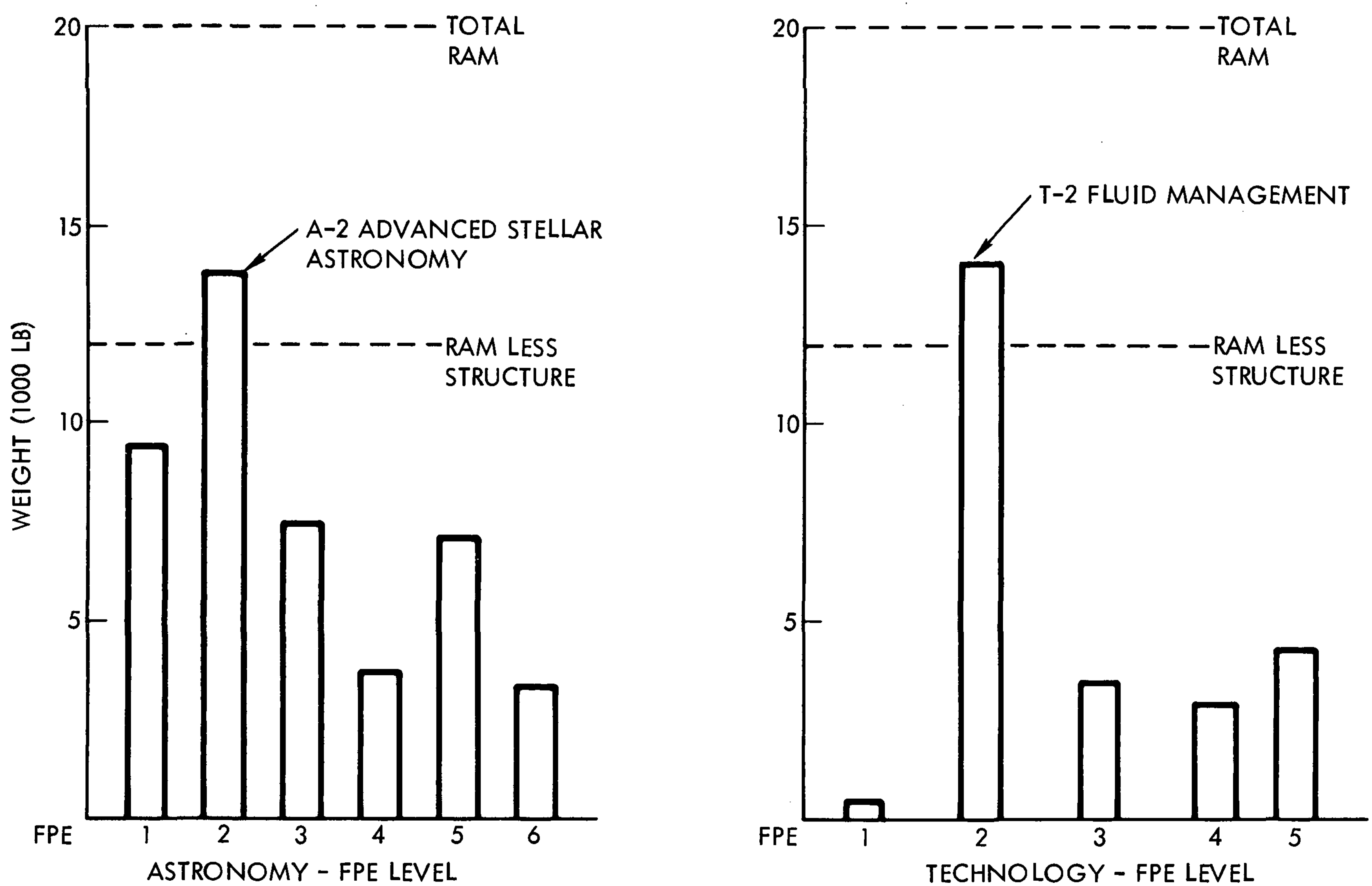


Figure 2-8. Weight Drivers (Astronomy and Technology)

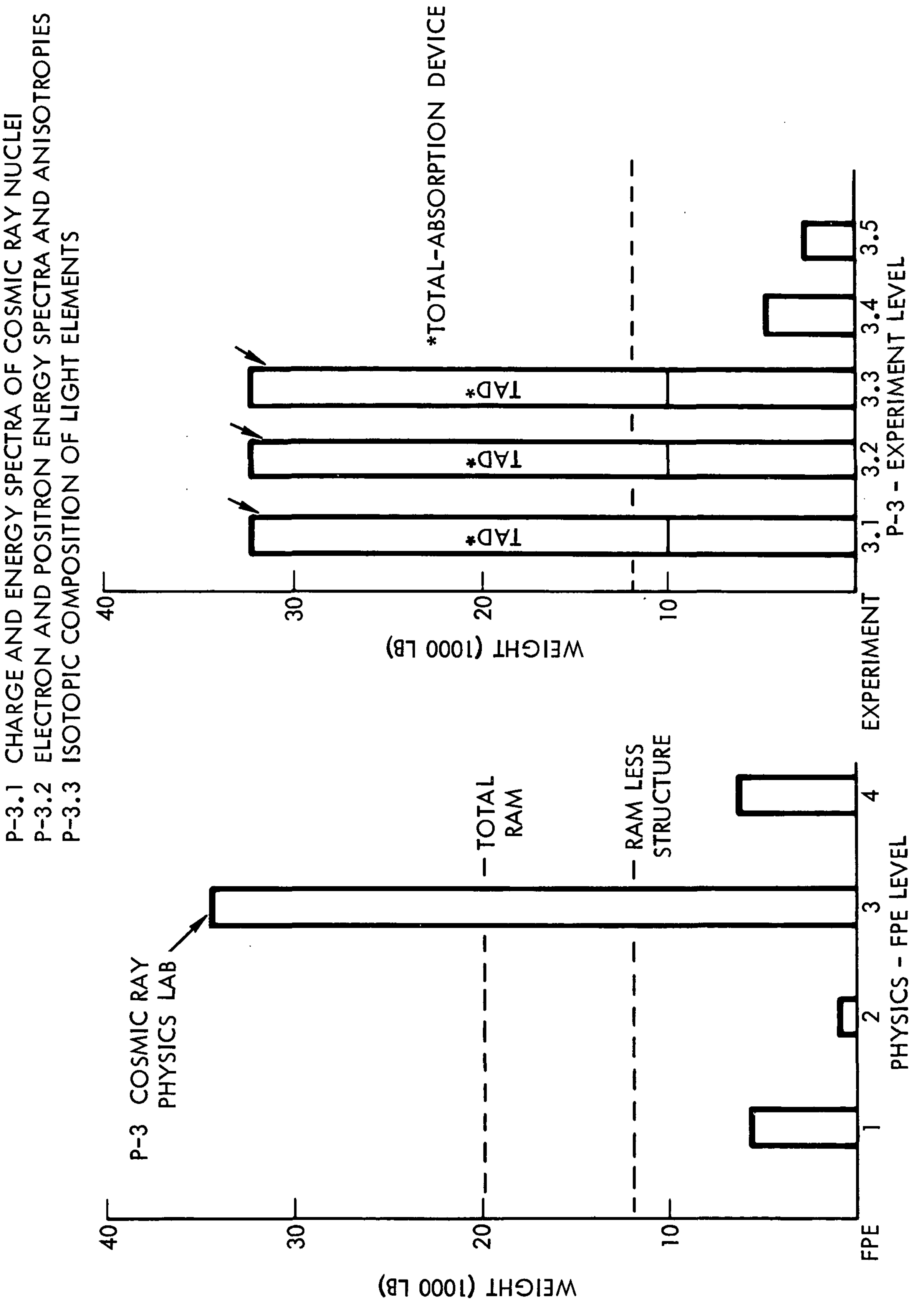


Figure 2-9. Weight Driver (Physics)

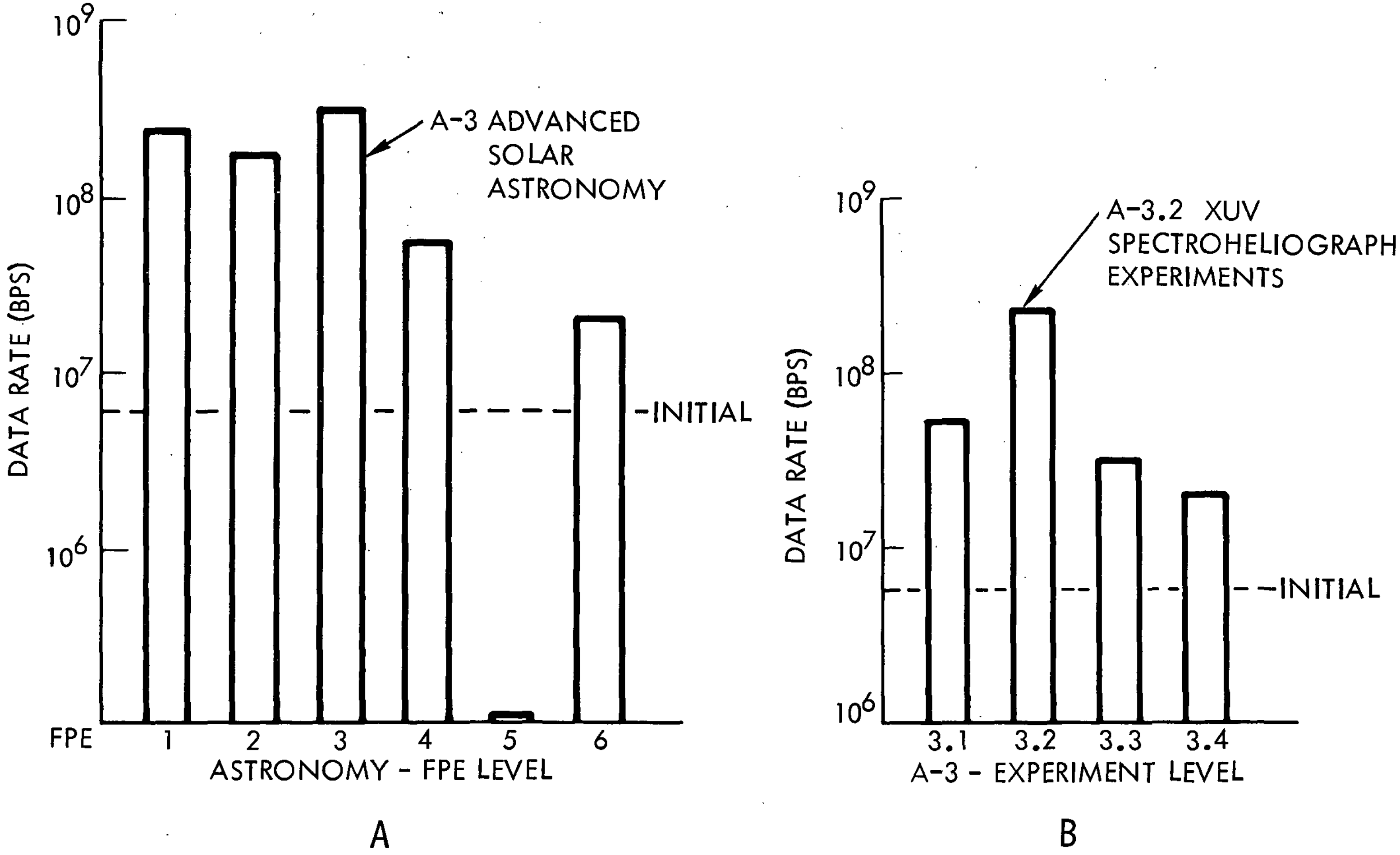


Figure 2-10. Data Rate Driver (Astronomy)

Earth observations data rates by experiment are displayed in Figure 2-11A. Looking at the output rates of the individual earth observations sensors (Figure 2-11B), one can see that only one, for the multispectral scanner, is a driver. An alternate implementation technique for this device was defined by NR and coordinated with Mr. R. Hergert, of MSC. This technique, discussed in detail in Section 7, removes this sensor as a driver.

No other FPE requirement exceeds 6×10^6 bits per second. In order to evaluate the feasibility of a 2×10^6 bits per second capability, all experiment digital data rate requirements were plotted (Figure 2-12). It can be seen that, when the alternate data handling techniques in astronomy and earth observations are implemented, no experiment requirement exceeds 2×10^6 bits per second. Thus, the desired objective has been achieved.

2.2.5 POINTING STABILITY

In this requirement area, astronomy, physics, and comm/nav contain drivers. Astronomy requirements by experiment are shown in Figure 2-13. There are two major classes of experiment requirements, with a large number at 1.0 arc-sec or better. All astronomy experiments exceed the station capability; thus, they are candidates for detached RAM's.

Both physics and comm/nav have individual instruments requiring stabilization in the 10 to 100 arc-sec range. It was assumed (with NASA concurrence) that stable platforms will be provided with the experiment equipment to accomplish this.

2.2.6 CREW TIME

Crew-time drivers can be eliminated by scheduling operations at the FPE or experiment levels, as required.

2.2.7 OTHER ISSUES

Orbit requirements for astronomy, physics, earth observations, and comm/nav are shown in Figure 2-14. It was decided that those with acceptable orbits within the station flight box would be accommodated there without further analysis. Those requiring other orbits would be considered for shuttle sorties.

In addition to these considerations, additional requirement drivers were analyzed and resolved, as follows. Subsatellite capability on the initial station would be limited to deployment and data acquisition. More sophisticated operations such as retrieval and close-in operations (for plasma wake measurements) would be deferred to the growth station.

Clean room capability for experiment maintenance would be maintained at the Class 100,000 level. Stricter requirements would be implemented on the ground or perhaps in small-volume glove boxes.

2.2.8 CONCLUSIONS

The above discussion shows that, with certain modifications in approach, all 1971 Blue Book experiments can be accommodated with an MSS whose experiment support capabilities are unchanged from the Phase A definition. Later refinement of both the experiment requirements and the station concept as part of the Phase B activity provided additional capabilities, such as effluent retention to reduce contamination, but no major resizing of MSS subsystems was required.

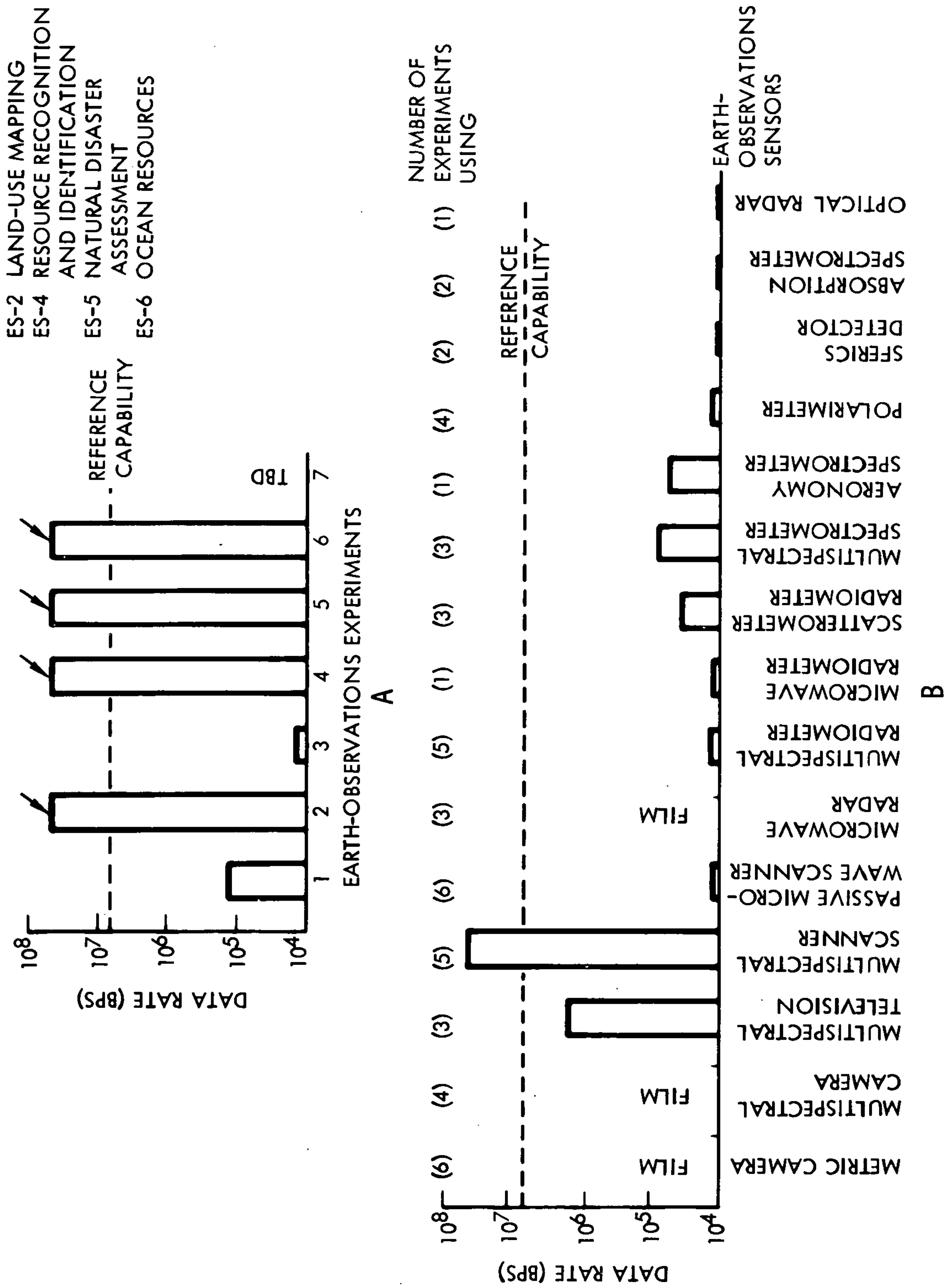


Figure 2-11. Data Rate Driver (Earth Observations)

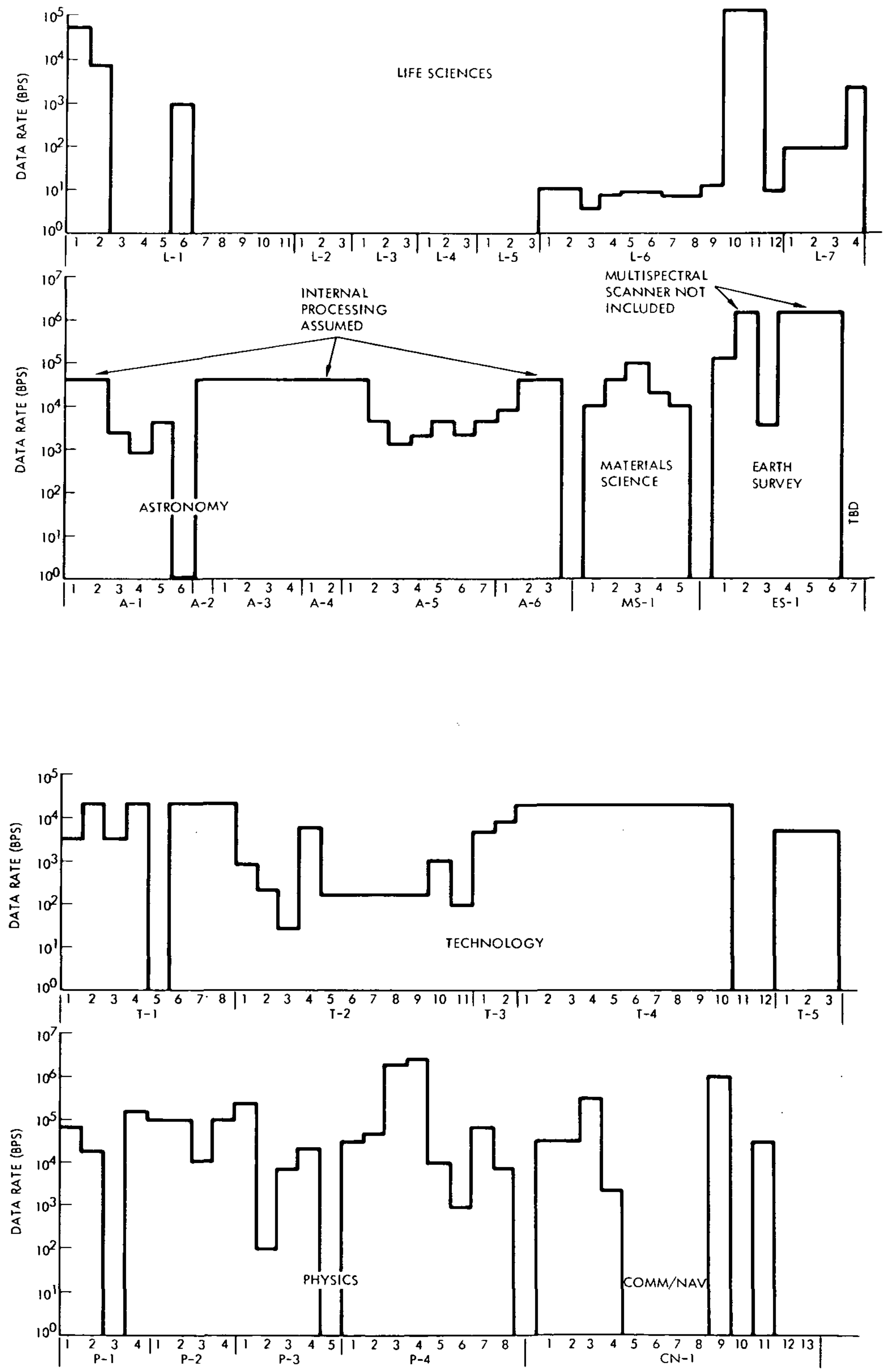


Figure 2-12. Digital Data Rate Requirements by Experiment

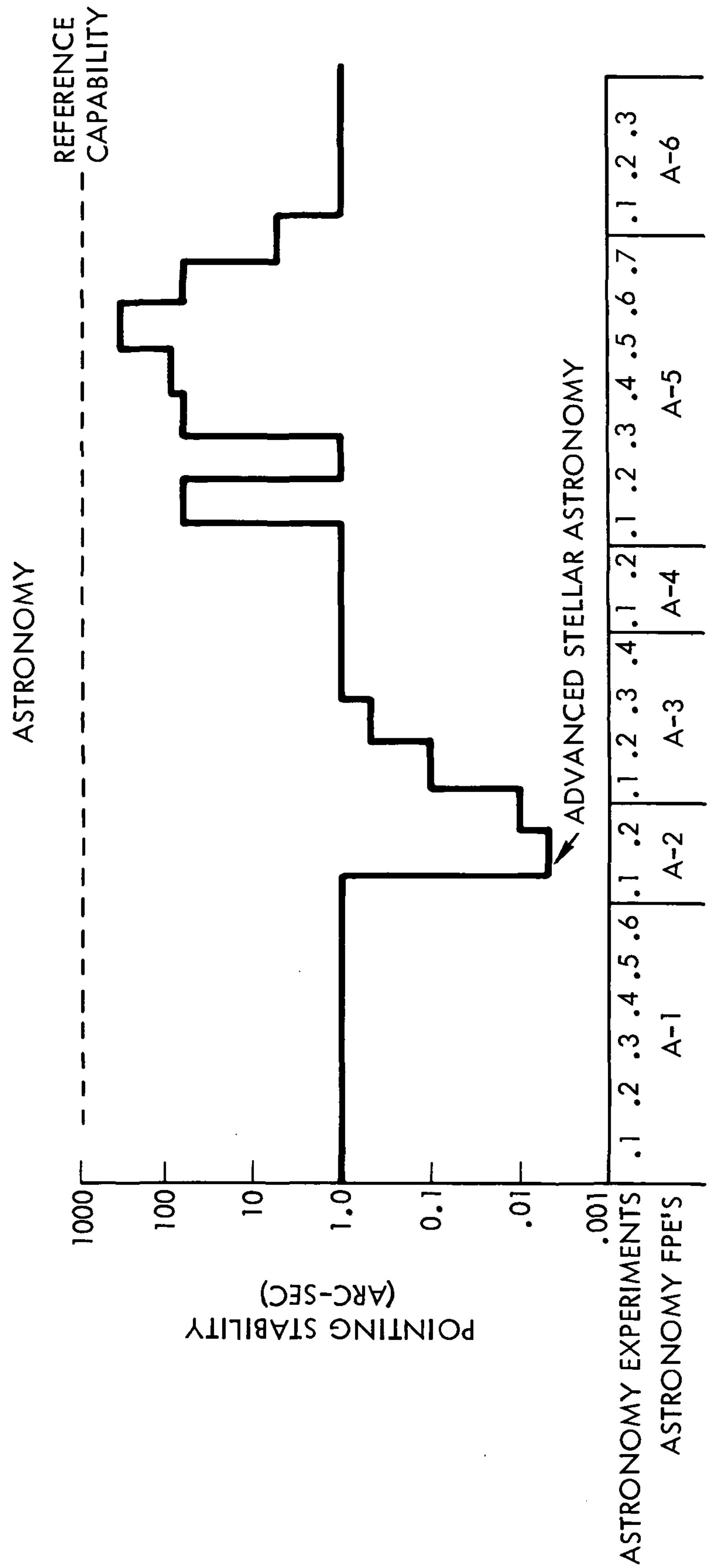


Figure 2-13. Pointing Stability Driver

SPACE STATION FLIGHT BOX
INCL - 55 DEG
ALT - 240 - 270 N MI

FPE		DESIRED ORBIT		ACCEPTABLE ORBIT		FURTHER ACTION
		INCL (DEG)	ALT (N MI)	INCL (DEG)	ALT (N MI)	
ASTRONOMY						
X-RAY STELLAR	A-1	0	400-500	0-55	200-400	
ADV STELLAR	A-2	28-55	360-450	> 0	250-360	
ADV SOLAR	A-3	SUN-SYNCHRONOUS		0-55	200-400	
UV TELESC	A-4	28-70	250-360	ANY	200-400	
HI ENERGY STEL	A-5	0	400-500	0-55	200-400	
IR ASTRON	A-6	50-60	270-300	25-60	250-400	
PHYSICS						
PHYSICS RES LAB	P-1	90	100	> 50	100	CONSIDER FOR SHUTTLE SORTIE MODE
PLASMA PHYSICS	P-2	POLAR	100	> 50	100	CONSIDER FOR SHUTTLE SORTIE MODE
COSMIC RAY	P-3	28	200	55	270	
EARTH OBSERV	ES-1	90	100	50-90	100-270	
COMM/NAV						
OPT FREQ	C/N-1	POLAR	100-300	> 28	100-300	
MM COMM	C/N-2	POLAR	100-300	> 28	100-300	
TRANSM BRKDN	C/N-7	28	80 X 400	80 - 90	80 X 400	CONSIDER FOR SHUTTLE SORTIE MODE
TERRES NOISE	C/N-8	POLAR	100-300	> 55	100-300	

Figure 2-14. Orbit Requirements

3. LABORATORY DEFINITIONS AND REQUIREMENTS

The following subsections provide definitions and requirements for the evolutionary laboratory concepts for accomplishing the space experiments defined in the NASA Blue Book. Two general laboratory classes are defined. These are the experiment laboratories for each of the Blue Book FPE's and the General-Purpose Laboratory (GPL), which provides support for all the experiment laboratories. A brief description is given for each of the 22 experiment laboratories in Subsection 3.1.1, and Subsection 3.1.2 provides further details in the form of summary charts for each laboratory. The GPL concept is described in detail in Subsection 3.2.

3.1 EXPERIMENT LABORATORY DEFINITIONS AND REQUIREMENTS

This section describes the analysis used to define experiment requirements for the MSS program definition effort. In general, the approach was to define laboratories whose capabilities evolve with time. This evolution is stepwise, with two, three, or four capability plateaus (levels) defined for each laboratory. In general, one laboratory is defined for each FPE in the 1971 Blue Book. The only exception is in life sciences, where FPE's LS-2, 3, 4, and 5 were combined into a single biosciences laboratory. Thus, there are 22 laboratories to accommodate the 25 FPE's. The laboratories are listed in Table 3-1.

In this analysis, the term "laboratory" refers to a set of experiment/support equipment and does not include RAM subsystems and structure or the MSS GPL. The laboratories defined in this task may be housed in RAM's or in the GPL.

Levels are designated I, II, IIA, and III. In general, laboratories at Level I are intended for implementation on shuttle sortie missions. The higher levels are implemented as part of the MSS program. Level II is designed to be compatible with the capabilities of the initial (six-man) MSS. Level III, by definition, can accomplish all of the experiments and requires all equipment assigned to a particular laboratory. When required, an intermediate level (IIA) is defined.

Table 3-1. Experiment Laboratories

FPE	Laboratory Title
A-1	X-Ray Stellar Astronomy Laboratory
A-2	Advanced Stellar Astronomy Laboratory
A-3	Advanced Solar Astronomy Laboratory
A-4	Intermediate Size UV Telescopes Laboratory
A-5	High Energy Stellar Astronomy Laboratory
A-6	Infrared Astronomy Laboratory
P-1	Space Physics Research Laboratory
P-2	Plasma Physics and Environmental Perturbation Laboratory
P-3	Cosmic Ray Physics Laboratory
P-4	Physics and Chemistry Laboratory
ES-1	Earth Observations Laboratory
C/N-1	Communications/Navigation Laboratory
MS-1	Materials Science and Manufacturing in Space Laboratory
T-1	Contamination Measurements Laboratory
T-2	Fluid Management Laboratory
T-3	Extravehicular Activity Laboratory
T-4	Advanced Spacecraft Systems Test Laboratory
T-5	Teleoperation Laboratory
LS-1	Medical Research Laboratory
LS-2, 3, 4, 5	Biosciences Research Laboratory
LS-6	Life Support and Protective Systems Laboratory
LS-7	Man-System Integration Laboratory

The definition of each laboratory at a particular level begins with the selection of a subset of objectives, typical experiments and equipment from the totality of 1971 Blue Book objectives, typical experiments, and equipment. This selection is based, in general, on the goal that lower-level laboratories should be relatively low in intrinsic cost and have little program/system cost impact. Conceptually, deferment of more costly requirements to a time when the funding peak for other program elements is past will permit a more balanced program funding level. In addition, each laboratory evolution step should represent a logical increase in capability and should support appropriately sequenced disciplinary objectives.

After selection of objectives, experiments, and equipment, an operational concept was defined for each laboratory at each level. This included such data as "duration" (that is, length of time the laboratory is on orbit before it is refurbished or upgraded to a higher level), "mode" (attached RAM, detached RAM, or GPL), and other overall requirements.

The selection of an operational concept for a laboratory at a particular level was guided by the requirement to accomplish the objectives established for that level of the laboratory. The mode of a laboratory was determined by both the desired modes of the experiments conducted using it (see Section 4) and cost considerations.

Note that some laboratories will not evolve in this model program—they will be initiated as complete facilities. Generally, this will be the case for laboratories containing one central major hardware item, such as the 3-meter-diameter stellar telescope of FPE A.2.

After each step of laboratory evolution was described in this manner (objectives, typical experiments, operational concept, experiment equipment), it was necessary to establish the level of support that must be provided to the laboratories at each of their evolutionary steps. Note that these support parameters apply to the laboratory as a whole, not to any specific experiment performed in the laboratory.

The experiments described in the 1971 NASA Blue Book were treated as typical experiments for the purpose of sizing these nominal laboratory support parameters. Operational scheduling was then performed on a laboratory-by-laboratory basis rather than experiment by experiment. This is consistent with the philosophy employed in the preparation of the reference Blue Book.

3.1.1 LABORATORY DESCRIPTIONS

Brief descriptions of the 22 research and applications laboratories are contained in the following paragraphs. Only Levels II and III laboratories are discussed since Level I laboratories are exclusively accommodated with shuttle sorties and are described elsewhere.

X-Ray Stellar Astronomy Laboratory (FPE A-1)

The X-ray stellar astronomy investigations are a long-term and continuing study for which an earth-orbiting space station will provide direct support only in early phases. Levels II and III experiments provide highly accurate and sensitive surveys and analyses for which detached modules are required to achieve platform stability. It is anticipated that cost considerations may limit the number of experiments that may be scheduled during the Level II period. The Level III experiments should be performed in a low-inclination, higher-altitude detached RAM, with revisits at approximately two-month intervals. This may preclude direct support by the space station.

Advanced Stellar Astronomy Laboratory (FPE A-2)

The advanced stellar astronomy experiments provide an opportunity to develop stellar astronomy capability in the UV-visible-IR spectral range with a 3-meter-diameter telescope in a man-tended laboratory. Because of the size and cost of the desired telescope, this is a nonevolving laboratory with essentially full capability at initial launching. Level II operations (such as during the initial station period) will allow evaluation of the telescope performance in the detached RAM. Contamination control procedures associated with revisits and routine servicing will also be developed. Level III operations will concentrate on the observational program and establish the capability to obtain diffraction-limited performance from a large space telescope. Data will be retrieved from the laboratory monthly or bimonthly, and the laboratory will be serviced as the RAM is docked to the space station. The entire laboratory will be returned to earth periodically for refurbishment.

Advanced Solar Astronomy Laboratory (FPE A-3)

Solar astronomy will continue to be an area of active scientific interest for many years, and an earth orbital laboratory can provide a desirable base for solar investigations. Experiments recommended for Level II can be accommodated in an attached RAM and still provide high resolution but not continuous monitoring of solar-disc activity and processes. Correlated XUV and X-ray solar imagery also may be obtained. A detached RAM in a sun-synchronous orbit is recommended for housing the Level III experiments. This may preclude direct support from the MSS. The Level III experiments accommodated in the free-flying RAM can provide continuous high-resolution monitoring of solar activity and also make corona observations.

Level II laboratories can be returned to earth for refurbishment at one-year intervals, while two-year refurbishment intervals may be adequate for the advanced Level III laboratory.

Intermediate-Size UV Telescopes Laboratory (FPE A-4)

The space laboratory provides a base from which UV astronomy investigations can be continued and expanded. Level II experiments can be accommodated in an attached RAM and can enlarge existing surveys of UV sources. Observations, including UV spectroscopy of selected sources, can be accomplished during several yearly orbit intervals, with the RAM returned to earth for refurbishment between operational periods. Later Level III experiment missions will require a detached RAM coorbiting with the MSS to provide accurate control of the larger UV telescope. Data stored on the detached RAM will be recovered monthly, certain consumables replaced in six-month cycles, and the Level III RAM returned to earth for refurbishment at approximately two-year intervals. The larger laboratory will provide spectral imaging of UV emission from nebulae, star clusters, and galaxies. It also can be used to observe activity of quasars and novae.

High-Energy Stellar Astronomy Laboratory (FPE A-5)

Advanced high-energy stellar astronomy investigations will be required to complete the astronomical observations in the MSS operational time period. Level II experiments can be accommodated in an attached RAM with the instrumentation installed to enable viewing of an entire celestial hemisphere. The laboratory defined can provide gamma ray background and source mapping, extend X-ray source surveys, and provide improved X-ray spectra of selected sources.

The Level III laboratory can extend both the energy range and the intensity range of the high-energy stellar astronomy measurements. Additional benefits from correlated measurements over a wide range of the high-energy spectrum can be attained. The Level III laboratory will be operated in a detached RAM mode—first coorbiting with the MSS and subsequently in 400- to 500-mile-altitude, low-inclination orbits, where direct support from the MSS may not be feasible.

Level II laboratories should be returned to earth for refurbishment at approximately six-month intervals. Level III laboratories will have design goals for two-year operational periods between refurbishments. The laboratories will, however, require EOS revisits on six-month cycles for servicing.

Infrared Astronomy Laboratory (FPE A-6)

The MSS period will be used for continued study of the IR luminosity and spectral characteristics of stellar objects. Level II laboratories will be used to conduct a complete survey of IR sources and determine photometric brightness, time variations, and spectrometry of selected objects. During Level III missions, the investigations will be extended to wider spectral ranges and lower luminosities and, in particular, galaxy and interstellar dust cloud sources.

Level III operations will require the detached RAM mode to achieve maximum instrumentation performance. Since the same basic instruments are used for both Level II and Level III periods, the Level II investigations could be delayed for cost reasons. RAM refurbishment should be scheduled at one-year intervals (Level II) and later at two-year intervals for the detached RAM. The alternation of a Level II attached RAM with a RAM from another astronomy FPE such as A-4 is a possible operational concept.

Space Physics Research Laboratory (FPE P-1)

The MSS scientific operations will be sensitive to the operational "atmospheric" environment surrounding the station. A Space Physics Research Laboratory is planned for investigating and monitoring phenomena that could influence the results of the other physics discipline experiments as well as the entire scientific space program. In addition, other Level II space physics experiments will concentrate on atmospheric and magnetospheric science studies and investigations, including UV observations, using a small optical astronomy telescope. Level II instrumentation will be based in an appropriate MSS GPL area, with a number of the sensors requiring deployment through an airlock on extendable booms.

For Level III investigations, additional analytical instrumentation will be provided in the GPL Space Physics Laboratory. The Level III operational period also will provide subsatellite deployment for gas release at a safe distance from the MSS. This gas release will support in-space studies of comet-tail mechanisms. Other Level III studies include more detailed investigations of quiet and disturbed atmospheres, the magnetosphere , and meteoroid fluxes and composition.

Plasma Physics and Environmental Perturbation Laboratory (FPE P-2)

The space environment provides conditions for extensive plasma physics studies. The effect of the existing MSS environment on these investigations also must be studied. Level II experiments will provide initial progress in these study areas. The experimental equipment will be located in the space station GPL, with deployment of certain sensors on booms through the MSS airlock. More detailed investigations of the above areas and the addition of experiments on the interaction of particles and VLF waves will be included in the Level III programs. The VLF studies will require the use of conjugate subsatellites and will need a high-capacity power supply, from either the MSS or a separate experiment power supply. Additional subsatellites will allow expansion of the wake measurement studies. Six-month operational increments appear adequate for the recommended investigations.

Cosmic Ray Physics Laboratory (FPE P-3)

Levels II and III investigations in the area of cosmic ray physics can do much to advance knowledge in this discipline. The Cosmic Ray Physics Laboratory can be started in an attached RAM during the initial station time period, with facilities for measuring cosmic ray particle fluxes, energy, and identity. The search can be extended to the rarer heavy nuclei during the Level III investigations. This laboratory requires very heavy equipment, but this can be built up on an incremental basis during the research program. One- to two-year continuous operations are desirable to achieve adequate counting statistics. Certain major components will have to be replaced annually.

Physics and Chemistry Laboratory (FPE P-4)

It is of scientific importance to conduct a large number of basic physics and chemistry laboratory experiments in the zero-g space environment. The proposed Physics and Chemistry Laboratory for the MSS can provide the facilities for these investigations—initially in the GPL and later (Level III) in an attached RAM. Level II studies will include items such as atmospheric component interactions and fluid thermodynamics in free convection. Level III studies will be expanded to include critical-point phenomena, heat transfer, and flame chemistry investigations. The use of the MSS airlock and extendable booms will be required for some experiments in both phases. A type of subsatellite is required for gas release at a distance from the MSS for cloud gas reaction studies. Safety measures will be very important in the performance of flame studies and the handling of toxic gases.

Earth-Observations Laboratory (FPE ES-1)

The manned earth-orbital space program will provide platforms for development of improved earth observation sensors and research programs. In particular, man-in-the-loop procedures can be implemented for increasing the effectiveness of such programs. The early Level II recommended experiments can be housed in the GPL, where groups of sensors can be deployed through the MSS airlock. Level III experiments are recommended for implementation in an attached RAM to allow simultaneous deployment of a larger number of sensors. This will provide expanded data acquisition and analysis capability and permit real-time regrouping of equipment for specific observation tasks. Recommended are three years of essentially continuous operations at Level II, followed by continuous operation at Level III. Certain required interruptions for laboratory repair and refurbishment are to be expected.

Communications/Navigation Laboratory (FPE C/N-1)

One of the earliest applications of earth-orbiting satellites was the establishment of communication relay satellites. Further development of communication techniques should be applied to the space-based portions of the various systems. The MSS Communications/Navigation Laboratory will provide an efficient base for rapidly testing and developing potential system improvements. Level II experiments will be housed in the GPL and used to expand development of satellite-to-ground techniques and other areas of satellite communication system applications. Partial completion of a wide variety of experiments will be planned in order to provide early benefits. The GPL mode of operation is suggested for Level II experiments, with groups of the sensor inventory deployed through the MSS airlock in a sequence of experiment operations. For one experiment, six months of continuous operation is desirable; other experiments can be performed in periods up to 30 days.

Level III experiments also will operate in the GPL mode, but more complete program facilities will be made available. Included will be sub-satellites and, where possible, cooperative subsystems on deep-space probes. The Level III investigations continue to develop and demonstrate improved communication technology; in addition, terrestrial navigation systems will be developed. Providing a clear field of view for some large communication/navigation sensors may be a design-installation problem. For one Level III experiment, 1.5 years of continuous operation is desirable, but others can be scheduled in 30-day increments.

Materials Science and Manufacturing in Space Laboratory (FPE MS-1)

The space station provides a unique environment that should assist in the manufacture of certain special items—where zero gravity and/or the space vacuum could be beneficial. In order to utilize this environment intelligently, it will be necessary to conduct an orderly investigation of materials science *in situ* to determine the best applications to manufacturing objectives. The recommended Level II and Level III experiments provide an evolutionary approach to determining feasibility of the various potential applications. Level II experiments can be performed in the station GPL. Two years of total operations in six-month intervals are recommended at this level. The Level II investigations will include research into the physical properties of fluids in zero gravity, crystal growth, medically oriented biological processing, and manufacturing process development. Partial completion of a wide variety of experiments will be emphasized as Level II operations, with completion of the recommended experiments as Level III operations. The Level III investigations will include advanced research in fluid properties and the preparation of exotic glasses. Pilot production operations of potential commercial manufacturing also may be accomplished. Open-ended operations of the Level III laboratory in two-year cycles (with three- to six-month intervals between) are the anticipated operational concepts for this discipline.

Contamination Measurements Laboratory (FPE T-1)

The objectives of the Contamination Measurements Laboratory are to survey the induced environment around the MSS, determine its effects on external scientific and operational sensors, and develop required contaminant control measures. The Level II experiments will first investigate external contaminant composition, quantity, sources, transport mechanisms, buildup rates, and dissipation rates. Contaminant control measures will then be tested and developed. Essentially the same type of investigations will be conducted as Level III experiments but will proceed with greater refinements and accuracies. These Level III experiments will include extended tests on the various contamination control measures and provide data for development of optimum contaminant control measures and procedures for the growth station time period.

The operational mode for the Contamination Measurements Laboratory will be from the station GPL, using the MSS airlocks, booms, and windows for sensor deployment and operation. The Level II experiments will require approximately six months of continuous operations, with Level III experiments estimated to require two years, starting with the initial operation of the 12-man station.

Fluid Management Laboratory (FPE T-2)

An area of concern in the planning of future spacecraft subsystems is limited knowledge of the detailed behavior of fluids in the space environment. The MSS provides a center from which investigation in this area can be accomplished. A common requirement of the selected experiments in this discipline is long-duration, very accurately controlled low-gravity levels (e.g., 10^{-3} to 10^{-5} g) without the Coriolis forces that would arise in a rotating environment. This necessitates the assignment of all fluid management experiments to the detached RAM mode of operation.

The Fluid Management Laboratory is a nonevolving facility. Essentially the same equipment is required and the same experiments performed at Levels II and III. In-depth studies will be performed of selected fluid management systems to support future spacecraft design objectives. One year of operation is anticipated for the investigations.

Extravehicular Activity (EVA) Laboratory (FPE T-3)

MSS operations will be designed to minimize astronaut extravehicular activity (EVA), but it cannot be entirely eliminated from future space operations. Therefore, advanced techniques and concepts in this area will be tested and developed in the EVA Laboratory. Two major classes of equipment are presently defined for development during the MSS period. These are the astronaut maneuvering unit (AMU) and the maneuvering work platform (MWP). The latter device is assigned as a Level III experiment for cost and complexity reasons.

The planned Level II operations will consist of a four-month sequence of EVA task tests of varying complexity to test the effectiveness of the "backpack" AMU designs in both tethered and free-flight modes. Level III operations will include both AMU and MWP tests to determine their effectiveness in assisting in the future orbital assembly of large space station and planetary vehicles. Approximately one year of Level III operations are planned. All Level II and III operations will be in the GPL mode, using the MSS airlocks.

Advanced Spacecraft Systems Test Laboratory (FPE T-4)

The MSS can provide an efficient center for the testing of various types of subsystems and components for future advanced space vehicles. The Advanced Spacecraft Systems Laboratory will be planned to perform a variety of such test-and-evaluation investigations. A representative set of experiments have been defined for this laboratory. Level II investigations are GPL-based. Four of the six experiments require the use of the MSS airlock. Level II operations, which will continue for one year, emphasize development of life support subsystems and safety techniques and procedures.

Level III experiments will lead to development of free-flying modules and demonstrate reliable operations of systems over extended time periods. Two years of Level III laboratory operations are recommended using the GPL/airlock mode. Inclusion of one test on a stable, free-flying RAM is a requirement.

Teleoperation Laboratory (FPE T-5)

It is desirable to develop the teleoperator principle as a substitute for astronaut EVA in future manned space operations. The objectives of the experiments will be to evaluate teleoperator flight performance and the man-machine interfaces, from both a MSS control center and an earth-surface station control. Operational safety procedures will be established and, finally, performance on actual MSS tasks will be evaluated. The recommended testing program can extend over a one-year interval using the GPL/airlock operating mode. This is a nonevolving laboratory—Levels II and III are identical.

Medical Research Laboratory (FPE LS-1)

Medical research experiments continue to be extremely important as the manned space program progresses to larger crews and longer missions. More effective sensors to monitor the astronauts' well-being are desired. The effectiveness of exercise equipment and other health maintenance procedures must be determined. When undesirable effects of space flight on the crew are discovered, the relative desirability of alternate courses of treatment must be determined. The MSS Medical Research Laboratory will be designed to accomplish objectives such as these.

A wide variety of Level II and Level III experiments in this discipline have been identified. All can be accommodated in the GPL of the MSS. A major floor space requirement exists for the rotating litter chair device during test operation periods. All crew members will be involved in the medical research program, as operators and/or subjects. Some of the experiments for each level will require regular testing of subjects throughout the full period of manned occupancy of the station.

Biosciences Research Laboratory (FPE's LS-2, 3, 4, 5)

Analysis of the Blue Book life sciences FPE's led to the conclusion that, for the purpose of the present study, four of these FPE's should be combined into one evolutionary laboratory concept with the general title of Biosciences Research. The four FPE's were: LS-2, Vertebrate Research; LS-3, Plant Research; LS-4, Cells and Tissues Research; and LS-5, Invertebrate Research. A major reason for this combination was the commonality of equipment requirements in the four FPE's. The resultant group of selected experiments for the MSS period seemed to fall naturally into three instead of two levels of experiment complexity. Level II experiments provide major activity in the area of cells and tissues; Level IIA experiments require isolation from the MSS atmosphere and include the earliest scheduled vertebrate experiments. The Level III experiments also require isolation from the main station and involve a large variety of small vertebrates as well as plant growth investigations. Long time periods at controlled low gravity also are required.

The Level II experiments can be accommodated in the GPL of the MSS, while Level IIA and Level III experiments require the attached RAM mode of operation. A duration of nine months is estimated for Level II experiments, while experiments recommended for Level IIA and Level III require 18 months and six years, respectively.

Life Support and Protective Systems Laboratory (FPE-LS-6)

The objective of the Life Support and Protective Systems (LSPS) Laboratory is to study the gravity-sensitive aspects of space life support systems. Twelve experiments in this area have been defined. Initial information is obtained from Level II experiments, while the major investigation effort is assigned to the Level III experiment program. Level III experiments evaluate advanced LSPS components, subsystems, and operations and evaluate man's ability to maintain and repair these systems. The experiments require a relatively high daily crew participation, and some require use of EVA airlocks. The operating mode involves the MSS GPL and airlock, and later a RAM. Two 37-month cycles of experiment operations are anticipated. This is a nonevolving laboratory.

Man-System Integration Laboratory (FPE LS-7)

The objectives of this laboratory include providing the facilities for observing man's capability to perform physical work in space, to quantify these capabilities for use in future space plans, to develop crew equipment for both IVA and EVA tasks, and to provide data on crew behavior in space for use in establishing crew selection criteria. Most selected experiments for this laboratory are designed to obtain data that support missions beyond the MSS time period. Therefore, the majority of experiments are recommended for growth station implementation.

Level II tasks are performed inside the station GPL, airlock, or attached RAM's to prepare for specific tasks in Level III experiments. The Level III experiments will involve EVA as well as IVA operations. A wide variety of equipment is required for the Level III sensory, skill, and behavioral assessment. Level II tests are estimated to require three three-month cycles for completion. The Level III experiments will require approximately eight three-month cycles for the defined program.

A special requirement exists for one group of Level III experiments in which a manned centrifuge is desired. Blue Book design for this unit indicates an approximate centrifuge radius of 112 inches, which would exceed the internal capability of the MSS station modules or RAM's.

3.1.2 EXPERIMENT LABORATORY DEFINITION AND REQUIREMENTS TABLES

Detailed results of the experiment laboratory definition and requirements analysis are presented in a series of 22 tables in the Appendix. Tables A-1A through A-22A contain objectives, selected experiments (with rationale for experiment selection and comments on laboratory implementation), and experiment equipment required for each of the laboratories at each implementation level.

As discussed previously, Level I contains experiments that should be performed early in the earth orbit research and applications program and could be accommodated on shuttle sortie missions. Level II represents activities and equipment appropriate for the initial (six-man) phase of the space station program, and a Level III laboratory contains the complete capability defined for the Blue Book FPE(s) supported by that laboratory.

Tables A-1B through A-22B contain descriptions of operational concepts for each Level II and Level III laboratory (further details of the Level I laboratories are included in Volume VII, Ancillary Studies, Sortie Analysis, SD 71-217-7). A duration is specified for each laboratory. This represents the recommended length of time that the laboratory should be continuously operational on orbit. Also included under this heading is the recommended number of repetitions for each lab and the ground refurbishment interval required.

An operational mode is recommended. Three modes are considered: GPL (corresponds to integral), attached RAM, and detached RAM. Mode recommendations result from a consideration of the desired mode for the experiments being conducted with the laboratory (Section 4) and from considerations of cost and logical evolution—a Level II lab may be accommodated by an attached RAM, whereas the Level III lab for the same FPE may be housed in a detached RAM. Servicing frequency is also listed. Finally, any laboratory special physical requirements are summarized.

Tables A-1C through A-22C contain laboratory subsystem and logistic support requirements for each laboratory at each level. These requirements are divided into two classes, nonschedulable and schedulable, described as follows:

Nonschedulable Parameters

This class of parameters refers to the physical properties of the laboratory equipment. Parameters determined were as follows:

1. Laboratory equipment weight

   Total

   By major item

2. Laboratory equipment envelope (by major item)

3. Laboratory equipment installation requirements and special physical requirements such as deployment, field of view, airlocks, etc.

Since weight and volume are readily available in the Blue Book, they are not tabulated in this document. Experiment equipment within each laboratory at each level is identified, and the total weight of this equipment is listed. Special physical requirements are listed in the description of each laboratory's operational concept.

Schedulable Parameters

These are parameters whose instantaneous values may vary throughout the duration of a particular laboratory level. Since these parameters depend upon interpretation of Blue Book data rather than on direct extraction, they are tabulated in detail in the Appendix.

No attempt was made to account for variations on a day-to-day or even month-to-month basis by detailed scheduling of experiments. Rather, the requirements of the Blue Book-defined typical experiments were used to establish an acceptable minimum level of support that must be provided to the laboratory throughout the duration of the level. This minimum acceptable level of support for each schedulable parameter, in general, is that required to conduct the single worst-case typical experiment in the subset assigned to the level, provided that the selected worst case is not anomalous. This ground rule is based on the criterion that a laboratory should be capable of performing any of the typical experiments assigned to it at a particular level in its evolution at any time during the duration of that level. Consistent with the 1971 Blue Book philosophy, it may be assumed that if a laboratory is on orbit throughout a particular time interval, its utilization rate during that interval will be sufficiently high to justify the commitment of such sustained levels of support.

It must be kept in mind that the Blue Book-defined experiments are to be considered as typical. That is, many more experiments will be conducted using the laboratory equipment than are described in the Blue Book when that equipment is available on orbit.

Schedulable parameters found in the Appendix are as follows:

1. Average Electrical Power Input (electrical energy per 24 hours). This is the 24-hour average rate at which electrical power must be provided to the laboratory for experiment operations. In other words, it is the electrical energy that must be delivered to the laboratory for each 24 hours. Time intervals for averaging

other than 24 hours could have been chosen (one orbit, one year), but, based on previous experience, 24 hours is the optimum basis. Shorter intervals fail to account for a significant number of fluctuations, whereas longer intervals require lengthier calculations but provide very little additional insight into energy requirements. These 24-hour averages may be scaled linearly to longer time intervals with confidence. Note that the 24-hour average heat output by the laboratory is assumed to be identical to this quantity unless otherwise specified.

2. Maximum Sustained Electrical Power. This is the maximum rate at which electrical energy must flow into the laboratory for sustained periods (periods exceeding one hour). Note that the maximum sustained rate of heat output by the laboratory is assumed to be identical to this quantity unless otherwise specified.

3. Peak Electrical Power. This is the maximum instantaneous rate at which electrical energy must flow into the laboratory, excluding transients, for periods of less than one hour. Note that the peak rate of heat output by the laboratory is assumed to be identical to this number unless otherwise specified.

4. Crew Support Requirements. The 24-hour average number of crew man-hours required to support the laboratory was determined and broken down by skill.

5. Data Output (or quantity of data per 24 hours). This is the total amount of data generated by the laboratory after internal processing and thus must be accommodated during each 24-hour interval. It is broken down by major classification such as TV, digital, analog, samples, film, magnetic tape.

6. Maximum Data Output Rate. This is the maximum rate at which data is generated by the laboratory after any internal processing, broken down by major classification. The internal processing of data may be as explicitly stated in the Blue Book or as estimated.

7. Data Disposition Requirements. For each class of data output identified above, the first major function that must be performed on it after leaving the laboratory is specified, and the portion of the output data subjected to this function is estimated. The functions considered include display, storage, real-time or near real-time transmission to ground, and real-time on-board processing.

8. Data Input Requirements. These are the data which must be provided to the laboratory in order to support its operations. Examples include ephemeris and attitude data, time signals, externally generated experiments data, etc.

9. Logistics Input Requirements. This is a specification of the quantity of consumables and replacement parts that must be provided to the laboratory. Consumables are specified by major type (cryogens, gases, etc.) only for those cases where potential overlap with MSS-provided stores exists. Consumables are specified on a 30-day basis; actual intervals for replacement parts shipments are specified.

10. Logistic Outputs. These are specified on the same basis as logistic inputs. Note that data-type outputs are specified under data output, not under logistics.

11. Guidance and Control Requirements. These are requirements for the stabilization, attitude control, or limitation of attitude rates of the laboratory as a whole. Data generated by the G&C subsystem to be used in controlling a portion of the laboratory are specified under data input requirements. The interface requirement on the supporting system is specified, after accounting for all internal capability, whether actual or assumed.

12. Operational Requirements. Each laboratory may have certain special operational requirements, such as flight mode (inertial or local vertical reference), environmental requirements (acceleration, vibration, temperature), etc. These are specified here.

3.2 GENERAL-PURPOSE LABORATORY

This subsection describes the methodology used to define a Level II General-Purpose Laboratory (GPL); identifies the functions for a GPL to go on board the initial space station; lists and defines the equipment selected for the GPL; summarizes the GPL requirements; and provides design concepts for a typical GPL configured for FPE's selected for the initial station. These functions, requirements, and equipment satisfy the experiment program defined in NASA Report, NHB 7150.1, Reference Earth Orbital Research and Applications Investigations, dated January 15, 1971 (NASA Blue Book).

3.2.1 METHODOLOGY

The methodology used in this study (Figure 3-1) is described in the following paragraphs.

The input to this portion of the study is the experiment definition data from the NASA Blue Book. This was expanded in a concurrent NR Space Experiments Laboratory (SEL) study, which identified 305 functions required for experiment functional support for all the FPE's. The results of this study are documented in SD 71-272, Space Experiment Laboratories Functional Requirements Definition and Data Bank.

The major evaluation criterion used in the selection of GPL functions from the list of candidates was commonality across FPE's. If a function applied to six or more FPE's, it was selected as a candidate GPL function. The rationale for the determination of this commonality level is discussed below.

The function data contained in SD 71-272 were analyzed, and the number of FPE's supported by each function was identified. Functions were grouped according to the number of FPE's they supported. The distribution of functions according to number of FPE's to which they are applicable is illustrated in Figure 3-2.

Figure 3-3 illustrates the distribution of all common FPE functions with respect to their level of commonality.

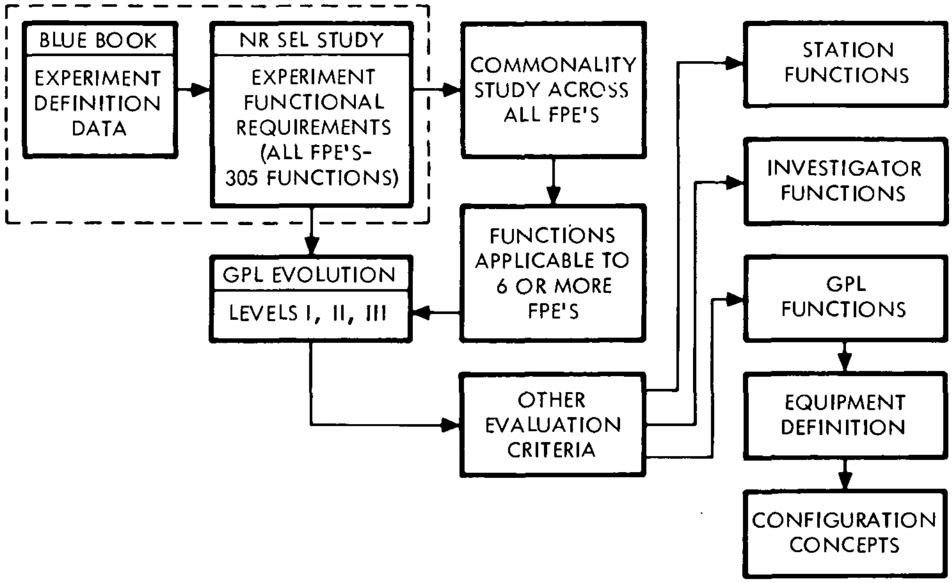


Figure 3-1. GPL Function/Equipment/Concept Methodology

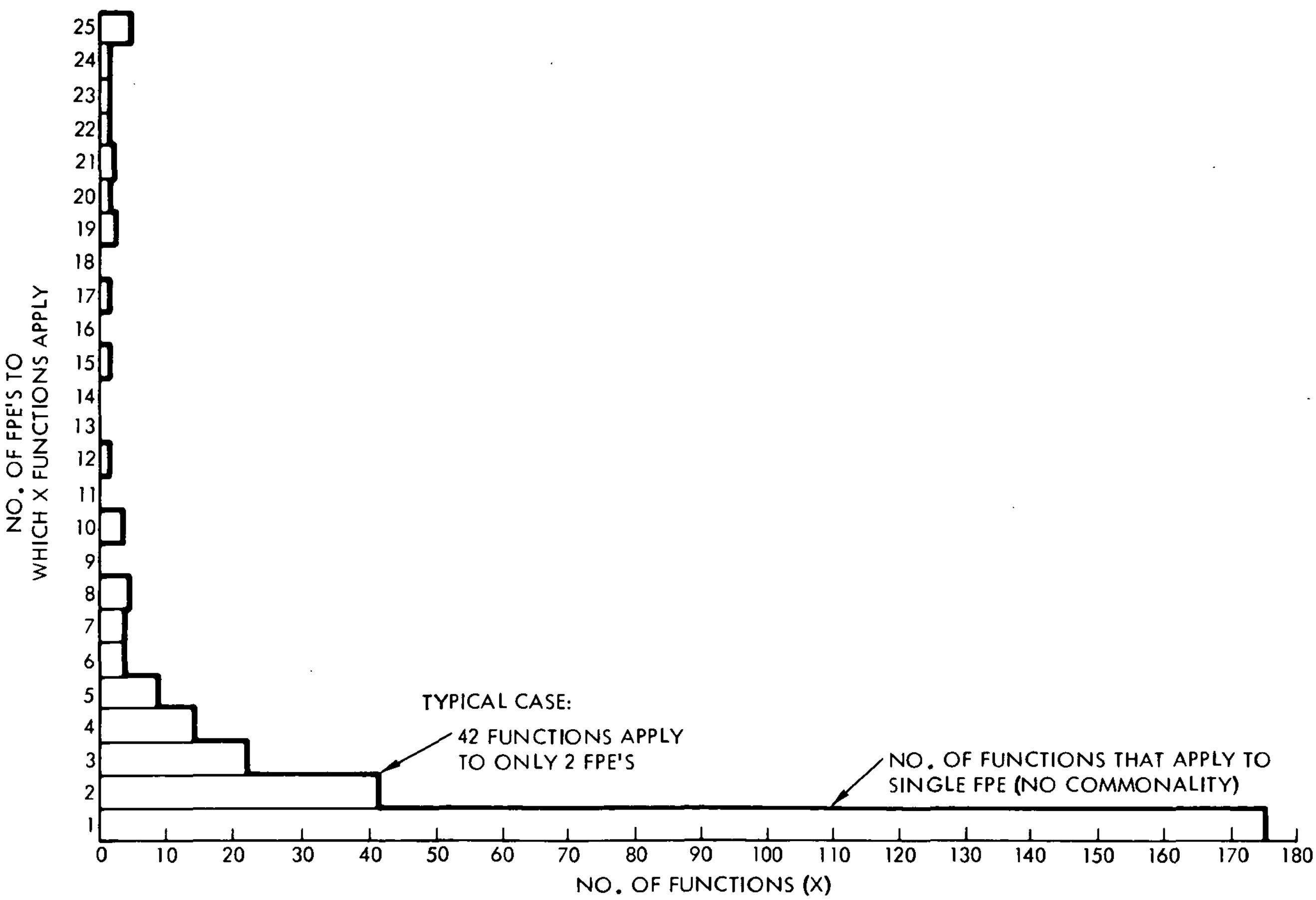


Figure 3-2. FPE Usage of Functions

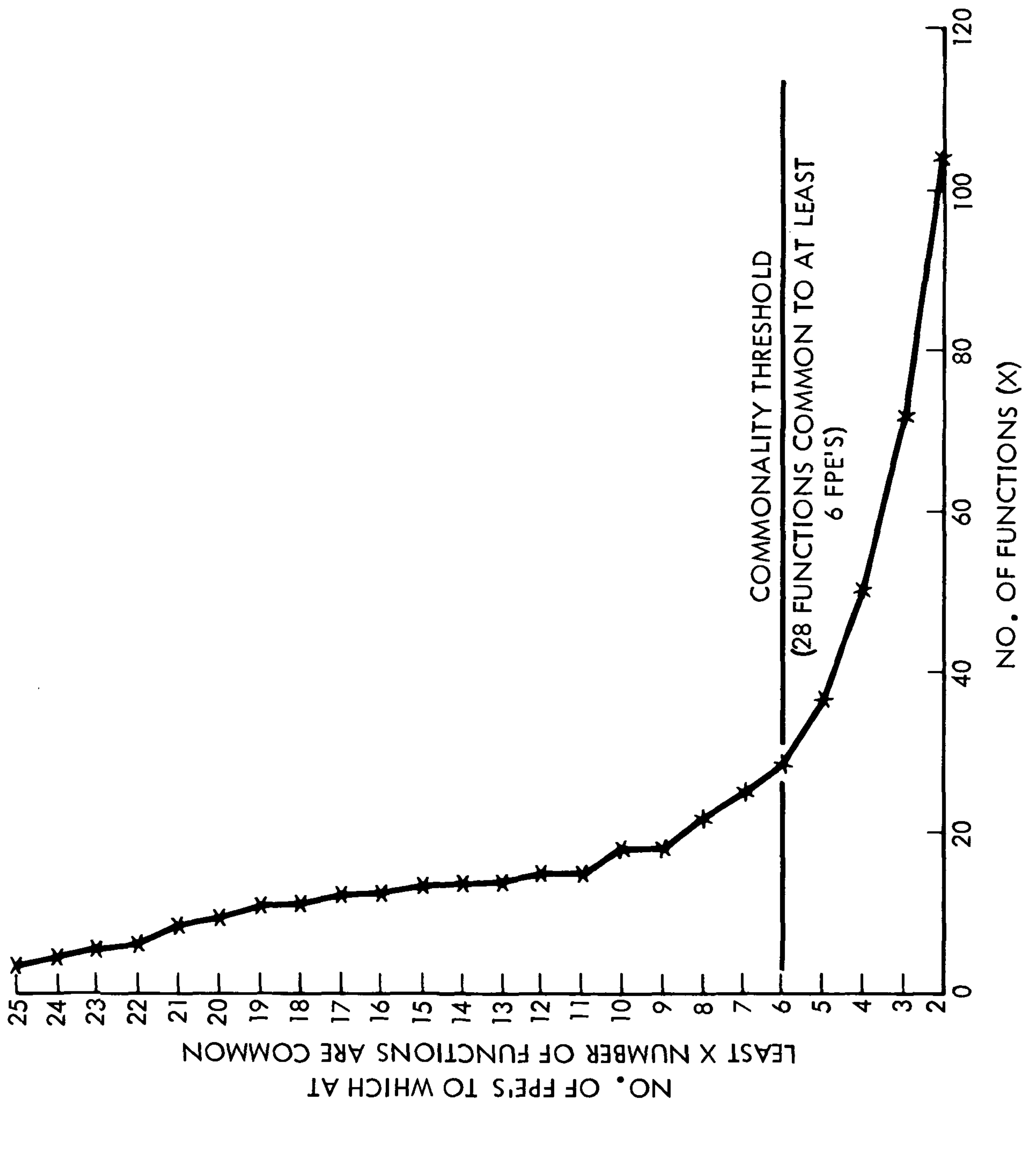


Figure 3-3. Determination of Function Commonality Threshold With Respect to Number of FPE's

Figure 3-3 shows that at the six-FPE level the distribution curve direction changes significantly. This was selected as the threshold for FPE commonality for a GPL function.

In addition to the commonality criterion, the evolution of station buildup to provide for an expanding scientific exploration program was considered. The GPL for Level I operations provides limited support and accommodation for conducting short-duration, high-benefit experiments. For Level II, the GPL provides the necessary general support and accommodation for conducting precursor-type experiments and a continuation of the high-benefit experiments requiring longer periods of operation. At Level III, the GPL offers a general support role for all experiments to be conducted and for conducting experiments requiring high crew involvement. Selection of functions for the GPL must consider these evolution criteria to facilitate an orderly buildup to the final configuration.

A more definitive illustration of the GPL evolution criteria, showing the objectives, experiment areas, and rationale, is contained in Table 3-2. This study considered in detail only Level II, as shown in the middle column of this table, in establishing the base GPL functions, equipment, and concepts.

In order to screen functions for applicability to the Level II GPL, the Level II experiment laboratory definitions contained in Subsection 3.1 were reviewed. Only Level II laboratories that are implemented in the initial space station contributed functions to the Level II GPL definition. These were of two kinds: (1) those totally accommodated within the GPL, and (2) those accommodated in attached RAMS, which require GPL support. The reference experiment program (Section 6) was used to identify applicable laboratories.

GPL-accommodated laboratories include:

- Space Physics Research Laboratory (FPE P-1)
- Plasma Physics and Environmental Perturbation Laboratory (FPE P-2)
- Physics and Chemistry Laboratory (FPE P-4)
- Earth-Observations Laboratory (FPE ES-1)
- Materials Science Laboratory (FPE MS-1)
- Contamination Measurements Laboratory (FPE T-1)
- Medical Research Laboratory (FPE LS-1)

RAM-accommodated, GPL-supported laboratories include:

Advanced Solar Astronomy Laboratory (FPE A-3)
High-Energy Stellar Astronomy Laboratory (FPE A-5)
Cosmic Ray Physics Laboratory (FPE P-3)

Other evaluation criteria considered are described below. No single criterion eliminated a function as a GPL candidate. Judgment was applied—using all the criteria—to determine the final selection.

If the function lent itself to centralized support, it was considered for GPL application. For example, "data reviewing" could be conducted at several locations in the GPL, but it is advantageous for a single facility to serve all experiments to avoid duplication of equipment and to make efficient use of time and crew skills.

The type of equipment required to perform a given function was another influencing factor. If the equipment required is portable, it complies with the GPL concept of common use or handling and storage. If, however, the equipment is fixed (or permanently installed), it does not lend itself as well to these aspects.

The required physical location of a given function also affected GPL selection. For example, the GPL could not perform a function on the exterior of the station. The GPL might provide other functions in support of the external function. Consequently, only those functions that would be performed within (or from within) the station were considered as GPL functions.

Commonality of functions across FPE's, which is the prime basis for GPL function selection, is subject to compatibility of equipment performance across the FPE's to which the function is common. If common equipment can be used for several functions, it was reassessed for GPL applicability even though these functions may be common to less than six FPE's.

Functions required by experiments conducted in separate modules (RAM's) or detached modules were not considered as GPL functions. Some functions associated with these experiments, however, would be GPL functions if they provide support to such experiments. An example of this type of support function is P011, photographic processing.

Functions selected for the GPL excluded functions performed by the basic station. However, if the required function level exceeds the station capability, the function was considered for GPL.

Table 3-2. General-Purpose Laboratory Evolution Criteria

Level I	Level II	Level III
OBJECTIVES		
Provide housing and common equipment for operation of low-cost "suitcase" experiments with orbit/acceleration sensitivity Provide low-level of experiment support capability	Provide housing and common equipment for operation of precursor and high-benefit/low-cost experiments Provide moderate level of experiment and station support capability	Provide housing and common equipment for operation of experiments requiring high level of crew involvement and leading to advanced systems development Provide high level of experiment and station support capability
EXPERIMENT AREAS		
Communications/Navigation Fluid Management Physics Earth Observations	Earth Observations Contamination Physics Communications/Navigation Biomedicine Materials Science	Earth Observations Technology Physics Life Sciences Communications/Navigation Materials Science
LABORATORY DESCRIPTORS		
Contain equipment common to selected "suitcase" and orbit-sensitive experiment areas Provide support equipment for command/control, minimum data display (engineering data), sensor deployment (small airlock with sensor platform, boom) Contain multipurpose work area	Contain equipment common to selected precursor, high-benefit/low-cost experiment areas Provide support equipment for moderate level of data analysis, sensor deployment (large airlocks) with earth and celestial viewing	Contain equipment common to high crew involvement and advanced systems development experiment areas Provide augmented data analysis, maintenance and repair, photo processing, and other support equipment

3.2.2 GPL FUNCTIONS FOR INITIAL SPACE STATION

The methodology described in the previous section was used to establish the Level II GPL functions for the initial MSS. The GPL will contain equipment, instrumentation, etc., designed into and provided as CFE with the station. This "portion" of the GPL is the "base GPL". In addition to the base GPL provisions, the GPL will provide floor space and station systems interface support to accommodate all other equipment required to fulfill the initial station experiment program. This equipment in the nonbase portion of the GPL will be GFE. This section determines the functions required in the base GPL and establishes the functions required in the nonbase portion of the GPL in order to determine station interface requirements (weight, power, volume, etc.). Base GPL functions are listed in Table 3-3; nonbase GPL functions are presented in Table 3-4.

Table 3-3. Base GPL Functions

Experiment Support Function	Experiment Function
A015 Analysis, Hydrocarbon	R008 Reflectometry, Portable
A016 Analysis, Nitrogen	
A017 Airlock Provision	
C005 Cell Counting	
C006 Colorimetry	
C007 Cytological Stain Preparation	
C009 Culturing, Bacteria	
C029 Centrifuge, Clinical (GD)	
D014 Data Reviewing/Viewing	
H001 Histology	
L002 Lighting, Photo and TV	
L005 Lyophilization	
M001 Maintenance and Calibration, Mechanical	
M002 Maintenance and Calibration, Electrical	
M003 Maintenance and Calibration, Optical	
M004 Maintenance and Calibration, Fluid System	
P002 Photography, Cine (Internal)	
P003 Photography, Still	
P011 Photographic Processing	
P013 Preservation, Culture (refrigeration)	
P014 Preservation, Culture (oven)	
S008 Spectrometry, Mass	
S017 Sterilization	
V004 Viewing, Airlock Window	

Table 3-4. Nonbase GPL Functions (no equipment provided in GPL)

Experiment Functions		Support Functions	
A019	Attitude Control, RF-Integrated	D015	Deploy, Instrument Probe
B001	Bone Densitometry (X-ray)	D016	Deploy, Deep-Space Probe
B002	Ballistocardiography	D017	Deploy, Electrical and Magnetic Sensors
B004	Body Mass Measurement (macro)		
B005	Bulk Properties - Light Transmission Testing		
B006	Bulk Properties - Density Testing		
B007	Bulk Properties - Volume Testing		
B008	Bulk Properties - Thermal Conductivity Testing		
B009	Bulk Properties - Electrical Property Testing		
B010	Bulk Properties - Tensile Testing		
B011	Bulk Properties - Compression Testing		
B012	Bulk Properties - Shear Testing		
B013	Bulk Properties - Ductility Testing		
C010	Chromatography		
C014	Coating, Thin-Film		
C015	Casting, Glass		
C016	Casting, Spherical		
C017	Casting, Composite		
C018	Coronagraphic Imaging, Contamination		
E002	Electrocardiography (ECG)		
E003	Electroencephalography (EEG)		
E004	Electronystamography (ENG)		
E005	Electromyography (EMG)		
E006	Electrocular (EOG)		
E007	Electrogalvanic Skin Response		
E009	Evaluation, Man's Dexterity		
E010	Evaluation, Man's Sound Response		
E011	Evaluation, Man's Strength		
E014	Ergometry		
F001	Fatigue Testing		
F003	Field Sensing, Electrical (External)		
F004	Field Sensing, Magnetic (External)		
F063	Forming, Single-Crystal		

Table 3-4. Nonbase GPL Functions (no equipment provided in GPL)(Cont)

Experiment Functions		Support Functions
I007	Isotope Tracing	
L018	Laser Tracking	
M014	Mapping, TV	
0001	Optical Array Exposure	
0003	Osmolality	
0005	Optical Frequency Transmission/ Receiving	
P008	Photography, UV Airglow	
P016	Plethysmography	
P017	Phoroptery	
P018	Phonocardiography	
P020	Photometry - Sky Background Brightness	
P022	Photometry - Star Fields/Polar Light	
R006	Radiometry, Meteor Flash	
R009	Refractometry	
S006	Spectrometry, Impact Mass	
S013	Spectrometry, Impact Flash	
S015	Spectrophotometry	
S016	Spirometry	
S025	Scanning, IR Horizon	
T009	Testing - Vision	
T010	Testing - Nystagmographic	
T016	Tracking, Star	
T017	Tracking, IR Cold Body	

3.2.3 GPL CHARACTERISTICS FOR INITIAL SPACE STATION

The following paragraphs describe the GPL concept defined to implement the above functional requirements.

To facilitate crew operations and efficient utilization of equipment, the GPL has been subdivided into several different functional areas to be placed in suitable locations throughout the basic station. These areas (for an initial station configuration) are identified in Figure 3-4.

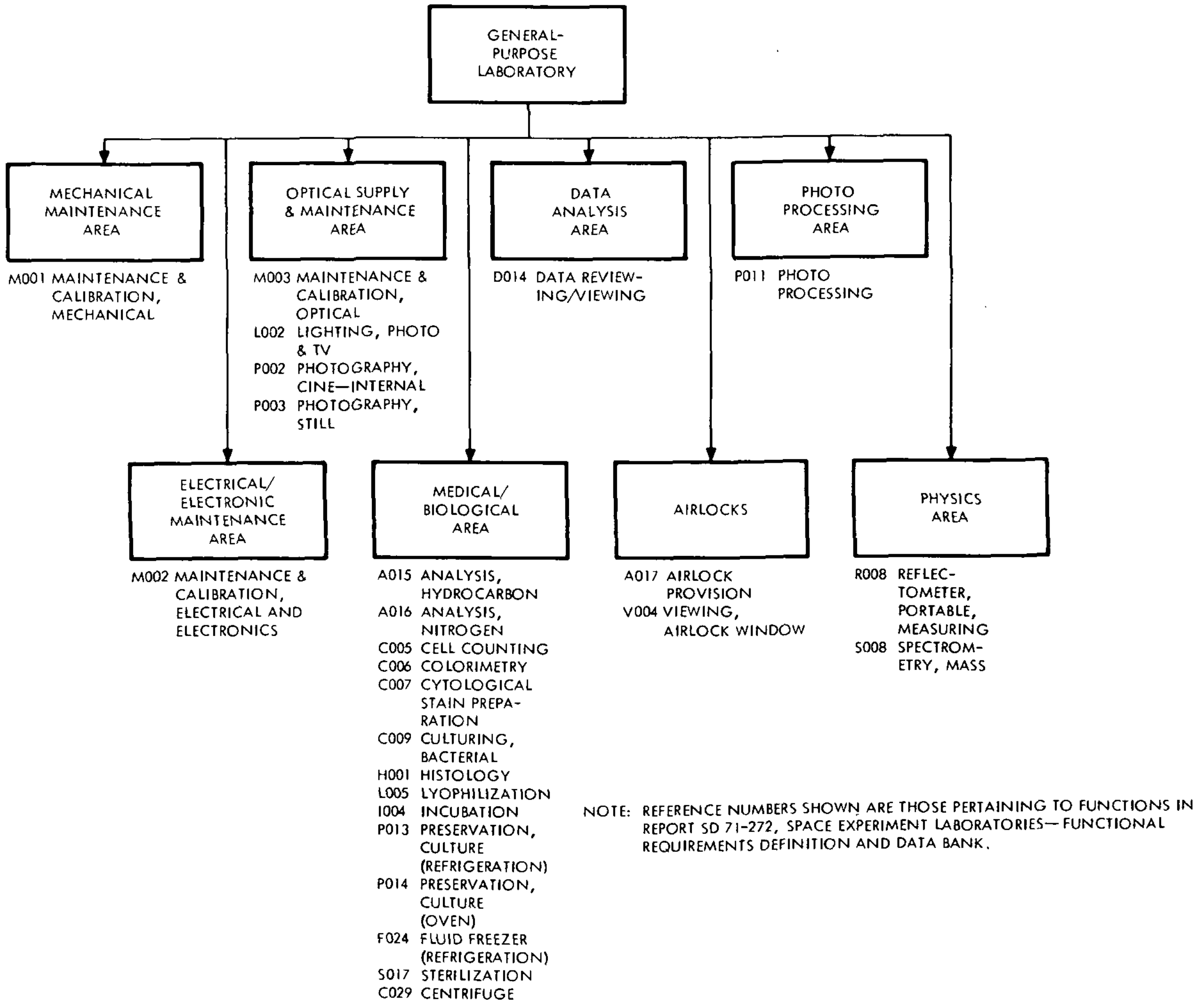


Figure 3-4. Functional Requirements for General-Purpose Laboratory

General requirements for the GPL that do not pertain to any of the GPL areas in particular are:

- Celestial and earth viewing windows

- Mounting and installation of an earth-viewing observation telescope capable of obtaining bearings of earth landmarks. This requirement will be fulfilled by the use of the guidance and control subsystem sextant/telescope assembly, with design modifications to allow separate in-flight retraction and replacement of either the sextant or the telescope. The assembly will be located and mounted so that the fixed line of sight is in the orbital plane and 45 degrees ahead of nadir with the station in the local vertical flight mode. The installation will provide a 120-degree conical field of view centered about the fixed location described above. Magnification of the telescope is 1.0, and of the sextant 28.0.

- Utilities interfaces at RAM berthing ports for resupply of experiment consumables during berthing periods. These interfaces include electrical power, data processing, audio transmission/reception, TV transmission/reception, and supply of nitrogen, oxygen, coolant, water, and freon.

Mechanical Maintenance Area

The mechanical maintenance area will support minor maintenance tasks, including disassembly, repair, calibration and adjustment of simple mechanical assemblies and equipment, and relatively simple mechanical adjustment and alignment. Tools and equipment for the installation and the *in situ* simple mechanical maintenance of experimental mechanical equipment throughout the station and attached and berthed detached modules will be provided. Provisions are also made for the atmospheric isolation and containment of small components for disassembly and reassembly operations.

Electrical/Electronic Maintenance Area

The electrical/electronic maintenance area will support noncomplex maintenance tasks such as disassembly, repair, reassembly, calibration/adjustment, and checkout of relatively small electrical and electronic components and instruments. Repair operations will involve component replacement only and will exclude soldering, potting, and similar processes.

Optical Supply and Maintenance Area

The optical supply and maintenance area will support the following requirements:

- Optical maintenance tasks, including lens and other optical cleaning, minor adjustment and calibration of optical subassemblies and instruments, and calibration of the IR sensors used in the earth observations and astronomy experiments.
- Supplemental lighting equipment will be provided for still and movie photography (e. g., floodlights, electronic flash, etc.). This equipment will be stowed in suitable containers and will be easily available.
- Cine and still cameras will be stored in this area for general support use throughout the experimental areas of the station.

Biomedical Area

The biomedical area will support the following requirements:

- Continuous monitoring and analysis of atmospheric hydrocarbon contaminants in cabin and animal modules.
- Determination of nitrogen content of wastes (urine, feces/ ammonia, titrate slurry) conducted on a batch-analysis basis.
- Determination of blood index condition in zero-g environment and comparison with 1-g data; requires dilution of blood samples (200 to 1).
- Estimation of gross red blood cells by comparison of blood samples with reference color plates.
- Preparation of blood sample slides for microscopic examination.
- Preparation of liquid and particulate samples and introduction into chambers for incubation and exposure evaluation. Requires addition of inert atmospheres to sample culture chambers to ensure controlled conditions.
- Viewing of microstructure of man, animal, and plant samples with microscopic equipment. Samples will be in the form of smears, thin slices, etc.

- Freeze-drying of man and animal plasmas, urine, and feces for later analysis in earth laboratories. Samples usually require centrifugation prior to freeze-drying.
- Elevated temperature cultivation of specimens and biological samples for subsequent inspection and analysis. Regulated temperature and pressure control under atmospheric gas conditions are necessary.
- Refrigerated storage of culture media (potato, agar, etc.).
- Elevated-temperature conditioning of sensitized culture media to ensure combination of antibodies and organisms.
- Preservation of pharmaceuticals in refrigerated environment.
- Cleansing of equipment and instruments used for biological or biomedical purposes by elimination of all microorganisms.
- Separation of particulate matter from fluid matter by centrifugal accelerations applied to the substance (e.g., separation of blood cells from blood plasma).

Data Analysis Area

The data analysis area will provide the capability for film and taped data review. This includes film editing, viewing, projection onto viewing screens, illuminated table film viewing, audio taping and playback, and X-Y plotting. This area is located close to the experiment control and monitoring console.

Photographic Processing Area

The photographic processing area supports low-level photographic processing, including developing and printing of small- and medium-sized formats (e.g., 35 mm and 150 mm), and film editing, splicing, and viewing, with lighted-table provisions. Shielded and temperature- and humidity-controlled storage of undeveloped color film for periods up to 30 days is required to accommodate shuttle revisits.

Physics Area

This area is located close to the zenith airlock and will fulfill the following requirements:

- Provide a portable reflectometer to measure the reflectance values of specimen contamination collectors on the exterior of the space station.

- Determine the chemical constituents of atmospheric and biological gases by mass spectrometry.

Experiment Airlocks

Two airlocks will be provided as part of the GPL to deploy scientific instruments to the space environment from the station pressurized volume. One airlock will be earth-pointed, and the other zenith-pointed. Its internal dimensions are as follows: 80 inches in diameter and 150 inches long. Windows will be provided so that the interior of the airlock can be viewed from the pressurized volume and EVA operations can be viewed from inside the airlock. A mounting platform and deployment mechanism will enable the crew to install sensors and equipment from the pressurized volume and to subsequently deploy them to the exterior of the airlock. These platforms will be universally designed so that a minimum of adaptation is required for individual sensor installations.

Utilities interfaces will be provided in each airlock to operate experiment equipment before and after deployment to the space environment. The utilities interfaces include electrical power, data processing, supply of nitrogen, oxygen, air, coolant, contamination removal, and temperature and humidity control.

Experiment Operations Area

This area will accommodate investigator-supplied equipment. Utilities connections and equipment attachment points and mounting interfaces will be provided at convenient locations for installation and operation of the investigator's equipment. The utilities connections interface includes electrical power, data processing, supply of nitrogen, coolant, and water. A volume of 262 cubic feet is required for installation and/or temporary storage of investigator-supplied instrumentation or equipment. It should be located adjacent to the GPL areas that directly support experiment operations (i.e., physics, biomedical, and airlocks).

Adequate clearance is needed around the airlock inner hatches to permit installation of equipment and instrumentation into the airlocks. These clearances require a floor area extending 10 feet into the module from the airlock inner hatch, in line with and the same width as the airlock diameter (80 inches).

An analysis was performed to determine the free floor space required for experiment operations. This was done by reviewing the experiment functions and applying the results of the scheduling analysis (Section 6). For functions that are to be accomplished on the initial space station, experiment equipment envelope sizes were determined and became the basis for the floor spacing requirement, to which was added equipment operations area and astronaut mobility requirements. This resulted in an experiment operations floor space requirement of 341 square feet, of which approximately 177 square feet are required in the biomedical laboratory area, which is shared with the physics area. Approximately 164 square feet are required for the conduct of other experiments.

An experiment airlock sizing study was also performed. The experiment airlock sizing study was based on an MSS study-derived requirement indicating a need for both zenith and nadir experiment airlocks. The study was initiated to determine the size of the airlock featuring low cost, simplicity, minimum acceptable volume, and maximum flexibility in its use. This study is described in Subsection 7.4.

3.2.4 GPL EQUIPMENT FOR INITIAL SPACE STATION

The equipment provided in the GPL is shown (by laboratory and function) in Table 3-5. To facilitate subsequent tasks, a new grouping was made by equipment and identification numbers given to these items (Figure 3-5). The design characteristics of these items are given in Table 3-6.

3.2.5 DESIGN CONCEPT

Figures 3-6, 3-7, and 3-8 present a concept of the areas of the GPL located in SM-1, SM-2, and SM-3 of the MSS. These approaches include all the equipment identified in the previous section and also satisfy the additional GPL requirements described in the previous sections.

Table 3-5. Base GPL Equipment (CFE)

Function Number	Function Name	Equipment
MEDICAL/BIOLOGICAL LABORATORY		
A015	Analysis, hydrocarbon	Total hydrocarbon analyzer
A016	Analysis, nitrogen	Nitrogen analyzer
C005	Cell counting	Autocytometer
C006	Colorimetry	Colorimeter
C007	Cytological stain	Staining apparatus
C009	Culturing, bacterial	Culture chamber
H001	Histology	Microscope and kit
L005	Lyophilization	Lyophilizer
I004	Incubation	Incubator
P013	Preservation, culture (R)	Refrigerator module
P014	Preservation, culture (O)	Incubator module
F024	Fluid freezer	Refrigerator
S017	Sterilization	Autoclave
C029	Centrifuge	Centrifuge
PHYSICS LABORATORY		
A017	Airlock provision	Experiment airlock
V004	Viewing, airlock window	Airlock window
R008	Reflectometry, portable	Portable reflectometer, samples and retrieval box
S008	Spectrometry, mass	Mass spectrometer (quadrupole) Workbench
DATA ANALYSIS LABORATORY		
D014	Data reviewing/viewing	Control console Workbench, desk Light table Film viewer/editor X-Y plotter Video tape unit Tape deck/strip chart Cabinet storage
OPTICAL SUPPLY AND MAINTENANCE LABORATORY		
M003	Maintenance and calibration, optical	Bench, zero-g light duty IR calibration device Precision work fixture Optical bench with ancillary equipment

Table 3-5. Base GPL Equipment (CFE) (Cont)

Function Number	Function Name	Equipment
OPTICAL SUPPLY AND MAINTENANCE LABORATORY		
L002	Lighting, photo and TV	Floodlights, electronic flash
P002	Photography, Cine—internal	Cine cameras (3) and miscellaneous mounting hardware
P003	Photography, still	Still cameras: 35-mm (3); 70-mm (1) Microscope/camera Time-lapse camera Miscellaneous mounting hardware
ELECTRICAL/ELECTRONICS MAINTENANCE LABORATORY		
M002	Maintenance and calibration, electrical/electronics	Electronic, all-duty work station Multipurpose test bench and work area Variable voltage source Storage area for portable instruments, reference materials, and experiment spares
MECHANICAL MAINTENANCE LABORATORY		
M001	Maintenance and calibration, mechanical	Mechanical work bench and storage Laminar flow glove box Miscellaneous mechanical tools and maintenance equipment kit
PHOTOGRAPHIC PROCESSING LABORATORY		
P011	Photo processing	Editor processing bench Light table Operations console Cabinet storage

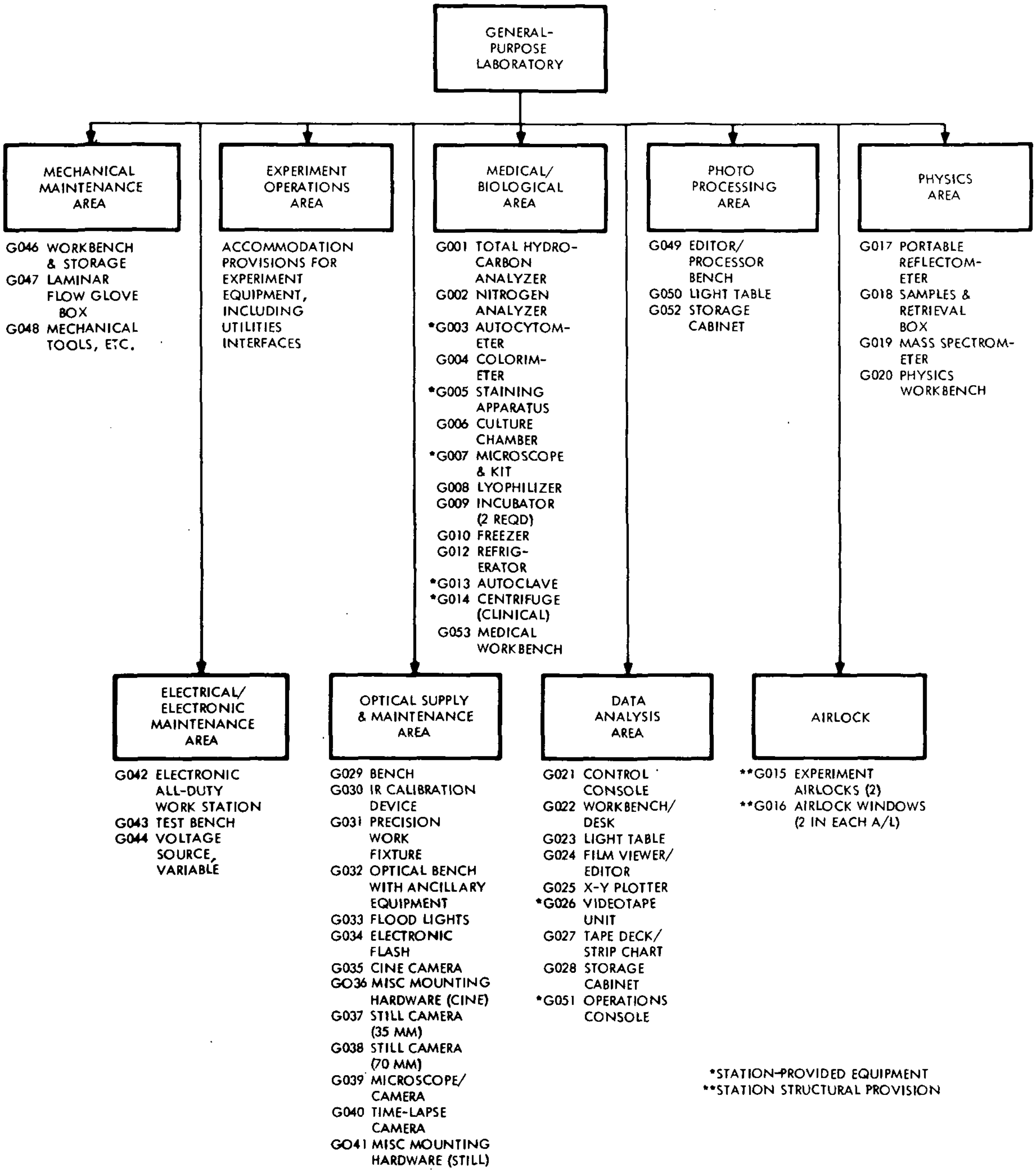


Figure 3-5. Equipment Assemblies for General-Purpose Laboratory

Table 3-6. GPL Equipment Characteristics

ID Number	Name	Operating Power	Weight (lb)	Volume (cu ft)	Size (in.- LxWxH)
	MEDICAL/BIOLOGICAL				
G001	Total hydrocarbon analyzer	25	20	1.5	15x15x10
G002	Nitrogen analyzer	0.9	3	0.03	8x4x2
G003	Autocytometer	20	10	0.4	8x12x8
G004	Colorimeter	20	10	0.4	8x12x8
G005	Staining apparatus	N/A	2.5	0.01	6x3x1
G006	Culture Chamber	N/A	1.0	0.01	6x3x1
G007	Microscope and kit	25	10	1.0	8x12x16
G008	Lyophilizer	0	10	0.8	16x8x18
G009	Incubator (2 required)	60	20	0.7	12x10x12
G012	Refrigerator	50	20	3	18x16x18
G010	Freezer	25	5	1	15x12x10
G013	Autoclave	1000	25	2	18x8x12
G014	Centrifuge (clinical)	100	8	0.25	8x8x7
G053	Medical workbench	N/A	80	120	96x36x84
	PHYSICS				
G017	Portable reflectometer	N/A	10	0.8	12x12x10
G018	Samples and retrieval box	N/A	27	0.25	12x12x1/4
G019	Mass spectrometer	35	25	0.4	9x10x8
G020	Physics workbench	N/A	50	67.5	60x30x36
	AIRLOCKS				
G015	Experiment airlock (2 required)	N/A	N/A	N/A	80 dia x 150
G016	Airlock window	N/A	N/A	N/A	15 dia
G054	Sensor deployment mechanism	TBD	TBD	TBD	TBD
G055	Sensor mounting platform	TBD	TBD	TBD	TBD
	DATA ANALYSIS				
G021	Control console		100	36	24x36x72
G022	Workbench/desk		120	38	24x76x36
G023	Light table		50	20	28x24x36
G024	Film viewer/editor		90	24	24x36x48
G025	X-Y plotter		50	12	24x24x36
G026	Videotape unit		136	18	36x24x36

Table 3-6. GPL Equipment Characteristics (Cont)

ID Number	Name	Operating Power	Weight (lb)	Volume (cu ft)	Size (in.-LxWxH)
	DATA ANALYSIS (CONT)				
G027	Tape deck/strip chart		50	15	24x30x36
G028	Storage cabinet		100	22.5	18x30x72
G051	Operations console		50		24x36x50
	PHOTO PROCESSING				
G049	Editor/processor bench		200		24x80x36
G050	Light table		120		48x18x36
G052	Storage cabinet		150		18x60x82
	OPTICAL SUPPLY AND MAINTENANCE				
G029	Bench, zero-g, light duty	N/A	120	79	60x30x76
G030	IR calib. device		75	6.5	20 dia x 90
G031	Precision work fixture	N/A	50	4.0	12x24x24
G032	Optical bench with ancillary equip.	N/A	450	78	160x24x36
G033	Floodlights		8	0.05	5 dia x 4
G034	Electronic flash	N/A	2	0.01	2x3x2
G035	Cine camera (3 required)	N/A	5	0.05	6x3x5
G036	Misc. mounting hardware (cine cameras)	N/A	15	0.25	12x6x6
G037	Still camera (35-mm) (3 required)	N/A	3	0.04	6x3x4
G038	Still camera (70-mm)	N/A	6	0.1	4x4x5
G039	Microscope camera	N/A	12	0.25	12x6x6
G040	Time-lapse camera	N/A	5	0.05	6x3x5
G041	Misc. mounting hardware (still cameras)	N/A	15	0.4	12x8x6
	MECHANICAL MAINTENANCE				
G046	Mechanical work bench and storage	N/A	175	52	30x84x36
G047	Laminar flow glove box	N/A	200	12	24x36x24
G048	Misc. mechanical tools and maintenance kit	N/A	100	4.0	24x24x12
	ELECTRICAL/ELECTRONIC MAINTENANCE				
G042	Electronic all-duty work stand		120	45	36x36x60
G043	Multipurpose test bench and work area		100	45	60x30x36
G044	Variable voltage source		100	24	36x24x48
G045	Storage area for portable instruments, etc.		200	104	48x48x78

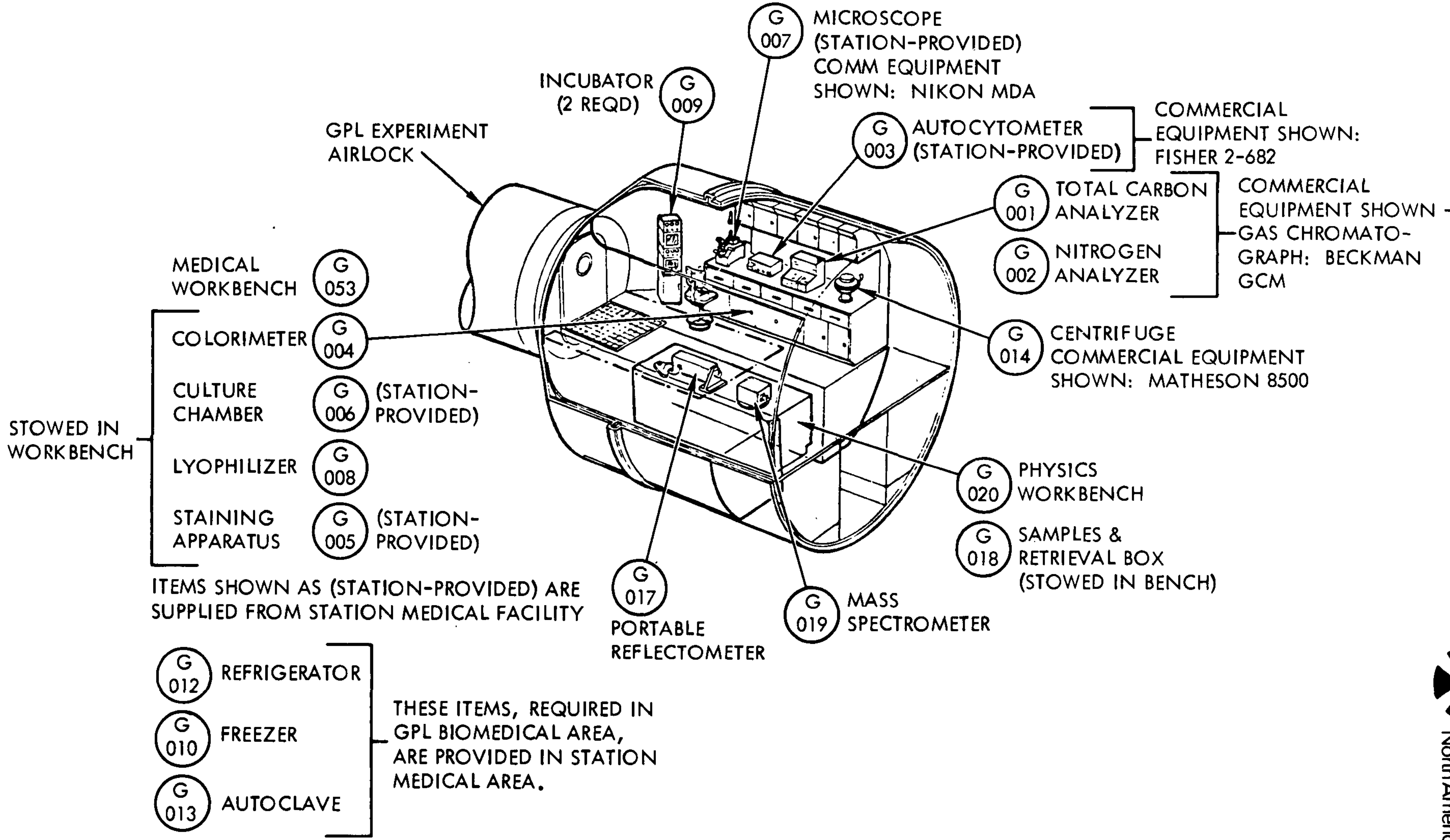


Figure 3-6. Equipment Arrangement in Initial-Station Physics and Biomedical/Biological Areas (General-Purpose Laboratory)

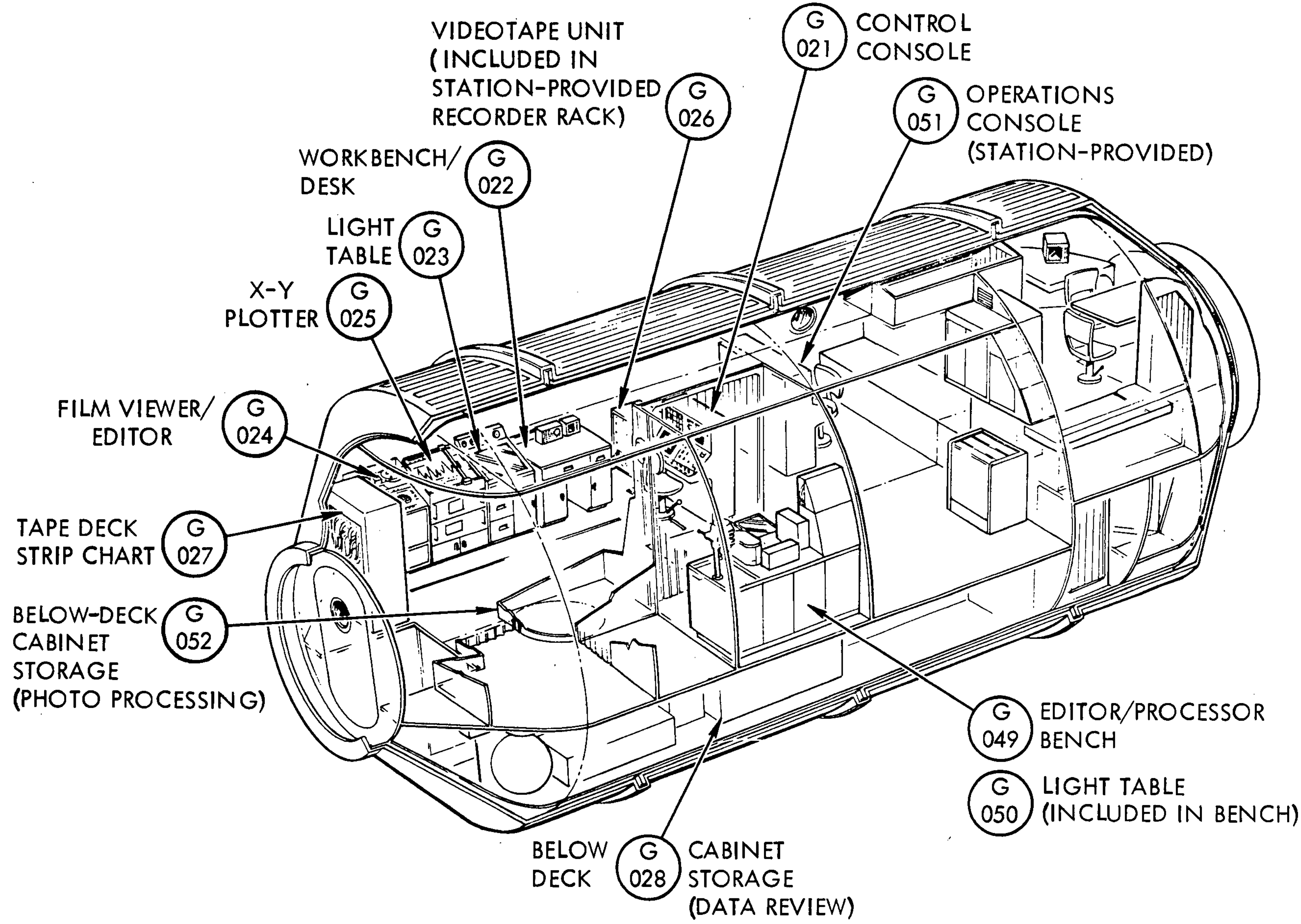


Figure 3-7. Equipment Arrangement in Initial-Station Data Analysis and Photo Processing Areas (General-Purpose Laboratory)

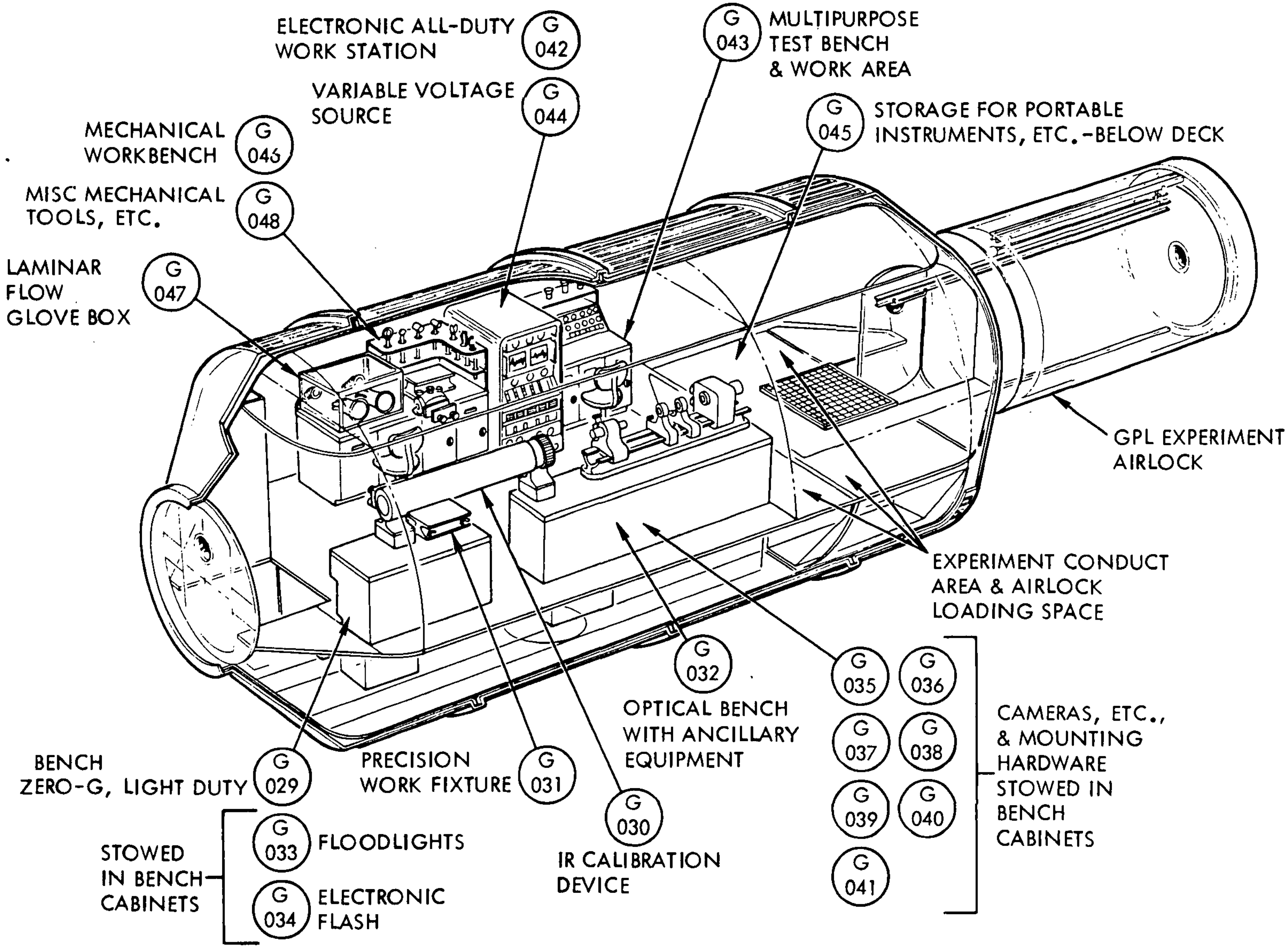


Figure 3-8. Equipment Arrangement in Initial-Station Electrical/Mechanical/ Optical Maintenance Areas (General-Purpose Laboratory)

4. EXPERIMENT MODE OF ACCOMMODATION

Each experiment in the 1971 Blue Book has been reviewed and classified in one of the following modes of accommodation:

GPL	General-Purpose Laboratory
FF RAM	Free-Flying Research and Application Module (DRAM)
Attached RAM	RAM that operates docked to the station (ARAM)

Additional variations to these modes are:

GPL/airlock - experiment that is housed in the GPL but requires airlock deployment

(+) Subsat - in addition, requires the deployment of a subsatellite

The basis for the mode selection is a qualitative analysis of the various filters used in previous Space Station Phase B analyses. Prominent among these criteria are stability, contamination, man involvement, electromagnetic interference, and partial gravity environment. Table 4-1 shows the recommended modes and the key driver or criterion. Explanatory notes are included at the end of the table.

Table 4-1. Experiment Mode of Accommodation

Discipline, FPE, and Experiment Designation	Title	Mode	Driver
A	Astronomy		
A-1	X-Ray Stellar Astronomy		
A-1.1	High-Resolution X-Ray Telescope Experiments	FF RAM	Contamination
A-1.2	Large-Area, Moderate-Resolution X-Ray Telescope Experiments	FF RAM	Contamination
A-1.3	Proportional Counter Array Experiments	FF RAM	Contamination
A-1.4	Scintillation Counting	FF RAM	Contamination
A-1.5	Crystal Spectrometer Experiments	FF RAM	Contamination
A-1.6	Transient X-Ray Phenomena Detection Experiment	FF RAM	Contamination
A-2	Advanced Stellar Astronomy		
A-2.1	Technology Experiments	FF RAM	
A-2.2	Stellar Observation Experiments	FF RAM	Stabilization and contamination
A-3	Advanced Solar Astronomy		
A-3.1	Photoheliograph Experiments	FF RAM	Contamination
A-3.2	XUV Spectroheliograph Experiments	FF RAM	Contamination
A-3.3	X-Ray Grazing Incidence Telescope Experiments	FF RAM	Contamination
A-3.4	Solar Coronagraph Experiments	FF RAM	(Note 1)
A-4	Intermediate-Size UV Telescope		
A-4.1	Narrow-Field UV Telescope Experiments	FF RAM	Contamination (Note 2)
A-4.2	Wide-Field UV Telescope Survey Experiments	FF RAM	Contamination (Note 2)
A-5	High-Energy Stellar Astronomy		
A-5.1	Low-Energy X-Ray Telescope Experiments (0.1 to 5 kev)	FF RAM	Contamination
A-5.2	X-Ray Source Mapping	FF RAM	Contamination
A-5.3	Narrow-Band Spectrometry and Polarimetry (6 to 10 kev)	FF RAM	Contamination
A-5.4	Large-Area X-Ray Counter Measurements (0.1 to 100 kev)	FF RAM	Contamination
A-5.5	Cosmic X-Ray Energy Spectra (6 to 400 kev)	FF RAM	Contamination
A-5.6	Gamma Ray Spectrometry (0.06 to 10 mev)	Attached RAM	(Note 3)
A-5.7	High-Energy Gamma Ray Measurements With Large-Area Spark Chamber	Attached RAM	(Note 3)
A-6	Infrared Astronomy		
A-6.1	Detector Array Scanning	FF RAM	Contamination
A-6.2	Radiometry	FF RAM	Contamination and stability
A-6.3	High-Resolution Spectrometry	FF RAM	Contamination and stability

Table 4-1. Experiment Mode of Accommodation (Cont)

Discipline, FPE, and Experiment Designation	Title	Mode	Driver
P	Physics		
P-1	Space Physics Research Laboratory		
P-1.1	Atmospheric and Magnetospheric Sciences (including aurora)	GPL/ airlock	Requires boom deployment
P-1.2	Cometary Physics—Gaseous Release	GPL/ airlock	Requires boom deployment
P-1.3	Meteoroid Science	GPL/ airlock	Requires boom deployment
P-1.4	Small Astronomy Telescope	GPL/ airlock	Requires boom deployment
P-2	Plasma Physics and Environmental Perturbation Laboratory		
P-2.1	Investigation of Plasma Wake Around Orbital Bodies	GPL/ airlock + subsat	(Note 4)
P-2.2	Investigation of Plasma Resonances and Their Harmonics	Subsat/ airlock	RF interference
P-2.3	Investigation of Wave-Particle Interactions with VLF	GPL/ airlock	Requires deployment of antenna
P-2.4	Investigation of Electron and Ion Beam Propagation	GPL/ airlock + subsat	Requires deployment
P-3	Cosmic Ray Physics Laboratory		
P-3.1	Charge and Energy Spectra of Cosmic Ray Nuclei	Attached RAM	Physical dimensions and EMI
P-3.2	Electron and Positron Energy Spectra and Anisotropies	Attached RAM	Physical dimensions and EMI
P-3.3	Isotopic Composition of Light Elements	Attached RAM	Physical dimensions and EMI
P-3.4	Search for Nucleonic Antimatter	Attached RAM	Physical dimensions and EMI
P-3.5	Extremely Heavy Nuclei	Attached RAM	Physical dimensions and EMI
P-4	Physics and Chemistry Laboratory		
P-4.1	Molecular Beam Scattering	GPL/ airlock	Man involvement
P-4.2	Gas-Surface Interactions	GPL/ airlock	Man involvement
P-4.3	Flame Chemistry and Reaction Kinetics at Zero g	GPL	Man involvement
P-4.4	Chemical Lasers	GPL/ airlock	Samples to be deployed through airlock
P-4.5	Quantum Effects at Low Temperature and Zero g	GPL	Man involvement
P-4.6	Gas Reaction in Space	GPL/ airlock	Requires boom deployment

Table 4-1. Experiment Mode of Accommodation (Cont)

Discipline, FPE and Experiment Designation	Title	Mode	Driver
P-4.7	Heat Transfer in a Convectionless Medium	GPL	Man involvement
P-4.8	Critical-Point Phenomena	GPL	Man involvement
E	Earth Observations		
E-1	Earth Observations Facility	Attached RAM	Viewing area requirements for concurrent observations using many sensors simultaneously make desirable an attached facility
E-1.1	Meteorology and Atmospheric Sciences	Attached RAM	
E-1.2	Land-Use Mapping	Attached RAM	
E-1.3	Air and Water Pollution	Attached RAM	
E-1.4	Resource Recognition and Identification	Attached RAM	
E-1.5	Natural-Disaster Assessment	Attached RAM	
E-1.6	Ocean Resources	Attached RAM	
E-1.7	Special Research	Attached RAM	
C	Communications/Navigation		
C-1	Communications/Navigation Research Facility		(Note 5)
C-1.1	Optical Frequency Demonstration	GPL + subsat	(Note 6)
C-1.2	Millimeter-Wave Communication System and Propagation Demonstration	GPL/ airlock + subsat	Requires deployment of antenna
C-1.3	Surveillance and Search and Rescue Systems Demonstration	GPL/ airlock + subsat	Antenna deployment (Note 7)
C-1.4	Satellite Navigation Techniques for Terrestrial Users	GPL/ airlock + subsat	Requires deployment of antenna (Note 8)
C-1.5	On-Board Laser Ranging	GPL + subsat	
C-1.6	Autonomous Navigation Systems for Space	GPL/ airlock	Antenna deployment
C-1.7	Transmitter Breakdown Tests	GPL/ airlock	Antenna deployment
C-1.8	Terrestrial Noise Measurements	GPL/ airlock	Antenna deployment
C-1.9	Noise Source Identification	GPL	
C-1.10	Susceptiblity of Terrestrial Systems to Satellite Radiated Energy	GPL/ airlock	Antenna deployment

Table 4-1. Experiment Mode of Accommodation (Cont)

Discipline, FPE, and Experiment Designation	Title	Mode	Driver
C-1.11	Tropospheric Propagation Measurements	GPL	
C-1.12	Plasma Propagation Measurements	GPL/ airlock + subsat	(Note 9)
C-1.13	Multipath Measurements	GPL/ airlock + subsat	Antenna deployment plus multipaths with aircraft and subsatellite
M	Materials Science and Manufacturing		
M-1	Materials Science and Manufacturing Facility		(Note 10)
M-1.1	Metallurgical Processes	GPL	Man involvement
M-1.2	Crystal Growth	GPL	Man involvement
M-1.3	Glass Processes	GPL	Man involvement
M-1.4	Biological Processing	GPL	Man involvement
M-1.5	Physical Properties of Fluids	GPL	Man involvement
T	Technology		
T-1	Contamination Measurements	GPL/ airlock	Requires deployment
T-1.1	Sky Background Brightness Measurements	GPL/ airlock	Requires deployment
T-1.2	Real-Time Contamination Measurements	GPL/ airlock	Requires deployment
T-1.3	Surface Degradation Experiment	GPL/ airlock	Requires deployment
T-1.4	Contaminant Cloud Composition Measurement	GPL/ airlock	Requires deployment
T-1.5	Contaminant Dispersal Measurements	GPL/ airlock	Requires deployment
T-1.6	Integrated Real-Time Contamination Monitor: Optical Module Evaluation	GPL/ airlock	Requires deployment
T-1.7	Active Cleaning Technique Evaluation	GPL/ airlock	Requires deployment
T-1.8	Contamination Control Evaluation	GPL/ airlock	Requires deployment
T-2	Fluid Management		(Note 13)
T-2.1	Liquid/Vapor Interface Stability	FF RAM	Microgravity control
T-2.2	Boiling Heat Transfer	FF RAM	Microgravity control
T-2.3	Capillary Studies	FF RAM	Microgravity control
T-2.4	Condensing Heat Transfer	FF RAM	Microgravity control
T-2.5	Two-Phase Flow Regimes	FF RAM	Microgravity control

Table 4-1. Experiment Mode of Accommodation (Cont)

Discipline, FPE, and Experiment Designation	Title	Mode	Driver
T-2.6	Propellant Transfer in Space	FF RAM	Microgravity control
T-2.7	Long-Term Cryogenic Storage	FF RAM	Microgravity control
T-2.8	Slush Propellant Behavior	FF RAM	Microgravity control
T-2.9	Two-Phase Dynamics	FF RAM	Microgravity control
T-2.10	Channel Flow Systems	FF RAM	Microgravity control
T-2.11	Conical Flow Systems	FF RAM	Microgravity control
T-3	Extravehicular Activity		
T-3.1	Astronaut Maneuvering Unit	GPL/ airlock	
T-3.2	Maneuvering Work Platform	Attached hangar	(Note 14)
T-4	Advanced Spacecraft Systems Tests		
T-4.1	Oxygen Recovery and Biowaste Resistojet	GPL/ airlock	Requires external mounting of R-jets
T-4.2	Maintainable Flight Electronics Package Experiment	GPL	Man involvement
T-4.3	Thermal Coating Refurbishment in Space	GPL/ airlock	External exposure
T-4.4	Absorption Refrigeration Cycle Experiment	GPL	Man involvement
T-4.5	Leak Detection and Repair	GPL/ airlock	External exposure
T-4.6	Maintainable Attitude Control Propulsion System	GPL/ airlock	Requires EVA
T-4.7	Ball Bearing Lubrication	GPL/ airlock	External exposure
T-4.8	Advanced Guidance Subsystems Evaluation	FF RAM	
T-4.9	Space Calibration of Solar Cell Standards	GPL/ airlock	Requires deployment
T-4.10	Space Exposure Effects on Material Bulk Properties	GPL/ airlock	Requires deployment
T-4.11	Space Exposure Effects on Material Fatigue Properties	GPL/ airlock	Requires deployment
T-4.12	Fire Sensing and Suppression	GPL	Man involvement
T-5	Teleoperation		
T-5.1	Initial Flight Experiment	GPL/ airlock	Teleoperator deployment
T-5.2	Functional Manipulation Experiment	GPL/ airlock	Teleoperator deployment
T-5.3	Ground Control Experiment	GPL/ airlock	Teleoperator deployment
L	Life Sciences		
L-1	Medical Research Facility		
L-1.1	Neurological Function	GPL	Man involvement
L-1.2	Cardiovascular Function	GPL	Man involvement

Table 4-1. Experiment Mode of Accommodation (Cont)

Discipline, FPE, and Experiment Designation	Title	Mode	Driver
L-1.3	Renal Function	GPL	Man involvement
L-1.4	Nutrition and Metabolic Function	GPL	Man involvement
L-1.5	Musculoskeletal Function	GPL	Man involvement
L-1.6	Pulmonary Function	GPL	Man involvement
L-1.7	Hematologic Function	GPL	Man involvement
L-1.8	Microbiology and Immunologic Function	GPL	Man involvement
L-1.9	Endocrine Function	GPL	Man involvement
L-1.10	Clinical/Therapeutic Function	GPL	Man involvement
L-1.11	Environmental Factors	GPL	Man involvement
L-2	Vertebrate Research Facility		(Note 11)
L-2.1	Role of Gravity in Mammalian Vital Functions	Attached RAM	Biocontamination + biocentrifuge
L-2.2	Role of Gravity in Vertebrate Life Processes	Attached RAM	Biocontamination + biocentrifuge
L-2.3	Effect of Space Environment on Performance and Behavior	Attached RAM	Biocontamination + biocentrifuge
L-3	Plant Research Facility		(Note 11)
L-3.1	Role of Gravity in Plant Life Cycles and Processes	Attached RAM	Biocontamination + biocentrifuge (Note 12)
L-3.2	Graviception and Tropism	Attached RAM	Biocontamination + biocentrifuge (Note 12)
L-3.3	Effect of Space Environment on Plant Genetics	Attached RAM	Biocontamination + biocentrifuge (Note 12)
L-4	Cells and Tissues Research Facility		(Note 11)
L-4.1	Role of Gravity in Life Processes of Microscopic Organisms and Cultured Tissues	Attached RAM	Biocontamination + biocentrifuge (Note 12)
L-4.2	Effect of Space Environment on Genetic, Subcellular, and Molecular Phenomena	Attached RAM	Biocontamination + biocentrifuge (Note 12)
L-4.3	Role of Gravity in Interspecies Relationships	Attached RAM	Biocontamination + biocentrifuge (Note 12)
L-5	Invertebrate Research Facility		(Note 11)
L-5.1	Role of Gravity in Invertebrate Life Processes	Attached RAM	Biocontamination + biocentrifuge
L-5.2	Effect of Space Environment on Invertebrate Behavior	Attached RAM	Biocontamination + biocentrifuge
L-5.3	Effect of Space Environment on Invertebrate Genetics	Attached RAM	Biocontamination + biocentrifuge
L-6	Life Support and Protective Systems		
L-6.1	Water Recovery Methods and Components	GPL	Crew involvement
L-6.2	Waste Management Methods and Components	GPL	Crew involvement

Table 4-1. Experiment Mode of Accommodation (Cont)

Discipline, FPE, and Experiment Designation	Title	Mode	Driver
L-6.3	Advanced Cooling System Methods and Components	GPL	Crew involvement
L-6.4	Zero-Gravity Whole-Body Shower	GPL	Crew involvement
L-6.5	Advanced Two-Gas Atmosphere Supply and Control Subsystem	GPL	Crew involvement
L-6.6	Atmosphere Supply Methods and Components	GPL	Crew involvement
L-6.7	Oxygen Regeneration Methods and Components	GPL	Crew involvement
L-6.8	Carbon Dioxide Collection Methods and Components	GPL	Crew involvement
L-6.9	Advanced Trace-Contaminant Control and Monitoring Subsystem	GPL	Crew involvement
L-6.10	Protective Clothing and Advanced Space Suit Assemblies	GPL	Crew involvement
L-6.11	EVA Suit and Biopack	GPL	Crew involvement
L-6.12	Food Storage, Preparation, and Feeding Methods	GPL	Crew involvement
L-7	Man-System Integration		
L-7.1	Behavioral Effects	GPL	Crew involvement
L-7.2	Performance Capability Assessment	GPL	Crew involvement
L-7.3	Habitability and Proficiency Maintenance	GPL	Crew involvement
L-7.4	Behavioral Effects and Performance in Rotogravitation	Attached RAM	Physical requirements of manned centrifuge cannot be accommodated in GPL mode

Notes:

1 Solar Coronagraph (Exp. A-3.4) may also be considered a candidate for the attached mode. However, it would be desirable to install the coronagraph in the same free-flying vehicle that performs the other solar measurements.

2 The narrow-field UV telescope and the wide-field UV telescope would be susceptible to space station-induced contamination levels and thus would be better accommodated in the free-flying mode. The attached mode could be considered a candidate mode of implementation provided that extreme measures are adopted to prevent gaseous sources of contamination and if the location of the instruments were carefully selected to prevent impingement or reflection from reaction control jets. Degradation levels for the experiments in the attached mode, even with the most severe precautions that are practical, may be quite significant.

3 Gamma Ray Spectrometry (Exp. A-5.6) and High-Energy Gamma Ray Measurements (Exp. A-5.7) require isolation from large mass and high-Z material in the station. A boom may be employed, but, due to the size of the equipment, airlock deployment is not practical.

4 Investigations of Plasma Wakes Around Orbital Bodies (Exp. P-2.1) requires measurements near the station that can be conducted through the use of airlock-deployed booms, also far-wake measurements approximately 300 meters away from the station that are only practical using a subsatellite.

5 The Communications/Navigation Research Facility may be implemented through the use of an attached RAM. However, the fact that the experiments may be operated nonconcurrently permits the consideration of the GPL mode as a viable one, since the deployable mechanisms may be deployed through an airlock on a time-sharing basis.

6 The Optical Frequency Demonstration experiment requires a space-to-ground link and a space-to-space link. The latter implies a subsatellite.

7 The Surveillance and Search and Rescue System Demonstration requires cooperative operation between the station, subsatellite, and suitable ground terminal facilities.

8 Satellite Navigation Techniques for Terrestial Users may employ cooperative equatorial synchronous satellites and/or low-orbit spacecraft, which does not preclude the necessity for subsatellites in special orbits.

9 The Plasma Propagation Measurements experiment requires a reentry vehicle (RV), from which experimental data will be transmitted to the space station.

10 The equipment specified for the Materials Science and Manufacturing Facility, taken as a whole, exceeds the volume allocation specified for the Materials Processing Lab in the Initial Experiment Capability Model. The mode recommended for the component experiments is GPL, assuming that the experiments will be nonconcurrent.

11 Biology FPE's L-2, L-3, L-4, and L-5 require the use of a Biocentrifuge, which is identified in the CORE equipment and which is too large for GPL accommodation. Biological isolation against contamination from both the crew and the biological subjects may be simplified by the use of a self-contained module.

12 Gravity levels for L-3, Plant Research Facility, and L-4, Cells and Tissues Research Facility, must be maintained below 10^{-5} (90 percent of the time). Special dynamic isolation approaches will have to be adopted to satisfy this requirement, and the use of an attached module may facilitate the solution of the vibration isolation problem.

13 Experiments in the Fluid Management FPE (T-2) require controlled gravity levels between 10^{-3} and 10^{-5} for prolonged periods of time. Besides the complexity this requirement would add if the experiment were accommodated in a GPL or attached RAM mode, the gravity levels would interfere with some of the biomedical and biological experiments requiring low-gravity thresholds.

14 The dimensions of the Manuevering Work Platform exceed the capabilities of the airlock, even if the platform were to be assembled in an EVA mode. A shroud or hangar to house this equipment is needed.

5. EXPERIMENT SELECTION AND PHASING ANALYSIS

The following is a description of the experiment selection and phasing analysis performed as an input to the experiment scheduling activity. The results of this activity were used to develop the reference experiment program, which became the basis for the mission sequence plan for the MSS program. It should be noted that this analysis is of experiment or FPE selection and phasing and that the scheduling activity described in Section 6 is for experiment laboratories.

Due to resource limitations (chiefly available crew time), it became necessary to select, from the 22 experiment laboratories, those that would be accommodated during the initial (six-man) era of the MSS program. The analysis described below provided data for that selection process. The purpose of this analysis was to provide a methodology to classify experiments according to the nature of their benefits and rate experiments within their discipline with respect to their relative worth. Programmatic considerations then led to the determination of experiment priorities for implementation.

The Blue Book (dated 15 January 1971) was the source of experiment definitions employed in this analysis. The programmatic requirement imposed to govern the assignment of priorities was to achieve a reasonable balance of socioeconomic benefit and scientific knowledge.

The results of this analysis reflect many estimates that should be used as "representative" data in the same manner that the specific experiments in the Blue Book are representative of MSS experimentation. Because of the inherent traceability of the methodology developed herein, any changes deemed necessary through the introduction of updated guidelines or more detailed analysis may be incorporated with a minimum of difficulty. This is particularly applicable in the development of priorities, where a large and nonhomogeneous sampling of individual judgments would improve the validity of the results.

5.1 PHASING RATIONALE

The main factors considered in time-phasing the experiments in the reference experiment program are: cost, availability of equipment and techniques, scheduling interrelationships and constraints, priority, system capabilities, and experiment requirements. The specific phasing data developed in this analysis consists of scheduling interrelationships and constraints and experiment priority. The system capabilities are defined in SD 71-205, Modular Space Station System Requirements Book. The latest cost information is contained in Cost Data for Preliminary Edition of the Reference Earth Orbital Research and Application Investigations, NASA Report No. ASR-PD-MP-71-1. Availability dates (for launch) were not known due to programmatic uncertainties relative to the initiation of the experiment development cycles. However, three important indicators may be used to estimate availability:

1. Development time (e.g., 4 to 6 years), as shown in the aforementioned NASA cost data book as well as in the Blue Book.

2. Technological factors that may prevent the initiation of the development cycle until some fundamental technology milestone has been achieved.

3. Projected funding constraints driving toward the postponement of the development of high-cost experiment systems having adverse impact on low early yearly funding requirements for the space station program.

5.2 EXPERIMENT PHASING INTERRELATIONSHIPS AND CONSTRAINTS

Table 5-1 shows a set of scheduling guidelines employed in the experiment phasing procedure.

5.3 FPE PRIORITY ASSIGNMENT

The methodology employed in the analysis of experiment priorities accounted for the two components that constitute a measure of the value of an experiment:

1. Benefit Category. A classification of the type of return to mankind expected from the accomplishment of the stated objectives. This is expressed in terms of the following broad categories:

    socioeconomic benefits

    scientific knowledge

   These are further classified as follows:

    direct or indirect benefits

    actual (measurable) or potential benefits

2. Worth Rating. A relative level on a scale of 1 through 5 that indicates the degree to which the experiment will contribute to the goals or objectives of the related discipline. Level 3 indicates moderate support, Level 4 indicates significant support, while Level 5 indicates support of such magnitude that very important results will be derived in an application sense or in terms of expanding the scope of human knowledge.

A numbering system was devised in which a Roman numeral followed by an Arabic numeral define completely the benefit category. The definitions of the various category combinations are as follows:

I. 1 Experiment directly supports objectives leading to socioeconomic benefits

I. 2 Experiment indirectly supports objectives leading to socioeconomic benefits

I. 3 Experiment directly supports objectives leading to potential socioeconomic benefits

I. 4 Experiment indirectly supports objectives leading to potential socioeconomic benefits

II. 1 Experiment directly supports objectives leading to scientific benefits

II. 2 Experiment indirectly supports objectives leading to scientific benefits

II. 3 Experiment directly supports objectives leading to potential scientific benefits

II. 4 Experiment indirectly supports objectives leading to potential scientific benefits

Where an FPE or experiment fits more than one category, it is so designated. For example, the Solar Astronomy FPE is rated as II. 1 and I. 2.

Table 5-2 summarizes the priority rating for the various FPE's. The list includes several ratings down to the experiment level in selected cases where this was deemed necessary. Table 5-3 includes comments related to the rationale for rating selection.

The desired balanced program requires a proper mixture of socioeconomic and scientific benefits. The hierarchy of priority rank selected to produce the desired mixture emphasizes worth, both in application and scientific experiments, as evidenced by top-ranking of Level 5 experiments in both Categories I and II. Placement of high-worth Category I experiments in a higher rank than Category II experiments is intended to establish a "reasonable" balance. The rationale for this choice is based on the fact that the momentum upon which the MSS program will depend for the development of its full potential (in all benefit areas) will come from socioeconomic benefits derived early in the program.

Actual (or measurable) benefits were emphasized as well as direct benefits. Thus, in selecting the order of rank according to benefit category, the order is I-1, I-3, I-2, I-4; the sequence -1, -3, -2, -4 also applies to Category II (scientific) experiments. Potential benefits were not ranked much lower than actual benefits since the predominant criterion was experiment worth. This relative placement of experiments with potential socioeconomic or scientific benefits is consistent with a balanced perspective in a program that is inherently developmental, and not operational, in nature. The hierarchy of priority rank is as follows:

I. 1 - 5
I. 3 - 5

I. 2 - 5
I. 4 - 5

II. 1 - 5
II. 3 - 5
II. 2 - 5
II. 4 - 5

I. 1 - 4
I. 3 - 4
I. 2 - 4
I. 4 - 4

II. 1 - 4
II. 3 - 4
II. 2 - 4
II. 4 - 4

etc.

Table 5-4 shows the rank designations for the various FPE/ experiments.

Table 5-1. FPE/Experiment Scheduling Constraints and Rationale

FPE Title	FPE No. (Expt No.)	Constraints	Rationale	Remarks
X-Ray Stellar Astronomy	A.1 (A-1.2)	Experiment A-1.2 - Large area moderate resolution. X-Ray telescope experiment should precede high resolution X-Ray telescope experiments whenever possible (A-1.1). However, A-1.2 launch date is 1981 or later.	Large area experiment will catalog position, intensity, and spectral distribution of X-Ray sources. High resolution X-Ray will make detailed studies. 7 year lead time required for instrument procurement.	Long focal length. Large mirror required. Difficult construction.
Advanced Stellar Astronomy Intermediate UV Telescopes	A-2 A-4	Space Physics - P-1 (P-1.4) Small telescopes could precede A-2 and A-4 by at least one year and could also be conducted concurrently with A-2 and A-4 i.e., Space Shuttle followed by GPL - Initial Station.	Use of P-1.4 early could show value of space telescopes in this configuration and intensify efforts on A-2 and A-4.	P-1.4 small telescope experiments physics P-1. Supplements A-2 and A-4, but could also do early precursor work of high interest phenomena.
Advanced Stellar Astronomy Advanced Stellar Astronomy	A-2 A-2	Launch schedule 1981 or later.	Diffraction limited, optical system development limiting.	
Advanced Solar Astronomy	A-3	Launch schedule 1979 or later.	Photoheliograph thermal control system development limiting.	
Infrared Astronomy	A-6	Launch schedule 1982 or later.	Cryogenic cooling system development limiting.	
Contamination Measurements X-Ray Stellar Astronomy Advanced Stellar Astronomy Advanced Solar Astronomy Intermediate UV Telescope Infrared Astronomy Earth Observations	T-1 A-1 A-2 A-3 A-4 A-6 ES-1	Contamination related experiments T-1 should be performed 2 years prior to astronomy experiments could be concurrent with ES-1 on initial station.	Contamination will aid in incorporation of proper countermeasures.	
Contamination Measurement Plasma Physics and Environmental Perturbations	T-1 P-2	Accomplish in same time frame (6 mo.)	Related experiments.	Spacecraft wake studies could be useful in gaining an understanding of the phenomena of contaminant dispersion.
Advanced Space System Tests	T-4 (T-4.8)	Advanced guidance system should be accomplished on first available FF module.	Data on maximum limits of accuracy and stability which can be achieved in orbit should be obtained as soon as possible.	Extreme stability required for astronomy experiments.
Physics and Chemical Lab Contamination Measurement Life Support and Protective Systems	P-4 T-1 LS-6	Accomplish in same time frame if feasible. LS-6.11- EVA	Both FPE's use airlocks. Same airlocks could be used.	Experiments could be accomplished early or late in program with airlock leakage penalty minimized.
Plasma Resonances Communication and Navigation	P-2.1- P-2.4 C/N-1.1- C/N-1.5 C/N-1.12	Subsatellites required for these FPE's could be designed for common use. Experiments accomplished in same time frame, if possible.	Subsatellite deployment is driver on station. Least number of satellites and least number of deployments is most economical.	
Cosmic Ray Physics	P-3	Launch schedule 1981 or later.	P-3 -Physics. 6 year development time. High energy astronomy observatory (HEOS) scheduled 1973-75. HEOS should precede P-3.	

Table 5-2. Priority Rating Summary

FPE Number	Applicable Experiment Number	Category Number	Worth Rating
A-1	All Experiments	II. 1	5
A-2	A-2. 1 Technology exp.	II. 2	3
	A-2. 2 Stellar obs.	II. 1	4
A-3	All Experiments	II. 1 and I. 3	5
A-4	All Experiments	II. 1	3
A-5	All Experiments	II. 1	5
A-6	All Experiments	II. 1	4
P-1	P-1. 1 Atmospheric/ Magnetospheric Sciences	II. 1 and I. 3	4
	P-1. 2 Cometary Physics	II. 1	3
	P-1. 3 Meteoroid Science	II. 2 and I. 1	3
	P-1. 4 Small Astronomy Telescope	II. 2	2
P-2	All Experiments	II. 1	3
P-3	All Experiments	II. 1	5
P-4	All Experiments	II. 1	4
E/S-1	E/S-1. 1 Meteorology and Atmospheric Sciences	I. 1 and II. 1	5
	E/S-1. 2 World Land Use Mapping	I. 1	5
	E/S-1. 3 Air and Water	I. 1	
	E/S-1. 4 Resource Recognition and Identification	I. 1	5
	E/S-1. 5 Natural Disaster Assessment and Identification	I. 1	5
	E/S-1. 6 Ocean Resources	I. 1 and II. 1	5
	E/S-1. 7 Special Research	I. 2	4
C/N-1	C/N-1. 1 Optical Frequency Demonstration	I. 4	4
	C/N-1. 2 Millimeter Wave Communication System and Propagation Demonstration	I. 4	4
	C/N-1. 3 Surveillance and Search and Rescue Demonstration	I. 2	4

Table 5-2. Priority Rating Summary (Cont)

FPE Number	Applicable Experiment Number	Category Number	Worth Rating
	C/N-1.4 Satellite Navigation for Terrestrial Users	I.2	4
	C/N-1.5 On Board Laser Ranging	I.4	3
	C/N-1.6 Autonomous Navigation	I.4	3
	C/N-1.7 Transmitter Breakdown	I.4	3
	C/N-1.8 Terrestrial Noise Measurement	I.2	3
	C/N-1.9 Noise Source Identification	I.3	4
	C/N-1.10 Susceptibility of Terrestrial Systems to Satellite Radiated Energy	I.4	3
	C/N-1.11 Tropospheric Propagation	I.4	3
	C/N-1.12 Plasma Propagation	I.4	3
	C/N-1.13 Multipath Measurements	I.4	3
MS-1	All Experiments	I.3	4
T-1	All Experiments	I.2 and II.2	3
T-2	All Experiments	II.4	3
T-3	All Experiments	I.4 and II.4	3
T-4	All Experiments	I.4 and II.4	4
T-5	All Experiments	I.4 and II.4	4
LS-1	All Experiments	I.2, II.2 and I.4	5
LS-2	All Experiments	II.3	3
LS-3	All Experiments	II.3	4
LS-4	All Experiments	II.3	4
LS-5	All Experiments	II.3	3
LS-6	All Experiments	I.2 and II.2	3
LS-7	All Experiments	I.2 and II.2	3

Table 5-3. Rationale for Experiment Rating

	FPE	Applicable Experiments	Category No.	Comments on Categorization	Worth Rating	Comments on Worth Rating
A-1	X-Ray Stellar Astronomy	All Experiments	II. 1	Directly supports scientific areas in X-Ray astronomy.	5	Very significant support of important high energy astronomy objectives.
A-2	Advanced Stellar Astronomy	A-2.1 Technology Experiments	II. 2	Technologically supports the stellar observation experiments.	3	Significant support of objectives related to stellar astronomy.
		A-2.2 Stellar Observations	II. 1	Directly supports astronomical observations.	4	
A-3	Advanced Solar Astronomy	All Experiments	II. 1 and I. 3	Will satisfy specific scientific objectives in solar investigations. Potentially useful in the development of solar flare prediction techniques	5	Significant support of objectives in solar astronomy and the study of the near-earth environment.
A-4	Intermediate Size UV Telescope	All Experiments	II. 1	Directly benefits scientific areas in UV astronomy.	3	Limited support in comparison with high resolution telescopes such as A-2.
A-5	High Energy Stellar Astronomy	All Experiments	II. 1	Directly benefits scientific areas in H. E. astronomy	5	Very significant support of important high energy astronomy objectives.
A-6	Infrared Astronomy	All Experiments	II. 1	Directly benefits scientific areas in IR astronomy	4	Significant support of IR measurement objective.
P-1	Space Physics Research Laboratory	P-1.1 Atmospheric/Magnetospheric Sciences	II. 1 and I. 3	Directly supports atmospheric science objectives; has potential benefit in establishing a weather prediction model.	4	Significant support of near-earth science; moderate support of possible application objectives.
		P-1.2 Cometary Physics	II. 1	Directly supports scientific objectives	3	Support of cometary physics objectives through a very specific technique, i.e., observation of gaseous releases.
		P-1.3 Meteoroid Science	II. 2 and II. 1	Indirectly supports scientific objectives through technology applicable to space vehicles; directly supports scientific objectives.	3	Supports the study of meteoroids both from scientific and technological points of min.
		P-1.4 Small Astronomy Telescope	II. 2	Indirectly supports those scientific objectives in astronomy that are attainable through larger optical systems.	2	Limited resolution due to limited size of optical aperture.
P-2	Plasma Physics and Environmental Perturbations	All Experiments	II. 1	Directly supports scientific objectives in the study of the magnetospheric environment.	3	Moderate support of scientific objectives.
P-3	Cosmic Ray Physics	All Experiments	II. 1	Directly supports scientific objectives.	5	Very significant support of objectives in high energy physics.
P-4	Physics and Chemical Laboratory	All Experiments	II. 1	Directly supports scientific objectives.	4	Significant support of physics objectives.

Table 5-3. Rationale for Experiment Rating (Cont)

FPE	Applicable Experiments	Category No.	Comments on Categorization	Worth Rating	Comments on Worth Rating
E/S-1 Earth Observation Facility	E-1.1 Meteorology and the Atmospheric Sciences	I.1 and II.1	Directly supports application and scientific objectives.	5	Very significant support of earth observation objectives.
	E.1-2 World Land Use Mapping	I.1	Directly supports Application Objectives.	5	Very significant support of earth observation objectives.
	E.1-3 Air and Water Pollution	I.1	Directly supports Application Objectives.	5	Very significant support of earth observation objectives.
	E-1.4 Resource Recognition and Identification	I.1	Directly supports Application Objectives.	5	Very significant support of earth observation objectives.
	E-1.5 Natural Disaster Assessment and Identification	I.1	Directly supports Application Objectives.	5	Very significant support of earth observation objectives.
	E-1.6 Ocean Resource	I.1 and II.1	Directly supports application and scientific objectives is oceanography.	5	Very significant support of earth observation objectives.
	E-1.7 Special Research	I.2	Indirectly supports development objectives having measurable socio-economic benefits.	4	Significant support of earth observation objectives.
C/N-1 Communications/Navigation	C/N-1.1 Optical Frequency Demonstration	I.4	Indirectly supports objectives related to potential socio-economic benefits, through investigations leading to the solution of problems in laser transmission.	4	Significant support of communication objectives.
	C/N-1.2 Millimeter Wave Communication System and Propagation Demonstration	I.4	Indirectly supports objectives having potential socio-economic benefits, through technological experiments and demonstrations.	4	Significant support of the communication objectives.
	C/N-1.3 Surveillance and Search and Rescue System Demonstration	I.2	Indirectly supports objectives related to air traffic control network developments.	4	Significant support of the communication objectives.
	C/N-1.4 Satellite Navigation for Terrestial Users	I.2	Indirectly supports objectives related to the development of navigational systems.	4	Significant support of the communication objectives.
	C/N-1.5 On Board Laser Rangine C/N-1.6 Autonomous Navigation C/N-1.7 Transmitter Breakdown	I.4	These are technological experiments supporting the development of communication systems with mission capabilities of potential socio-economic value.	3	Moderate support of communication system objectives.
	C/N-1.8 Terrestial Noise Measurements	I.2	Indirectly supports objectives in general communications.	3	Moderate support of communication system objectives.
	C/N-1.9 Noise Source Identification	I.3	Supports objectives related to electromagnetic surveillance having potential direct benefits to mankind.	4	Significant support of application objective.
	C/N-1.10 Inceptibility of Terrestial Systems to Satellite Radiated Energy C/N-1.11 Tropospheric Propagation C/N-1.12 Plasma Propagation C/N-1.13 Multipath Measurements	I.4	These are technological experiments supporting various aspects of communication investigations in behalf of advanced missions with potential socio-economic value	3	Moderate support of the preliminary objectives concerning advanced missions.

Table 5-3. Rationale for Experiment Rating (Cont)

FPE		Applicable Experiments	Category No.	Comments on Categorization	Worth Rating	Comments on Worth Rating
MS-1	Materials Science and Manufacturing	All Experiments	I. 3	Directly supports application objectives having potential socio-economic benefits.	4	Significant support of the objectives leading to the establishment of a manufacturing facility in space.
T-1	Contamination Measurements	All Experiments	I. 2 and II. 2	Measurements are related to the detection and/or elimination of contamination effects; indirectly support application and scientific objectives in space.	3	Moderate support of the related scientific and application objectives.
T-2	Fluid Management	All Experiments	II. 4	These investigations are in support of the development of advanced chemical propulsion vehicles for future exploration missions.	3	Moderate support of objectives related to future space exploration missions.
T-3	Extravehicular Activity	All Experiments	I. 4 and II. 4	Through the development of capability for extravehicular manned operations, the experiments indirectly support potential scientific and application objectives.	3	Moderate support of objectives concerning scientific and application objectives. (This rating is based on the present guidelines regarding EVA as a non-routine operational approach, in system design.)
T-4	Advanced Spacecraft System Tests	All Experiments	I. 4 and II. 4	Technology experiments support the development of advanced spacecraft systems having potential scientific and socio-economic benefits.	4	Significant support of advanced vehicle development.
T-5	Teleoperation	All Experiments	I. 4 and II. 4	Through the development of capability for remote manipulation, the experiments indirectly support scientific and application objectives.	4	Significant support of advanced applications and scientific mission objectives.
LS-1	Medical Research Facility	All Experiments	II. 2, I. 2 and I. 4	Through the development of the capability to utilize man's unique contribution in space missions, the experiments indirectly support a large spectrum of scientific and application experiments/operations. The I. 4 rating reflects the potentiality for spin-offs in terrestial medicine that may result from this endeavor.	5	Very significant support of a large spectrum of scientific and application objectives.

Table 5-3. Rationale for Experiment Rating (Cont)

FPE	Applicable Experiments	Category No.	Comments on Categorization	Worth Rating	Comments on Worth Rating
LS-2 Vertebrate Research Facility	All Experiments	II. 3	Directly supports scientific investigations with potential scientific returns in biology.	3	Moderate support of vertebrate biology scientific objectives.
LS-3 Plant Researcy Facility	All Experiments	II. 3	Directly supports basic research which may lead to general hypotheses concerning the significance of weightlessness in the study of biological processes.	4	Significant support of plant biology objectives.
LS-4 Cells and Tissues	All Experiments	II. 3	Directly supports basic research which may lead to general hypotheses upon which subsequent space biology research will be based.	4	Significant support of biology research objectives.
LS-5 Invertebrate Research Facility	All Experiments	II. 3	Directly supports scientific investigations with potential scientific return in biology.	3	Moderate support of invertebrate biology scientific objectives.
LS-6 Life Support and Protective Systems	All Experiments	I. 2 and II. 2	Experiments support application and scientific objectives in two indirect ways: (a) by improving the systems that will permit man to enhance the application and scientific missions, and (b) by providing an advanced technological base that will aid in the development of earth-based systems.	3	The degree to which improvements in life support system technology will benefit application and scientific missions is not known, and will depend on the nature and duration of man involvement required in those missions. Spin-offs from this technological endeavor are estimated to be of moderate importance.
LS-7 Man-System Integration	All Experiments	II. 2 and I. 2	Indirectly support scientific and application objectives, through the development of the capability to utilize man's unique contribution in space missions.	3	Moderate support of the objectives in the life sciences.

Table 5-4. Balanced Program - Priority Rating

Benefit Category	Worth Rating	Experiment No.	Rank Designation
I. 1 and II. 1	5	ES-1. 1, -1. 6	First
I. 1	5	ES-1. 2, -1. 3, -1. 4, -1. 5	Second
I. 3, II. 1	5	A-3	Third
I. 2, II. 2, I. 4	5	L/S-1	Fourth
II. 1	5	A-1 A-5 P-3	Fifth
I. 3, II. 1	4	P-1. 1	Sixth
I. 3	4	C/N-1. 9 M/S-1	Seventh
I. 2	4	E/S-1. 7 C/N-1. 3, -1. 4	Eighth
I. 4	4	T-4, -5 C/N-1. 1, -1. 2	Ninth
II. 1	4	A-2. 2 P-4	Tenth
II. 3	4	L/S-3, -4	Eleventh
I. 2 I. 2 I. 2	3 3	T-1 L/S-6, -7 C/N-1. 8	Twelfth
I. 4	3	C/N-1. 5, -1. 6, -1. 7, -1. 10 C/N-1. 11, -1. 12, -1. 13 T-3	Thirteenth
II. 1	3	A-4 P-1. 2, -1. 3, -2	Fourteenth
II. 3	3	L/S-2, -5	Fifteenth
II. 2	3	A-2. 1	Sixteenth
II. 4	3	T-2	Seventeenth
II. 2	2	P-1. 4	Eighteenth

6. EXPERIMENT SCHEDULING

The results of the experiment selection and phasing analysis (Section 5) consist of a set of experiment implementation priorities for a so-called balanced program as well as scheduling interrelationships that are to be satisfied in the scheduling process. This section summarizes the application of this analysis in producing the Reference Experiment Program (REP). more detailed account of this process is contained in Volume II Operations and Crew Analysis, SD 71-217-2.

The REP is the time-phased sequence of on-orbit experiment laboratories. Each laboratory, when it is on orbit, consumes resources at a rate that depends on its implementation level. This, in turn, is defined by the typical experiments selected to be performed in the laboratory at each implementation level, as described previously.

In general, Level I laboratories were defined so as to be compatible with the shuttle sortie mode of implementation. Thus, no Level I laboratory was selected for the MSS REP, which begins at the time of initial orbital capability (IOC) of the initial (six-man) MSS. Similarly, the requirements of Level II laboratories were designed to be compatible with the initial MSS, and Level III with the growth MSS.

There was no a priori constraint applied to the scheduling process that prevented a Level III laboratory's being assigned to the initial MSS, provided that its resource requirements could be met. Limitations on available crew time (35 man-hours per day for the initial MSS) resulted, however, in all Level III (and some Level II) labs' being deferred until the growth MSS era.

The following steps were followed in scheduling laboratories (Steps 1 and 2 are described in Section 3; Step 3 is described in Section 5):

1. Experiments were assembled into groupings having commonality of objectives, equipment, and operational requirements. The laboratory approach was used in establishing which experiments should be grouped together. (Because of the laboratory orientation of the 1971 Blue Book, the FPE is often a good line of demarcation for such a grouping.)

2. A systematic progression in capability for each laboratory was defined consistent with a logical growth in application or scientific achievement in space.

3. Based on the roadmap in Step 2, the experiments were ordered chronologically, to establish a preferred sequence for conducting the experiments.

4. A composite laboratory sequence was assembled considering priorities, interrelationships, and scheduling constraints, to accomplish as well as possible the desired experiment sequence. This sequence is shown in Table 6-1.

5. Laboratory requirements were accommodated within the station capabilities and scheduling constraints. In situations where requirements exceed the station capabilities, priorities were used to resolve conflicts in determining which laboratories should take precedence.

The laboratory schedule that resulted from this procedure is shown in Figure 6-1, which indicates the relative time phasing of the laboratories and their implementation levels and modes. This is the Reference Experiment Program, which forms the basis for the Mission Sequence Plan.

Many scheduling products were derived from the REP. These are presented in detail in Volume II, Operations and Crew Analysis, SD 71-217-2. One such derivative that displays the relative level of effort devoted to each Blue Book discipline is the experiment program schedule by man-hours per day per discipline (Figure 6-2).

It should be noted that the REP provides, in general, only one cycle (as defined in Section 3) of each experiment laboratory at each level. This arbitrary restriction resulted from earlier scheduling efforts which produced a 35-year program. Duration of the REP shown is slightly more than 15 years.

The REP has Level II laboratories only during the five years of initial station operations. There are about 1.5 years of overlapped Level II and Level III operations after growth station IOC, and only Level III laboratories thereafter.

A major objective in defining Level II laboratories was to phase the buildup in experiment requirements in parallel with the buildup in station capabilities. An additional objective was to defer the peak annual funding requirement for experiments to a point in time that is significantly different

Table 6-1. Laboratory Scheduling Sequence

FPE No.	Laboratory	Preferred Sequence	
		Level II	Level III
P-4	Physics and Chemistry	1	3
T-1	Contamination Measurements	1	1
P-2	Plasma Physics and Environmental Perturbations	1	12
ES-1	Earth-Observations	2	1
A-3	Advanced Solar Astronomy	3	2
LS-1	Medical Research	4	3
A-1	X-Ray Stellar Astronomy	5	4
A-5	High-Energy Stellar Astronomy	5	4
P-3	Cosmic Ray Physics	5	4
P-1	Space Physics Research	6	5
MS-1	Materials Science and Manufacturing in Space	7	6
C/N-1	Communications/Navigation	7	6
T-4	Advanced Spacecraft Systems Test	8	7
T-5	Teleoperation	9	7
A-2	Advanced Stellar Astronomy	9	8
A-6	Infrared Astronomy	9	8
LS-2, 3, 4, 5	Biosciences Research	10	9
LS-6	Life Support and Protective Systems	11	10
LS-7	Man-System Integration	11	10
T-3	Extravehicular Activity	12	11
A-4	Intermediate-Size UV Telescopes	13	12
T-2	Fluid Management	14	13

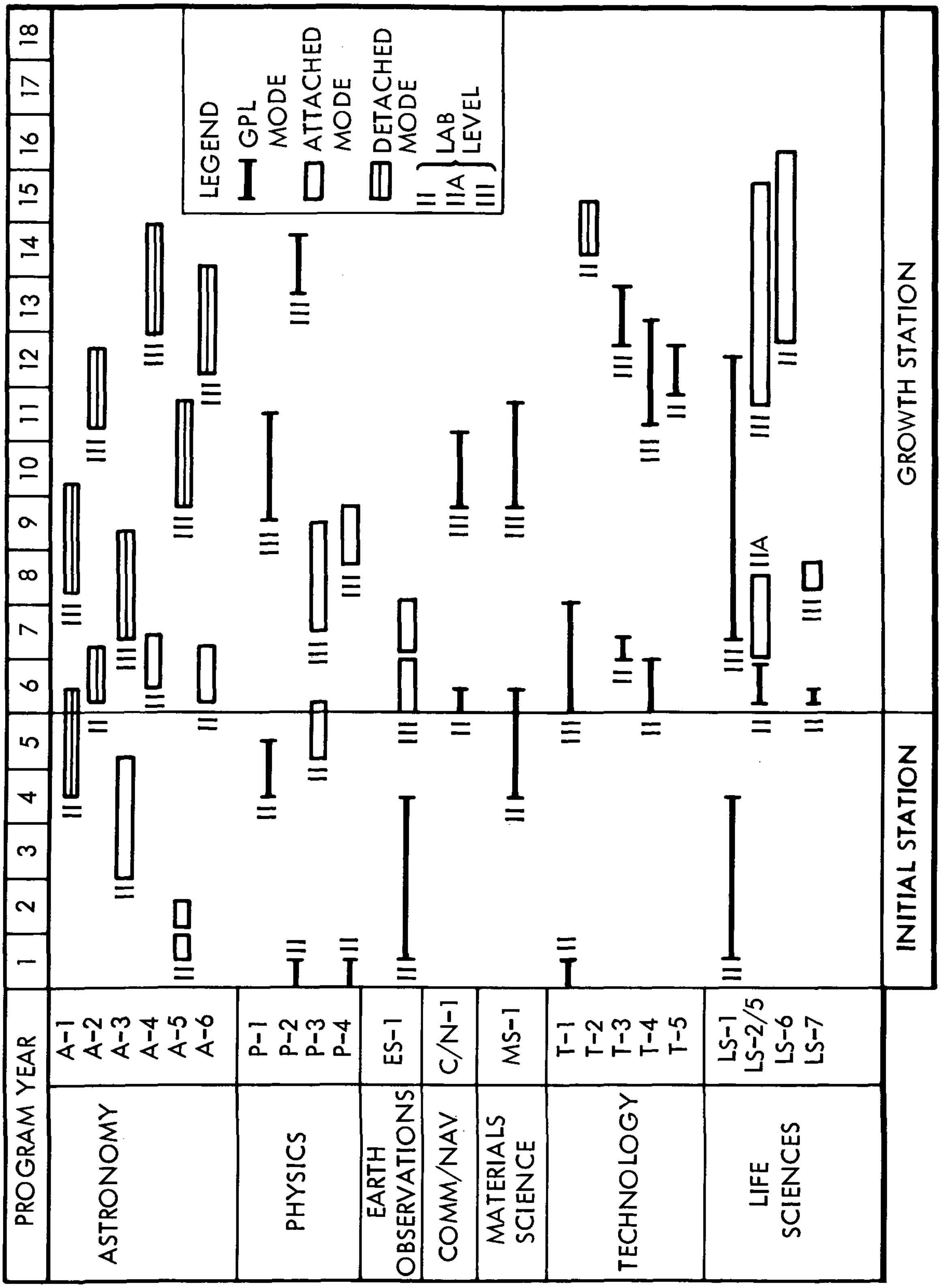


Figure 6-1. Reference Program for Levels II and III (Station Accommodations Only)

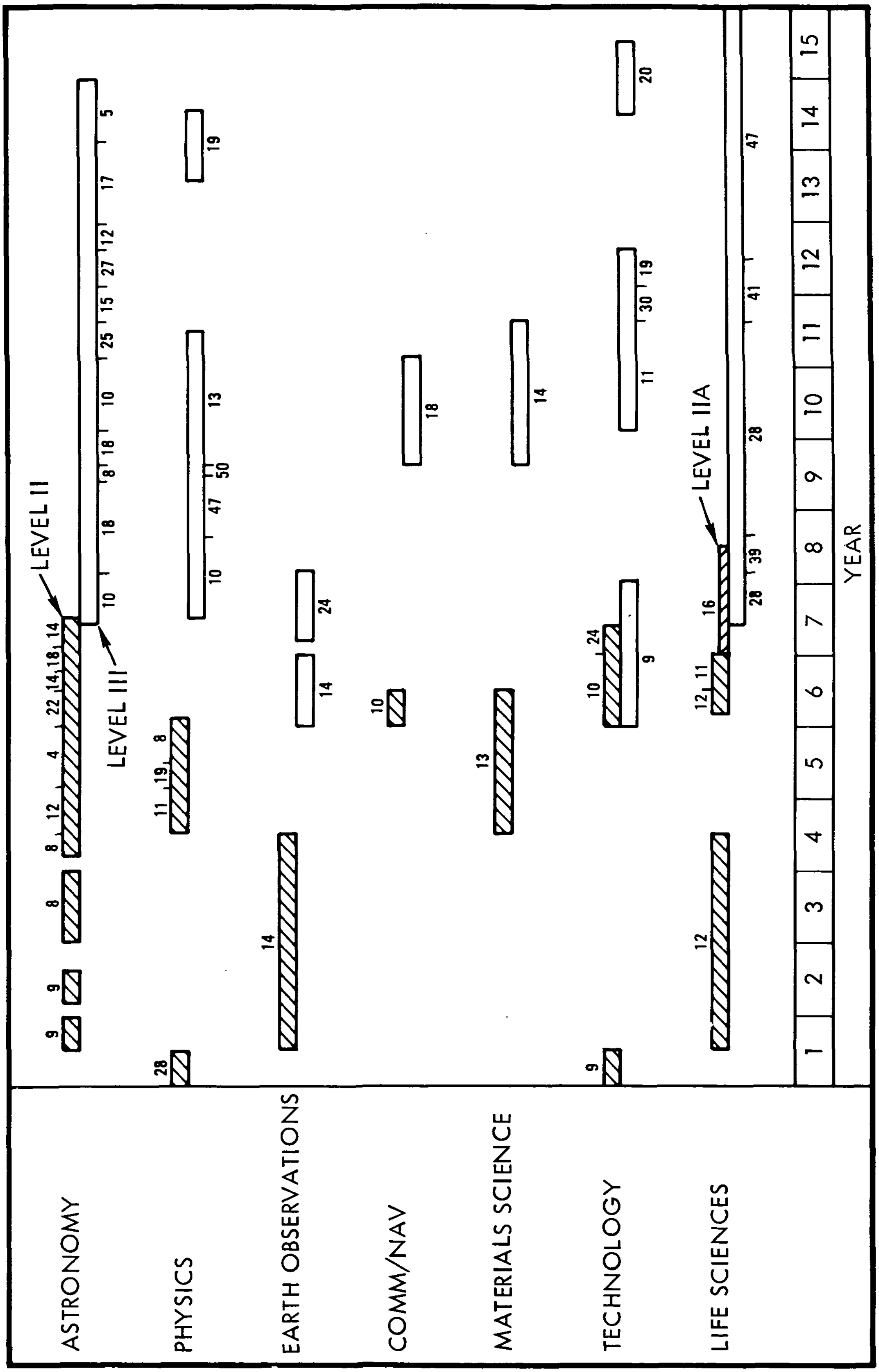


Figure 6-2. Experiment Program Schedule by Man-Hours Per Day Per Discipline

from the time of the peak annual funding requirement for the MSS itself. In this way, the overall program funding requirement could be more evenly distributed. To verify that this was the case, an "all-Level III" program was defined (Figure 6-3). The funding requirements of the REP and the all-Level III program are overlapped in Figure 6-4. It can be seen that a five-year deferment in the peak annual funding requirement for experiments (including experiment equipment, RAM's, and operations) has been achieved. Since the peak annual funding for experiments is approximately $500 million, a significant smoothing of program funding requirements results.

Cost data for experiment equipment and operations were supplied by NASA for this comparison.

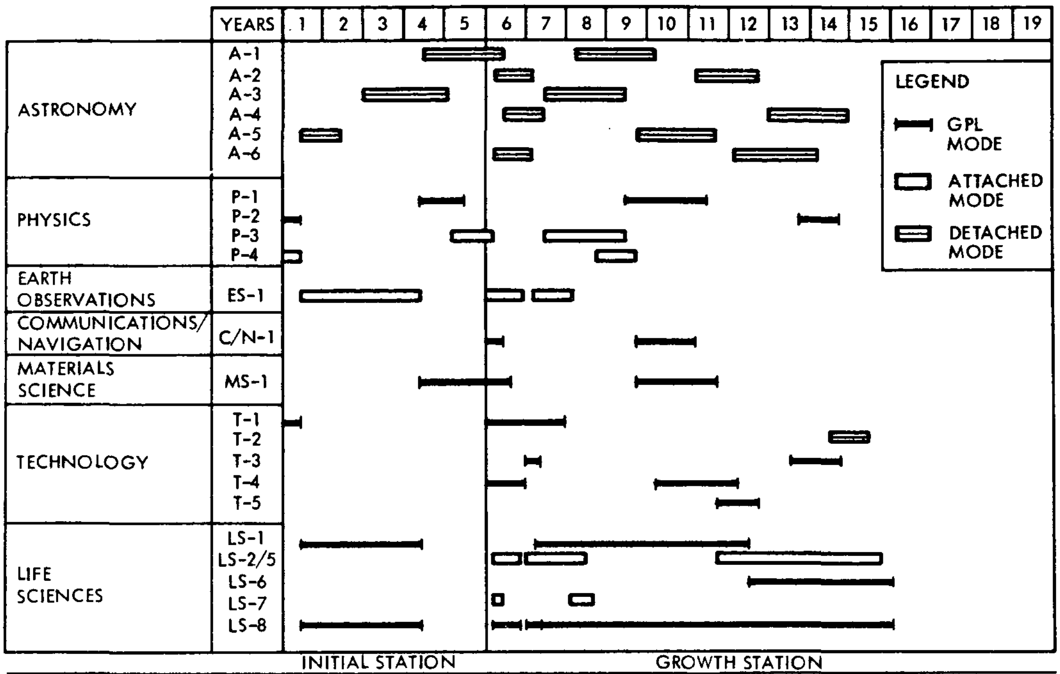


Figure 6-3. Level III Program

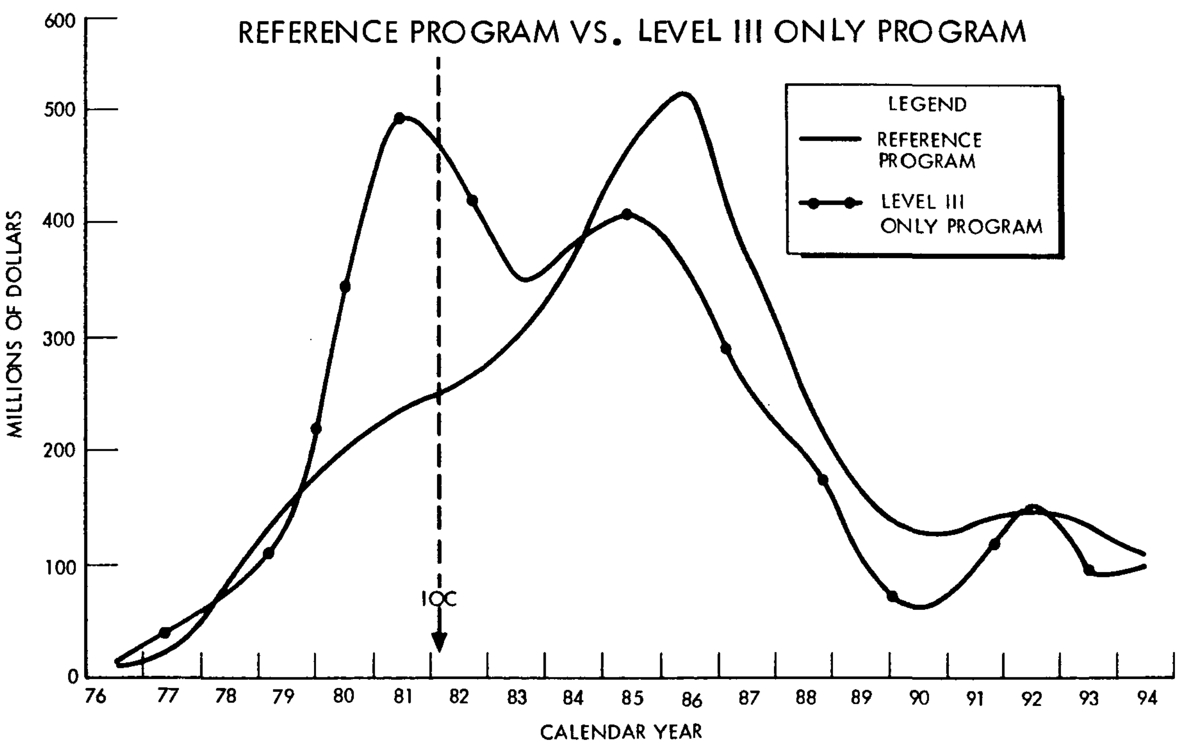


Figure 6-4. Comparison of Experiment Annual Funding

7. SUPPLEMENTAL EXPERIMENTS STUDIES

Several special studies related to the experiment analysis task were performed during the MSS contract activities. Described in this section are four of these studies: (1) data user requirements, (2) multispectral scanner mechanization, (3) experiments field-of-view requirements, and (4) airlock requirements.

7.1 DATA USER REQUIREMENTS

The objective of this subsection is to identify user data requirements associated with the earth-observations experiments to be conducted during the space station program. These experiments are defined in the NASA Blue Book. This analysis was started with data in the 1969 Blue Book, but it has been updated with the applicable information in the 1971 Blue Book. The general objectives and study results for the experiments selected for the analysis remain unchanged.

Figure 7-1 illustrates the major functional system elements required to accomplish the earth-observations experiment program. Except for the obvious space/ground separation, the physical location of the various elements is not meant to be indicated. For example, the potentially large amount of RF data coming to the ground may necessitate the collocation of data acquisition and data processing facilities.

7.1.1 DEFINITION OF TERMS

Two terms critical to this report are "data user" and "baseline data acquisition system." These are defined below.

Data User

In this report, the term "data user" is used to identify any individual, or group of individuals, who controls the acquisition of, manipulates, or applies the experimental data. The term, therefore, includes:

Spacecraft crewmen who control experiment operations and perform on-board data processing functions.

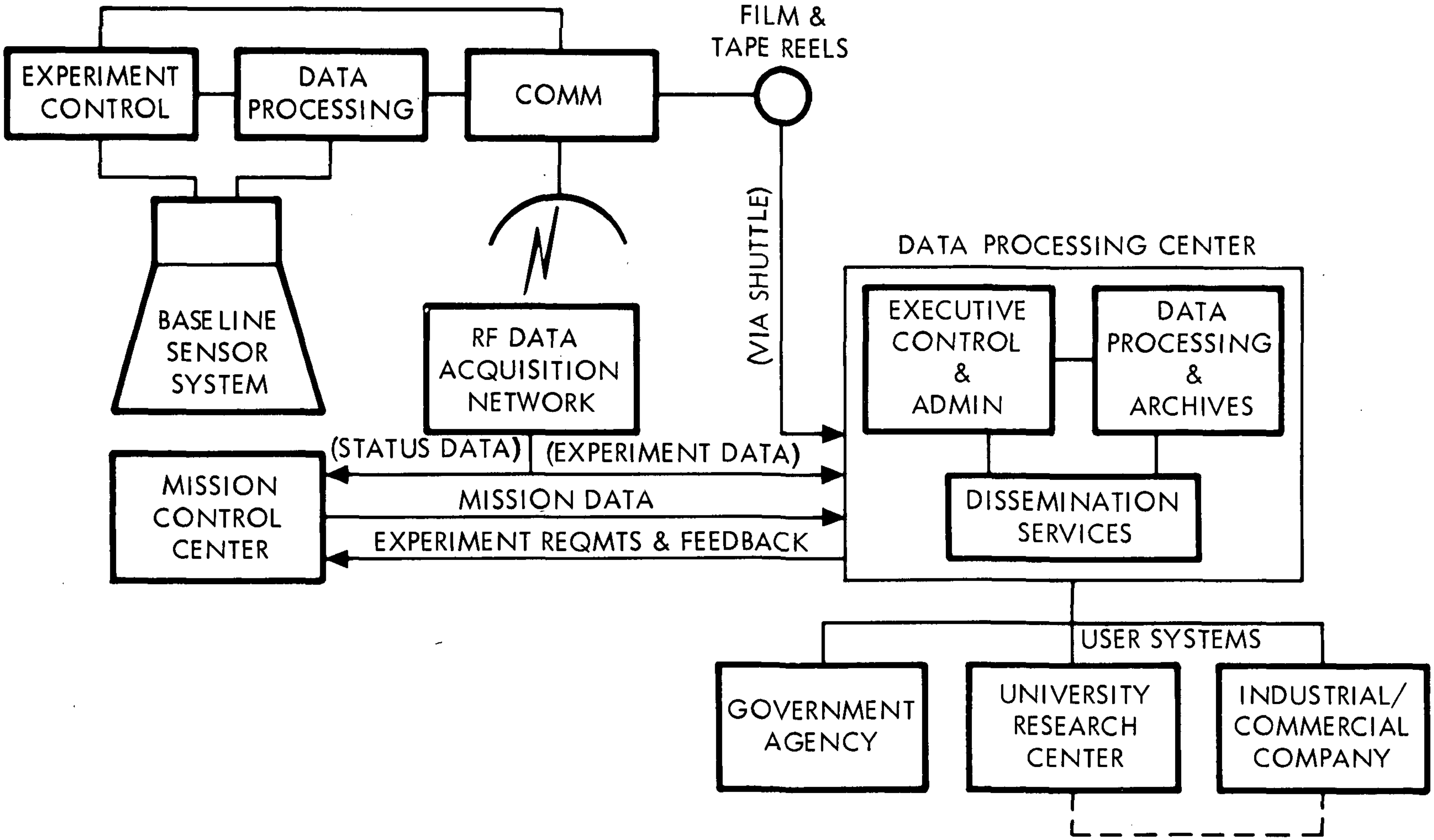


Figure 7-1. Ground and Spaceborne System Functions for Advanced Earth-Observation Experiment Program

Ground personnel who control the interchange of experiment data and sensor systems status data.

Personnel who perform central processing and distribution functions.

Scientists and engineers who develop and modify experiment procedures and interpret/apply the experiment data.

Agencies and individuals that apply the data to practical problems.

As will be seen later, this study of user data requirements did not include the latter two types. Thus, the study does encompass the requirements of all users who acquire and distribute experiment data but do not apply it to research and applications programs. What these "ultimate users" do with the data was outside the scope of the current study.

Baseline Data Acquisition System

The sensors that acquire earth-observations data for users are described in the NASA Blue Book. This study is restricted to these experimental sensors, with the capabilities and limitations described. It is important to realize that this baseline system sets the limits on the types of raw data that may be utilized to meet the requirements of the data users.

The set of sensors selected for the Blue Book have been chosen for maximum representation. With little data available on the applicability of various sensor types to specific problems of remote sensing, it was necessary to posit a broad-reaching array composed of many potentially redundant sensors. As a result, however, the baseline system is not tailored to specific user needs. Rather, it is designed for a developmental program. The new Blue Book (January 15, 1971) shows some changes reflecting our increased knowledge. It is reasonably certain, however, that we may expect even further changes as our remote sensing research produces further results. These data will likely cause the tailoring of the sensor array to the specific needs of data users.

7.1.2 APPROACH TO THE PROBLEM

A major factor in defining the problem of user data requirements is the period during which these activities are expected to be carried out. It was especially important here to consider the forerunner efforts in earth observations, on manned and unmanned space flights as well as aircraft programs. The extent of the user requirements and, especially, the sophistication with which data analysis would be carried out depend heavily on the execution of previous programs. In general, NR has assumed the successful completion of 3-4 ERTS and the Skylab missions as well as steady progress in the aircraft earth-observations program.

The assessment of on-board user requirements is a direct outgrowth of the many diverse efforts to define the role of earth-observations programs. Analytic and simulation studies have been conducted over the past five years and were used as the basis of the analyses reported in Subsection 7.1.4.

The definition of the needs of ground data users (Subsection 7.1.5) was derived from a study of recent publications that have addressed the problem. These included reports of research, expected user needs, and data processing center proposals written by representatives of government, university centers, and private industrial and consulting firms.

7.1.3 BASELINE SYSTEM CHARACTERISTICS

Earth-Surveys Sensors

The Blue Book defines the baseline sensor configuration for earth surveys. The experiment sensors are listed and briefly described below.

Several important operational characteristics of the baseline sensors are shown in Table 7-1. Each sensor is typed by reference to the region of the electromagnetic spectrum that it senses and its "instantaneous" field of view. The coverage that this group of sensors supplies is shown graphically in Figure 7-2 (on which both 1969 and 1971 Blue Book sensor characteristics are shown).

The regions covered are, of course, highly appropriate for characterizing different types of materials and phenomena. In the region between 0.32-4.0 μ, one observes primarily the spectral reflectance of direct and scattered solar radiations. Certain spectral variations develop from the selective absorptions of certain substances and differential scattering. In the 4.5 to 15 μ region, one observes thermal emission originating largely at the surface of solids and liquids. This emission is generally proportional to the surface temperature of the material. In the microwave region (1 to 300 mm), one also observes thermal emissions that are proportional to surface temperatures.

The third and fourth columns of Table 7-1 indicate the resolution of the baseline sensors—that is, their performance accuracy. The entries in these columns could not always be found in the 1969 Blue Book, nor derived from its contents. In these cases, where an equivalent sensor was described in the January 1971 Blue Book, the data from the latter source were used. The next three columns describe the scientific data generation characteristics of the baseline sensors.

The last six columns indicate the applicability of the baseline sensors to different experiment areas. This presentation is at a somewhat gross level here: it is expanded in Sections 3 and 4.

Table 7-1. Characteristics and Applicability of Baseline Earth-Surveys Sensors

Sensor	Sensor Type		Resolution* (Accuracy)		Scientific Data Generation			Applicability					
	Spectral Range	FOV Rad (deg)	Spatial mrad	Spectral	Type	Media	Generation Rate	Agriculture/ Forestry	Cartography	Applied Mineralogy	Water Resources	Meteorology	Oceanography
1. Metric Camera	0.4-0.9 μm	0.72 x 1.23 (41 x 70)	0.4		F	Film (240 & 70mm)	1 frame/min	X	X	X	X		
2. Multispectral Camera	0.4-10.0 μm	0.72 x 0.72 (41 x 41)	0.8	0.1 μm	F	Film (70mm)	2 frames/min	X	X	X	X		X
3. Multispectral IR Scanner	0.6-13 μm	0.35 (20)	0.06 to 0.12	1.0 μm	D	Tape (25mm)	15 Mbps	X		X	X		X
4. IR Interferometer/ Spectrometer	6-50 μm	0.05 (3)	35.0	3 cm^{-1}	D	Tape (25mm)	4.0 kbps					X	
5. IR Atmospheric Sounder	1.8-5.0 μm	0.22 x 0.22 (12.5 x 12.5)		25 & 10 cm^{-1} (for two detectors)	D	Tape [1] (25mm)	75.0 kbps					X	
6. IR Spectrometer/ Radiometer	6.5-13.0 μm	0.003 x 0.003 (0.2 x 0.2)	3.5		D	Tape [1] (25mm)	1.9 kbps	X		X			X
7. MW Scanner Radiometer	10 GHz	0.03 (1.5)	0.08		D	Tape (25mm)	100 bps	X	X		X		
8. Multifrequency MW Radiometer	10-32.4 GHz	2.1 (120)	20.0		D	Tape (25mm)	500 bps			X	X	X	X
9. MW Atmospheric Sounder	10-52.8 GHz	±1.0 (±60)	10.0		D	Tape [1] (25mm)	100 bps					X	
10. Radar Imager	8-10 GHz	0.15 (8.6)	0.02		A	Film [2] (70mm)	50 + MHz	X	X	X	X		
11. Act/Pass MW Radiometer	8500 MHz	0.18 (10)			D	Tape (25mm)	3.2 kbps				X		X
12. Visible Wavelength Polarimeter	0.38-0.58 μm	0.05 (3)	52	100 Å	D	Tape (25mm)	160 bps			X		X	
13. UHF Sferics	610 MHz	2.1 (120)	1.04	1 MHz	D	Tape [1] (25mm)	260 bps					X	
14. Absorption Spectrometer	0.28-0.50 μm	0.32 (18)	17	8 Å	D[3]	Tape [1] (25mm)	1.2 kbps					X	
15. Laser Altimeter	0.69 μm	6 x 10-4 sterad (0.034)	0.6	20 Å	D	Tape (25mm)	100 bps		X	X			
16. UV Imager/Spectrometer	3500-4000 Å	0.26 (15)		0.5 Å	D[3]	Tape [1] (25mm)	40 kbps			X			
17. Radar Altimeter Scatterometer	8 GHz	1.0 x 0.02 (60 x 1)	20.0		D	Tape (25mm)	3.2 kbps		X	X		X	X
18. Photo-Imaging Camera	0.525, 0.630, + 0.76 μm	0.28 (16)	1.3	100 Å	D	Tape (25mm)	5.0 Mbps	X	X		X		X
19. Data Collection System	450 MHz	1.74 (100)		4.1 kHz	D	Tape (25mm)	2.56 kbps				X	X	X

*This information was taken from the new (1/15/71) "Blue Book" if not available from the version being used 9/15/69.

[1] Primary media used is tape for temporary data storage; some data will be transferred to 70mm film for on-board analysis.

[2] Analog data stored on film in real time.

[3] The Absorption Spectrometer and UV Imager Spectrometer also generate 70 mm film data at the rate of 1 frame/min.

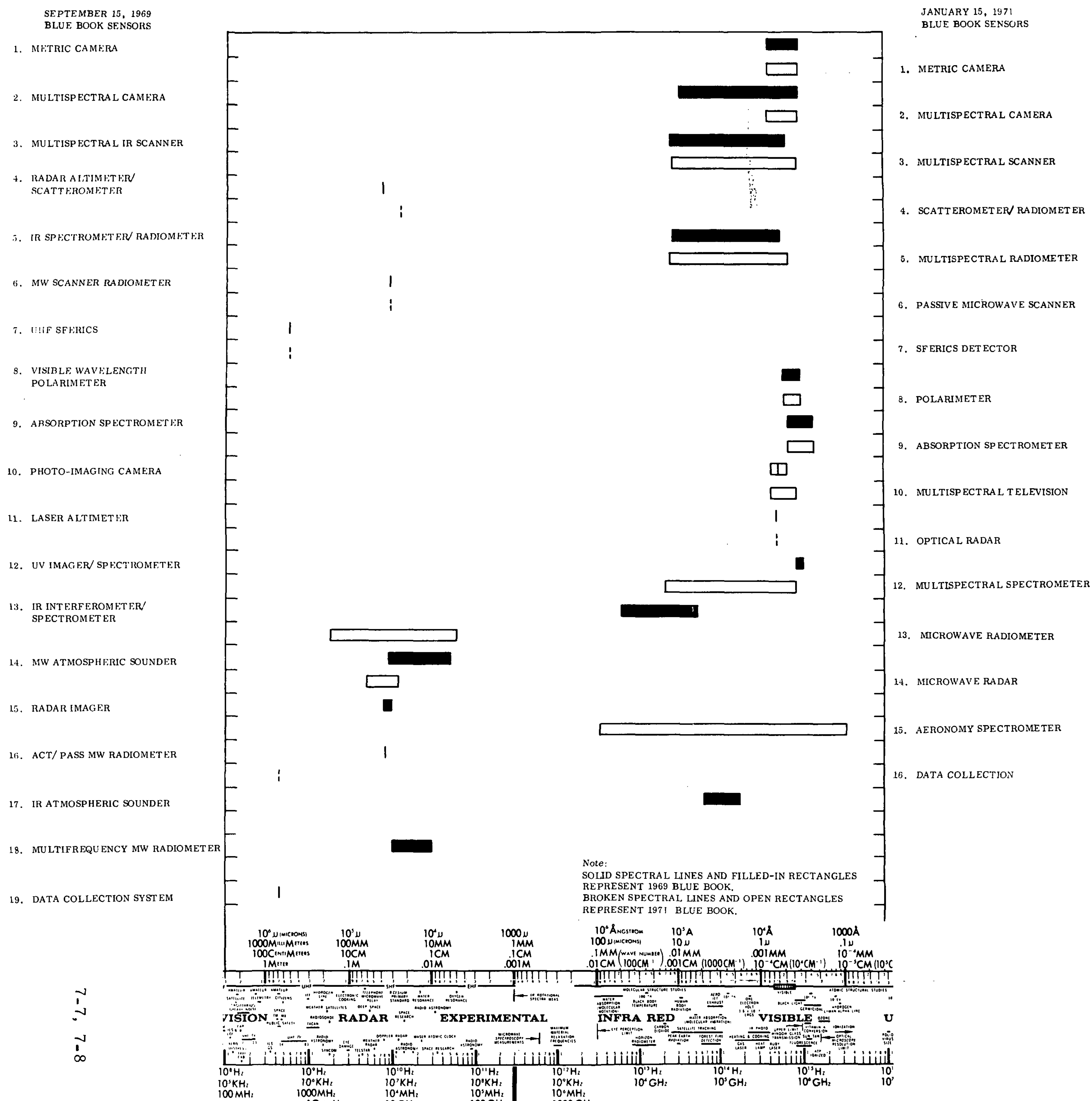


Figure 7-2. Spectral Coverage for Earth Observations (1969 and 1971 Blue Books)

The total amount of data produced daily by the baseline sensors is shown in Table 7-2. These data were established by considering the sensors used for each experiment area, their average daily data production, and the degree of expected applications overlap between data collected.

Earth-Surveys Operations

The following paragraphs describe the general operation modes employed in conducting the earth-surveys experiment program. Descriptions of more specific functional operations, in terms of users employing them, are contained in Sections 3 and 4.

Comprehension of the following description of data acquisition, processing and distribution operations will be aided by reference to Figure 7-1. It is assumed that the acquisition of raw experiment data will be carried out onboard the MSS in either of two broad modes: automatically, without the assistance of crewmen, and semiautomatically, where space station crewmen will manually assist in the data collection process. In general, the one or two crewmen assigned to earth surveys will engage in such activities for up to 10 hours a day. If two crewmen are available, it is further assumed that they will work during the same shift on a cooperative, complementary basis. Thus, the semiautomatic mode will be employed up to 10 hours per day, while fully automatic data collection may be carried out 14 or more hours.

It should be noted that the prime difference between the two acquisition modes lies in the control processes involved. In the automatic mode, control of the data acquisition process is predetermined and carried out by the onboard computer. Switching to the semiautomatic mode occurs when one crewman (or both) chooses to exercise an override capability, which introduces his inputs into the sensor operation logic. Actual data collection is always carried out by the sensor systems, but these will at times be under the control of the crew.

In addition to the collection of raw data, limited data processing will be carried out aboard the spacecraft. Most of this will be done for the purpose of checking sensor and program operations, although some will be for data reduction and experimental purposes.

Digital data from the sensors will be accumulated on magnetic tape for later transmission to the ground. Data recorded on film will be sent to the ground via shuttle.

All of the data will receive general processing at a central location. The level of processing to be done here will be rather preliminary in nature. Gross compression and editing may be carried out as well as developing of all film. This center is expected to provide an integration function for

Table 7-2. Total Daily Data Generation of Earth-Surveys Experiments

Experiment Area	Film Data			Digital Data		
	Terrain Photos (70-mm frames)	Radar Analog (70-mm linear ft)	Stellar Photos (70-mm frames)	Experiment Bits ($\times 10^9$)	Housekeeping Bits ($\times 10^9$)	Total Bits ($\times 10^9$)
Agriculture/Forestry	630	163	90	38.44	2.44	38.44
Cartography	630	163	90	9.74	0.70	9.74
Applied Mineralogy	662	163	90	29.07	3.69	29.08
Water Resources	630	163	90	38.57	3.43	38.57
Meteorology	320	-	-	5.14	13.97	5.16
Oceanography	540	-	-	38.74	3.94	38.74
Total	1792	326	180	82.23	20.53	82.25

research and applications queries. Dissemination of data to meet these queries will have to be kept on a relatively broad-based, general level to prevent conflict of interest and favoritism problems from developing. For example, data that locate underground water sources could be used by special interests in unfair real estate purchases. Prevention of such problems can be handled best by limited processing of raw data and distributions through regulating government agencies. Thus, the detailed processing of data by applications users has been excluded from this study.

Similarly, the specific and unique processing of data by experimenters to answer experimental hypotheses is outside the scope of this study. As far as NR is concerned here, operations of the central processing center involve primarily the limited processing of data for enhanced intelligibility and dissemination.

The overall control of orbital operations will reside in the Mission Control Center. Mission Control will provide the crew with time lines, establish priorities for conducting special-purpose missions, and carry out the orderly progression of individual experiments. The flexibility options given to the orbital crew are expected to be generally delineated by the investigator, administrator, or other individual (or group) responsible for the experiment design.

7.1.4 ON-BOARD USER DATA REQUIREMENTS

This subsection describes the data requirements of on-board crewmen who are actively engaged in the conduct of the earth-surveys experiment program. Depending on the total number of crewmen on the space station, it is expected that one or two will be concerned with the earth-surveys experiment operations. These crewmen are likely to be engineers or scientists who have had extensive training in the sensor complement and their operations.

The data requirements of these crewmen, with respect to the earth-observations experiments, are identified in Table 7-3. These are arranged by source of the data—that is, the sensor system responsible for its generation. This method was chosen because the on-board user is generally oriented toward sensor operations rather than the experimental category. For the most part, his tasks are concerned with operation of the sensors and monitoring their performance. Only to a lesser degree is he involved with analysis or interpretation of sensor data for application to an experimental problem. Further, the crew functions and data requirements described in Table 7-3 for each sensor are generally applicable across all experiments in which they are used.

Table 7-3. On-Board User Data Requirements

Data Source	User Function	Display/Format Requirements	User Analysis Requirements: Level II	User Analysis Requirements: Level III	Supplementary Data Requirements	Control Functions	Temporal Factors
Metric Camera and Multispectral Camera	Monitor Sensor Performance	a. Lighted display for out-of-tolerance condition, failure to exercise command, etc. b. Sample film clip displayed on film viewer.	Identification of alarm and turn off assy, prior to maintenance. Visual check for general quality.	Troubleshoot malfunction condition using computer printout. Detailed check of film quality and camera pointing.	Camera assembly normal condition. Spacecraft ephemeris accuracy data. Prior photos for comparison.	On/off and activate camera assembly (perhaps selective control of camera composing assembly.) Computer call-up controls.	Continuous monitor of malfunction indicators. Film check once/14 days.
	Calibrate Sensor	Light input and shutter settings on alphanumeric display and/or sample film clips taken under known conditions (star field).	Compare automatic shutter settings to expected response for known input.	Photometric analysis of processed film.	Expected light distribution from calibration star field.	Camera activate. Shutter adjust controls.	Five-minute calibration periods. Once/ 14 days.
	Record/ Evaluate Targets of Opportunity (fire, flood, crop disease, damage assessment)	a. Telescope view of intended target-high resolution b. Film clips of targets c. Real time display of data from complimentary sensors, (i.e., IR radiometer for fires)	Damage boundary identification.	Loss estimating and prediction of boundary change.	Pre-damage photos for comparison, overlay maps for resource identification. Target coordinates.	Point telescope and camera assemblies, on/off and activate camera. May desire single terrain camera activation. Select other sensor data display.	As required. Approximately 50-150 frames/month.
	Slave Camera to Another Sensor	Feedback alphanumerics indicating successful completion of function.	None	None	None	Select sensor to be matched and time to initiate. Requires nominal program interrupt.	As required. Not common.
	Manual Setting of Shutter Speed and f-stop	Feedback alphanumerics.	None	None	None	Remote controls for manual override of automatic shutter settings.	As required for research.
	Modify Automatic Data Collection Sequencing	Feedback alphanumerics.	None (Performed on basis of instructions from ground)	None	None	Computer keyboard entry of new instruction.	As required.

Table 7-3. On-Board User Data Requirements (Cont)

Data Source	User Function	Display/Format Requirements	User Analysis Requirements: Level II	User Analysis Requirements: Level III	Supplementary Data Requirements	Control Functions	Temporal Factors
Multispectral IR Scanner and IR Spectrometer/ Radiometer and Photo-Imaging Camera	Monitor Sensor Performance	a. Lighted display for out-of-tolerance condition, failure to exercise command, etc. b. Observe sensor output on video display.	Identification of alarm and turn-off sensor prior to maintenance. Visual check for general quality.	Trouble-shoot malfunction condition using automatic diagnostic routine. Detailed check of sensor output for test (standard) input.	Spacecraft ephemeris accuracy data. Microfilm of "truth" data for comparison.	On/off control. Selective band control for display.	Continuous monitor of alarm display. Data check once/ 10 days.
	Calibrate Sensor	Video display of scanner output (one scene stored on tape) and microfilm (or video) display of same scene from earlier, "truth" data.	Visual check for general quality.	Detailed check of amplitude response in each band.	"Truth" data on microfilm or video tape.	Select output for separate temporary storage in display buffer, separate selection/brightening of different bands.	Once/month.
	Record/ Evaluate Targets of Opportunity	a. Telescopic view of intended target-high resolution. b. Microfilm or video display of prior data on target. c. Real time display of data sensor.	None unless target opportunity is natural disaster, than perform boundary identification.	Preliminary spectral signature identification, damage assessment, prediction of future state of target.	Target coordinates. Prior target data for comparison.	Point telescope, slave sensor(s) to telescope. Alternate display selection.	As required.
	Slave Scanner to Another Sensor	Feedback alphanumerics indicating successful completion of function.	None	None	None	Select sensor to be matched, initiate slave mode.	As required.
	Modify Automatic Data Collection Sequencing	← SAME AS METRIC CAMERA →					

Table 7-3. On-Board User Data Requirements (Cont)

Data Source	User Function	Display/Format Requirements	User Analysis Requirements		Supplementary Data Requirements	Control Functions	Temporal Factors
			Level II	Level III			
IR Interferometer/ Spectrometer, IR Atmospheric Sounder, MW Atmospheric Sounder, Visible Wavelength Polarimeter and UHF Sferics	Monitor Sensor Performance	a. Lighted display for out-of-tolerance condition, failure to exercise commands, etc. b. Observe sensor output on video display.	Identification of alarm and shut down sensor prior to maintenance. Visual check for general quality.	Trouble-shoot malfunction condition using automatic diagnostic routine. Detailed check of sensor output for test (standard) input.	Spacecraft ephemeris accuracy data. Microfilm of past sensor data.	Sensor on/off control. Video display control.	Continuous monitor of alarm display. Data check once/ 30 days.
	Modify Automatic Data Collection Sequencing	← SAME AS METRIC CAMERA →					
MW Scanner Radiometer and Multifrequency MW Radiometer	Monitor Sensor Performance	← SAME AS MULTISPECTRAL IR SCANNER →					
	Calibrate Sensor (Multifrequency MW Radiometer only).	← SAME AS MULTISPECTRAL IR SCANNER →					
	Slave Scanner to Another Sensor	← SAME AS METRIC CAMERA →					
	Modify Automatic Data Collection Frequencing.	← SAME AS METRIC CAMERA →					

Table 7-3. On-Board User Data Requirements (Cont)

Data Source	User Function	Display/Format Requirements	User Analysis Requirements: Level II	User Analysis Requirements: Level III	Supplementary Data Requirements	Control Functions	Temporal Factors
Radar Imager	Monitor Sensor Performance.	a. Lighted display for out-of-tolerance condition, failure to exercise command, etc.	Identification of alarm and shut down of sensor prior to maintenance.	Trouble-shoot mal-function condition using automatic diagnostic routine.	Spacecraft ephemeris accuracy data. Nominal sensor state. Prior photos for comparison.	On/off control. Slew and track.	Continuous monitor of alarm display. Data check once/10 days.
		b. Sample film clip displayed on film viewer.	Visual check for general quality.	Detailed check of film quality. Compare with metric camera output.			
	Calibrate Sensor.	Sample film clips taken under test (standard) conditions.	Visual check with known photos.	Photometric analysis of processed film. Analyze light output of cathode ray tubes in recorder assembly.	Sample, known photos. CRT calibration data.	Slew and track. Activate. CRT adjustments.	Once/month.
	Record/ Evaluate Targets of Opportunity.	a. Telescopic view of intended target-high resolution. b. Film clips of targets c. Display of display from other sensors (film viewer and/or video display).	Target location and extent.	Detailed target identification and predictions of changes.	Pre-dated photos for comparison, overlap graphics for resource identification aid. Target coordinates.	Telescope and imager pointing. Search mode on telescope, slave/track mode for radar.	As required.
	Slave to Other Sensor.	← SAME AS METRIC CAMERA →					
	Modify Automatic Data Collection Sequencing.	← SAME AS METRIC CAMERA →					
Active/Passive MW Radiometer	Monitor Sensor Performance.	← SAME AS MULTISPECTRAL IR SCANNER →					
	Mode Switching	Feedback alphanumerics indicating successful completion of function.	None	None	None	Active/passive mode selection.	As required.

Table 7-3. On-Board User Data Requirements (Cont)

Data Source	User Function	Display/Format Requirements	User Analysis Requirements: Level II	User Analysis Requirements: Level III	Supplementary Data Requirements	Control Functions	Temporal Factors
	Record/ Evaluate Targets of Opportunities	← SAME AS MULTISPECTRAL IR SCANNER →					
	Modify Automatic Data Collection Sequencing	← SAME AS METRIC CAMERA →					
Absorption Spectrometer and UV Imager/Spectrometer	Monitor Sensor Performance.	a. Lighted display for out-of-tolerance condition, failure to execute command, etc.	Identification of alarm and sensor turn off prior to maintenance.	Trouble-shoot malfunction condition using automatic diagnostic routine.	Nominal output samples. Microfilm or film.	On/off, activate, display select.	Continuous monitor of alarm display. Data check once/ week.
		b. Observe photomultiplier output on video display.	Visual check for general quality.	Detailed check of sensor output on a test (standard) input.			
		c. Sample film clip displayed on film viewer.	Visual check for general quality.	Detailed check of film on a test (standard) input.			
	Record/ Evaluate Targets of Opportunity.	a. Telescopic view of intended target-low to moderate resolution. b. Film clips of target. c. Video display of digital data output.	Estimate geothermal/ pollutant effect by film overlay. SO_2 absorption should be estimated automatically from digital data sample.	Estimate source of detected gas with previous extent of gas source, and make growth projections.	Film overlays. Other sensor data (metric cameras, IR radiometer, etc.) for same target. Gross target coordinate and spacecraft location.	Slew and track for optical telescope and spectrometer. Engage automatic analysis of digital data.	
	Modify Automatic Data Collection Sequencing.	← SAME AS METRIC CAMERA →					
Laser Altimeter (Operates as a subsystem of the Metric Camera Assembly)	Monitor Sensor Performance.	a. Lighted display for out-of-tolerance condition, failure to execute command, etc.	Identification of alarm and sensor turn off prior to maintenance	Trouble-shoot malfunction condition using automatic diagnostic routine.	None	On/off, activate.	Continuous.

Table 7-3. On-Board User Data Requirements (Cont)

Data Source	User Function	Display/Format Requirements	User Analysis Requirements		Supplementary Data Requirements	Control Functions	Temporal Factors
			Level II	Level III			
Radar Altimeter/ Scatterometer	Monitor Sensor Performance.	a. Lighted display for out-of-tolerance condition, failure to execute command, etc. b. Observe sensor display on video display.	Identification of alarm and sensor turn off prior to maintenance. Visual check for general quality.	Trouble-shoot malfunction condition using automatic diagnostic routine. Detailed check of sensor output using automatic calculation of scattering coefficient.	Spacecraft ephemeris accuracy data. Scattering coefficient variation. Microfilm record of past (test) sensor data.	Sensor on/off control, video display select.	Continuous monitor of alarm display. Data check once/ 30 days.
	Slave to Other Sensor	SAME AS METRIC CAMERA					
	Modify Automatic Data Collection Sequencing	SAME AS METRIC CAMERA					

Monitoring and Control User Functions

As previously noted, most of the on-board crewmen's tasks are concerned with monitoring and, to some extent, controlling day-to-day operations of the sensors. All of the sensors are capable of being controlled automatically by programs that are prepared on the ground. In fact, this type of operation, in which the activation, pointing, and data acquisition are automatic, is likely to be more prevalent. This assumption is based on the large number of sensors that must be managed and the small number of crew man-hours available. Further, a number of the sensors are not particularly amenable to manned operation.

It is expected that the crewmen will activate the sensors and place them in an automatic operations mode. Various status signals will be continuously monitored by an automatic system. Occurrence of an out-of-tolerance condition or a failure to execute a command will cause a visual alarm to be illuminated. The alarm display will be used by the crewman to grossly identify the malfunction and initiate corrective maintenance. For certain failures, automatic diagnostic routines will be initiated and appropriate status information will be displayed.

On a routine basis, the performance of various sensors will be monitored by an inspection of their output. This function will be performed on a schedule that is independent of the occurrence of alarm conditions. Its purpose is to maintain data quality at the highest possible level. On a less frequent basis, the performance of appropriate sensors will be actively calibrated. This function, unlike the monitoring one, will be performed on an off-line basis.

From the foregoing, it may be seen that the on-board user requires the capability to display the output of all sensors in their appropriate form. Those that generate digital data should be displayed on a high-resolution video display. The format to be utilized will be an image, profile, or A-scan type, as appropriate. The analog data output of the radar imager should be displayed as an image stream. With regard to sensors producing film data, it should be possible to obtain a processed negative or positive transparency of selected frames at the desire of the crewmen. Since it seems reasonable to assume that the option of selecting film frames for viewing can be selected in advance, it would be desirable to select such a mode without interfering with nominal operations. In effect, this might require that these sensors be fitted with a second "off-line" film pack that could be placed in the optical output path. This secondary film pack could hold small strips, perhaps 5 to 10 frames in length, that could be selectively chosen for on-board processing without disturbing the primary "on-line" film pack. The advantage of holding the primary processing of film for ground action is very great, especially in those cases in which special developing techniques are required. In any event, sufficient crew time will probably not be available for processing the large amount of film data to be collected.

With respect to the nominal sensor control functions required, those identified thus far are relatively simple. The crew should be given the capability of applying/withdrawing power; exercising a warm-up, standby, or operational mode; and, for most sensors, activating/deactiving the data collection function. In addition, the capability of selecting sensor outputs for real-time display should be provided as well as the option to superimpose various outputs. Simultaneous display of up to three data outputs may be required as well as selective call-up of data from storage. This data call-up should be provided for magnetic tape as well as for hard copy microfilm, as appropriate for the particular sensor.

Experiment Data Operations

In general, the on-board user will not perform extensive processing of experiment data. The most likely role that can be identified at present concerns his recording and evaluating targets of opportunity. This function requires interrupting the automatic data collection sequence, acquiring and tracking the target with a moderate-high-resolution optical telescope, slaving selected sensors to the telescope, and activating the sensors' data collection function.

The initiation of the on-board user's functioning in this fashion will probably be undertaken in either of two ways. First, specific targets at specific locations may be identified by ground personnel. Second, a general search may be initiated at the request of ground personnel in which the crewman's options of specific target selection are broader. Therefore, the on-board crewmen will extend the capabilities of the earth surveys mission by providing real-time modifications to data collection sequences in response to real-time changes in the environment.

Performance of this function requires the highest possible resolution in displays, accurate and responsive telescope tracking capability, and full control over the pointing and activation of critical sensors. In addition, real-time communications with the ground must be provided for a major part of the crewman's work day. He must be able to receive instructions and advice and to transmit intelligence regarding his observations. Although it may be possible to transmit occasionally full sensor data to the ground in real time, this function will, for the most part, be limited to a voice transmission of the on-board user's interpretation of the data. Naturally, in the case of film data, the crewman's role becomes more critical. The delay in sending film to the ground will require a small film developing facility and a film viewer.

Other than the on-board user's major role with regard to targets of opportunity, his active participation in experiment data collection and evaluation is expected to be limited to control and adjustment tasks. He will be able to control the automatic data collection sequence and to modify it by entry of new instructions into the on-board computer. He will also perform important tasks related to the calibration and alignment of sensors. By observing their response in real-time, he can make on-the-spot adjustments to enhance the quality of the data and avoid wasted time. Modifications of sensor operations and changes of components such as lenses and filters can also be carried out. The contribution of these tasks depends to a large extent, however, on the provision of adequate data displays. With these, the crewmen can assure the collection of high-quality data for a maximum amount of time. In many cases, improperly operating sensors and facility data collection operations can be quickly modified without waiting for the data to be received, processed, and evaluated on the ground.

7.1.5 GROUND USER DATA REQUIREMENTS

This subsection describes data and control/display requirements for ground personnel concerned with the control of the earth-surveys experiments, initial processing of the raw data, and dissemination of the results. With reference to Figure 7-1, the personnel of interest are those concerned with carrying out the functions identified within the "data processing center" box.

As noted previously, certain data users are excluded from this report. The users excluded are those who will actually apply the data collected on the spacecraft to the solution of research and applications problems. The manipulations that they will apply to the data are only grossly known at the present time and are not amenable to detailed study. Such detailed study will be possible only when current/future research programs are successfully completed.

Experiment and Data Control Functions

An essential responsibility of the ground personnel will be the overall planning and control of the earth-surveys experiment program. Within the total crew time lines, power and communication profiles, and overall mission planning established by the Mission Control Center, a sequence and interleaving plan for the earth-surveys experiments will be developed for implementation by the on-board users. This plan will be modified in near real time to accommodate changing conditions aboard the spacecraft and provide feedback from experimental data. Implementation of this function will require extensive intercommunication links between experiment planners, mission controllers, and on-board crewmen. Displays for monitoring the status of communication lines, experiment systems, and subsystem conditions will be required, as will be controls for their operation.

2. Black and white, positive transparency
3. Black and white, positive print
4. Color, film negative
5. Color, positive transparency
6. Color, positive print
7. Computer-compatible tape

The formats selected were, for the most part, considered reasonably good choices for this report. Consequently, the format numbers shown in Tables 7-4 through 7-9 were derived from the above list.

Table 7-10 was adapted from a paper presented at a 1970 AIAA meeting.[1] It represents the repetitive data update interval desired by user agencies to minimize data obsolescence. The inclusion of this type of information in Tables 7-4 through 7-9 is useful for two major purposes: first, it can be used to size the data processing capabilities required for a ground center; second, it may be used as a major factor affecting the scheduling of data collection activities for the experiments.

[1] Humiston, H. A. An Operational Earth Resource Satellite System— What Does the User Expect? Paper presented at the AIAA Earth Resource Observations and Information Systems Meeting, Annapolis, Maryland, March 2-4, 1970.

Table 7-4. Ground User Data Requirements—Agriculture/Forestry Experiment

Objective/Parameter	User(s)	Raw Data Type	Raw Data Sensor	Processing Requirements	Format/Display	Supplementary Data Requirements	Scheduling Factors	Remarks
Agriculture Inventory Crop Type and Density Expected Yield Farm/Forest Boundaries	Dept. of Agriculture Dept. of Commerce Research Centers Farmers Agribusiness	F	Metric Camera	Film color developing	Formats 1, 2, 3, 4, 5	a. Location indices b. Truth site verification of crop identification c. Rainfall and temperature prediction (especially extremes, viz., frost, drought, etc.)	April-September once/month	a. Not all sensors will be used by Dept. of Agriculture simultaneously. b. Photo-imaging camera output could be used to produce false color photos.
		F	Multispectral Camera	Film color positive-automatic photometric analysis for crop signature.	Formats 4, 5, 6 Image maps with crop identification coding.			
		A	Radar Imager	Mosaicking	Formats 1, 2, 3			
		D	Multispectral IR Scanner	Generate multi-color images in register-quantitative analysis of radiation in various bands.	Formats 4, 5, 6 Computer-generated boundary maps coded for crop identification.			
		D	MW Scanner Radiometer	Analyze for estimates of vegetative cover and moist soil zones.	Vegetation boundary maps. Formats 4, 5, 7			
		D	Photo-Imaging Camera	Crop identification and vigor by automatic photometric analysis of color transparencies.	Tabular formats containing crop acreage and probable yield. Formats 4, 5, 6.			
Agricultural Infestation Disease and Insect Detection Disease and Insect Damage Patterns	Dept. of Agriculture Famers Research Centers	D	Multispectral IR Scanner	Automatic analysis for large known differences in crop spectral signatures.	Infestation detection alarms.	a. Location indices b. Truth site verification	May-August once/week for detection. Pattern images as required.	
		D	Photo-Imaging Camera	Computer analysis for boundary demarcation.	High resolution infestation pattern maps. Formats 4, 5, 6.			
Agricultural Land Use Soil Texture and Moisture	Dept. of Agriculture	D	Multispectral IR Scanner	Spectral signature analysis (automatic) for moisture content.	Contour maps showing terrain roughness and moisture content. Formats 5, 6.	a. Location indices b. Spacecraft position and attitude accuracy data.	2-3 times/year.	
		D	Radar Altimeter/ Scatterometer	Compute scattering coefficient.	Graphic printouts of surface texture (curves of scattering coefficient versus angle).			
Forest Inventory and Distribution Forest Texture and Boundaries Tree Types and Count Logging Yield and Production	Dept. of Agriculture Wood/Paper Manufacturers Research Centers	F	Metric Camera	Color Positive	Forest photos. Formats 1, 2, 4, 5.	a. Location indices b. Truth site verification	Quarterly	May require snow cover discrimination in winter-MW Scanner Radiometer can be used.
		A	Radar Imager	Mosaicking	Forest photos through bad weather. Formats 1, 2, 3.			
		D	Multispectral IR Scanner	Automatic estimation of tree types and count (density) by spectral analyses.	Color coded graphic plots of forest indicating tree type and density. Formats 4, 5, 6.			
Forest Fire, Disease and Reclamation Fire Location and Damage Estimation Insect/Disease Damage	Dept. of Agriculture Fire Fighting Services Lumber Companies	F	Multispectral Camera	False Color Processing.	Formats 5, 6. Showing diseased/burned/ healthy boundaries.	a. Location indices b. Truth site verification	Disease/insect infestation-monthly. Fire detection-as requested on basis of fire probability model of forestry service.	
		D	IR Spectrometer/ Radiometer	Automatic analysis for fire detection.	Alarm messages-area, extent, location.			
		F	Metric Camera	Color Positive	Photo maps of forest fire area when required. Formats 1, 2, 4.			

Table 7-5. Ground User Data Requirements—Cartography Experiment

Objective/Parameter	User(s)	Raw Data Type	Raw Data Sensor	Processing Requirements	Format/Display	Supplementary Data Requirements	Scheduling Factors	Remarks
Land Use Studies Mapping Location of Major Lakes Reservoirs, Rivers, Snow Cover, Ice Pack Urbanization Patterns	Urban/Suburban Planners Dept. of Interior	F	Metric Camera	Color positives	Used for construction of 1:50,000 scale maps (Formats 1, 2, 3).	a. Precision spacecraft attitude and position data. b. Truth site verification.	On request, probably bi-monthly (low priority).	
		F	Multispectral Camera	Multicolor film developing with special filters.	Formats 4, 5, 6 for identification of major surface features including man-made structures.			
		D	MW Scanner Radiometer	Computer processing of amplitude and generation of MW images.	Grid print maps (Formats 1, 2) illustrating water/land, water/snow boundaries and snow depths.			
		A	Radar Imager	Mosaicking	High-resolution topographical maps (Formats 1, 2, 3)			
		D	Laser Altimeter	Selected extracting of key data points.	Selected printouts of altitude for referencing of other data.			
Urban Planning Population Distribution Location, Size and Distribution of Settlements Industrial Plant Locations	Urban Planners Dept. of Interior HEW Dept. of Transp.	F	Metric Camera	Color positives	Construct overlays in "true" and "false" colors. Photo enhancement needed for improved resolution (Formats 4, 5, 6).	Census data - rail/highway identification and locations locations.	Annually	
		F	Multispectral Camera	Special film processing.				

Table 7-6. Ground User Data Requirements—Applied Mineralogy Experiment

Objective/Parameter	User(s)	Raw Data Type	Raw Data Sensor	Processing Requirements	Format/Display	Supplementary Data Requirements	Scheduling Factors	Remarks
Petroleum and Minerals Detection/Classification Lithology Studies Soil Density and Compacting Surface Stratification Earth Folds/Outcropping	U.S. Department of the Interior Commercial Petroleum/Mining Interests AEC U.S. Geological Survey Bureau of Mines	F	Metric Camera	Standard film developing.	Formats 1, 2, 4.	a. Spacecraft location indices b. Sensor pointing parameters. c. Truth site verification of sampled data.	Survey of specific locations performed once (might be backup evaluation at 1-5 year intervals).	Complete area survey requires broad spectral coverage.
		D	Laser Altimeter	None.	Digital printout directly on Metric Camera film.			
		F	Multispectral Camera	Developing of multiband film. Overlay in close registration.	Formats 4, 5.			
		D	Multispectral IR Scanner	Generate multicolor images in register. Quantitative analysis of radiation in different bands.	Formats 5, 6, 7.			
		A	Radar Imager	Standard film developing.	Formats 1, 2, 3.			
		D	IR Spectrometer/Radiometer	Computer match of input spectra to stored curves to determine bulk composition of rock.	Formats 1, 2, 3, 7.			
		D	Visible Wavelength Polarimeter	Analyze atmospheric aerosol from polarization parameters such as Stoke's Parameters.	Atmospheric aerosol contents displayed on graph.			
		D/F	UV Imager/Spectrometer	Analyze UV energy for petroleum and luminescent materials.	Formats 4, 5 (false color), and 7.			
		D	Radar Altimeter Scatterometer	Compute scattering coefficient.	Formats 1, 2, 3, 7.			
Volcano Activity Monitoring Thermal Disturbances Lithological Studies	USDI U.S. Geological Survey	F	Multispectral Camera	Developing of multiband films. Overlay in close registration.	Formats 4, 5, 6.	a. Spacecraft Location Indices b. Seismic activity	Bimonthly monitoring of subject areas.	
		D	Multispectral IR Scanner	General multicolor (false) images in registration	Formats 4, 5, 6.			
		D	IR Spectrometer/Radiometer	Computer correction of input spectra to stored standard curves.	Formats 2, 3, 7.			
		D	Multifrequency MW Radiometer	Image conversion and automatic calculation of surface temperatures.	Formats 2, 3, 7.			
Earthquake Prediction Microtemperature Anomalies Slope Distribution Crust Anomalies Soil Moisture/Granularity		A	Radar Imager	Standard film developing.	Formats 1, 2, 3.	a. Spacecraft Location Indices b. Seismic activity	Weekly-monthly monitoring of suspect areas.	
		D	Multifrequency MW Radiometer	Automatic calculation of surface moisture/temperature gradients.	Formats 2, 3, 7.			
		D	Radar Altimeter/Scatterometer	Surface roughness estimation.	Formats 1, 2, 3.			

Table 7-7. Ground User Data Requirements — Water Resources Experiment

Objective/Parameter	User(s)	Raw Data Type	Raw Data Sensor	Processing Requirements	Format/Display	Supplementary Data Requirements	Scheduling Factors	Remarks
Water Inventory River Effluents Reservoir Levels Drainage Basin Features Irrigation Surveys	USDI ESSA USGS Bureau of Reclamation Federal Water Quality Administration Bureau of Recreation	F	Metric Camera	Standard film processing.	Formats 1, 2, 3.	a. Spacecraft location b. Weather reports c. Sensor pointing parameters.	Monthly	
		F	Multispectral Camera	Development of multiband films (false color induced)	Formats 5, 6.			
		D	Multispectral IR Scanner	Image conversion and film developing.	Formats 5, 6.			
		A	Radar Imager	Standard film processing.	Formats 2, 3.			
		D	MW Scanner Radiometer	Image conversion and film processing.	Formats 2, 3.			
Flood Control Flood Location/Measurement Damage Assessment Erosion Patterns Rainfall Monitoring Ice/Snow Pack Monitoring	USDI ESSA Bureau of Reclamation	F	Metric Camera	Standard film processing.	Formats 1, 2, 3.	a. Spacecraft location b. Atmospheric water content c. Truth site verification	As required - perhaps daily during spring runoff season.	
		D	MW Scanner Radiometer	Image conversion and film developing.	Formats 1, 2, 3.			
		A	Radar Imager	Standard film processing.	Formats 1, 3.			
		D	Photo Imaging Camera	None.	Format 7.			
		D	Multifrequency MW Radiometer	Digital processing for snow/ice pack depth, extent.	Format 7. Printouts of snow field potentials.			
		D	Active/Passive MW Radiometer	Image conversion and film developing.	Formats 1, 2.			
Water Pollution Salinity Surveys Pollution Content/Source	USDI ESSA Federal Water Quality Administration	F	Multispectral Camera	Developing of multiband film.	Formats 5, 6.	a. Spacecraft location b. Site verification c. Water content analyses (ground chemical studies)	Weekly for potential pollution areas.	
		D	Multispectral IR Scanner	Image conversion - spectral signature analysis - photo developing (false color).	Formats 5, 6.			
		D	Photo Imaging Camera	None.	Format 7.			

Table 7-8. Ground User Data Requirements—Meteorology Experiment

Objective/Parameter	User(s)	Raw Data Type	Raw Data Sensor	Processing Requirements	Format/Display	Supplementary Data Requirements	Scheduling Factors	Remarks
Weather Forecasting Temperature Profiles Water Vapor Profiles Atmospheric Density and Ozone Level	ESSA	D	Multifrequency MW Radiometer	Automatic generation of water profiles.	Hard copy printouts of humidity profiles.	a. Spacecraft location b. Ground station data c. Balloon data	Daily for most sensors.	Aim of collecting data almost continuously is to support prediction model for extended forecasting. With improvement of model, data input may be required less frequently.
		D	MW Atmospheric Sounder	Automatic generation of temperature/water vapor profiles.	Hard copy printouts of temperature/humidity profiles.			
		D	UHF Sferics	Threshold monitoring.	Printouts showing noise activity locations.			
		D	IR Atmospheric Sounder	Automatic generation of temperature profiles - calculation of atmospheric turbulence	Temperature/turbulence profile printouts.			
		D	IR Interferometer/ Spectrometer	Automatic generation of ozone profiles, surface/ vertical temperature profiles.	Printouts showing altitude profiles for ozone, temperature.			
Severe Storm Monitoring Cloud Top Altitude Turbulence Profiles Sferics Events	ESSA U.S. Coast Guard	D	UHF Sferics	Radio noise profiles - detection of major events.	Printouts showing severe thunderstorm activity locations.	Same as above.	As required - routine searching during hurricane spawning season.	
		D	IR Interferometer/ Spectrometer	Image conversion-film developing for cloud top cover.	Formats 1, 2, 3 printouts of vertical temperature profiles.			
		D	Radar Altimeter/ Scatterometer	Automatic generation of surface wind velocity (and possibly direction).	Surface wind profiles for water areas.			
		D	MW Atmospheric Sounder	Automatic generation of temperature/water vapor profiles.	Hard copy printouts of vertical temperature/ humidity profiles.			
Atmospheric Pollution Monitoring	ESSA USDI	D/F	Absorption Spectrometer	Detection and monitoring of aerosol content.	Horizontal pollutant identification by type and amount.	a. Ground station monitor reports.	Continuous.	Prediction of pollutant movement and dispersion can be achieved by adding wind/turbulence data.
		D	Visible Wavelength Polarimeter	Detection and monitoring of aerosol content.	Horizontal pollutant identification by type and amount.			

Table 7-9. Ground User Data Requirements—Oceanography Experiment

Objective/Parameter	User(s)	Raw Data Type	Raw Data Sensor	Processing Requirements	Format/Display	Supplementary Data Requirements	Scheduling Factors	Remarks
Shipping Traffic Advisement Sea State Currents Hazard Identification	U.S. Coast Guard ESSA SPOC-NAVOCEANO	D	Radar Altimeter/ Scatterometer	Computing of scattering coefficient and generation of sea state profiles.	Graphic power spectra showing sea roughness component. Format 7.	a. Spacecraft location data b. Truth site verification c. Ship/aircraft reports	Daily to weekly depending upon season. Weekly reports on monimal sea state. Daily reports on ice mass breakup.	
		D	Multifrequency MW Radiometer	Computation of sea temperature gradients.	Map generation showing ice pack locations.			
		D	IR Spectrometer/ Radiometer	Computation of sea/ surface temperature.	Map generation showing temperature isotherms.			
		D	Active/Passive MW Radiometer	Digital data processing for sea/ice boundary.	Formats 2, 3.			
Sea Food Production Kelp/Chlorophyll Locations Surface/Subsurface Temperature Water Color Sea State	SPOC-NAVOCEANO USDC Fishing Industries	D	Multifrequency MW Radiometer	Computation of sea temperature gradients.	Map generation showing vertical sea temperature profiles.	a. Spacecraft location data b. Ship verification	Twice weekly.	Probably localized interest by season.
		F	Multispectral Camera	Multiband film developing.	Format 4, 5, 6.			
		D	Multispectral IR Scanner	Image generation-film developing in false color.	Format 5, 6.			
		D	Photo Imaging Camera	None.	Format 7.			
Pollution Monitoring Oil Slick Detection	U.S. Coast Guard SPOC-NAVOCEANO	D	Multispectral IR Scanner	Spectral analysis-automatic.	Pollutant identification.	a. Spacecraft location data b. Truth site verification	Weekly except for coastal areas, especially basins where search for pollutants should be as often as possible.	
		F	Multispectral Camera	Multiband film developing.	Format 4, 5, 6.			

Table 7-10. Data Aging Limitations

Time Interval (hr)	Event	
10^0	Earthquake	Emergencies
	Fire	Emergencies
	Flood	Emergencies
	Storm	Emergencies
10^1	Commercial Fishing	Emergencies
	Oil Spills	Emergencies
10^2	Sea Traffic	Emergencies, Management
	Water Quality	Emergencies, Management
10^3	Irrigation	Management
	Agriculture	Management
	Watershed Management	Management
	Forest/Parkland Management	Management
	Conservation	Management
10^4	Land Management/Reclamation	Management, Planning and Study
	Zoning/Land Use	Management, Planning and Study
	Urbanization	Planning and Study
10^5	National Atlas	Planning and Study
	Census	Planning and Study

generated for each channel. The output of each detector is a continuously varying voltage; thus, the instrument is inherently analog. Conversion of the analog signals to a digital format is accomplished in an analog-to-digital (A/D) converter.

The NR-recommended alternate mechanization concept employs the natural analog output of each detector. This is illustrated in Figure 7-4. Here a frequency multiplexer is used to put the several analog channels onto the single audio/video bus of the MSS information subsystem. Whereas the handling of digital data requires a capability of 5.0×10^7 bits per second, the analog procedure requires only a bandwidth of 3.5×10^6 Hz.

Figure 7-5 illustrates how this concept interacts in general with the ISS. Experiment equipment is outlined by the heavy rule. The RACU's (remote acquisition and control unit) control inputs and outputs to the digital bus. The AVU's (audio/video units) perform a similar function for the analog bus.

Figures 7-6 through 7-11 illustrate various ways the concept shown in Figure 7-5 can be used. The heavy lines show the route taken by the signal from the experiment equipment.

Figure 7-6 shows an internally processed signal being recorded (in video format) for later display on board. Control of the experiment equipment, illustrated in Figure 7-7, is performed digitally at a very low bit rate. For real-time evaluation, the internally processed signal bypasses the video recorder (Figure 7-8). For real-time transmission to the ground, the raw analog signal is brought directly to the communications equipment and transmitted as a video signal (Figure 7-9). There is no need to preprocess the raw data—they can be stored directly, as illustrated in Figure 7-10. Finally, recorded data can be transmitted to the ground via the TV downlink, as illustrated in Figure 7-11. Selective digital processing can be performed but it is not illustrated. A scan converter or similar device is required to format the raw analog data so that it is compatible with video-type displays.

The NR concept for mechanizing the earth-observations multispectral scanner is summarized in Figure 7-12. This concept can be used with any multichannel analog device, with equally significant reduction in bandwidth requirements. If necessary, internal digitizing of the analog data can be accomplished to assure greater precision for later data processing. The concept outlined above is the only reasonable one that retains the capability for real-time or nearby real-time data utilization.

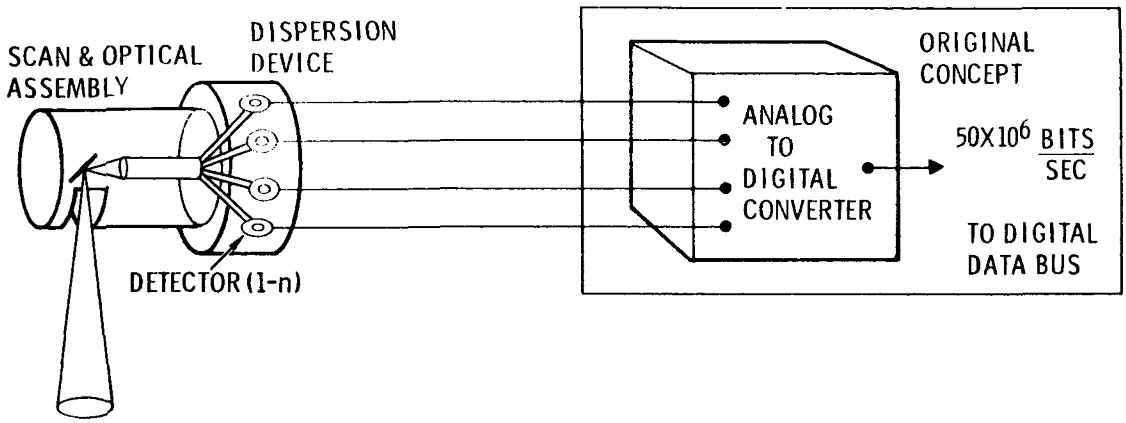


Figure 7-3. Blue Book Multispectral Scanner Concept

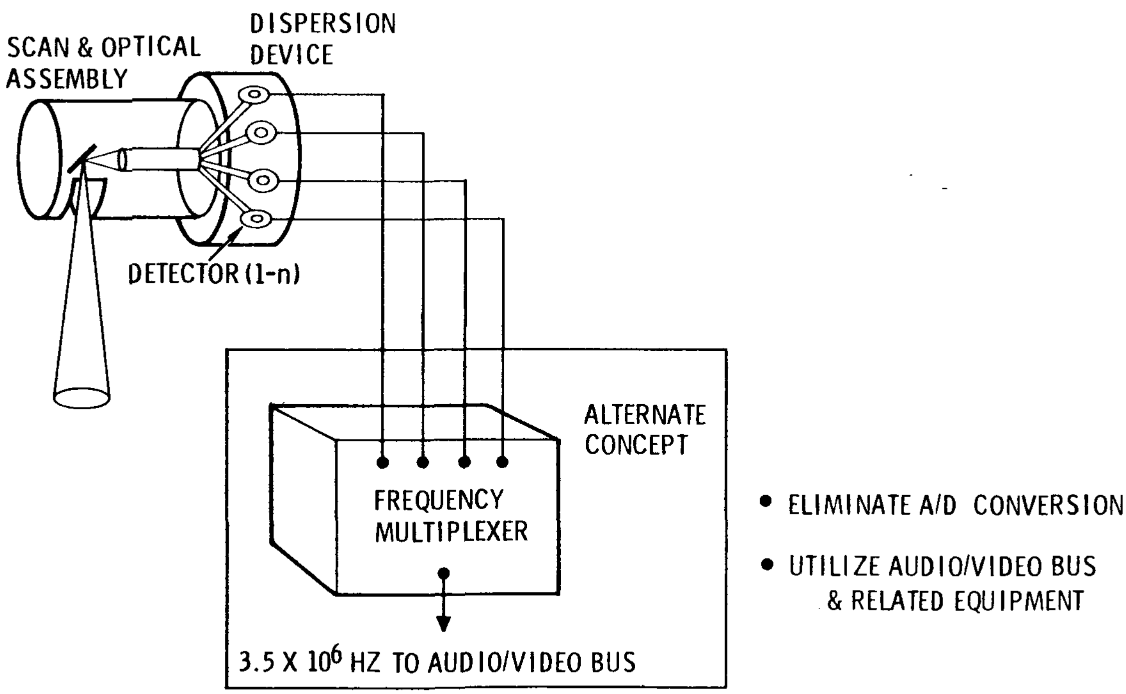


Figure 7-4. NR-Recommended Multispectral Scanner Concept

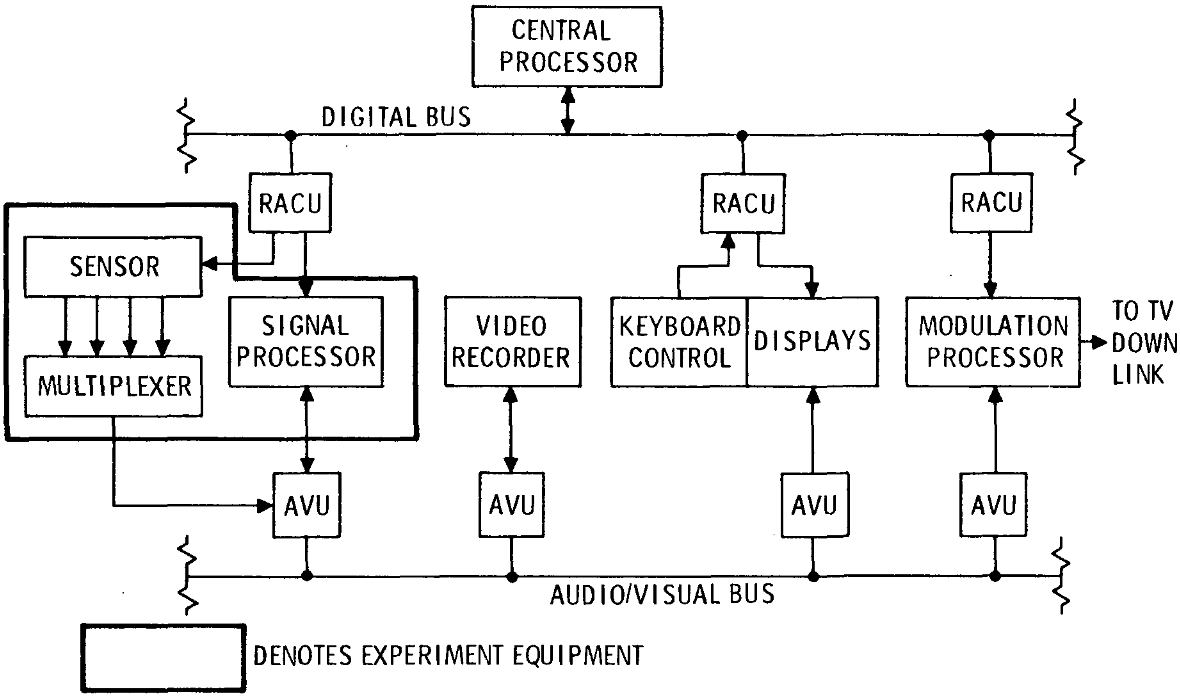


Figure 7-5. Mechanization Concept

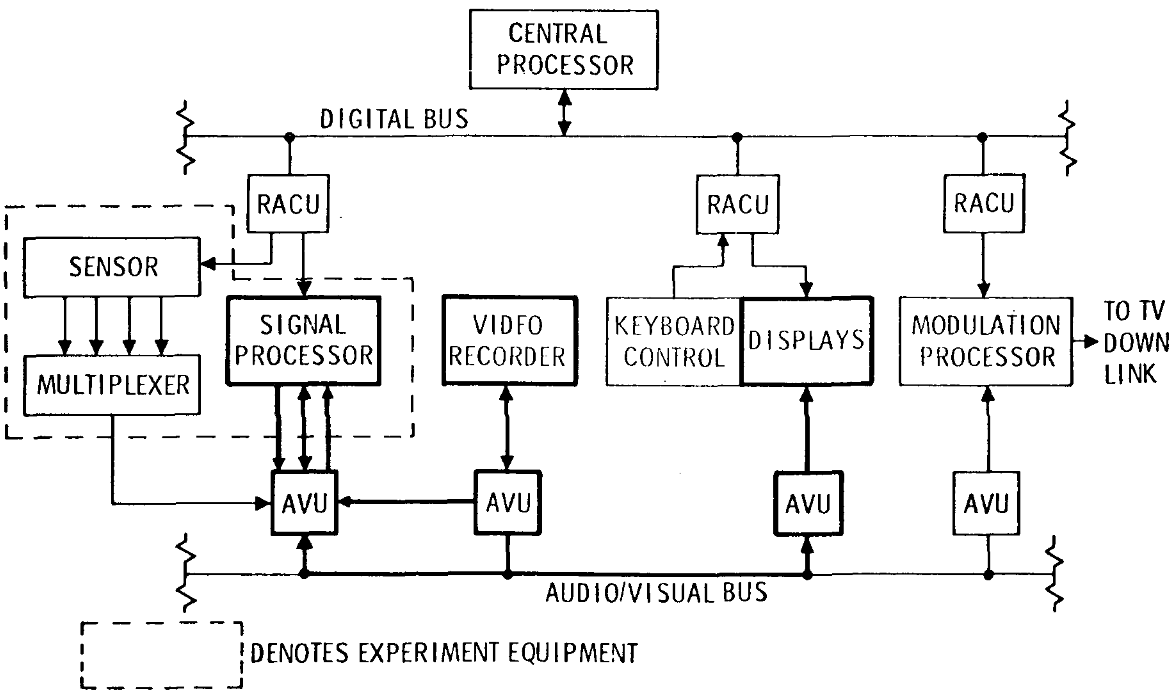


Figure 7-6. Time-Delayed Data and Sensor Evaluation

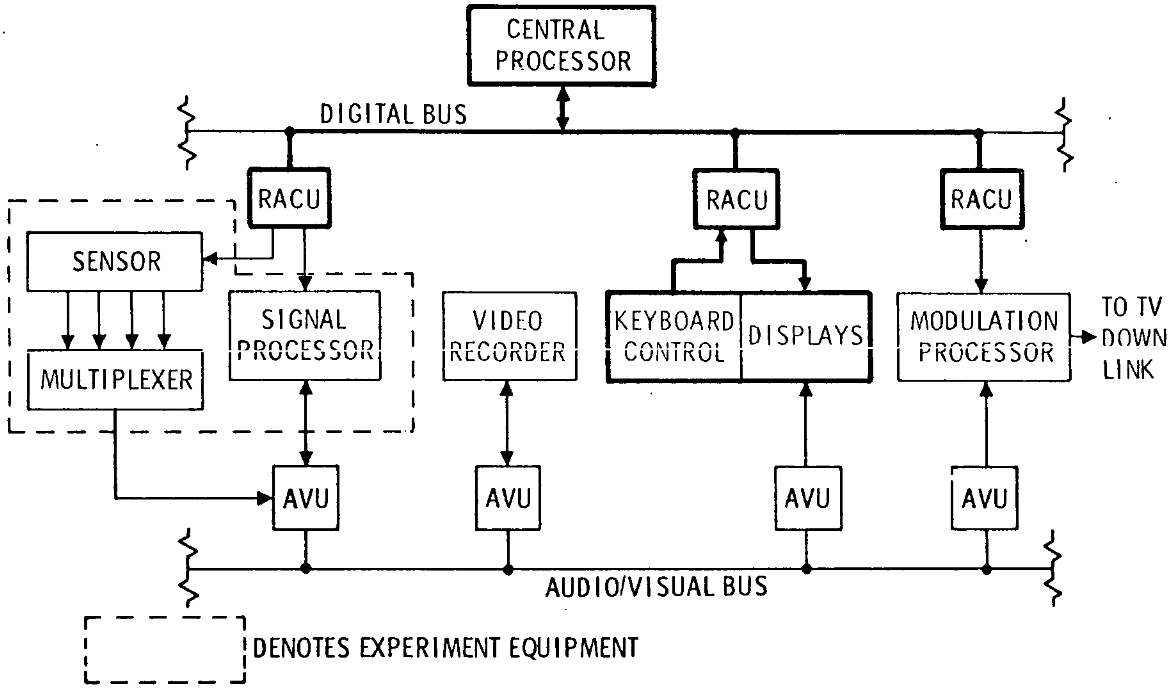


Figure 7-7. Sensor Control and Housekeeping

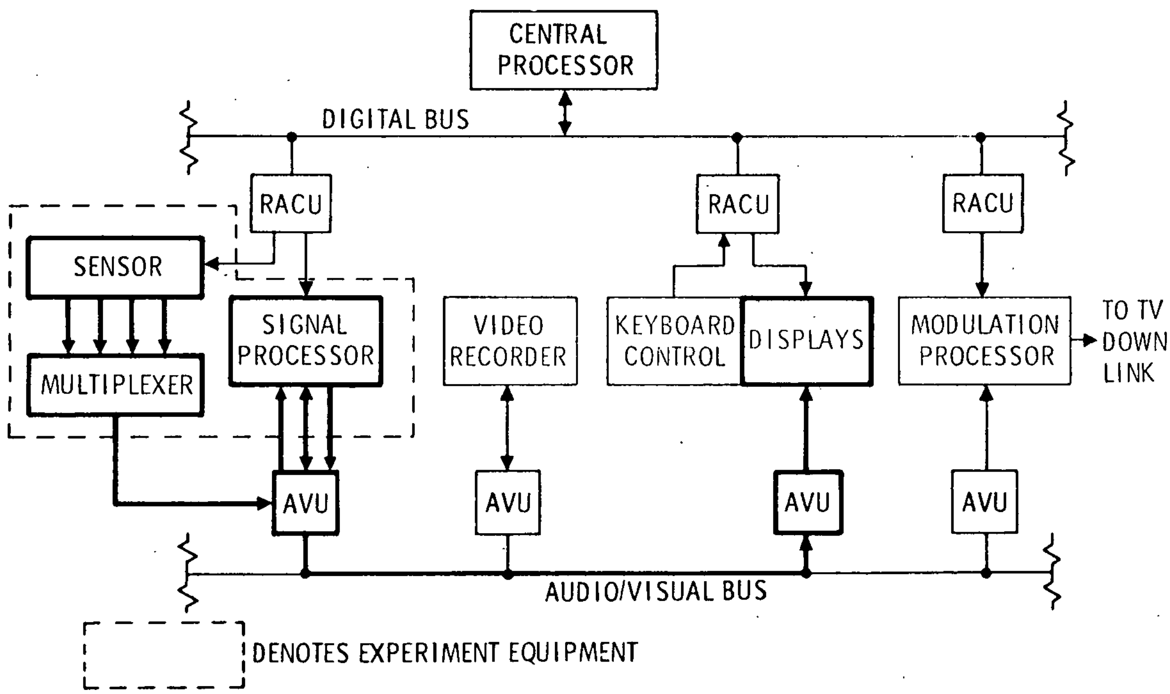


Figure 7-8. Real-Time Sensor and Data Evaluation

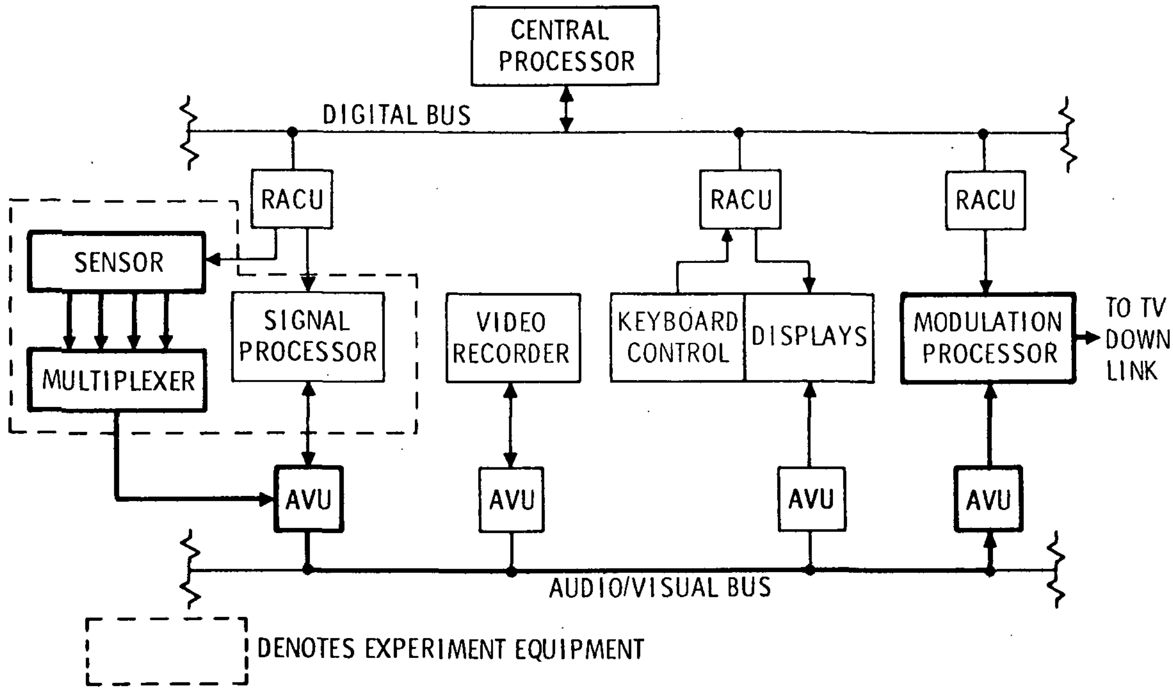


Figure 7-9. Real-Time Data Acquisition and Transmission

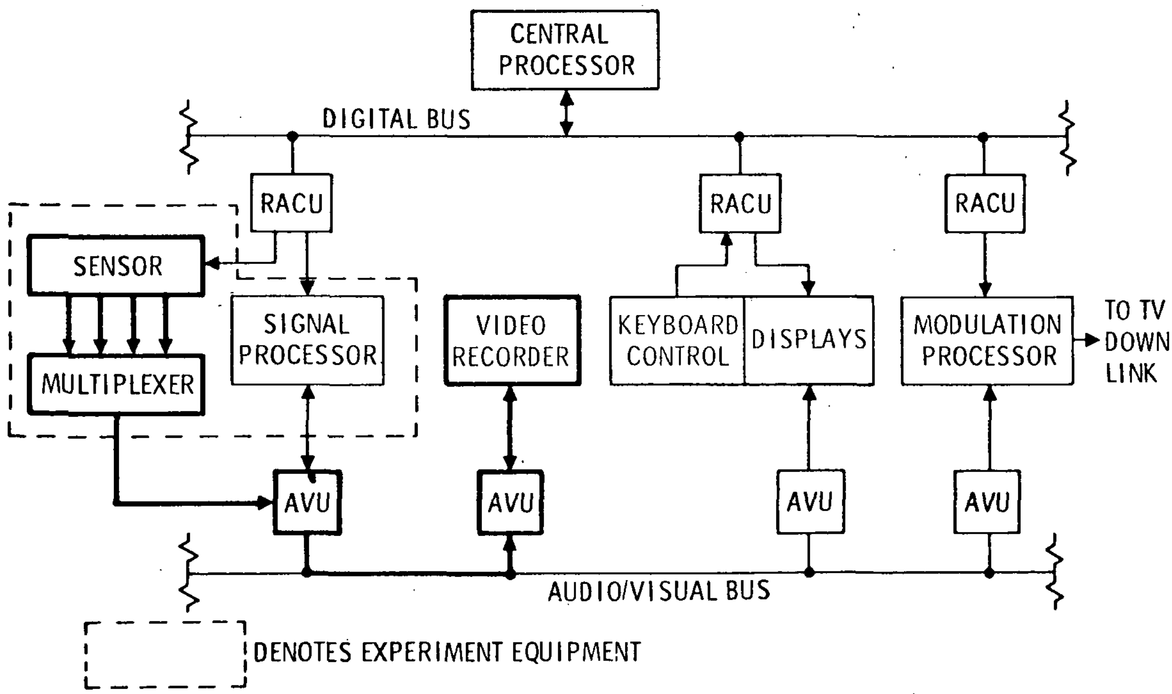


Figure 7-10. Data Acquisition and Storage

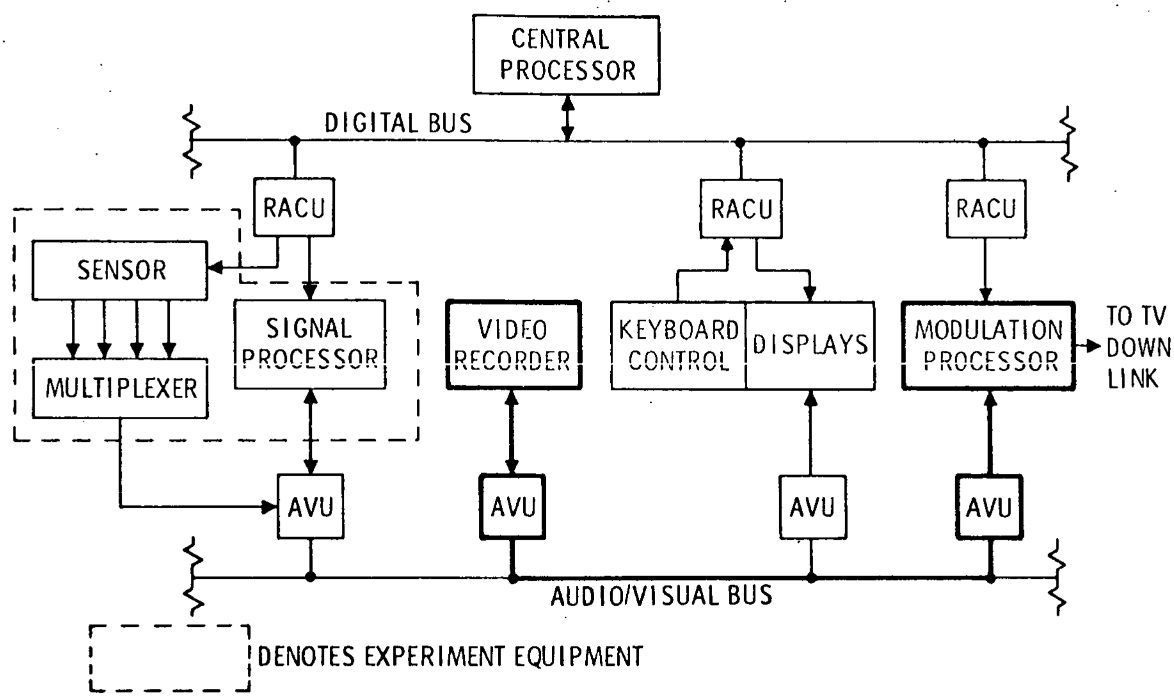


Figure 7-11. Time-Delayed Data Transmission

- SENSOR CONTROL AND HOUSEKEEPING VIA DIGITAL BUS
- SENSOR EVALUATION, DATA ACQUISITION, AND DATA TRANSMISSION VIA ANALOG

STATION EQUIPMENT	CAPABILITY AVAILABLE FOR EXPERIMENTS	MULTISPECTRAL SCANNER REQUIREMENT
AUDIO/VIDEO BUS	39 MHz (6 CHANNELS AT 6.5 MHz)	3.5 MHz
TV DOWNLINK		
BANDWIDTH	6.5 MHz	3.5 MHz
TIME	24 HR/DAY (SHARED) (REAL-TIME OR DELAY)	75 MINUTES/DAY (3 RUNS)
VIDEO RECORDER		
BANDWIDTH	6.5 MHz	3.5 MHz
TIME	30 MIN/TAPE	25 MINUTES/RUN

Figure 7-12. Mechanization Summary

7.3 EXPERIMENTS FIELD-OF-VIEW REQUIREMENTS

Another area of special interest was the sensor field-of-view requirements for the earth-observations laboratory. The primary objective was to determine possible field-of-view (FOV) interference that the various sensors might encounter—for example, the solar arrays during normal operations.

During the study, each of the earth-observations sensors was analyzed for its instantaneous FOV, total FOV, scanning, pointing, tracking, and maximum clear FOV requirements. Table 7-11 is a list of the results of this analysis; however, the table does not indicate the complex interrelationships among the individual sensors and their influence upon each other. These are illustrated in Figure 7-13. Since some of the information required to determine these relationships was not available in the 1971 Blue Book, it was necessary to infer some of the sensor requirements in order to complete the analysis.

In general, these inferences were drawn from data on similar sensors contained in the 1969 Blue Book or other standard references. They may be summarized as follows:

<u>1971 Blue Book Earth-Observations FOV Requirements</u>

1. Four stellar reference cameras (Item 1a) are rigidly mounted to metric camera (Item 1) and have 25-degree conic FOV's pointed +105 degrees from the nadir at 90-degree azimuth spacing, with azimuthal orientation dictated only by clear FOV requirements.

2. Multispectral TV camera (Item 3) has 10-degree square FOV (equivalent to a 15-degree cone).

3. Multispectral scanner (Item 4) has 13.2-degree (±6.6 degrees) square FOV (equivalent to 18.5-degree cone).

4. Passive microwave scanner (Item 5) has a fan beam consisting of 2-degree FOV conic elements, points +40 degrees in track by being inclined (fixed), and scans ±20 degrees cross track.

5. Microwave radar imager (Item 6) points laterally 45 degrees and scans ±15 degrees from direction (30 degrees to 60 degrees to nadir), with a fan beam measuring 0.001 arc-minute (by 15 feet) IT by 5 degrees (by 5 feet) XT.

6. Multifrequency MW radiometer (Item 8) requires ±60 degree pointing (tracking) IT and XT.

7. Scatterometer/radiometer/altimeter (Item 9) scans 0 to 52 degrees IT and ±XT and has a 1.5-degree cone FOV.

8. Multispectral spectrometer (Item 10) has a 0.4-degree cone FOV.

9. Aeronomy spectrometer (Item 11) uses narrow-angle telescope optics.

10. Spectral polarimeter (Item 12) has a 120-degree cone FOV.

11. Sferics detector (Item 13) has a 120-degree cone FOV.

12. Absorption spectrometer (Item 14) uses wide-angle telescope optics.

13. Optical radar (Item 15) requires 3-degree cone clear FOV and is mounted with telescope (Item 16a).

14. Observation telescope (Item 16) requires search/pointing/tracking capability of ±60-degrees IT and XT.

15. Data collection system (Item 18) has a 100-degree cone FOV.

16. Passive MW scanner and MW radar imager (Items 5 and 6) use frequency scanning (not mechanical).

17. All microwave instrument FOV's must have 10-degree clearance of obstructions, and no interference (saturation) will occur if this is maintained (FOV's may cross).

The complete FOV requirements will be a major driver for the MSS configuration. The following are some of the more significant problem areas:

1. Mounting and Separation of Sensors. In Figure 7-13, it can be seen that an area approximately 108 feet in length and 49.5 feet in width is required to mount the sensors so that no FOV interference exists between sensors. It becomes apparent that such

a requirement is too demanding and that some compromises will be required. For example, these could include:

- Reduction in the total number of sensors—that is, to alternate operation of sensors that require great separation distances.
- Reduction in the size of the sensors being deployed.
- Moving the sensors closer together and accepting the FOV interferences.

2. Operational Requirements. It also can be seen in Figure 7-13 that the required separation presents a major problem in, for example, folding the sensors prior to bringing them back into the station module. In addition, the manipulator mechanism must be monitored so as not to damage any of the sensors. Another, and probably most serious concern, is the possible interference that might be encountered during shuttle docking periods. Finally, due to the rigid pointing requirements, the large sensors could cause some serious thermal problems by producing unwanted shading or reflective conditions.

Table 7-11. Earth-Observations Sensors Viewing Requirements

Item No.	Name	Instantaneous FOV (IT/XT)	Instrument Scan (IT/XT)	Total Instrument FOV (IT/XT)	Pointing Requirement (IT/XT)	Special Pointing Requirements	Tracking Requirement (IT/XT)	Maximum Required Clear FOV (IT/XT)
1	Metric Camera	41°/62°	-	41°/62°	Nadir	-	-	±21°/±31°
1a	Stellar Reference Camera	25° cone	- (2)	4 FOV's pointing +115° from nadir, 90° apart		-	- (2)	25° cone, 4 places
2	Multispectral Camera	21°/21°	-	21°/21°	Nadir	-	±60°/±60° (10)	±71°/±71°
3	Multispectral TV Camera	10°/10°	-	10°/10°	Nadir	-	±60°/±60° (10)	±65°/±65°
4	Multispectral Scanner	13.2°/12.3°	-	13.2°/13.2°	Nadir	(5)	-	±7°/±7°
5	Passive MW Scanner	2°/2° (6)	0°/±20°	2°/42°	+40°/0°	-	-	+51°/+29° /±31° (4)
6	MW Radar (Imager)	.001°/5° (7)	0°/(1)	.001°/65°	0°/45°(1)	(1)	-	±11°/±63° (4)
7	Multispectral Radiometer	.02° cone	-	.02°/.02°	Nadir	-	±60°/±60° (10)	±61°/±61°
8a	Multifrequency MW Radiometer	1° cone (8)	-	1°/1°	Nadir	-	±60°/±60°	±71°/±71° (4)
8b	Multifrequency MW Radiometer	4.5° cone (9)	-	4.5°/4.5°	Nadir	-	±60°/±60°	±73°/±73° (4)
9	Scatterometer/Radiometer/ Altimeter	1.5° cone	+52°/-00 /53°	Nadir	-	-	-	+53°/-1° /±53°
10	Multispectral Spectrometer	.4° cone	-	.4°/.4°	Nadir	(3) (5)	±60°/±60° (10)	±61°/±61°
11	Aeronomy Spectrometer	Uses observation telescope optics						
12	Spectral Polarimeter	120° cone	-	120°/120°	Nadir	-	-	±60°/±60°
13	Sferics Detector	120° cone	-	120°/120°	Nadir	-	-	±60°/±60°
14	Absorption Spectrometer	Uses observation telescope optics						
15	Optical Radar (Laser Altimeter)	3° cone	-	3°/3°	Nadir	-	-	±2°/±2°
16a	Observation Telescope	.4° cone	-	.4°/.4°	Nadir	-	±60°/±60°	±75°/±75°
16b	Observation Telescope	30° cone	-	30°/30°	Nadir	-		
16c	Observation TV Camera	Uses observation telescope optics						
18	Data Collection System	100° cone	-	100°/100°	Nadir	-	-	±50°/±50°

NOTES

(1) One side only, scans between +60° and +30° or -60° and -30°
(2) Special FOV to clear obstructions—part of metric camera
(3) Calibrated by sun-illuminated disc (no other data known)
(4) Includes 10° clearance of all obstructions
(5) May have radiator requiring 60° x 120° clear FOV to deep space
(6) 14-foot-square antenna
(7) 15-foot-long (IT) antenna
(8) 10-foot-diameter antenna
(9) 30-foot-diameter antenna
(10) Gimbaled platform

Definitions and Abbreviations Used in Table 7-11

Instantaneous FOV = instantaneous field of view of the sensor regardless of pointing direction or scanning or tracking requirements.

Instrument scan = inherent scanning capability of the sensor instrument.

Total instrument FOV = summary of Items 1 and 2.

Pointing requirement = orientation of the centerline of the total instrument field of view (centerline of scan where applicable).

Special pointing requirements = additional definition of pointing direction or requirements other than those covered by sensor field of view (i. e., calibration requirement).

Tracking requirement = capability of installation that permits controlled slewing of the sensor in either along-track (in-track) or cross-track direction. These requirements are in addition to any scanning capability inherent in the sensor instrument (see Item 2).

Maximum Required Clear FOV = sum of Items 3, 4, 5, and 6, and any additional clearance required.

IT = in track, or along velocity vector. Positive angles are measured from nadir (0°) in the direction of the velocity vector; negative angles are measured in the direction opposite to the velocity vector.

XT = cross track, or at 90° to the velocity vector. Positive angles are measured to the right of nadir (0°) when facing in the direction of the velocity vector; negative angles are measured to the left.

"Gimbaled platform" means "gimbaled for tracking" (see Items 2, 3, 7, 10, and 11).

Observation telescope aeronomy spectrometer and absorption spectrometer (Items 11, 14, 16a, and 16c) have common optics and mountings, with astronaut operator access for sighting.

Items 2, 3, 7, 8a, 8b, 9 and 10 can be on a common platform for gimbaling (no independent target requirement). Gimbal centerline is in plane of rim of antenna (Item 8).

Gimbaling through a 120-degree cone will satisfy all requirements (stability, search, pointing, tracking, calibration, servicing).

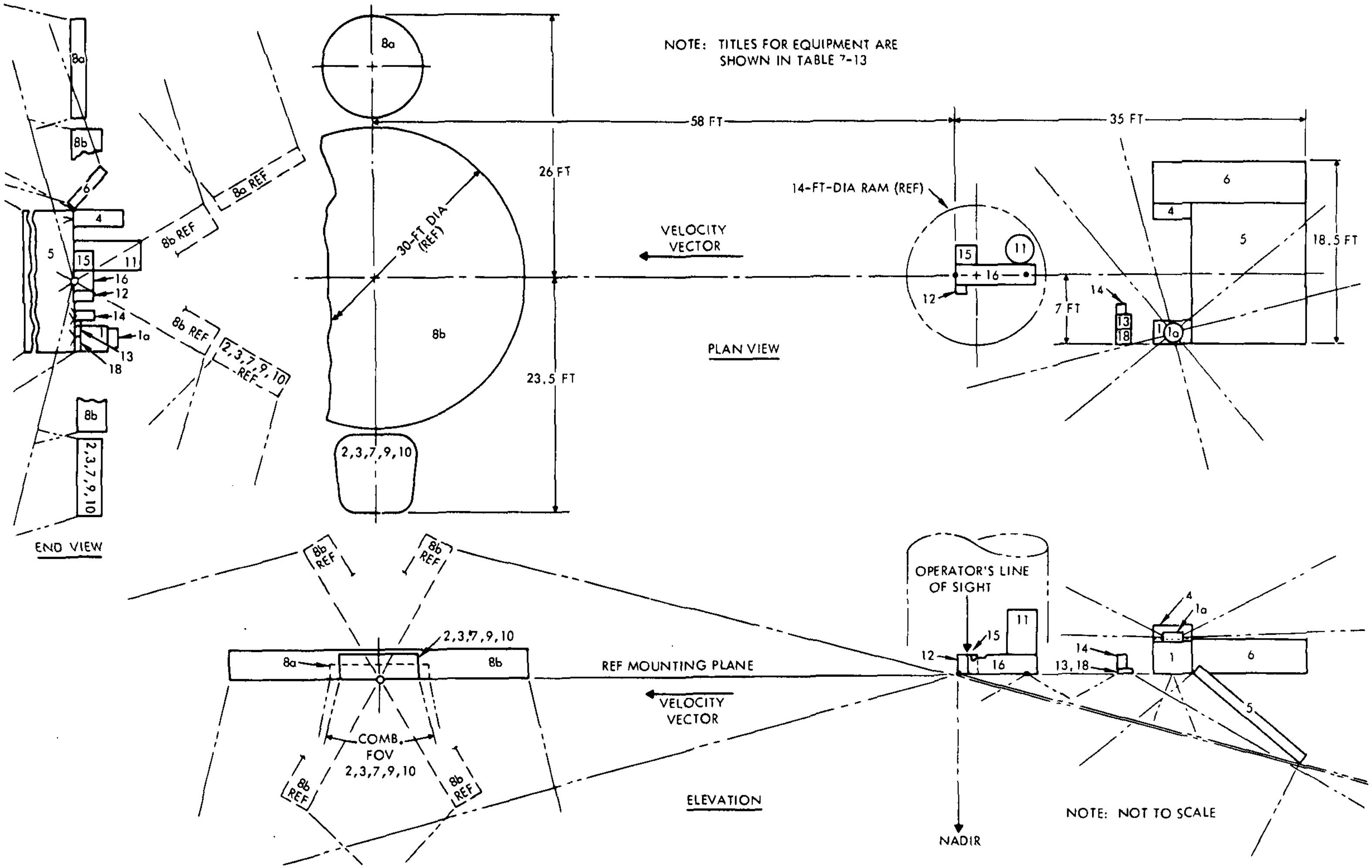


Figure 7-13. Field-of-View Requirements for Earth-Observations Experiment Sensor

7.4 AIRLOCK REQUIREMENTS

The experiment airlock requirements study was based on an MSS study-derived requirement indicating a need for both zenith and nadir experiment airlocks. The study was initiated to determine the size of an airlock featuring low cost, simplicity, minimum acceptable volume, and maximum flexibility in its use.

7.4.1 AIRLOCK CONFIGURATION

Meeting the requirements of design simplicity and low cost, the preferred configuration is a simple cylinder with a standard docking/berthing port interface with the MSS. Since the docking/berthing ports are 80 inches in diameter, an 80-inch-internal-diameter airlock seemed to be a reasonable starting point.

The next task was to review the envelope characteristics of 1971 Blue Book experiment equipment items requiring the use of an airlock. This review uncovered eight items that were potential size drivers (Table 7-12). To determine the possible impact, layouts were prepared using two approaches: (1) accommodating the largest single equipment items and, (2) accommodating the largest group of items working together to support a particular experiment.

The maneuvering work platform shown in Figure 7-14 is the largest single equipment item that must be placed in the airlock, along with two EVA-suited astronauts. It should be noted that the absolute minimum internal length of this installation is 10.5 feet. It should also be noted that the work platform is made up of modular packages assembled in the airlock and that if the astronauts were not deployed along with the platform, space would still be required for assembly of the unit within the airlock.

The length of the package consisting of the largest number of items operated as a group is shown in Figure 7-15. This is an earth-observations package selected for the initial station. Its minimum internal length is 12 feet. This layout excludes E006 and E009 of Table 7-12. While adequate information does not exist in the earth-observations volume of the 1971 Blue Book with which to evaluate the feasibility of resizing or repackaging these items, it was felt that they could be scaled down to a compatible size when stowed.

In both the above cases, the airlock diameter was held to 80 inches. It was felt that an additional 6 inches would be required to ensure complete enclosure within the airlock in the above situation.

7.4.2 CONCLUSIONS AND RECOMMENDATIONS

The earth-observations equipment items are key drivers of both the length and the diameter of the airlock. It is considered highly probable that a packaging and deployment mechanism can be used to keep the diameter to 80 inches and still maintain the complete complement of equipment items. (Verifying the feasibility of this assumption was beyond the scope of this analysis.) Therefore, an 80-inch-diameter by 156-inch-length airlock (6 feet 8 inches by 12 feet 6 inches) is satisfactory for the MSS concept. Since two were identified, they should be identical.

Table 7-12. Experiment Equipment Size Drivers

Equipment No.	Name	Equipment Envelope
		Deployed (in.)
E006	Passive Microwave Scanner	13.4 x 13.4 x 1
E009	Microwave radiometer	30-dia x 3
		Stowed (in.)
C026	AMD Space-Erectable Antenna	4.5-dia x 3
T090	Maneuverable Work Platform	5.6 x 4.3 x 7.5
T130	Teleoperator	3.7 x 3.7 x 4
T136	Satellite	4-ft dia x TBD
T106	Radiators (80 cubic feet)	3 x 3 x 9
T117	Experiment Mounting Assembly	0.25 x 3 x 7

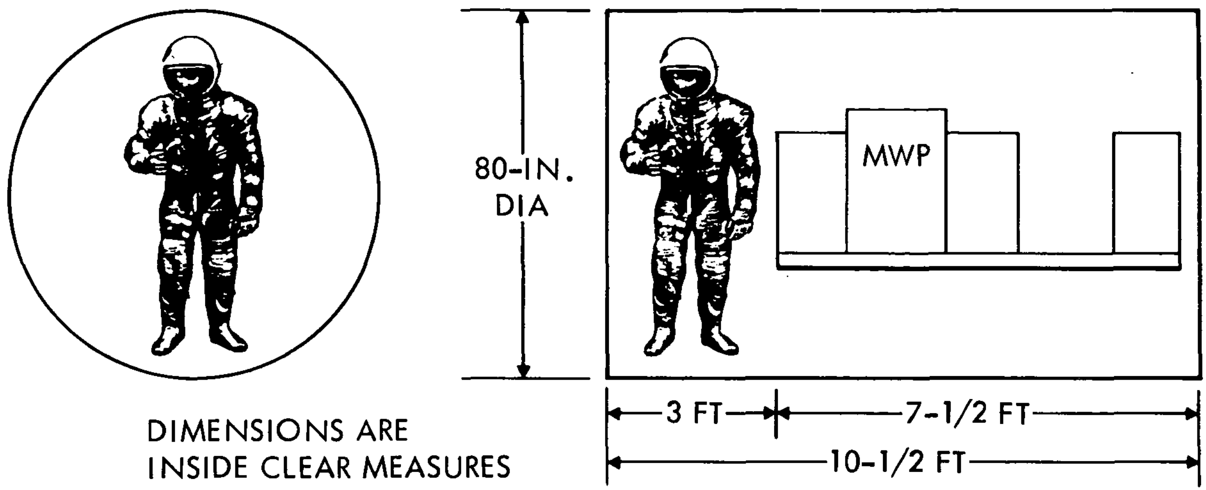


Figure 7-14. Maneuvering Work Platform Installation in Airlock

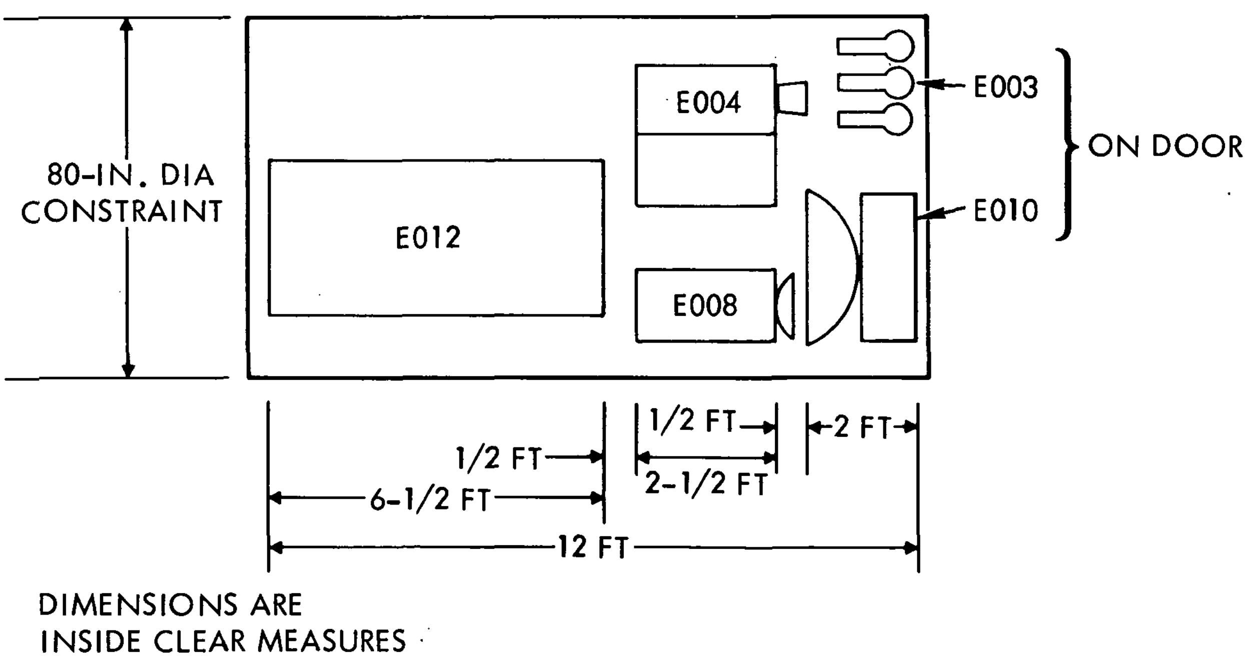


Figure 7-15. Required Airlock Length—Earth-Observations Sensor Set

APPENDIX

The following tables contain definitions of and requirements for the 22 experiment laboratories described in Subsection 3.1. The headings used in the tables are defined in that section.

Tables A-1A through A-22A show objectives, selected experiments, and equipment required for each laboratory at each level. Tables A-1B through A-22B describe the operational concepts for Levels II and III laboratories, and Tables A-1C through A-22C present the subsystem and logistic support requirements for each Level II and Level III laboratory.

Table A-1A. Evolution Summary, X-Ray Stellar Astronomy Laboratory (FPE A-1)

OBJECTIVES		
Level I	Level II	Level III
Establish performance level of selected instruments and support systems/subsystems Perform survey-type observations of selected areas of sky to locate moderate strength sources	Continue survey-type observations Increase detection sensitivity for X-ray sources Utilize station-supported operation mode	Expand range of measurements to higher energies Perform specialized investigations of specific spectral lines and transient phenomena

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
A-1.1 High-Resolution X-Ray Telescope	X	X	X
A-1.2 Large-Area, Moderate Resolution X-Ray Telescope		X	X
A-1.3 Proportional Counter Array	X	X	X
A-1.4 Scintillation Counting			X
A-1.5 Crystal Spectrometer			X
A-1.6 Transient X-Ray Phenomena Detection			X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Major instrument tested-requires complete set of support capabilities Data obtained useful directly and in later experiment operations Exploits orbit flexibility of shuttle Costs may force deferment to initial station phase	Lower-cost system performing key observations Reasonable state of art projections Station mode (coorbiting detached) may reduce costs Cost may force deferment to growth station phase	Sensitivity and energy range extended (A-1.4) Specialized measurements performed (A-1.5, 6) Desired inclination (zero degree) may be implemented

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
A001	High-Resolution X-ray Telescope	X	X	X
A002	Aspect Optics	X	X	X
A003	Aspect Detector	X	X	X
A004	Imaging Detector	X	X	X
A005	Transmission Grating	X	X	X
A006	Filter Wheel	X	X	X
A007	Spectrometer (Crystal)	X	X	X
A008	Radioactive Calibration Source	X	X	X
A009	Large-Area Moderate-Resolution X-Ray Telescope		X	X
A010	Solid-Stage Detector		X	X
A011	Multianode Proportional Counter		X	X
A012	Mosaic Polarimeter		X	X
A013	LiH Polarimeter		X	X
A014	Graphite Polarimeter		X	X
A015	Proportional Counter Array	X	X	X
A016	Scintillation Counter Assembly			X
A017	Flat Crystal Spectrograph Assembly			X
A018	Transient X-Ray Phenomena Detection Array			X
	Total Weight (lb)		8557	9350

Table A-1B. Levels II and III Operational Concepts, X-Ray Stellar Astronomy Laboratory (FPE A-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Two cycles, two years each, separated by three- to six-month ground refurbishment periods	Detached RAM, coorbiting, docked once per month	None (one-month data retrieval cycle, six-month spares and consumables cycle)
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Two-year cycles separated by ground refurbishment periods of three to six months	First cycle: coorbiting detached RAM docked once per month. Subsequent cycles: detached RAM at 0-degree inclination, 400-500 nm altitude revisited once every two months	None (two-month data retrieval cycle, six-month spares and consumables cycle)

Table A-1C. Levels II and III Subsystem and Logistics Support, X-Ray Stellar Astronomy Laboratory (FPE A-1)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 4.8 KWH	MAXIMUM SUSTAINED POWER: 221 W	PEAK POWER: 500 W	24 HOUR ENERGY: 5.3 KWH	MAXIMUM SUSTAINED POWER: 433 W	PEAK POWER: 526 W
CREW SUPPORT	Skill Code 5 12 14 or 15	Hrs/Day 4 10 10	In concentrated periods (when docked)	Skill Code 5 12 14 or 15	Hrs/Day 8 10 10	In concentrated periods (when docked)
DATA OUTPUT	24 HOUR QUANTITY 7×10^8 Bits/Day 1 Lb/Day Hard Data	Continuous TV (High Res)	MAX. SUST. RATE 4.7×10^4 Bits/Second (Note 1)	24 HOUR QUANTITY 8×10^8 Bits/Day 2 Lb/Day Hard Data	Continuous TV (High Res)	MAX. SUST. RATE 5.1×10^4 Bits/Second (Note 1)
DATA DISPOSITION	Digital: Transmit - 10% within one orbit, 100% within one day (24 Hours) Display - 10% + TV		HARD DATA - STORE	Digital: (Note 2) Transmit - 10% within one orbit, 100% within one day (24 Hours) Display - 20% + TV		HARD DATA - STORE
DATA INPUT	Location (ECI Coordinates) ± 1 mile, all directions		Commands 10^2 Bits/Second	Location (ECI Coordinates) ± 1 mile, all directions		Commands 150 Bits/Second
LOGISTICS INPUT/OUTPUT	INPUT 314 Lb/6 Mos. Spares 44 Lb/6 Mos. Cons		OUTPUT 322 Lb/6 Mos.	INPUT 314 Lb/6 Mos Spares 44 Lb/6 Mos Cons.		OUTPUT 322 Lb/6 Mos.
GUIDANCE AND CONTROL/ OPERATIONS	DNA (Detached Mode)			DNA (Detached Mode)		

NOTES:

(1) Internal processing assumed - reduces maximum rate from any imaging instrument to 4×10^4 bits/second

(2) RAM non-coorbiting in second and subsequent cycles - data exchange possibly not feasible with station on continuous basis

Table A-2A. Evolution Summary, Advanced Stellar Astronomy Laboratory (FPE A-2)

OBJECTIVES

Level I	Level II	Level III
None	Evaluate performance of telescope and RAM subsystems Evaluate contamination control procedures associated with revisits and routine operations	Observe discrete and extended stellar objects in UV-visible-IR spectral ranges Establish capability to obtain diffraction-limited performance from large space telescope

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
A-2.1 Technology		X	X
A-2.2 Stellar Observation			X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Cost causes deferment to later levels Nonevolving laboratory		

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
A019	3-Meter-Diameter Aperture Telescope		X	X
A020	Alignment and Calibration Instrumentation		X	X
A021	Information Processing Computer		X	X
A022	Auto Focus Equipment		X	X
A023/ A024	Guide Star Trackers (2)		X	X
A025	Outer Field Correlator		X	X
A026	Image Mover		X	X
A027	F/60 Imaging Microscope		X	X
A028	6-Inch-Diameter Electronic Imaging Camera		X	X
A029	254 X 254-mm Plate Camera		X	X
A030	Spectro photometer		X	X
A031	Modified Echelle Spectrometer		X	X
A032	Rowland Circle Spectrometer		X	X
A033	IR Fourier Spectrometer		X	X
A034	Polarimeter		X	X
	Total Weight (lb)		13,200	13,200

Table A-2B. Levels II and III Operational Concepts, Advanced Stellar Astronomy Laboratory (FPE A-2)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Two six-month cycles separated by three- to six-month intervals	Detached RAM, coorbiting, docked once per month	None (one-month data retrieval cycle, six-month consumables and spares cycle)
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuous 1.5-year operating periods separated by three-month ground refurbishment period	Detached RAM, coorbiting, docked once every two months	None (two-month retrieval cycle, six-month consumables and spares cycle)

Table A-2C. Levels II and III Subsystem and Logistics Support, Advanced Stellar Astronomy Laboratory (FPE A-2)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 0.8 KWH	MAXIMUM SUSTAINED POWER: 265 W	PEAK POWER: 510 W	24 HOUR ENERGY: 8.2 KWH	MAXIMUM SUSTAINED POWER: 565 W	PEAK POWER: 1.1 KW
CREW SUPPORT	Skill Code: 5, 15, 12	Hr/Day: 4, 10, 10 (10, 10 When Docked)		Skill Code: 5, 15, 12	Hr/Day: 15, 10, 10 (10, 10 When Docked)	
DATA OUTPUT	24 HOUR QUANTITY: $6x10^8$ Bits/Day 1 lb/day Hard Data	Continuous TV (High Res)	MAX. SUST. RATE: $4x10^4$ Bits/sec (see Note)	24 HOUR QUANTITY: $1.3x10^9$ Bits/Day 2 lb/day Hard Data	Continuous TV (High Res)	MAX. SUST. RATE: $4x10^4$ Bits/Sec (see Note)
DATA DISPOSITION	Digital: Transmit-10% within 1 Orbit 100% within 1 Day Display -10% + TV Hard Data: Process 10% (Film); Store 100%			Digital: Transmit-10% within 1 Orbit -100% within 1 Day Display -20% + TV Hard Data: Process 1%, Store 100%		
DATA INPUT	Location (ECI Coordinates) ±1 Mile, All Directions Commands 10^3 Bits/Sec			Location (ECI Coordinates) ±1 Mile, All Directions Commands 10^3 Bits/Sec		
LOGISTICS INPUT/OUTPUT	INPUT: 30 $\frac{lb}{6\ mo}$ Spares 480 $\frac{lb}{6\ mo}$ Consumables	OUTPUT: 425 $\frac{lb}{6\ mo}$		INPUT: 60 $\frac{lb}{6\ mo}$ Spares 960 $\frac{lb}{6\ mo}$ Consumables	OUTPUT: 820 $\frac{lb}{6\ mo}$	
GUIDANCE AND CONTROL/ OPERATIONS	DNA (Detached Mode)			DNA (Detached Mode)		

NOTE: Internal processing assumed--reduces maximum rate from imaging sensors to $4x10^4$ Bits/Sec.

Table A-3A. Evolution Summary, Advanced Solar Astronomy Laboratory (FPE A-3)

OBJECTIVES

Level I	Level II	Level III
Sensor and total system qualification Utilize shuttle orbit flexibility	Monitor solar disk activity and processes at moderate resolution Obtain correlated XUV and X-ray solar imagery	Provide continuous monitoring of solar activity at highest resolution Observe corona

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
A-3.1 Photoheliograph	X	X	X
A-3.2 XUV Spectroheliograph	X	X	X
A-3.3 X-ray Grazing Incidence Telescope	X	X	X
A-3.4 Solar Coronagraph			X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Potential beneficial FPE warrants early implementation Sun-synchronous orbit available	Could operate attached with degraded performance Cost deferment by delaying coronagraph	Adopt sun-synchronous orbit with free-flying RAM

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
A035	1.5-Meter Photoheliograph	X	X	X
A036	Alignment and Calibration Equipment	X	X	X
A037	Aspect Sensor	X	X	X
A038	Echelle Spectrograph	X	X	X
A039	Lyot Birefringent Filter	X	X	X
A040	Electronic Imaging Camera	X	X	X
A041	Optical Transmission Filters	X	X	X
A042	Magnetograph Analyzer	X	X	X
A043	0.25-Meter XUV Spectroheliograph	X	X	X
A044	Band-Selection Grating	X	X	X
A045	0.5-Meter X-Ray Telescope	X	X	X
A046	X-Ray Imaging Sensor	X	X	X
A047	Transmission Grating	X	X	X
A048	Proportional Counter	X	X	X
A049	Crystal Spectrometer	X	X	X
A050	Coronagraph Assembly	X	X	X
	Total Weight (lb)		6445	7340

Table A-3B. Levels II and III Operational Concepts, Advanced Solar Astronomy Laboratory (FPE A-3)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Three years, with two-month refurbishment period at the end of each year	Attached RAM	Field of view is 5-degree cone centered on the spacecraft-sun line
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuously, with three-month ground refurbishment cycle at the end of every two years	Detached RAM in 500-NM sun-synchronous orbit	None (one-month data retrieval cycle, six month consumables and spares cycle)

Table A-3C. Levels II and III Subsystem and Logistics Support, Advanced Solar Astronomy Laboratory (FPE A-3)

PARAMETER	LEVEL II			LEVEL III		
	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER
ELECTRICAL POWER	9 KWH	720 W	1.1 KW	10 KWH	780 W	1.2 KW
CREW SUPPORT	Skill Code 5 15 12 14	Hrs/Day 5 1 1		Skill Code 5 15 12 14	Hrs/Day 10 10 } When docked 10 10	
	24 HOUR QUANTITY		MAX. SUST. RATE	24 HOUR QUANTITY		MAX. SUST. RATE
DATA OUTPUT	6×10^8 Bits/Day 5 lb/day hard data	Continuous TV (High Res)	4×10^4 Bits/Sec (note 1)	3×10^9 bits/day 15 lb/day hard data	Continuous TV (High Res)	4×10^4 bits/sec (note 1)
DATA DISPOSITION	Digital: Transmit - 25% within 1 orbit 100 % within 1 day Display - 10% +TV Hard Data - Store			Digital: (Note 2) Transmit - 25% within 1 orbit 100 % within 1 day Process - 5% Display - TV + 15% Hard Data - Store		
DATA INPUT	Location (ECSI Coordinates) ± 1 mile, all directions			Location (ECSI Coodinates) ± 1 mile, all directions		
	INPUT		OUTPUT	INPUT		OUTPUT
LOGISTICS INPUT/OUTPUT	380 lb / 6 mos cons. 350 lb spares / 6 mos		600 lb / 6 mos	520 lb / 6 mos cons 400 Lb spares / 6 mos		810 lb / 6 mos
GUIDANCE AND CONTROL/ OPERATIONS	Attitude Stability ± 1 arc sec/90 sec (10 times/orbit) Rate limit 10 sec/sec Mode: Solar inertial (note 3)			DNA (detached RAM)		

NOTES:

(1) Internal processing assumed - reduces max. rate from imaging sensors to 4×10^4 bits/sec.

(2) RAM non-coorbiting throughout this phase - data exchange with station possibly not feasible on continuous basis

(3) These are sensor requirements. Previous analysis indicates this is compatible with 0.25 deg. att. stab. & 0.01 deg/sec rate limit employing state-of-the-art supplemental RAM stabilization.

Table A-4A. Evolution Summary, Intermediate-Size UV Telescopes Laboratory (FPE A-4)

OBJECTIVES		
Level I	Level II	Level III
Initiate survey to locate UV sources Develop technology of UV telescope and supporting systems	Complete survey Observe selected strong sources UV spectroscopy	Spectral imaging of galactic emission, nebulae, star clusters, galaxies Observation of quasars and novae

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
A-4.1 Narrow-Field UV Telescope			X
A-4.2 Wide-Field UV Telescope Survey	X	X	X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Wide-field experiment can be used to qualify support systems and to locate areas for more detailed analysis	Continued use of wide-field telescope in attached mode is feasible	Detached mode required

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
A051	0.94-Meter UV Narrow-Field Telescope			X
A052/A053	Guide Star Trackers (2)			X
A054	Field TV Relay/Performance Monitor			X
A055	Combined Electronic/Backup Film Camera			X
A056	High-Dispersion Spectrometer			X
A057	Low-Dispersion Spectrometer			X
A058/A061	Objective Gratings	X	X	X
A059	Optional Star Tracker/Inertial Reference Assembly	X	X	X
A060	0.3-Meter Wide-Field UV Telescope	X	X	X
A062	Broad Band Filters	X	X	X
A063	Wide-Field UV Electronic Camera Assembly	X	X	X
A064	Backup Film Holder and Film Magazine Assembly	X	X	X
A065	Pattern Recognition Star Field Lock-on Unit	X	X	X
	Total Weight (lb)		950	3370

Table A-4B. Levels II and III Operational Concepts, Intermediate-Size UV Telescopes Laboratory (FPE A-4)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Three years, with one- to two-month ground refurbishment period at the end of each year	Attached RAM	Field of view: access to entire celestial hemisphere, π steradians, required; 5-degree cone required for individual targets
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuous two-year periods separated by two-month ground refurbishment cycle	Detached RAM, coorbiting	None (data recovery on one-month cycle, consumables replacement on six-month cycle)

Table A-4C. Levels II and III Subsystem and Logistics Support, Intermediate-Size UV Telescopes Laboratory (FPE A-4)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 5.0 kwh	MAXIMUM SUSTAINED POWER: 300 watts	PEAK POWER: 500 w	24 HOUR ENERGY: 6.5 kwh	MAXIMUM SUSTAINED POWER: 600 w	PEAK POWER: 800 w
CREW SUPPORT	Skill Code: 5, 15, 12, 10	Man Hr/Day: 10, 2, 1, 1		Skill Code: 5, 15, 12, 10	Man-Hr/Day: 5, 10, 10, 10	when docked (10, 10, 10)
DATA OUTPUT	24 HOUR QUANTITY: 1.6×10^9 bits, 1 lb/day hard data	Continuous TV (high res.)	MAX. SUST. RATE: 4×10^4 bits/sec (Note 1)	24 HOUR QUANTITY: 3.0×10^9 bits, 2 lb/day hard data	Continuous TV (high res.)	MAX. SUST. RATE: 4×10^4 bits/sec (Note 1)
DATA DISPOSITION	Digital Display: 10% + TV Transmit: 25% within 1 day Store (long term) - 100%		Film: Process 5% Store 100%	Digital Display: 10% + TV Transmit: 25% within 1 day Store (long term) - 100%		Film Process 1% Store 100%
DATA INPUT	Commands 100 bits/sec Location: ±1 mile, all directions			Location ±1 mile, all directions Commands 300 bits/sec		
LOGISTICS INPUT/OUTPUT	INPUT: 74 lb / 6 mo consumables		OUTPUT: 52 lb / 6 mo	INPUT: 150 lb / 6 mo cons.		OUTPUT: 98 lb / 6 mo
GUIDANCE AND CONTROL/ OPERATIONS	Stabilization of MSS ±0.5 deg provides instrument stabilization to ±1 arc-sec Attitude: Inertial			DNA (detached mode)		

Note 1: Internal processing assumed - reduces maximum data rate from sensors to 4×10^4 bits/sec

Table A-5A. Evolution Summary, High-Energy Stellar Astronomy Laboratory (FPE A-5)

OBJECTIVES

Level I	Level II	Level III
Develop and evaluate operational techniques and equipment	Complete X-ray sky survey and initiate gamma-ray background and source mapping	Extend energy and intensity ranges of measurements
Collect spectral intensity data on known sources	Obtain improved energy spectra of X-ray sources	Perform specialized measurements
Initiate X-ray sky survey to locate promising regions for later high-resolution studies	Utilize capabilities of space station for experiment support	Provide capability for correlated measurement over wide range of energies and intensities, including high-resolution imagery

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
A-5.1 Low-Energy X-Ray Telescope (0.1-5 kev)			X
A-5.2 X-Ray Source Mapping (1-20 kev)	X	X	X
A-5.3 Narrow-Band Spectrometry and Polarimetry (6-10 kev)			X
A-5.4 Large-Area X-Ray Counter Measurements (0.1-100 kev)	X	X	X
A-5.5 Cosmic X-Ray Energy Spectra (6-400 kev)		X	X
A-5.6 Gamma-Ray Spectrometry (60-10 kev)		X	X
A-5.7 High-Energy Gamma-Ray Measurements (10 Mev-30 Gev)			X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Selected experiments require variety of operational support functions, including attitude stabilization to 60 arc-sec/observation	Selected experiments compatible with attached mode if supplemental attitude stabilization provided	Worst-case stabilization (1 arc-sec/obs) implemented; may require detached RAM
X-ray sky survey initiated (A-5.2)	Spectrometry extended to higher energies (A-5.5, 5.6)	Higher sensitivity requirements and desired low inclination also suggest detached mode
	Experiments requiring highest stabilization deferred (A-5.1, 5.3)	

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
A066	Wolter Type I Grazing Incidence X-Ray Telescope			X
A067	Aspect Sensor	X	X	X
A068	Imaging Detector			X
A069	Transmission Grating			X
A070	Bragg Spectrometer			X
A071	Composite Alignment and Calibration Equipment	X	X	X
A072	Venetian Blind X-Ray Telescope	X	X	X
A073	X-Ray Proportional Counter			X
A074	Asymmetric Crystal Cone Spectrometer/Polarimeter Assembly			X
A075	Large X-Ray Counter Array	X	X	X
A076	Mapping Module	X	X	X
A077	Modulation Collimators	X	X	X

Table A-5A. Evolution Summary, High-Energy Stellar Astronomy Laboratory (FPE A-5) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
A078	Control Gas Source	X	X	X
A079	Low-Background Detector Array		X	X
A080	6- to 400-kev Detector Units		X	X
A061	High-Resolution Gamma Ray Spectrometer		X	X
A082	Ge(Li) Detector/Refrigerator		X	X
A083	Large-Area Spark Chamber			X
	Total Weight (lb)		4390	7510

Table A-5B. Levels II and III Operational Concepts, High-Energy Stellar Astronomy Laboratory (FPE A-5)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Two year, with one-month ground refurbishment period every six months	Attached RAM	Field of view: access to entire celestial hemisphere required; 30-degree cone required for each target
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuous two-year cycles with three-month ground refurbishment cycle every two years	First cycle: detached RAM, coorbiting, docked once every six months Subsequent cycles: detached RAM, 400- to 500-mile altitude, 0-degree inclination	None (six-month revisit cycle for servicing)

Table A-5C. Levels II and III Subsystem and Logistics Support, High-Energy Stellar Astronomy Laboratory (FPE A-5)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY 3 KWH	MAXIMUM SUSTAINED POWER 120 W	PEAK POWER 210 W	24 HOUR ENERGY 7.2 KWH	MAXIMUM SUSTAINED POWER 250 W	PEAK POWER 520 W
CREW SUPPORT	Skill Code 5 6 10	Hr/Day 4 4 1		Skill Code 5 6 10	Hr/Day 14 10 10 when docked	
DATA OUTPUT	24 HOUR QUANTITY 5.2×10^8 bits No film/tape	Continuous TV	MAX. SUST. RATE 1.3×10^4 bits/sec	24 HOUR QUANTITY 3×10^9 bits/day No film/tape	Continuous TV	MAX. SUST. RATE 4×10^4 bits/sec
DATA DISPOSITION	Transmit: 10% within 1 day Display: TV + 10% digital Store: 100%			Transmit: 10% within 1 day Display: TV + 10% digital Store: 100%		
DATA INPUT	Location: ±0.5 mile, all directions Time Ref: ±1 microsecond Commands: 500 bits/sec			Location: ±0.5 mile, all directions Commands: 10^3 bits/sec		
LOGISTICS INPUT/OUTPUT	INPUT 360 lb/6 mo spares 171 lb/6 mo consum.	OUTPUT 480 lb/6 mo		INPUT 495 lb/6 mo spares 171 lb/6 mo consum.	OUTPUT 610 lb/6 mo	
GUIDANCE AND CONTROL/ OPERATIONS	Stabilization: ±0.02 deg/24 hr (max) (NOTE 1) Mode: Inertial			DNA (attached RAM)		

NOTES:
(1) Assumed compatible with station capability of ±0.5 deg continuous employing expt-provided stable platform.

Table A-6A. Evolution Summary, Infrared Astronomy Laboratory (FPE A-6)

OBJECTIVES

Level I	Level II	Level III
High-resolution observation of selected targets Initiate sky survey to identify infrared objects and determine their luminosity and spectral characteristics Qualify infrared telescope and support systems	Complete sky survey to identify IR sources; determine photometric brightness and time variations; high-resolution spectrometry of detected objects	Same as initial, extended to wider spectral ranges and lower luminosities, in particular, for galaxies and interstellar dust clouds

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
A-6.1 Detector Array Scanning		X	X
A-6.2 Radiometry	X	X	X
A-6.3 High-Resolution Spectrometry	X	X	X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Total sky survey requires 12 months All equipment required for any single experiment Cost may cause deferment to later program phase	Attached mode possible Cost may cause deferment to later program phase All equipment required for each experiment	Detached operation to obtain maximum instrument performance

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
A085	Telescope	X	X	X
A086	Aspect Sensor Guide Star Trackers	X	X	X
A087 and A088	Cooling Equipment (each)	X	X	X
A089	Alignment and Calibration Equipment	X	X	X
A090	Linear Detector Array	X	X	X
A091	Michelson Interferometer	X	X	X
	Total Weight (lb)		3300	3300

Table A-6B. Levels II and II Operational Concepts, Infrared Astronomy Laboratory (FPE A-6)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Four one-year periods separated by 1- to 3-month ground refurbishment periods	Attached RAM (may alternate with RAM for FPE A-4)	Access to entire celestial hemisphere required; 10-degree cone clear field of view required for individual targets
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuous two-year increments separated by three-month ground refurbishment cycles	Detached coorbiting RAM	None (revisits on six-month basis)

Table A-6C. Levels II and III Subsystem and Logistics Support, Infrared Astronomy Laboratory (FPE A-6)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 9.6 KWH	MAXIMUM SUSTAINED POWER: 750 W	PEAK POWER: 1.1 KW	24 HOUR ENERGY: 9.6 KWH	MAXIMUM SUSTAINED POWER: 750 W	PEAK POWER: 1.1 KW
CREW SUPPORT	Skill Code 5 12 or 15	Hr/Day 10 4		Skill Code 5 12 or 15	Hr/Day 12 10 when docked	
DATA OUTPUT	24 HOUR QUANTITY: 6×10^8 bits/day No film/tape	Continuous TV	MAX. SUST. RATE: 4×10^4 bits/sec (Note 1)	24 HOUR QUANTITY: 8×10^8 bits/day No film/tape		MAX. SUST. RATE: 4×10^4 bits/sec (Note 1)
DATA DISPOSITION	Display: TV + 10% digital Store: 100% digital Transmit: 5% digital (within 1 day)			Display: TV + 10% digital Store: 100% digital Transmit: 15% digital (within 1 day)		
DATA INPUT	Position ±1 mile, all directions Commands: 10^2 bits/sec			Position ±1 mile, all directions Commands: 10^2 bits/sec		
LOGISTICS INPUT/OUTPUT	INPUT: 1100 lb/180 days consumables (NOTE 2)	OUTPUT:		INPUT: 1100 lb/180 days consumables (Note 2)	OUTPUT:	
GUIDANCE AND CONTROL/OPERATIONS	Stabilization: ±1 arc sec/4 hr (Note 3) Attitude: 1 yr - local vert OK 3 yr - inertial			DNA (detached RAM)		

NOTES:
(1) Assumed internal processing reduces max. data rate to value shown
(2) Consists of 600 lb LNe + 500 lb LHe
(3) Assumed compatible with station capability of ±0.25 deg. continuous employing supplemental expt-provided stabilization.

Table A-7A. Evolution Summary, Space Physics Research Laboratory (FPE P-1)

OBJECTIVES		
Level I	Level II	Level III
Operational checkout of atmospheric and magneto-spheric sensors and small astronomy optics Short-term observations of selected targets	Preliminary survey of atmosphere and magnetosphere Measure external induced environment Observe UV stellar and inter-stellar sources	Detailed study of quiet and disturbed atmosphere and magnetosphere Study comet tail mechanisms Determine meteoroid fluxes, mass, and compatibility

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
P-1.1 Atmospheric and Magnetospheric Sciences	X	X	X
P-1.2 Cometary Physics			X
P-1.3 Meteoroid Science			X
P-1.4 Small-Telescope Astronomy	X	X	X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
P-1.1 - Sortie allows early evaluation of large number of atmospheric and magneto-spheric sensors Shuttle sortie orbit versatility (e.g., high inclination allows good auroral observations)	P-1.1 and P-1.4 - No subsatellite required P-1.2 deferred to growth for gas release safety and contamination avoidance	P-1.2 - Subsatellite available for safe gas release for distance P-1.3 - Provides with long-duration mission

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
P001	Photometric Cluster	X	X	X
P002	Interferometer Spectrometer	X	X	X
P003	Scanning Grating Spectrometer	X	X	X
P004	EUV Spectrometer	X	X	X
P005	Image Isocon Television	X	X	X
P006	Image Tube Optical System	X	X	X
P007	Open-Source Mass Spectrometer	X	X	X
P008	Closed-Source Mass Spectrometer	X	X	X
P009	Neutral Gas Temperature	X	X	X
P010	Ion Mass Spectrometer	X	X	X
P011	Ion Trap	X	X	X
P012	Electrostatic Probe	X	X	X
P013	Electric Field Probes	X	X	X
P014	Flux Gate Magnetometer	X	X	X
P015	Magnetometer Coil	X	X	X
P016	VLF Sensor	X	X	X
P017	Aluminum Foil Exposure Device	X	X	X
P018	Particle Sensor Cluster	X	X	X
P019	NH_3 Release Device			X
P020	ICN Release Device			X
P021	Cosmic Dust Composition Analyzer			X

Table A-7A. Evolution Summary, Space Physics Research Laboratory (FPE P-1) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
P022	Optical Meteoroid Detector			X
P023	Cosmic Dust Mass and Velocity Sensor			X
P024	Thick Material Penetration Panels			X
P025	Recoverable Panels			X
	Total Weight (lb)		3732	5800

Table A-7B. Levels II and III Operational Concepts, Space Physics Research Laboratory (FPE P-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Continuous for one year (two six-month increments separated by three-month interval are an acceptable alternative)	GPL	Sensor locations, geometry, and operating schedules should be such that minimum contamination from induced particle and field environments is incurred. Sensors for atmospheric and magnetospheric measurements require deployment through one or more airlocks. Simultaneous operation of sensors that measure potentially correlatable phenomena is to be achieved to the extent permitted by multiple sensor-accommodating pallets, extendable booms, and interference considerations, involving fields of view and undesirable electric and magnetic field effects.

Table A-7B. Levels II and III Operational Concepts, Space Physics Research Laboratory (FPE P-1) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuously for two years (two-year periods separated by a three-month interval are an acceptable alternative.	GPL	500 square feet of external area on forward and aft skirts of MSS is required to accommodate Experiment P-1.3 meteoroid sensors. Subsatellite is required for safe release of gas at distance for Experiment P-1.2 cometary physics.

Table A-7C. Levels II and III Subsystem and Logistics Support, Space Physics Research Laboratory (FPE P-1)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY 35.6 KW-HR	MAXIMUM SUSTAINED POWER 1604 W	PEAK POWER 2284 W	24 HOUR ENERGY 38.9 KW-HR	MAXIMUM SUSTAINED POWER 1628 W	PEAK POWER 5137 W
CREW SUPPORT	11 man-hr/24-hr	Skill Code 5 6 12	Hr/Day 1 5 5	13 man-hr/24-hr	Skill Code 5 6 12	Hr/Day 2 7 4
DATA OUTPUT	24 HOUR QUANTITY 1.5×10^{10} bits		MAX. SUST. RATE 2×10^5 BPS dig. or 2.4×10^5 Hz analog	24 HOUR QUANTITY 1.7×10^{10} bits		MAX. SUST. RATE 2×10^5 BPS digital or 2.4×10^5 Hz analog
DATA DISPOSITION	5% display 10% real time trans. to gnd. 30% delayed trans. to gnd 55% storage 70% on-board processing			5% display 5% real time trans. to gnd 20% delayed trans. to gnd. 70% storage 95% on-board processing		
DATA INPUT	Time signals, ephemeris ±1 mi.(all axes) Attitude: 2 min stable platform			Time signals, ephemeris ±1 mi.(all axes) Attitude: 2 min stable platform		
LOGISTICS INPUT/OUTPUT	INPUT 180 lb Film Data tape	OUTPUT 180 lb Film Data tape		INPUT 280 lb Film, Samples Data tape, Gases	OUTPUT 225 lb Film, Bombarded Data tape, samples	
GUIDANCE AND CONTROL/ OPERATIONS	Altitude: ±1 nautical mile Attitude Hold: ±2 deg pointing ±0.01 deg/sec stability Att. Ref: 20% LV, 20% inertial, 60% any			Altitude: ±1 nautical mile Attitude Hold: ±2 deg pointing ±0.01 deg/sec stability Att. Ref: 20% LV, 20% inertial, 60% any		

Table A-8A. Evolution Summary, Plasma Physics and Environmental Perturbation Laboratory (FPE P-2)

OBJECTIVES

Level I	Level II	Level III
Preliminary wake measurement Generate charged particle beams and observe interactions with magnetosphere	Establish plasma physics laboratory Evaluate environment for plasma experiments Wake effect on other experiments	Establish capability for large-antenna deployment and stabilization Study nearby nonlinear plasma effects

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
P-2.1 Plasma Wake	X	X	X
P-2.2 Plasma Resonances		X	X
P-2.3 Wave-Particle Interactions With VLF			X
P-2.4 Electron and Ion Beam Propagation	X	X	X

COMMENTS AND RATIONALE

Level I	Level II	Level III
P-2.1 - Wake measurement of additional spacecraft in vicinity—requires 3-axis translational capability; may be deferred, due to cost, to growth phase P-2.4 Can be operated at low power with conjugate point observations from ground	P-2.1 - Self-wake observed from long articulated boom(s) P-2.2 deferred to growth phase for conjugate subsatellite requirement P-2.4 continued on noninterference basis	Availability of 1 to 3 subsatellites, allowing more extensive wake measurements and support of all of above experiments P-2.2 - Higher RF power available for altering ambient plasma P-2.4 - Operated at high power and with observations from conjugate satellite

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
P026	Electron Density and Temperature Measurement Device	X	X	X
P027	Planar Thermal Ion Trap	X	X	X
P028	Quadrupole Mass Spectrometer	X	X	X
P029	Measurement of AC Electric Field	X	X	X
P030	Measurement of DC Electric Field	X	X	X
P031	Flux Gate Magnetometer	X	X	X
P032	Suprathermal Electron Measurement	X	X	X
P033	Cylindrical Electrostatic Probe	X	X	X
P034	VLF Transmitter	X	X	X
P035	VLF Antenna	X	X	X
P036	Magnetic Antenna for VLF			X
P037	Electron Scintillation Spectrometer	X	X	X
P038	Hemispherical Analyzer	X	X	X
P039	Balloon-Sphere			X
P040	Balloon-Cylinder			X
P041	RF Transmitter			X
P042	RF Antenna Resonance (2)			X

Table A-8A. Evolution Summary, Plasma Physics and Environmental Perturbation Laboratory (FPE P-2)(Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
P043	RF Antenna - Transmitter			X
P044	Boom			X
F045	Boom Cables			X
P046	RF Electronics			X
P047	RF Antenna (2)			X
P048	VLF Electronic Receiver	X	X	X
P049	High-Energy Measurement Device	X	X	X
P050	Low Energy-Range Analyzer	X	X	X
P051	Electron Accelerator	X	X	X
P158	Particle Detectors (0-2 kev)			X
P159	Particle Detectors (0. 5-20 kev)			X
P160	Particle Detectors (10-500 kev)			X
P161	Transmitter	X	X	X
	Total Weight (lb)		1066	1350

Table A-8B. Levels II and III Operational Concepts, Plasma Physics and Environmental Perturbation Laboratory (FPE P-2)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Six months (two three-month increments separated by a three-month interval are an acceptable alternative)	GPL	The requirement for a VLF transmitter for Experiment P-2.1 requires a large power source, which is presently proposed (1971 Blue Book) to be 4400 pounds of batteries. Consideration should be given to obtaining this power from the MSS. A second alternative consists of dropping this power requirement by postponing application of the VLF transmitter to Experiment P-2.1 until Level III operations. Articulated boom is required for measurement of near-wake plasma distribution Sensor locations, geometry, and operating schedules should be such that minimum contamination is obtained.

Table A-9B. Levels II and III Operational Concepts, Plasma Physics and Environmental Perturbation Laboratory (FPE P-2) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
One year (two six-month increments separated by a three-month interval are an acceptable alternative)	GPL	Each plasma physics experiment is best supported by the use of one or more sub-satellites to measure distant wakes and VLF radio reception free of MSS noise and conjugate satellites to measure effects along magnetospheric ducts in hemisphere opposite MSS.
Experiment Number	Subsatellite Support	Conjugate Satellite
P-2.1	3	-
P-2.2	1	-
P-2.3	1	1
P-2.4	-	1

Table A-8C. Levels II and III Subsystem and Logistics Support, Plasma Physics and Environmental Perturbation Laboratory (FPE P-4)

PARAMETER	LEVEL II	LEVEL III
ELECTRICAL POWER	24 HOUR ENERGY: 6.6 KW-HR MAXIMUM SUSTAINED POWER: 250 W PEAK POWER: 1000 W	24 HOUR ENERGY: 7.2 KW-HR MAXIMUM SUSTAINED POWER: 350 W PEAK POWER: 10,000 W
CREW SUPPORT	18.5 man-hr/24 hr Crew Skill / Hr/Day: 6 / 10; 12 / 8.5	19 man-hr/24 hr Crew Skill / Hr/Day: 6 / 12; 12 / 6.5
DATA OUTPUT	24 HOUR QUANTITY: 8.6×10^9 bits MAX. SUST. RATE: 1×10^5 BPS digital, 1 MHz analog (1)	24 HOUR QUANTITY: 8.6×10^9 bits MAX. SUST. RATE: 1×10^5 BPS digital, 1MHz analog (2), 500kHz analog (3)
DATA DISPOSITION	5% display 15% real time trans. to gnd 30% delayed trans to gnd (within 1 day) 50% storage 30% on-board processing	5% display 10% real time trans. to gnd. within one orbit; 20% delayed trans. to gnd. (within one day); 65% storage; 75% on-board process
DATA INPUT	Data to support: 1 deg/min stability for 2 experiments (4) 0.25 deg/min stab. for 1 experiment (5)	Data to support: 1 deg/min stability for 3 experiments (6) 0.25 deg/min stab. for 1 experiment
LOGISTICS INPUT/OUTPUT	INPUT: 18 lb — Film, data tape, Fuel for accelerator OUTPUT: 18 lb — Film, data tape, Other replaced components	INPUT: 24 lb — Film, data tape, fuel for accelerator, photos and spares OUTPUT: 24 lb — Film, data tape, replaced components, photos
GUIDANCE AND CONTROL/ OPERATIONS	Altitude: ±1 n mi Attitude: ±0.5 deg pointing (7) ±0.25 deg/min stability Ref: Local vertical	Altitude: ±1 n mi Attitude: ± 0.5 deg pointing (7) ±0.25 deg/min stability Ref: Local vertical

NOTES:
(1) 9 Channels
(2) 9 Channels
(3) 12 Channels
(4) Experiments P-2.1 & P-2.4
(5) Experiment P-2.2
(6) Experiments P-2.1, P-2.3 & P-2.4
(7) Station provides 3 deg/min continuous & 0.6 deg/min fine pointing stability

Table A-9A. Evolution Summary, Cosmic Ray Physics Laboratory (FPE P-3)

OBJECTIVES		
Level I	Level II	Level III
Utilize shuttle orbit flexibility	Establish cosmic ray lab Measure particle number, energy, and identity	Conduct searches for expected extremely rare phenomena Investigate more high-energy particles than available with ground-based accelerators

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
P-3.1 Charge and Energy Spectra of Cosmic Ray Nuclei		X	X
P-3.2 Electron and Position Spectra and Anisotropies	X	X	X
P-3.3 Isotopic Composition of Light Elements	X	X	X
P-3.4 Nucleonic Antimatter		X	X
P-3.5 Extremely Heavy Nuclei			X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
P-3.2 and P-3.3 performed in attached RAM without total absorption device (TAD) High-inclination orbits P-3.1 deferred due to weight and cost P-3.4 and P-3.5 deferred due to duration requirement	All above experiments in attached RAM TAD buildup phased to defer cost and weight P-3.5 deferred to growth due to duration and emulsion processing requirements	P-3.5 - On-board emulsion development required to minimize radiation damage after exposure (high cost) P-3.1 - High-energy measurements possible with full TAD weight accommodated

EQUIPMENT				
ID Number	Item	Level I	Level II	Level II
P052	Total Absorption Device (TAD)		Partial	X
P053	TAD-Photomultipliers		Partial	X
P054	Total Absorption Shower Counter (TASC)	X	X	X
P055	TASC-Photomultipliers	X	X	X
P056	Magnet-Dewar Assembly	X	X	X
P057	Liquid Cerenkov Counter			X
P058	Spectrometer Assembly	X	X	X
P059	Detector Bay 1	X	X	X
P060	Detector Bay 2	X	X	X
P061	Detector Bay 3	X	X	X
P062	Detector Bay 4			X
P063	High-Z Shielded Detector Package			X
P064	Control Console	Partial	Partial	X
P065	Computer With Microfilm Recorder	X	X	X
P066	Emulsion Processing			X
P067	Microfilm Storage	X	X	X
	Total Weight (lb)		25,800	34,200

Table A-9B. Levels II and III Operational Concepts, Cosmic Ray Physics Laboratory (FPE P-3)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Continuously one year (provided that the cosmic ray facility is functioning properly, one-year duration is an accepted minimum, because a lesser duration would in general result in inadequate counting statistics from the sensors).	Attached RAM	TAD (P052) is operated initially with one-half ultimate weight of absorber. Portions are added in 350-pound segments compatible with shuttle weight capabilities. Magnet/Dewar assembly (P056) is annually replaced as a unit (3000 pounds). Dedicated computer requirement should be examined to see if MSS ISS can perform same function with less weight penalty.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuously for two years (two one-year-duration missions separated by a one- to three-month interval would be acceptable but not quite as desirable as the two-year continuous mission)	Attached RAM	Magnet/Dewar assembly (P056) is annually replaced as a unit (3000 pounds). TAD (P052) is built up to full size (24, 000 pounds) in 350-pound segments brought up by shuttle.

Table A-9B. Levels II and III Operational Concepts, Cosmic Ray Physics Laboratory (FPE P-3) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
		On-board emulsion development and/or shielding is required to minimize radiation damage after exposure. Dedicated computer requirement should be examined to see if MSS ISS can perform same function.

Table A-9C. Levels II and III Subsystem and Logistics Support, Cosmic Ray Physics Laboratory (FPE P-3)

PARAMETER	LEVEL II	LEVEL III
ELECTRICAL POWER	24 HOUR ENERGY: 16.9 KW-HR MAXIMUM SUSTAINED POWER: 702 W PEAK POWER: 2000 W	24 HOUR ENERGY: 17.1 KW-HR MAXIMUM SUSTAINED POWER: 712 W PEAK POWER: 2200 W
CREW SUPPORT	8 man-hr/24 hr Skill Code / Hr/Day: 7 / 5; 12 / 3	10 man-hr/24 hr Skill Code / Hr/Day: 7 / 6; 12 / 4
DATA OUTPUT	24 HOUR QUANTITY: 2.4×10^{10} bits MAX. SUST. RATE: 3×10^5 BPS	24 HOUR QUANTITY: 2.6×10^{10} bits MAX. SUST. RATE: 3×10^5 BPS
DATA DISPOSITION	10% display 30% on-board processing 5% real time trans. to gnd. 30% delayed time trans. to gnd. 40% storage	10% display 90% on-board processing (1) 5% real time trans. to gnd. 90% delayed time trans. to gnd 10% storage
DATA INPUT	Time signals: ±1 microsecond Ephemeris data: ±60 mi (all axes) Attitude: ±1 deg	Time signals: ±1 microsecond Ephemeris data (±60 mi, all axes) Attitude: ±1 deg
LOGISTICS INPUT/OUTPUT	INPUT 300 lb: Emulsion plates, Microfilm OUTPUT 300 lb: Emul plates (282 lb), Microfilm (dig. data) (28 lb)	INPUT 345 lb: Emulsion plates, Microfilm OUTPUT 345 lb: Emul plates (313 lb), Microfilm (dig. data) (32 lb)
GUIDANCE AND CONTROL/ OPERATIONS	No pointing or stabilization - require knowledge of orientation from ephemeris and real time latitude and longitude to ±1 deg over celestial sphere (inert. ref. ±1 deg) (2)	No pointing or stabilization - require knowledge of orientation from ephemeris and real time latitude and longitude to ±1 deg over celestial sphere (2) Inert. Ref: ±1 deg.

NOTES:
(1) Dedicated computer on-board cosmic ray physics laboratory
(2) Orbital requirement such that minimum time is spent in South Atlantic anomaly - preferably 28° inclination

Table A-10A. Evolution Summary, Physics and Chemistry Laboratory (FPE P-4)

OBJECTIVES		
Level I	**Level II**	**Level III**
Precisely define environment for subsequent experiments Conduct sample physics and chemistry lab experiments	Establish lab to study fluid thermodynamics in free convection region Study atmospheric component interactions	Conduct a large number of basic physics and chemistry lab experiments Refine thermodynamic parameters—e.g., critical-point phenomena

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
P-4.1 Molecular Beam Scattering		X	X
P-4.2 Gas-Surface Interactions	X	X	X
P-4.3 Flame Chemistry and Reaction Kinetics in Zero g			X
P-4.4 Chemical Lasers		X	X
P-4.5 Quantum Effects at Low Temperature			X
P-4.6 Gas Reactions in Space	X	X	X
P-4.7 Heat Transfer in Convectionless Medium			X
P-4.8 Critical-Point Phenomena			X

COMMENTS AND RATIONALE		
Level I	**Level II**	**Level III**
Selected experiments will indicate feasibility of conductive similar ones later P-4.2 deferred to initial phase due to cost and lower priority P-4.3, P-4.4, and P-4.5 deferred due to safety (fire and high pressure)	P-4.3 deferred due to fire hazard P-4.4 - Early result desired on zero-g laser P-4.5 and P-4.7 deferred due to cost, complexity, weight, and priority	Trained specialists more likely to be available for growth phase P-4.3 accommodated with adequate safety P-4.6 continued with subsatellite P-4.8 - High-cost and complex items included

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
P100	Reference Junction		Partial	X
P101	Optical Calorimeter			X
P102	Optical Pyrometer			X
P103	Gas Chromatograph			X
P104	Emission Spectrometer			X
P105	Pressure and Vacuum Sensors		Partial	X
P106	Temperature Sensors	X	X	X
P107	Displacement Sensors	X	X	X
P108	Velocity Sensors	X	X	X
P109	Acceleration Sensors	Partial	Partial	X
P110	Special-Purpose Power Supplies	X	X	X
P111	Nuclear Particle Detectors	X	X	X
P112	Polarimeter	X	X	X
P113	Electron Spin Resonance Spectrometer	X	X	X
P114	Recorders		X	X
P115	Electronics		X	X
P116	Quartz Microbalance	X	X	X

Table A-10A. Evolution Summary, Physics and Chemistry Laboratory (FPE P-4) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
P117	Energy Transfer Probe	X	X	X
P118	Test Surfaces	X	X	X
P119	Data Monitor	X	X	X
P120	Mass Spectrometer			X
P121	Camera			X
P124	Data Display and Interface			X
P125	Experiment Setup			X
P126	Fuels and Oxidant			X
P127	Polycarbonate Fuel Rods		X	X
P128	Oxygen		X	X
P129	Contamination Coupons		X	X
P130	Laser Cavity		X	X
P131	Mass Spectrometer		X	X
P132	High-Voltage Supply		X	X
P134	Data Recorder		X	X
P137	Electrostatic Positioning Plate (3)			X
P068	Airlock (2)	Partial	Partial	X
P069	Feedthroughs	X	X	X
P070	View Ports (Visible)	X	X	X
P071	View Ports (IR)	Partial	X	X
P072	View Ports (UV)	Partial	X	X
P073	Bench Area	Partial	X	X
P074	Bench Area - (g isolation)			X
P075	Vacuum Lines			X
P076	Fire and Emergency System			X
P077	Waste Disposal System			X
P078	Environmental Chamber			X
P079	High-Vacuum Chamber			X
P080	Super Conducting Magnet			X
P081	Glove Boxes (Vacuum)	X	X	X
P082	Glove Boxes (Clean)	X	X	X
P083	Glove Boxes (Hazardous)	X	X	X
P084	N_2 Cryogenic (Logistic Item)			X
P084	He Cryogenic (Logistic Item)			X
P085	Extendable Boom	X	X	X
P086	Data-Acquisition System	X	X	X
P087	Camera (Cine)	X	X	X
P088	Camera (Still)	X	X	X
P089	Camera (TV)	X	X	X
P090	Gas Supplies		Partial	X
P091	Mass Spectrometer	X	X	X
P092	Spectrophotometer		X	X
P093	Magnetic Field Meter			X
P094	Electric Field Meter	X	X	X
P095	Data Displays	Partial	X	X
P096	Oscilloscope	X	X	X
P097	Voltmeters	X	X	X
P098	Ammeters	X	X	X
P099	Frequency Meter	X	X	X
P138	Canisters		X	X
P139	EUV Photometer	X	X	X
P140	Electron Probe	X	X	X
P141	EUV Spectrometers (2)	X	X	X
P142	Visible-IR Spectrometer	X	X	X
P143	Cine Camera	X	X	X
P144	Mass Spectrometer (Subsatellite/Boom)	X	X	X
P145	Electron Probe (Subsatellite/Boom)	X	X	X
P146	Electrometer (Subsatellite/Boom)	X	X	X

Table A-10A. Evolution Summary, Physics and Chemistry Laboratory (FPE P-4) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
P147	Temperature Probe (Subsatellite/Boom)	X	X	X
P148	Telemetry Package (Subsatellite/Boom)	X	X	X
P149	Boiling Test Tank			X
P150	Condensing Test Tank			X
P151	Camera and Light Source			X
P152	Circulation Pump			X
P153	Condensing/Vaporization Cooler/Heater Package			X
P154	N_2 Gas Supply			X
P155	Water Supply			X
P156	Freon Supply			X
P157	Critical-State Experiment			X
	Total Weight (lb)		5610	6200

Table A-10B. Levels II and III Operational Concepts, Physics and Chemistry Laboratory (FPE P-4)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Continuously for six months (two three-month increments separated by three-month interval are an acceptable alternative)	GPL	Airlock and extendable boom are required for deployment of samples and instrumentation. Experiments P-4.1, P-4.2, P-4.4, and P-4.6 are performed externally to the MSS. Fire-detection and extinguisher equipment is required in case of uncontrollable fires in connection with Experiment P-4.4 chemical laser. Gravitational field should be limited to 10^{-2} g.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuously for one year (two six-month increments separated by a three-month interval are acceptable)	Attached RAM	Gravitational field should be limited to 10^{-4} g for laboratory. Experiments P-4.3 and P-4.4 require provisions for detecting and extinguishing fires.

Table A-10B. Levels II and III Operational Concepts, Physics and Chemistry Laboratory (FPE P-4) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
		In Experiment P-4.6, gas must be released a sufficient distance from MSS to avoid contamination. Therefore, experiment requires subsatellite or spring-driven canister with delayed gas release. Sensors for measuring gas reactions in cloud require either long booms, or, preferably, subsatellite. Safe handling and disposal of liquids, solids, and gases used in candidate experiments are required to avoid toxic effects and fires.

Table A-10C. Levels II and III Subsystem and Logistics Support, Physics and Chemistry Laboratory (FPE P-4)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY 0.980 KW-HR	MAXIMUM SUSTAINED POWER 340 W	PEAK POWER 1000 W	24 HOUR ENERGY 5.2 KW-HR	MAXIMUM SUSTAINED POWER 3850 W	PEAK POWER 12,000 W
CREW SUPPORT	9.3 man-hr/24 hr	Skill Code 6 9 25 12	Hr/Day 2.1 2.2 2 3	37.3 man-hr/24 hr	Skill Code 6 9 25 12	Hr/Day 9 8.7 9.3 10.3
DATA OUTPUT	24 HOUR QUANTITY 2×10^{10} bits		MAX. SUST. RATE 2×10^6 BPS	24 HOUR QUANTITY 2×10^{10} bits		MAX. SUST. RATE 2×10^6 BPS
DATA DISPOSITION	20% display 30% on-board processing 5% real time trans. to gnd. 70% delayed trans. to gnd 30% storage			40% display 70% on-board processing 5% real time trans. to gnd. 70% delayed trans. to gnd. 30% storage		
DATA INPUT	Time signals, local vertical attitude to ±1 deg into "air" stream or toward cloud			Time signals, local vertical attitude to ±1 deg to "air" stream or toward cloud		
LOGISTICS INPUT/OUTPUT	INPUT 100 lb Film, data tapes, spare components	OUTPUT 100 lb Film, data tapes, replaced components		INPUT 200 lb Film, data tapes, fuel gases	OUTPUT 180 lb Exposed film, data tapes, notes	
GUIDANCE AND CONTROL/ OPERATIONS	Att. ref. - local vertical, 20%; any, 80% No pointing or stability required except ±1 deg pointing into "air" stream or toward cloud			Att. ref. - local vertical, 20%; any, 80% No pointing or stability required except ±1 deg pointing into "air" stream or toward cloud		

Table A-11A. Evolution Summary, Earth-Observations Laboratory (FPE ES-1)

OBJECTIVES		
Level I	Level II	Level III
Evaluate individual sensor performance Study effects of atmosphere on target signatures Develop total earth-surveys information management system Gather data on slowly varying phenomena	Gather data in each experiment area Evaluate Blue Book sensor group Support resource management Develop man-in-loop capability Observe atmosphere and oceans and monitor pollution	Implement full-capability earth-observations lab Evaluate effectiveness of varying sensor combinations Develop new sensors and techniques Study weather control Provide real-time analysis and user notification

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
ES-1.1 Meteorology and Atmosphere Science	X	X	X
ES-1.2 World Land-Use Mapping	X	X	X
ES-1.3 Air and Water Pollution		X	X
ES-1.4 Resource Recognition and Identification	X	X	X
ES-1.5 Natural Disaster Assessment		X	X
ES-1.6 Ocean Resources		X	X
ES-1.7 Special Research			X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Variety of sensors evaluated for performance, operation ES-1.2, 1.4 examine slowly varying quantities ES-1.1 studies effects of atmosphere on signatures Variety of data types, rates, and quantities produced Meteorological data can support research programs	All sensor groups evaluated Serial operation of sensor groups may permit lower-cost implementation Use GPL airlock for sensor deployment Provide minimum data analysis, maintenance, and repair capability Users supported partly in real time; no delay for time-critical data	Simultaneous deployment of all sensors utilizing attached RAM-permits real-time regrouping Provide expanded data analysis and other support capability Users supported chiefly in real time and near real time, employing on-board analysis Scientific (geophysics, atmospheric science, etc.) objectives supported by higher-precision measurements

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
E001	Metric Camera	X	X	X
E002	Stellar Camera	X	X	X
E003	Multispectral Camera	X	X	X
E004	Multispectral TV		X	X
E005	Multispectral Scanner	X	X	X
E006	Passive Microwave Scanner	X	X	X
E007	Microwave Radar	X	X	X
E008	Multispectral Radiometer	X	X	X
E009	Microwave Radiometer	X	X	X
E010	Scatterometer/Radiometer	X	X	X
E011	Multispectral Spectrometer	X	X	X

Table A-11A. Evolution Summary, Earth-Observations Laboratory (FPE ES-1) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
E012	Aeronomy Spectrometer	X	X	X
E013	Polarimeter	X	X	X
E014	Sferics Detector	X	X	X
E015	Absorption Spectrometer	X	X	X
E016	Optical Radar			X
E017	Observation Telescope	X	X	X
E018	Telescope Computer		X	X
E019	Data Collection System	X	X	X
E020	Cloud Chamber		X	X
E021	Controls and Displays	X	X	X
E022	Data Analysis Electronics		X	X
E023	Photo Analysis		X	X
E024	Maintenance and Repair		X	X
	Total Weight (lb)		7350	7720

Table A-11B. Levels II and III Operational Concepts, Earth-Observations Laboratory (FPE ES-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Continuously for three years (four six-month periods separated by three-month intervals are an acceptable alternative)	GPL	Sensors to be deployed by groups as follows (one group at a time): Group 1 E001, E002, E006, E008, E009, E010 E011, E012, E013, E014 Group 2 E001, E002, E003, E005, E006, E007, E008, E010, E011, E013 Group 3 E001, E002, E003, E004, E005, E006 E008, E013, E015 Group 4 E001, E002, E003, E005, E006, E007 E008, E011, E015, E015 Group 5 E001, E002, E003, E004, E005, E006 E007, E008, E014 Group 6 E001, E002, E004, E005, E006, E010 Earth-observations sensor field-of-view and tracking (platform) requirements are contained in Section 7. In addition, the observation telescope (E017) must be installed with the field of view identified in Section 7. NOTE: Some ES equipment (namely, E018, E019, E021, E023, and E024) performs functions potentially provided by the MSS itself and should be examined for potential elimination of duplication. Two ES sensors (E006—13.4 x 13.4 x 1 ft—and E009—30-ft diameter x 3 ft) have operating envelopes which create special physical integration problems.

Table A-11B. Levels II and III Operational Concepts, Earth-Observations Laboratory (FPE ES-1) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Continuously (one-year increments separated by no more than two-month intervals are acceptable)	Attached RAM	Module field-of-view requirement given by worst case in Section 7—namely, ±75 degrees in track and cross track, referenced to the nadir, plus four 25-degree cones separated by 90 degrees and referenced 115 degrees from nadir (for stellar reference cameras). The observation telescope (E017) is required, as stated in Section 7.

Table A-11C. Levels II and III Subsystem and Logistics Support, Earth-Observations Laboratory (FPE ES-1)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 4.1 KWH	MAXIMUM SUSTAINED POWER: 4.1 KW	PEAK POWER: 5.1 KW	24 HOUR ENERGY: 17 KWH	MAXIMUM SUSTAINED POWER: 4.1 KW	PEAK POWER: 5.1 KW
CREW SUPPORT	14 man-hr/day		Skill Code / Hr/Day: 12 / 3 14 / 1 Any(1) / 10	Skill Code / Hr/Day: 12 / 1 14 / 0.5 16 / 4 8 / 4		Skill Code / Hr/Day: 18 / 4 20 / 4 26 / 2 19 / 2 27 / 2 Total 23.5 man-hr/day
DATA OUTPUT	24 HOUR QUANTITY: Digital, 4.7×10^9 bits Film/tape: 5 lb (Note 2)		MAX. SUST. RATE: 1.4×10^6 bits/sec (digital)	24 HOUR QUANTITY: Digital: 6.0×10^9 bits Film/tape: 15 lb (Note 2)		MAX. SUST. RATE: 1.4×10^6 bits/sec
DATA DISPOSITION	Display: 25% (Note 3) Store (long term): 100% Transmit (real time - within orbit) - 10% Store for processing - 10%		Film-store 99% Develop 1%	Display - 100% Store (long term) 100% Transmit (real time - within 1 orbit) 40% Store for processing--60%		Film-store 80% Develop 20%
DATA INPUT	Time reference; ephemeris; attitude ±1 msec; ±1 mile all axes; ±0.1 deg			Time reference; ephemeris; attitude ±1 msec; ±1 mile all axes; ±0.1 deg		
LOGISTICS INPUT/OUTPUT	INPUT: 240 lb spares 25 lb consumables	OUTPUT: 260 lb		INPUT: 820 lb spares 100 lb consumables	OUTPUT: 900 lb	
GUIDANCE AND CONTROL/ OPERATIONS	Attitude stability: ±0.5 deg Rate limit ±0.05 deg/sec (±0.01 deg/sec, 30 min/day) Mode: Local vertical			Attitude stability: ±0.05 deg Rate limit ±0.05 deg/sec (±0.05 deg, 30 min/day) Mode: Local vertical		

NOTES:
(1) Skill denoted "any" means any resource scientist or group of resource scientists possessing the following skills (in decreasing order of preference) - 16, 8, 18, 20, 26, 19, 27.
(2) Assumes recording of high data rate equipment output employing expt-provided equipment.
(3) Dedicated control/store/display/process equipment included with lab equipment for film & electronic data.

Table A-12A. Evolution Summary, Communications/ Navigation Laboratory (FPE C/N-1)

OBJECTIVES		
Level I	Level II	Level III
Test techniques and equipment prior to station era Exploit orbital capabilities of shuttle Determine effects of weather on RF transmission	Expand application of space technology and satellite systems Develop satellite-to-ground techniques Provide early data on high-benefit experiments	Develop and demonstrate technology applicable to space communications, navigation, and traffic control needs Optimize use of EM spectrum for communications and navigation systems Provide understanding of space communications and navigation sciences, permitting NASA to fulfill role as consultant to government and industry

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
C/N-1.1 Optical Frequency Demonstration	Partial	Partial	X
C/N-1.2 Millimeter-Wave Communications and Propagation	Partial	Partial	X
C/N-1.3 Surveillance Search and Rescue	Partial	Partial	X
C/N-1.4 Satellite Navigation Technique		Partial	X
C/N-1.5 On-Board Laser Ranging		Partial	X
C/N-1.6 Autonomous Navigation System			X
C/N-1.7 Transmitter Breakdown	X		Partial
C/N-1.8 Terrestrial Noise		X	X
C/N-1.9 Noise Source Identification		X	X
C/N-1.10 Susceptibility of Terrestrial System to Satellite-Radiated Energy	Partial	X	X
C/N-1.11 Tropospheric Propagation		X	X
C/N-1.12 Plasma Propagation			X
C/N-1.13 Multipath Measurements			X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Early benefits (C/N-1.3) Short duration (30-day) seasonal missions (C/N-1.1, 1.2, 1.3) Variable-orbit missions (C/N-1.7) Partial experiments (space to ground only) (C/N-1.1, 1.2, 1.3, 1.10) Validation of large expandable structures (C/N-1.10)	Partial experiments (space to ground and space to space—no satellite or deep-space probes)[1] Early benefits (C/N-1.3) Commonality of large equipment[2] Fly circular orbit (all except C/N-1.7) [1](C/N-1.1, 1.2, 1.3 1.4, 1.5) [2](C/N-1.8, 1.9, 1.10, 1.11)	Complete program facilities available Simultaneous experiments performance permits correlation of data Much commonality of equipment Perform experiments using satellites and deep-space probes Completion of C/N-1.7 requires varying orbital altitude

Table A-12A. Evolution Summary, Communications/ Navigation Labortory (FPE C/N-1) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
C001	Voice Communication System to Ground	X	X	X
C022	Telemetry System to Ground	X	X	X
C003	DC Ammeter	X	X	X
C005	AC Voltmeter	X	X	X
C006	Multimeter (20 Hz-700 MHz)	X	X	X
C007	Power Meter	X	X	X
C008	Oscillosope (50 MHz, 0. 1 s/cm)	X	X	X
C009	Wide-band Spectrum Analyzer (10 MHz-40 GHz)	X	X	X
C010	-Wave and mm-Wave Noise Generators	X	X	X
C011	VSWR Meter	X	X	X
C012	Frequency Counters	X	X	X
C013	Function Generator	X	X	X
C014	Calibrated Wave Guide	X	X	X
C015	RF - Receiver Common Blocks	X	X	X
C016	RF - Transmitter Common Blocks	X	X	X
C017	Modulator	X	X	X
C018	Demodulator	X	X	X
C019	Data Processor (common blocks)	X	X	X
C020	Clock		X	X
C021	Multiplexer/Demultiplexer	X	X	X
C022	A-D/D-A Converter	X	X	X
C023	Encoder/Decoder	X	X	X
C024	General-Purpose Computer		X	X
C025	Bit Error Counter	X	X	X
C026	AMD Space-Erectable Antenna		X	X
C027	Changeable Feeds, Transmission Line 3 for WB	X	X	X
C028	Antenna Tracking System	X	X	X
C029	Antenna-Position Readout	X	X	X
C030	Ensemble of Dipole Array and Antennas	X	X	X
C031	Boresight Telescope	X	X	X
C032	Ephemeris Data Presentation	X	X	X
C033	C/N RF Integrated Attitude Control	X	X	X
C034	Analog Recorder (10-Channel)	X	X	X
C035	Narrow-Band Recorder	X	X	X
C036	Wide-Band Recorder		X	X
C037	35-mm Camera	X	X	X
C038	70-mm Camera	X	X	X
C039	RF, Experiment Blocks - Transmitter	X	X	X
C040	RF Auxiliary Acquisition - Transmitter	X	X	X
C041	Optical Transmitter	X	X	X
C042	Optical Auxiliary Acquisition - Transmitter	X	X	X
C043	RF Experiment Blocks - Receiver	X	X	X
C044	RF Auxiliary Acquisition - Receiver	X	X	X
C045	Radiometer Calibrator Receiver		X	X
C046	Optical Receiver	X	X	X
C047	Optical Auxiliary Acquisition Receiver	X	X	X
C048	Data Processor Experiment Blocks	X	X	X
C049	Modulator-Peculiar Blocks	X	X	X
C050	IR Horizon Scanner			X
C051	Communication to Deep-Space Probe		X	X
C052	Transponder	X	X	X
C053	Subsatellite			X
C054	1-Meter Antenna (Parabola)	X	X	X
C055	Antenna (3)	X	X	X

Table A-12A. Evolution Summary, Communications/ Navigation Laboratory (FPE C/N-1)(Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
C056	Power Output Scales		X	X
C057	Receiving Transponder Electronics		X	X
C058	Clock and Code Generator		X	X
C059	Antenna (2/5)		X	X
C060	Laser Tracking Systems	X	X	X
C061	Electromagnetic Sensors			X
C062	Inertial Sensors			X
C063	Instrument Probes - Optical	X	X	X
C064	Instrument Probes - Plasma	X	X	X
C065	Instrument Probes - Pressure	X	X	X
C066	Instrument Probes - Temperature	X	X	X
C067	Mass Spectrometer	X	X	X
C068	Star Tracker			X
C069	TV Mapping			X
C070	IR Cold-Body Tracker			X
C071	Transmitter and Modulator	X	X	X
C072	Instrumentation	X	X	X
C073	Microwave Receiver and Processor		X	X
C074	mm-Wave Receiver and Processor		X	X
C075	3-Meter Expandable Antennas	X	X	X
C076	5-Meter Expandable Antennas	X	X	X
C077	Modulation Envelope Generator	X	X	X
C078	Antenna - VHF			X
C079	SHF - Polarized Horn			X
	Total Weight (lb)		1459	1670

Table A-12B. Levels II and III Operational Concepts, Communications/Navigation Laboratory (FPE C/N-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Six months continuously for one experiment; all others, one month of accumulated experiment time	GPL	Airlock sensors to be deployed by groups as follows (one group at a time): Group I: C041, C042, C046, C047, C060, C053 Group 2: C014, C028, C030, C052, C054, C055, C059 Group 3: C014, C026, C027, C028, C030, C054, C075, C076 Sensor FOV and platform requirements are shown in Section 7. A tracking telescope (C031) is required. NOTE: The tracking telescope used in earth observations may be used here. The following items have operating envelopes that create special physical integration problems: C026 (deployed envelope not given); C030 (60-foot boom with 60-foot dipoles); C075 (10-foot dia.); C076 (17-foot dia.).

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
1.5 years continuously for one experiment; all others over period of 30 days of accumulated time	GPL	Sensor FOV and platform requirements are in Section 7. Tracking telescope is required and may be shared with earth observations. Same interference problems encountered at Level II occur with large-envelope-deployed instruments.

Table A-12C. Levels II and III Subsystem and Logistics Support, Communications/Navigation Research Laboratory (FPE C/N-1)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 10.8 KWH	MAXIMUM SUSTAINED POWER: 960 W Worst Case	PEAK POWER: 1500 W Worst Case	24 HOUR ENERGY: 11.3 KWH	MAXIMUM SUSTAINED POWER: 1070 W Worst Case	PEAK POWER: 1500 W Worst Case
CREW SUPPORT	Skill Code / Hr/Day %: 10 – 50; 12 – 5; 14 – 5; 17 – 40	Total 10 MH-day		Skill Code / Hr/Day%: 10 – 50; 12 – 15; 14 – 15; 17 – 30	Total 18 MH/day	
DATA OUTPUT	24 HOUR QUANTITY: Digital: 4.32×10^9 bits; Film: 5 lb; Mag. tape: 38 lb		MAX. SUST. RATE: 1×10^6 BPS	24 HOUR QUANTITY: Digital: 4.32×10^9 bits; Film: 8 lb; Mag tape, 54 lb; Logs: 1.0 lb		MAX. SUST. RATE: 1×10^6 BPS
DATA DISPOSITION	Real time transmission: 10% Direct record: 100% Photography (store): 100% Display: 25%			Real time transmission: 10% Direct record: 100% Photography (store): 100% Logs (store): 100% Display: 25%		
DATA INPUT	Time and ephemeris as secondary information			Same as level II		
LOGISTICS INPUT/OUTPUT	INPUT: 42 lb - consumables	OUTPUT: 42 lb		INPUT: 63 lb - consumables	OUTPUT: 63 lb	
GUIDANCE AND CONTROL/ OPERATIONS	Attitude stability: ± 0.01 deg per 10 min. Rate limits: 0.10 deg per 10 minutes (assume stab. platform used)			Same as level II		

NOTES: Guidance & Control - Compatible with station capability using stable platform.
Consumables - Consist of film, logs and magnetic tape.
Data Input - To experiments is backup to data produced by experiments.
Electrical Power - Assumes worst case.
Crew Support - Is given in a percentage of skill requirement of the total man-hr/day shown.

Table A-13A. Evolution Summary, Materials Science and Manufacturing in Space Laboratory (FPE MS-1)

OBJECTIVES		
Level I	**Level II**	**Level III**
Determine basic physical properties of fluids in zero gravity Determine technical feasibility of processes Determine adequacy and performance of equipment	Same as Level I, plus: Detailed research of physical properties of fluids in zero gravity Conduct broad-spectrum experiments in materials processing Develop equipment and techniques for manufacturing	Same as Level II, plus: Advanced research in physical properties of fluids in zero gravity Conduct advanced experiments in materials processing Develop pilot production operations for commercial processing of materials in space

SELECTED EXPERIMENTS			
Experiment	**Level I**	**Level II**	**Level III**
Metallurgical Processes			
MS-1.1.1 Composite Materials	Partial	Partial	X
MS-1.1.2 Metal Foams and Controlled-Density Materials	Partial	Partial	X
MS-1.1.3 Free Casting of Metals		Partial	X
MS-1.1.4 Liquid Dispersions		Partial	X
Crystal Growth			
MS-1.2.1 Crystal Growth from Solution	X	X	X
MS-1.2.2 Single Crystal Growth From Melts		Partial	X
MS-1.2.3 Crystal Growth From Vapor		Partial	X
MS-1.2.4 Supercooling and Homogeneous Nucleation			X
Glass Processes			
MS-1.3.1 Preparation of Glasses			X
MS-1.3.2 Glass Processing			X
Biological Processing			
MS-1.4.1 Electrophoretic Separation		X	X
MS-1.4.2 Lyophilization		X	X
Physical Properties of Fluids			
MS-1.5.1 Convection	Partial	X	X

COMMENTS AND RATIONALE		
Level I	**Level II**	**Level III**
Perform precursor experiments as early as possible Select early experiments that are least dependent upon precursor data	Perform additional precursor experiments for advanced experiments Perform broadest possible spectrum of metallurgical process and crystal growth experiments using common equipment Perform biological processing experiments early due to high medical and economic value	Continue research in physical properties Delay sophisticated experiments on crystal growth to take maximum advantage of physical properties experiments Delay glass experiments due to highest power requirements, some unique equipment, and highest data transmission requirements

Table A-13A. Evolution Summary, Materials Science and Manufacturing in Space Laboratory (FPE MS-1) (Cont)

COMMENTS AND RATIONALE		
Level I	Level II	Level III
		Delay part of metallurgical process and crystal growth experiments requiring controlled atmosphere and active cooling chambers

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
M001	Controlled Atmosphere Chamber			X
M002	Environmental Chamber A Passive Cooling	X	X	X
M003	Environmental Chamber B Passive Cooling			X
M004	Environmental Chamber C Active Cooling			X
M005	Biological Enclosure		X	X
M006	Liquid Metal Supply System		X	X
M007	General-Purpose Lab Installation	X	X	X
M008	Instrumentation and Control Center	X	X	X
M009	Atmosphere Supply and Control System	X	X	X
M010	Power Conditioning and Distribution System	X	X	X
M011	Resistance-Heated Furnace (1600 C)	X	X	X
M012	Furnace—2600 C Inert/Vacuum			X
M013	Furnace—3200 C Oxygen			X
M014	Heating and Positioning Coils (Sets)			X
M015	Plasma Electron Beam Unit			X
M016	Mold Insertion System	X	X	X
M017	Liquid Sphere Deployment System			X
M018	Hollow Bodies Deployment System			X
M019	Membrane Drawing Tool			X
M020	Zone Melter		X	X
M021	Czochralski Crystal Puller		X	X
M022	Dispersion Control System	X	X	X
M023	Susceptor for Silicate Melts	X	X	X
M024	High-Temperature Colorimeter		X	X
M025	Seed Injector	X	X	X
M026	Internal Friction Measuring Device		X	X
M027	Stationary Electrophoretic Column		X	X
M028	Continuous Electrophoretic Column		X	X
M029	Buffer Recovery/Waste Disposal System		X	X
M030	Gas Elimination/Cooling System		X	X
M031	Lyphilization Apparatus		X	X
M032	Molds, Cavities, Crucibles (Sets)	X	X	X
M033	Miscellaneous Internal Attachments	X	X	X
M034	Continuous Atmosphere Analysis Apparatus		X	X
M035	High-Temperature Viewing Device		X	X
M036	Chill System	X	X	X
M037	Motion-Picture Camera	X	X	X
M038	TV Camera	X	X	X
M039	Remote Measuring - Mass (Dimension)	X	X	X
M040	Mixing Unit L/S, L/L	X	X	X
M041	Mixing Unit L/G	X	X	X
M042	Slip Cast Injection System		X	X
M043	Vibrator	X	X	X
M044	Microscope Stage Attachment	X	X	X

Table A-13A. Evolution Summary, Materials Science and Manufacturing in Space Laboratory (FPE MS-1) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
M045	Photometric Densitometer	X	X	X
M046	UV Microdensitometer		X	X
M047	Holographic Interferometer		X	X
M048	Model Zone Refiner	X	X	X
M049	Isotope Tracer Counter	X	X	X
M050	VHF Power Unit	X	X	X
M051	External Molds and Containers	X	X	X
M052	Minor External Components	X	X	X
M053	Process Control Computer	X	X	X
M054	Heat-Rejection System	X	X	X
M055	Cleanup and Refurbishment Equipment	X	X	X
M056	Materials Analysis Equipment	X	X	X
M057	Photographic Processing Lab	X	X	X
M058	Open Materials and Fluid Storage	X	X	X
M059	Controlled Atmosphere Fluids Storage		X	X
M060	Accident Control System	X	X	X
	Total Weight (lb)		7417	8300

Table A-13B. Levels II and III Operational Concepts, Materials Science and Manufacturing in Space Laboratory (FPE MS-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Open-ended (recommended minimum of two years, with option of four six-month periods separated by three- to six-month intervals)	GPL	Spacecraft thermal control system will be required to absorb heat rejected by materials science support equipment items M053 through M060. Equipment item M054 contains reasonable provisions for dissipation of heat rejected by experiment apparatus. Additional capability for heat storage or dissipation may be required. A large-diameter duct must be provided from unit M009 to hard vacuum.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Open-ended (two-year cycles separated by three- to six-month intervals)	GPL	Same as those for Level II

Table A-13C. Levels II and III Subsystem and Logistics Support, Materials Science and Manufacturing in Space Laboratory (FPE MS-1)

PARAMETER	LEVEL II			LEVEL III		
	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER
ELECTRICAL POWER (See notes 1 & 2)	124 KWH	5 KW	5 KW (8 KW)	124 KWH	5 KW	5 KW (8.5 KW)
CREW SUPPORT	Skill Code 1 12 23 24	Hr/Day 2 4 3 4	Total Man-Hr/Day 13 max.	Skill Code 1 12 23 24	Hr/Day 2 4 4 4	Total Man-Hr/Day 14 max.
DATA OUTPUT	24 HOUR QUANTITY 8.64×10^8 bits, digital data 2.02×10^{10} bits, TV Samples/film: 13.2 lb		MAX. SUST. RATE 10^4 BPS-data 10^7 BPS-TV 13.2 lb/day	24 HOUR QUANTITY 2.88×10^9 bits, dig. data 6.75×10^{10} bits - TV Samples/film - 13.2 lb		MAX. SUST. RATE 10^5 BPS-data 10^7 BPS-TV 13.2 lb/day
DATA DISPOSITION	Digital data - display 25%, store 100% TV & voice - direct 20%, store/replay 100% Film - store 100% Samples - store 100%			Digital data - display 25%, store 100% TV & voice - direct 20%, store/replay 100% Film - store 100% Samples - store 100%		
DATA INPUT	Acceleration level ±10% Time code			Acceleration level ±10% Time code		
LOGISTICS INPUT/OUTPUT	INPUT Expmt mat'l, 515 lb Refurb. mat'l, 88 lb	OUTPUT Expmt prod. 339 lb Waste mat'l 264 lb		INPUT Expmt mat'l, 515 lb Refurb mat'l, 88 lb	OUTPUT Expmt prod. 339 lb Waste mat'l, 264 lb	
GUIDANCE AND CONTROL/ OPERATIONS	No pointing requirement Accel. lim. $= 0 \pm 10^{-4}$ G			No pointing requirement Accel. lim. $= 0 \pm 10^{-4}$ G		

NOTES:
(1) Value indicated in parentheses is supplied from laboratory batteries
(2) Maximum power demand on spacecraft = 5 KW, including 2 KW continuous requirement for battery charging and support equipment.

Table A-14A. Evolution Summary, Contamination Measurements Laboratory (FPE T-1)

OBJECTIVES

Level I	Level II	Level III
Survey the induced environment about the shuttle to obtain data needed to predict effect upon sensors and spacecraft from shuttle sorties Determine adequacy and performance of equipment	Perform comprehensive investigation of contaminant composition, quantity, sources, transport mechanisms, buildup rates, dissipation rates, and effects Develop contaminant control measures	Conduct extended tests to measure the effectiveness of contaminant control measures Develop advanced contaminant control measures

SELECTED EXPERIMENTS

Experiment	Level I	Level II	Level III
T-1.1 Sky Background Brightness Measurements	X	X	X
T-1.2 Real-Time Contamination Measurements	X	X	X
T-1.3 Surface Degradation Experiment		X	X
T-1.4 Contaminant Cloud Composition Measurement	Partial	X	X
T-1.5 Contaminant Dispersal Measurements	Partial	X	X
T-1.6 IRTCM[1] Optical Module Evaluation		X	X
T-1.7 Active Cleaning Technique Evaluation		X	X
T-1.8 Contamination Control Evaluation		X	X

[1]Integrated Real-Time Contamination Monitor

COMMENTS AND RATIONALE

Level I	Level II	Level III
Obtain early data from instruments during qualifying flights	Institute early measures for contaminant control Monitor contaminants during operation of sensors	Implement advanced contaminant control measures Conduct extended monitoring to follow station buildup

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
T001	Photoelectric Polarimeter	X	X	X
T002	Control Panel #1	X	X	X
T003	Contaminant Gage (16)	X	X	X
T004	Control Panel #2	X	X	X
T005	Transit Case (4)	X	X	X
T006	Portable Spectroreflectometer		X	X
T007	Exposure Racks		X	X
T008	Transit Case w/30 samples		X	X
T009	Mass Spectrometer (2)	X	X	X
T010	Operating Panel #4	X	X	X
T011	Camera (2)	X	X	X
T012	Film Magazine (2)	X	X	X
T013	Operating Panel #5 (2)	X	X	X
T014	TV Camera	X	X	X
T015	Optical Module		X	X
T016	Control Panel #6		X	X
T017	Active Cleaning Device (2)		X	X
T018	Contamination Control System		X	X
T019	Storage/Panels		X	X
T020	Console		X	X
T021	Boom	X	X	X
	Total Weight (lb)		420	420

Table A-14B. Levels II and III Operational Concepts, Contamination Measurements Laboratory (FPE T-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Continuously for six months	GPL	Airlocks and booms are required for deployment of all sensors to avoid EVA requirements. Instrumentation and power feedthroughs and mounting provisions are required on external surfaces of the vehicle in specified areas of interest. Sensors T003, T008, T009, T015, T017, and T018 are involved. Small airlocks similar to those shown for Space Station A on NR Drawings V030-902137 (RCS Engine Installation) and V030-902139 (Guidance and Navigation Components - Shirtsleeve Service and Replacement) may be utilized to minimize or eliminate sophisticated boom requirements. Window provisions are required for nondeployed use of sensors T011 and T014.

Table A-14B. Levels II and III Operational Concepts, Contamination Measurements Laboratory (FPE T-1) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Two years (must coincide with initiation of growth station)	GPL	Same as those for Level II

Table A-14C. Levels II and III Subsystem and Logistics Support, Contamination Measurements Laboratory (FPE T-1)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY 1.7 KWH	MAXIMUM SUSTAINED POWER 400 W	PEAK POWER 400 W	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER
CREW SUPPORT	Skill Code: 6, 12	Hr/Day: 3, 6	Total: 9 Man Hr/Day	Same as Level II		
DATA OUTPUT	24 HOUR QUANTITY 2.72x10^9 Bits 10 MHz (TV) x 2 Hr		MAX. SUST. RATE 107 KBPS 10 MHz	24 HOUR QUANTITY		MAX. SUST. RATE
DATA DISPOSITION	Digital Data--Display - 25%, Store - 100% TV--Display & Store - 100% Film--Store - 100% Samples--Store - 100%			Same as Level II		
DATA INPUT	Crew Comments S/C orientation rel. to sun ±0.5 deg Time Code Operational Data (S/C)--Dumps, RCS, Leakage			Same as Level II		
LOGISTICS INPUT/OUTPUT	INPUT Optical Components, film, tape, instruments, tracer gas, purge gas, samples--33 lb/month	OUTPUT 33 lb/month		INPUT	OUTPUT	
GUIDANCE AND CONTROL/ OPERATIONS	±0.5 Degrees 0.05 Degrees/Second Ref: Solar Inertial --10%, Local Vert --50%			Same as Level II		

NOTES:
1. No station light leaks during operation of T-1.1 (sky background brightness)
2. Computer controlled scan pattern for T-1.1, T-1.4 and T-1.5
3. Station operational data correlation required
4. Solar vector orientation required occasionally for T-1.3

Table A-15A. Evolution Summary, Fluid Management Laboratory (FPE T-2)

OBJECTIVES		
Level I	Level II	Level III
Initial indications of zero-g and low-g effects on basic fluid physical behavior Obtain initial parametric data on a range of fluid flows, temperature, accelerations, and heat transfer rates—for use in later experiment designs	Continued investigations of zero-g and low-g effects on basic fluid behavior Extend parametric data in previous and new areas	Continued investigations of zero-g and low-g effects on basic fluid behavior Extend parametric data in previous and new areas

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
T-2.1 Liquid/Vapor Interface Stability	X	X	X
T-2.2 Boiling Heat Transfer	X	X	X
T-2.3 Capillary Studies	X	X	X
T-2.4 Condensing Heat Transfer	X	X	X
T-2.5 Two-Phase Flow Regimes	X	X	X
T-2.6 Propellant Transfer in Space	X	X	X
T-2.7 Long-Term Cryogenic Storage		X	X
T-2.8 Slush Propellant Behavior	X	X	X
T-2.9 Two-Phase Dynamics	X	X	X
T-2.10 Channel Flow Systems	X	X	X
T-2.11 Conical Flow Systems	X	X	X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Short-duration experiments (except T-2.7) Shuttle must provide controlled linear acceleration (all) Early data will be helpful in experiment modification for later designs	Initial station to be kept stable; therefore, cannot supply low-g environment. Free-flying RAM for low-priority experiments deferment to growth station recommended	Provide a balanced capability for extension of knowledge of fluid management in future space applications Use free-flying module with improved control capability

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
T022	Fluid	X	X	X
T023	Tanks	X	X	X
T024	Structure	X	X	X
T025	Instrumentation	X	X	X
T026	Tanks	X	X	X
T027	Structure	X	X	X
T028	Propellant[1]	X	X	X
T029	Transducer System	X	X	X
T030	Vent System	X	X	X
T031	Pressurization System	X	X	X
T032	Instrumentation	X	X	X
T033	Chambers	X	X	X
T034	Tanks	X	X	X
T035	Methanol	X	X	X

Table A-15A. Evolution Summary, Fluid Management Laboratory (FPE T-2) (Cont)

ID Number	Item	Level I	Level II	Level III
T036	Ethanol[1]	X	X	X
T037	Pentane	X	X	X
T038	Support	X	X	X
T039	Conditioning Pack	X	X	X
T040	Support Equipment	X	X	X
T041	Fluids[1]	X	X	X
T042	Cameras	X	X	X
T043	Heat Sink	X	X	X
T044	Power Supply	X	X	X
T045	Instrumentation	X	X	X
T046	Controls	X	X	X
T047	Miscellaneous	X	X	X
T048	Structure	X	X	X
T049	Fluid[1]	X	X	X
T050	Tanks and Structure	X	X	X
T051	LH_2[1]	X	X	X
T052	GHe[1]	X	X	X
T053	Fill and Vent System	X	X	X
T054	Instrumentation	X	X	X
T055	Insulation	X	X	X
T056	Test Equipment	X	X	X
T057	TV	X	X	X
T058	Pressurization System	X	X	X
T059	Tank		X	X
T060	Shroud		X	X
T061	LH_2[1]		X	X
T062	Fill and Vent		X	X
T063	Instrumentation		X	X
T064	Insulation		X	X
T065	Test Equipment		X	X
T066	TV		X	X
T067	Pressurization System		X	X
T068	Tank and Insulation	X	X	X
T069	Heaters	X	X	X
T070	Structures	X	X	X
T071	Pressurization System	X	X	X
T072	Test Equipment	X	X	X
T073	Slush	X	X	X
T074	Fill and Vent	X	X	X
T075	Instrumentation	X	X	X
T076	Test Section	X	X	X
T077	Support	X	X	X
T078	Instrumentation	X	X	X
T079	Test Section	X	X	X
T080	Support	X	X	X
T081	Instrumentation	X	X	X
T082	Test Section	X	X	X
T083	Support	X	X	X
T084	Instrumentation	X	X	X
	Total Weight (lb)		14,041	14,041

[1]Potential logistics item

Table A-15B. Levels II and III Operational Concepts, Fluid Management Laboratory (FPE T-2)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
One year of continuous operations or two six-month periods separated by an interval of up to six months for equipment refurbishment; program may be repeated when new fluid technology equipment or techniques are developed	Free-flying RAM	All fluid management experiments require controlled g levels of 10^{-3} to 10^{-5} for varied duration intervals during experiment performance. Therefore, all must be accommodated in a free-flying RAM or RAM's. Large volume requirements of two experiments and long-duration fluid storage for one experiment suggest use of more than one RAM for the laboratory operations. The free-flying RAM must be returned periodically to the MSS for servicing and experiment modification.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Same as that for Level II	Free-flying RAM	Same as those for Level II

Table A-15C. Levels II and III Subsystem and Logistics Support, Fluid Management Laboratory (FPE T-2)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER
	SAME AS LEVEL III			1.2 KWH	250 W	250 W
CREW SUPPORT				Skill Code: 12, 12, 9 Hr/Day: 8, 8, 4		Total: 20 Man Hr/Day
DATA OUTPUT	24 HOUR QUANTITY		MAX. SUST. RATE	24 HOUR QUANTITY		MAX. SUST. RATE
				Digital 3.6×10^7 Bits Film--4400 feet		Digital 5.8×10^3 Bits/sec Analog (TV) 5.8 MHz
DATA DISPOSITION				Record Digital - 100% Display Analog - 100% Film--Return to Earth - 100%		
DATA INPUT				Transmit experiment control instructions to FF RAM Est. rate 10^3 bits/sec		
LOGISTICS INPUT/OUTPUT	INPUT	OUTPUT		INPUT	OUTPUT	
				370 lb/month	31 lb/month	
GUIDANCE AND CONTROL/ OPERATIONS				Maintain FF RAM within communication range limits from station during program of controlled low-G propulsion maneuvers		

Table A-16A. Evolution Summary, Extravehicular Activity Laboratory (FPE T-3)

OBJECTIVES		
Level I	Level II	Level III
Understand the problems of astronaut maneuvering in EVA activities	Develop operational EVA skills	Test advanced concepts of EVA equipment and procedure Determine effectiveness of maneuvering work platforms (MWP) in assisting astronaut EVA tasks

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
T-3.1 Astronaut Maneuvering Unit	X	X	X
T-3.2 Maneuvering Work Platform			X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Develop improved capability for EVA as early as practical in tethered flights (three-man crew) Work platform (T-3.2) considered too complex at this phase	Test AMU design improvements and free-flight EVA MWP deferred—extra complexity of support systems too costly at this phase	Continue development of EVA capability to prepare for large space station assemblies and planetary mission assemblies

EQUIPMENT				
ID NUMBER	Item	Level I	Level II	Level III
T085	Astronaut Maneuvering Unit	X	X	X
T086	CCTV and Video Recorder	X	X	X
T087	Motion-Picture Camera	X	X	X
T088	TLM Receiver and Data Displays	X	X	X
T089	Voice Communication Link and Recorder	X	X	X
T090	Maneuverable Work Platform			X
T091	Hydrazine			X
T092	O_2 (Potential logistics items)			X
T093	LiOH (Potential logistics items)			X
T094	H_2O			X
T095	Propellant Transfer			X
T096	Battery Recharge & Monitor Station			X
	Total Weight (lb)		265	3865

Table A-16B. Levels II and III Operational Concepts, Extravehicular Activity Laboratory (FPE T-3)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Four months continuously (may be repeated when new EVA astronaut maneuvering units or techniques are developed)	GPL/airlock	EVA activities require the simultaneous use of three crewmen— one performing the EVA tasks with use of the AMU, a second in the EVA airlock and EVA pressure suit in a backup/ rescue mode, and a third at the experiment control center. Station-furnished EVA airlock is assumed for the initial station operations.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
One year continuously or two six-month periods separated by up to six months for MWP modifications	GPL/airlock	For the growth station, EVA activity will be augmented by the use of the MWP. Two MWP's will be required, with rescue procedures to be developed during the experiment program. A space hangar for the two MWP's must be provided with astronaut EVA airlock, through the space

Table A-16B. Levels II and III Operational Concepts, Extravehicular Activity Laboratory (FPE T-3) (Cont)

Duration	Mode	Special Physical Requirements
		hangar structure or the MSS EVA airlock. Servicing and repair facilities for the MWP must be provided, preferably in a shirt-sleeve environment.

Table A-16C. Levels II and III Subsystem and Logistics Support, Extravehicular Activity Laboratory (FPE T-3)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 1.6 KWH	MAXIMUM SUSTAINED POWER: 330 W	PEAK POWER: 370 W	24 HOUR ENERGY: 4.1 KWH	MAXIMUM SUSTAINED POWER: 330 W	PEAK POWER: 400 W
CREW SUPPORT	Skill Code / Hr/Day 12 / 8 12 / 8 12 / 8		Total: 24 Man Hr/Day	Skill Code / Hr/Day 12 / 8 12 / 8 12 / 8		Total: 24 Man Hr/Day
DATA OUTPUT	24 HOUR QUANTITY: Digital-1.44x10^8 Bits Film-21,600 feet		MAX. SUST. RATE: Digital 5x10^3 Bits/sec Analog 2.9 MHz (TV)	24 HOUR QUANTITY: Digital-2.3x10^8 Bits Film-21,600 feet		MAX. SUST. RATE: Digital 8x10^3 Bits/sec Analog 2.9 MHz (TV)
DATA DISPOSITION	Display and Record Video Record Digital Data, Voice Film Return to Earth			Display and Record Video Record Digital Data, Voice Film Return to Earth		
DATA INPUT	Voice Transmission to EVA Activity			Voice Transmission to EVA Activity		
LOGISTICS INPUT/OUTPUT	INPUT: 220 lb/month Maneuver Propellants and Film	OUTPUT: 22 lb/month		INPUT: 1000 lb/month Maneuver Propellants and Film	OUTPUT: 22 lb/month	
GUIDANCE AND CONTROL/ OPERATIONS	Limited MSS Maneuvers During EVA Activities			Limited MSS Maneuvers During EVA		

NOTE: Coordinate EVA experiment activity with T.5 teleoperator FPE to provide comparative evaluation of standard taskboard operations.

Table A-17A. Evolution Summary, Advanced Spacecraft Systems Test Laboratory (FPE T-4)

OBJECTIVES		
Level I	Level II	Level III
Develop new technology for all phases of space flight Establish testing techniques and procedures	Ensure that advanced components will function properly in space Support development of life support systems, space enclosures, and safety procedures	Develop systems requiring free-flying modules Demonstrate reliable operation of advanced spacecraft systems over extended time periods

SELECTED EXPERIMENTS

	Experiment	Level I	Level II	Level III
T-4.1	Oxygen Recovery and Biowaste Resistojet			X
T-4.2	Maintainable Flight Electronics Package	X	X	X
T-4.3	Thermal Coating Refurbishment			X
T-4.4	Absorption Refrigeration Cycle Experiment	X	X	X
T-4.5	Leak Detection and Repair	X		X
T-4.6	Maintainable Attitude Control Propulsion			X
T-4.7	Ball Bearing Lubrication	X	X	X
T-4.8	Advanced Guidance Subsystem Evaluation			X
T-4.9	Space Calibration of Solar Cell Standards	X	X	X
T-4.10	Space Exposure Effects—Material Bulk Properties			X
T-4.11	Space Exposure Effects—Fatigue Properties		X	X
T-4.12	Fire Sensing and Suppression	X	X	X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Perform simple and short-duration experiments in shuttle sorties (Experiments 2, 4, 7, 9) Experiments 5, 12 provide precursor experiments contributing to MSS safety	Experiments 1, 3, 5, 6, 10 deferred; lead to advanced systems development. Also will incur cost/complexity of EVA alternative Experiment 8 deferred; requires free-flying module	Continue development of improved spacecraft systems for use in MSS and advanced missions Experiment 8 may be combined with other FPE (e.g., T-2), requiring free-flying module; share costs Experiments 1, 3, 5, 6, 10 require EVA; alternate implementation will increase costs

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
T098	Oxygen Recovery Equipment			X
T099	Resistojet Subsystem			X
T100	Maintainable Electronics Package	X	X	X
T101	Exposure Racks			X
T102	Camera			X
T103	Video Camera			X

Table A-17A. Evolution Summary, Advanced Spacecraft Systems Test Laboratory (FPE T-4) (Cont)

ID Number	Item	Level I	Level II	Level III
T104	Instrument Panel	X		X
T105	Absorption Refrigeration Cycle System	X	X	X
T106	Radiator	X	X	X
T107	Leak Detector	X		X
T108	Support Equipment	X		X
T109	Experiment RCS			X
T110	Motor Mounting System	X	X	X
T111	Control Panel	X	X	X
T112	Gyro Test Package			X
T113	Acceleration Package			X
T114	Inertial Package			X
T115	Experiment Console			X
T116	Solar Cell Package	X	X	X
T117	Experiment Mounting Assembly			X
T118	Specimens (1000)			X
T119	Colorimeter			X
T120	Radiation Detectors			X
T121	Mass Spectrometer			X
T122	Specimen Chamber		X	X
T123	Shipping Container		X	X
T124	Fatigue Tester		X	X
T125	IR Scanner Fire System	X	X	X
T126	Fire Detection System	X	X	X
T127	Cine Camera (2)	X	X	X
T128	Fire Extinguisher System (8)	X	X	X
T129	Consumables	X	X	X
T130	Combustibles	X	X	X
T131	Propane	X	X	X
T132	Film	X	X	X
	Total Weight (lb)		562	1652

Table A-17B. Levels II and III Operational Concepts, Advanced Spacecraft Systems Tests Laboratory (FPE T-4)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
One year of continuous operation	GPL/airlock	Four of the six experiments in the initial laboratory program require the use of the GPL airlock.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Two years of continuous operation	GPL/airlock, free-flying RAM (one experiment)	Six of the 12 experiments require use of an airlock. Six of the 12 experiments require EVA operations (see 1971 Blue Book, Volume VII, page 4-2). One experiment, advanced guidance subsystems evaluation (T-4.8), is to be performed on a free-flying RAM of another laboratory such as FPE T-2, fluid management, or an astronomy detached module.

Table A-17C. Levels II and III Subsystem and Logistics Support, Advanced Spacecraft Systems Test Laboratory (FPE T-4)

<table>
<tr><th>PARAMETER</th><th colspan="6">LEVEL II</th><th colspan="6">LEVEL III</th></tr>
<tr><td rowspan="2">ELECTRICAL POWER</td><td colspan="2">24 HOUR ENERGY</td><td colspan="2">MAXIMUM SUSTAINED POWER</td><td colspan="2">PEAK POWER</td><td colspan="2">24 HOUR ENERGY</td><td colspan="2">MAXIMUM SUSTAINED POWER</td><td colspan="2">PEAK POWER</td></tr>
<tr><td colspan="2">12.0 KWH</td><td colspan="2">3.0 KW</td><td colspan="2">3.0 KW</td><td colspan="2">23.0 KWH</td><td colspan="2">3.0 KW</td><td colspan="2">3.0 KW</td></tr>
<tr><td>CREW SUPPORT</td><td colspan="6">Skill Codes: 9,10,11,12, 23,25
Hr/Day: e.g., (10)-4 Hr, (12)-6 Hr
(see Note)
Total: 10 Man Hr/Day</td><td colspan="6">Skill Codes: 9,10,11,12, 23,25
Hr/Day (Typical): (11)-5 Hr, (12)-6 Hr
(see Note)
Total: 11 Man Hr/Day</td></tr>
<tr><td rowspan="2">DATA OUTPUT</td><td colspan="4">24 HOUR QUANTITY</td><td colspan="2">MAX. SUST. RATE</td><td colspan="4">24 HOUR QUANTITY</td><td colspan="2">MAX. SUST. RATE</td></tr>
<tr><td colspan="4">Digital--1.0x10^8 Bits</td><td colspan="2">Digital 2.7x10^4 Bits/Sec
Analog 2.9 MHz</td><td colspan="4">Digital--1.1x10^9 Bits
Analog--2.9 MHz</td><td colspan="2">Digital 3.5x10^5 Bits/Sec</td></tr>
<tr><td>DATA DISPOSITION</td><td colspan="6">Record Digital and Voice,
Return to Earth: Samples, Notes, Film
Display Analog</td><td colspan="6">Record Digital and Voice
Return to Earth: Samples, Notes, Film
Display Analog</td></tr>
<tr><td>DATA INPUT</td><td colspan="6">Solar Vector Direction versus MSS Attitude to ±5 degrees</td><td colspan="6">Solar Vector Direction versus MSS Attitude to ±5 degrees</td></tr>
<tr><td rowspan="2">LOGISTICS INPUT/OUTPUT</td><td colspan="3">INPUT</td><td colspan="3">OUTPUT</td><td colspan="3">INPUT</td><td colspan="3">OUTPUT</td></tr>
<tr><td colspan="3">72 lb</td><td colspan="3">42 lb</td><td colspan="3">160 lb</td><td colspan="3">130 lb</td></tr>
<tr><td>GUIDANCE AND CONTROL/ OPERATIONS</td><td colspan="6">No Requirements</td><td colspan="6">Not Applicable for MSS--Expt. T.4.8, Adv. Guidance, is performed on FF RAM, requires stable vehicle</td></tr>
</table>

NOTE: Primary Skill Requirement--Skill code 12 @ 6 hours per day each day--additional man hours per day to be divided sequentially among codes 9, 10, 11, 23, 25.

Table A-18A. Evolution Summary, Teleoperation Laboratory (FPE T-5)

OBJECTIVES		
Level I	Level II	Level III
None	Evaluate teleoperator flight control and man-machine interfaces Establish safety procedures for operation Evaluate performance of actual MSS tasks Test T/O performance at extended distances from station and under earth-surface station control	Same as those for Level II

SELECTED EXPERIMENTS			
Experiment	Level I	Level II	Level III
T-5.1 Initial flight		X	X
T-5.2 Functional Manipulation		X	X
T-5.3 Ground Control		X	X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
		Recommend laboratory be deferred to growth for safety reasons and resultant program cost impact.

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
T130	Teleoperator		X	X
T131	Control Station		X	X
T132	Docking Adapter		X	X
T133	Refueling System		X	X
T134	Battery Charger		X	X
T135	Spares/Tools		X	X
T136	Task Board Subsatellite		X	X
T137	Airlock Task Board		X	X
	Total Weight (lb)		1500	1500

Table A-18B. Levels II and III Operational Concepts, Teleoperation Laboratory (FPE T-5)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
One year continuously (may be divided into three four-month periods separated by six-month intervals for development modifications)	GPL/airlock	Operational deployment and retrieval of teleoperator (T/O) requires that a docking platform be extended from the airlock used for storage and refurbishment of T/O between runs.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Same as that for Level II	GPL/airlock	Same as those for Level II

Table A-18C. Levels II and III Subsystem and Logistics Support, Teleoperation Laboratory (FPE T-5)

PARAMETER	LEVEL II	LEVEL III
ELECTRICAL POWER	24 HOUR ENERGY / MAXIMUM SUSTAINED POWER / PEAK POWER: SAME AS LEVEL III	24 HOUR ENERGY: 3.7 KWH MAXIMUM SUSTAINED POWER: 300 W PEAK POWER: 300 W
CREW SUPPORT		Skill Code / Hr/Day: 10 / 6; 11 / 6; 12 / 7 Total: 19 Man Hr/Day
DATA OUTPUT	24 HOUR QUANTITY / MAX. SUST. RATE	24 HOUR QUANTITY: Digital Calculation: 5.8×10^8 Bits; Digital Record: 7.1×10^7 Bits MAX. SUST. RATE: Digital 4.0×10^4 Bits/sec
DATA DISPOSITION		Display and Record 2 Channels Video, Record T/O Subsystems Data Transmit T/O Instructions, MSS to T/O
DATA INPUT		Range, Range Rate to T/O, $\pm 1\%$ ± 0.5 ft/sec
LOGISTICS INPUT/OUTPUT	INPUT / OUTPUT	INPUT: 400 lb/mo Cold Gas (N_2) Propellant OUTPUT: None
GUIDANCE AND CONTROL/ OPERATIONS		No MSS Maneuvers During T/O Docking

NOTE: Experiment program requires coordination with T.3, Extravehicular Activity Laboratory, to provide comparative evaluations of standard task board activities.

Table A-19A. Evolution Summary, Medical Research Laboratory (FPE LS-1)

OBJECTIVES		
Level I	Level II	Level III
Observe effects of short-duration space flight on man Investigate means of predicting onset of undesirable effects Verify new (post-Skylab) instrumentation and measurement techniques	Determine effects of space flight on man by external techniques Determine the most effective means of preventing or correcting undesirable effects of space flight Determine means of predicting onset and severity of undesirable effects	Determine the effects of space flight on man and the time course of these effects Determine the specific mechanisms by which the effects are mediated Determine means of predicting the onset and severity of undesirable effects Determine the most effective means of preventing or correcting undesirable effects Obtain information of value to conventional medical research Obtain specific information on the combined effects of stress and zero g using animal subjects

SELECTED EXPERIMENTS

Experiment		Level I	Level II	Level III
LS-1.1	Neurological Function			
LS-1.1.1	Human Vestibular Function		X	X
LS-1.1.2	Neurological Experiment - EEG	X	X	X
LS-1.1.3	Sleep Monitoring		X	X
LS-1.1.4	Circadian Rhythms		X	X
LS-1.2	Cardiovascular Function			
LS-1.2.1	Use of LBNP Device to Prevent CV Deconditioning	X	X	X
LS-1.2.2	Vectorcardiogram		X	X
LS-1.2.3	Arterial Pressure Control System		X	X
LS-1.2.4	Intraocular Arterial Blood Pressure		X	X
LS-1.2.5	Cardiac Dynamics - Ballistocardiograph		X	X
LS-1.2.6	Peripheral Arteriolar Reactivity		X	X
LS-1.3	Renal Function			
LS-1.3.1	Renal Blood Flow			X
LS-1.3.2	Indices of Renal Function			X
LS-1.3.3	Renal Calculus Formation in Rats			X
LS-1.3.4	Renal Infection in Rats			X
LS-1.4	Nutrition and Metabolic Function			
LS-1.4.1	Mineral Balance		X	X
LS-1.4.2	Biochemistry of Body Fluids		X	X
LS-1.4.3	Gastrointestinal Motility and pH		X	X
LS-1.5	Musculoskeletal Function			
LS-1.5.1	Bone Densitometry			X
LS-1.5.2	Specimen Mass Measurements			X
LS-1.5.3	Deconditioning Indices - EMG		X	X
LS-1.6	Pulmonary Function			
LS-1.6.1	Metabolic Activity		X	X
LS-1.6.2	Body Mass Measurements		X	X
LS-1.6.3	Ventilatory Mechanics		X	X

Table A-19A. Evolution Summary, Medical Research Laboratory (FPE LS-1) (Cont)

SELECTED EXPERIMENTS

Experiment		Level I	Level II	Level III
LS-1.6.4	Blood and Ventilatory Gas Exchange		X	X
LS-1.7	Hematologic Function			
LS-1.7.1	Blood Volume and Red Cell Life Span			X
LS-1.7.2	Red Blood Cell Metabolism			X
LS-1.7.3	Special Hematologic Effects			X
LS-1.7.4	Blood Coagulation			X
LS-1.8	Microbiology and Immunologic Function			
LS-1.8.1	Human Immunity - In-Vitro Aspects			X
LS-1.8.2	Cytogenic Studies of Blood			X
LS-1.8.3	Microbial Profiles of Crew Members			X
LS-1.9	Endocrine Function			
LS-1.9.1	Endocrine Assays			X
LS-1.9.2	Thermoregulation			X
LS-1.10	Clinical/Therapeutic Function			
LS-1.10.1	Exercise Conditioning			X
LS-1.10.2	Wound Healing			X
LS-1.11	Environmental Factors			
LS-1.11.1	Airborne and Surface Contamination			X
LS-1.11.2	Radiation Effects			X

COMMENTS AND RATIONALE

Level I	Level II	Level III
Early identification of problems in new techniques for initial phase Minimum support by shuttle interfaces Intermittent crew time Body mass measurement, bicycle ergometer, or metabolic analyzer items can be performed here if Skylab results indicate a requirement	Expand medical data base and sample range Concentrate on external observations of man Experiments requiring radiobiology unit deferred to Level III due to system cost impact	Long-duration, continuous experiments, combined-environment effects Medical techniques requiring penetration deferred to this level Animal support for comparative analysis deferred to this level (LS-1.3) Radiobiology unit deferred to this level (LS 1.5, LS 1.11.2)

EQUIPMENT

ID Number	Item	Level I	Level II	Level III
L001	Impedance Cardiograph			X
L002	ECG/VCG (leads and preamp)	X	X	X
L003	EEG (leads and preamp)	X	X	X
L004	Dynamometers		X	X
L005	EMG (leads and preamp)		X	X
L006	EOG (leads and preamp)		X	X
L007	Phonocardiogram		X	X
L008	Legs Plethysmographs	X	X	X
L009	Metabolic Analyzer		X	X
L010	Pulmonary Flow Meter		X	X
L011	Tape Measure		X	X
L012	Flow Meter, Transcutaneous Doppler			X

Table A-19A. Evolution Summary, Medical Research Laboratory (FPE LS-1) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
L013	Pulse Wave Indicator			X
L014	Bicycle Ergometer		X	X
L015	LBNP Device	X	X	X
L016	Specimen Mass Measurement Device		X	X
L017	Body Mass Measurement Device		X	X
L018	Rotating Litter Chair		X	X
L019	Blood Pressure Assembly	X	X	X
L020	Stowage Container	X	X	X
L021	Ear Canal Temperature Probe	X	X	X
L022	Electro Analytical Apparatus		X	X
L023	Spectrophotometer			X
L024	Miscellaneous Fluid Transfer Equipment		X	X
L025	Freezer		X	X
L026	Retractometer		X	X
L027	Microcentrifuge		X	X
L028	Timer		X	X
L029	Urine Sampling and Volume Measurement System		X	X
L030	Waste Measurement System		X	X
L031	Sample Container and Log Books		X	X
L032	Blood Analysis Equipment		X	X
L033	Mechanical Scanner With Radionuclide Source		X	X
L034	Metabolic Assessment Maintenance		X	X
L035	Metabolic Access			X
L036	Automatic Urine Analyzer		X	X
L037	Urine Storage		X	X
L038	Refrigerator			X
L039	Tissue Fixtures		X	X
L040	Specific Hormone Assembly Equipment			X
L041	Microscope			X
L042	Cardiotachometer		X	X
L043	Autoclave			X
L044	Colony Counter			X
L045	Media Preparation Containers			X
L046	Microbial Air Sampler			X
L047	High-Temperature Sterilizer			X
L048	Galvanic Skin Reaction Equipment		X	X
L049	Behavioral Measurement		X	X
L050	Movie Camera	X	X	X
L051	Metabolic Cage - Rat			X
L052	Metabolic Cage - Rabbit			X
L053	Small-Animal Holding Unit			X
L054	Rack and Manifold System			X
L055	Occlusive Cuffs		X	X
L056	Plethysmographic Goggles		X	X
L057	Incubator			X
L058	Vision Test Target		X	X
L059	Ballistocardiograph		X	X
L060	Roll Film Camera		X	X
L061	Histology Kit/Slide Cabinet			X
L062	Histological Staining System			X
L063	Bacteriological Staining System			X
L065	Biochemical Analysis Equipment		X	X
L066	Blood Gas Analyzer		X	X
L067	Auto Physiological Gas Analyzer		X	X
L068	Oximeter		X	X
L069	Lyophilizer			X
L070	Skin Temperature Thermocouples			X
	Total Weight (lb)		6485	6675

Table A-19B. Levels II and III Operational Concepts, Medical Research Laboratory (FPE LS-1)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Three years—the duration of individual cycles must coincide with the duration of the on-orbit crew stay time. The experimental activity is continual; it may be interrupted only for those durations that man is not in orbit.	GPL	The rotating litter chair (7 feet long and 3 feet wide) requires a clear space for its operation; the space should allow rotation of the flat surface about its longitudinal and lateral axes and occasional rotation about an axis perpendicular to the station "floor." The lower body negative pressure device (LBNP) requires sufficient overhead clearance to allow a man to stand in it. The device requires low levels of vacuum when operating. The body mass measurement device oscillates with the subject seated in it and should be in a clear space. The bicycle ergometer - for metabolism study - should be considered as a potential substitute for the exercise equipment required by Paragraph 2.41617 of Guidelines and Constraints (NASA MSC-03696).

Table A-19B. Levels II and III Operational Concepts, Medical Research Laboratory (FPE LS-1) (Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Five years	GPL	Same as those for Level II Radiobiological equipment must be installed in an area that will protect the rest of the crew. For isolation, the unit may be installed in a RAM rather than in the GPL.

Table A-19C. Levels II and III Subsystem and Logistics Support, Medical Research Laboratory (FPE LS-1)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY 0.72 KW-Hr/Day	MAXIMUM SUSTAINED POWER 0.05	PEAK POWER 0.30	24 HOUR ENERGY 2.81 KW-Hr/Day	MAXIMUM SUSTAINED POWER 1.26	PEAK POWER 1.5
CREW SUPPORT	Skill: Subj (any), 1, 2, 3 Time/Day: 2.6, 4.5, 0.75, 0.5	Skill: 13 Time: 0.5	Avg - 245 Man-Hr/Mo.	Skill: Subj (any), 1, 2, 3 Time/Day: 4.3, 7.5, 4.5, 0.5	Skill: 13, 22 Time/Day: 1.5, 0.1	Avg - 555 Man-Hr/Mo.
DATA OUTPUT	24 HOUR QUANTITY 9.18x10^8 Bits		MAX. SUST. RATE 25 Kbps Analog- 320 sps	24 HOUR QUANTITY 9.18x10^8 Bits		MAX. SUST. RATE 25 Kbps Analog- 320 sps
DATA DISPOSITION	Digital Display - 25% Store - 75% Analog Display - 100%			Display - 15% Store - 85% Film-Store Analog Display - 100%		
DATA INPUT	Station Atmosphere Composition			Station Atmosphere Composition		
LOGISTICS INPUT/OUTPUT	INPUT 25 lb/month	OUTPUT 25 lb/month		INPUT 94 lb/month	OUTPUT 94 lb/month	
GUIDANCE AND CONTROL/ OPERATIONS	No Maneuvers During Vestibular Test (Approximately 1 hr/day)			No Maneuvers During Vestibular Test (Approximately 1 hr/day)		

Table A-20A. Evolution Summary, Biosciences Research Laboratory (FPE's LS-2, 3, 4, 5)

OBJECTIVES			
Level I	Level II	Level IIA	Level III
Determine mechanism and thresholds for graviception and tropism of plants Observe effect of zero g on life process of microorganisms Observe effect of combined environments on human tissue cultures Determine effect of zero g (and other earth influences) on host parasite relationships Determine mechanism involved in modification of invertebrate behavior	Study effect of zero g space on cellular functions Observe effect of space on alteration of cells, tissues, structure of functions Observe variations in adaptation to space Develop prediction capability Observe effect of zero g on molecular reactions of biological interest Determine mechanism of alternations in basic life processes Evaluate importance of gravity vector in behavior	Determine some specific effects if zero g on one animal type Study role of gravity on vertebrate life processes Determine effect of zero g on behavior and performance Determine effect of zero g on life cycle of plant processes Determine effect of zero g on host-parasite relationships Determine mechanisms of alterations in basic life processes, behavior-regeneration Detect modifications in the genetics of invertebrates	Determine effects of space and combined environments on vertebrate life processes, plant processes and cycles, cells and tissues life cycles, and invertebrate life processes Apply results to extension of manned space flight capabilities Produce strain of invertebrates adapted to weightlessness

SELECTED EXPERIMENTS					
Experiment		Level I	Level II	Level IIA	Level III
LS-2.1	Role of Gravity in Mammalian Vital Functions				
LS-2.1.1	Primates				X
LS-2.1.2	CV Adaptation			Partial	X
LS-2.1.3	Reduced-g Effects on Bioelectric Potentials and Bone Metabolism				X
LS-2.1.4	Immune Response of Animals				X
LS-2.1.5	Tissue/Cell Morphology With and Without Endocrine Gland Ablations			Partial	X
LS-2.1.6	Tissue Growth and Repair			Partial	X
LS-2.2	Role of Gravity in Vertebrate Life Processes				
LS-2.2.1	Role of Gravity in Life Processes of Mammals				X
LS-2.2.2	Necessity of Gravity for Normal Growth of Turtles				X
LS-2.2.3	Weightlessness, Growth and Rhythms			X	X
LS-2.2.4	Effect of Weightlessness on Chickens				X
LS-2.2.5	Circadian Rhythms				X
LS-2.2.6	Central Nervous System Function in Hibernating or Hypothermic Mammals in Weightlessness				X
LS-2.2.7	Role of Gravity in Avian Bone Metabolism				X
LS-2.3	Effect of Space Environment on Performance and Behavior				
LS-2.3.1	Vestibular Research in Space				X
LS-2.3.2	Vestibular Apparatus Development			X	X

Table A-20A. Evolution Summary, Biosciences Research Laboratory (FPE's LS-2, 3, 4, 5) (Cont)

SELECTED EXPERIMENTS					
	Experiment	Level I	Level II	Level IIA	Level III
LS-2.3.3	Neural Correlates of Function of the Mammalian Vestibular System			X	X
LS-2.3.4	Effects of Changes in Gravity on the Otolith				X
LS-2.3.5	Neural and Behavioral Development in Inbred Mice				X
LS-2.3.6	Force of Isometric Contraction of Nonvestibular/Vestibular Muscle in Low-Gravity Environments				X
LS-3.1	Role of Gravity in Plant Life Cycles and Processes				
LS-3.1.1	Metabolism and Energetics in Hypogravity			X	X
LS-3.1.2	Plant Growth at Low-g level			X	X
LS-3.1.3	Orbital Growth of Dicotyledenous Seedlings			X	X
LS-3.1.4	Biochemical and Biorhythmic Changes in Plants due to Reduced Gravity			X	X
LS-3.1.5	Effects of Weightlessness on Gametogenesis and Morphogenesis in Gametophytes			X	X
LS-3.2	Graviception and Tropisms				
LS-3.2.1	Physiological Response of Plants to a Hypogravity-Gradient Environment				X
LS-3.2.2	Growth Transients in Roots Exposed to a Weightless Environment	X	X	X	X
LS-4.1	Role of Gravity in Life Processes of Organisms/Tissues				
LS-4.1.1	Life Processes of Small Organisms		X	X	X
LS-4.1.2	Effect of Combined Environments on Soil Sample		X	X	X
LS-4.1.3	Zero g on Morphogenesis/Embryogenesis		X	X	X
LS-4.1.4	Effect of zero g on Bone Tissue Cultures (calcium loss)	X	X	X	X
LS-4.1.5	Effect of Space on Conidial Formation in Fungi		X	X	X
LS-4.1.6	Effect of Zero g on Vertebrate Embryos		X	X	X
LS-4.1.7	Effect of Zero g on Bone Culture Mineral Metabolism		X	X	X
LS-4.1.8	Effect of Zero g on Calcium Metabolism		X	X	X
LS-4.2	Effect of Space Environment on Genetic Subcellular Phenomena				
LS-4.2.1	Effect of Zero g on Human Tissue Cultures	X	X	X	X
LS-4.2.2	Effect of Zero g on Molecular Reactions		X	X	X
LS-4.2.3	Effect of Space Environment on Rate of Mutation		X	X	X
LS-4.3	Role of Gravity in Interspecies Relationships				
LS-4.3.1	Effect of Zero g on Plant Tumor Tissues			X	X
LS-4.3.2	Effect of Space on Insect Viruses	X	X	X	X
LS-4.3.3	Effect of Hypogravity on Host/Parasite Relationships				X
LS-5.1	Role of Gravity in Invertebrate Life Processes				
LS-5.1.1	Longevity and Behavioral Changes			X	X
LS-5.1.2	Effect of Space on Aging and Longevity		X	X	X
LS-5.1.3	Effect of Zero g on Regeneration of Planaria			X	X
LS-5.2	Effect of Space on Invertebrate Behavior				
LS-5.2.1	Circadian Periodicity of Cockroach Activity				X
LS-5.2.2	Circadian Rhythm of Vinegar Gnat Eclosion	X	X	X	X
LS-5.2.3	Effect of Zero g on Spider Web Building		X	X	X
LS-5.3	Effect of Space on Invertebrate Genetics				
LS-5.3.1	Combined Space and Irradiation Effects			X	X
LS-5.3.2	Effect of Space on Genetic Changes			X	X
LS-5.3.3	Effect of Space on Sperm/Ovum			X	X
LS-5.3.4	Chromosome Rejoining at Zero g			X	X

Table A-20A. Evolution Summary, Biosciences Research Laboratory (FPE's LS-2, 3, 4, 5) (Cont)

COMMENTS AND RATIONALE			
Level I	Level II	Level IIA	Level III
Short-duration experiments Minimum crew activities Verification of techniques for initial phase Potential medical yield for future crews (4. 1. 4, 4. 2. 1) Radiation and centrifuge environment phases deferred to higher levels due to cost Single-chamber plant module (3. 2. 2)	Zero-g and single-environment conditions to establish reference data Verify invertebrate techniques for zero g (5. 1) Brief daily crew times only for the experiments Simple station interfaces for electrical power and life support and stabilization	Begin small-animal tests on one type (rats) in zero g only (2. 1) Tests related to anticipated problems of extending man's orbital stay time (2. 1) Investigate problems of blood sampling in space (2. 1) Expand station interfaces to accommodate one animal type (2. 1) Plant multichamber module required (3. 1) Expand crew tasks to include plant core and monitoring (3. 1) Zero-g information on invertebrates (5. 1, 5. 3)	Combine experiments requiring gravity, radiation, and their combination Long-time periods at 10^{-5} g Large variety of small vertebrates (2. 1. 2 through . 6) and primates (2. 11), with multisubsystem interface requirements Bioscience research for advanced programs

EQUIPMENT					
ID Number	Item	Level I	Level II	Level IIA	Level III
L116	Miscellaneous Hardware (lab)	X	X	X	X
L117	Miscellaneous Hardware (centrifuge)	X	X	X	X
L118	Experiment Equipment Container			X	X
L119	Automatic/Semiautomatic Experiment Management Equipment	X	X	X	X
L122	Experiment Apparatus (12 modules)		X	X	X
L124	Microbial and Chemical Analysis		X	X	X
L125	Experiment Package		X	X	X
L125A	Experiment Package			X	X
L126	Invertebrate Holding Unit (lab)				
L127	Invertebrate Holding Unit (centrifuge)				X
L128	Rack and Cabinet				X
L129	Vials, Bottles, etc.				X
L130	Miscellaneous Counters and Transducers				X
L131	Specific Tool and Zero-g Aids				X
L132	Experiment A Package				X
L133	Experiment B Package			X	X
L134	Experiment C Package			X	X
L135	Experiment Management and Display Equipment	X	X	X	X
L138	Laminar Flow Bench			X	X
L139	Specimen Preservation Equipment			X	X
L140	Optical Magnifiers			X	X
L141	Experiment Package				X

Table A-20A. Evolution Summary, Biosciences Research Laboratory (FPE's LS-2, 3, 4, 5) (Cont)

EQUIPMENT					
ID Number	Item	Level I	Level II	Level IIA	Level III
L142	Invertebrate Zero g Centrifuge Mount			X	X
L143	Insert Radiation/Weightlessness Modules			X	X
L144	LET Modules			X	X
L145	Breeding Container Modules			X	X
L146	Radiation Source				X
L051	Rat Cage (inserts for mice)			X	X
L052	Metabolic Cage (rabbit)				X
L053	Small-Animal Holding Unit			X	X
L054	Rack and Manifold System			X	X
L071	Exerciser/Ergometer				X
L072	Primate Calorimetry Module				X
L073	Primate Holding Unit Cage				X
L074	Rack and Module System				X
L075	Primate Holding Unit				X
L076	Primate Transfer Module				X
L077	Primate				X
L078	TV Cameras			X	X
L079	Signal Conditions and Display Equipment			X	X
L080	Biochemical/Biophysical Analysis Unit			X	X
L081	Standard Cage (rat, marmot)			X	X
L082	Colony Cage (rat, marmot)			X	X
L083	Metabolic Cages (rat, marmot)			X	X
L084	Standard Cage (rabbit)				X
L089	Aquaria				X
L090	Transport Module			X	X
L091	Cabinet, Drawer, and Rack Storage			X	X
L092	Storage Cabinet for Cages			X	X
L093	Transducer Inventory			X	X
L041	Microscope			X	X
L060	Camera-Roll Film			X	X
L094	Plant Lighting System	X	X	X	X
L095	Photo-TV Accessories	X	X	X	X
L096	Clock and Timer	X	X	X	X
L097	Rack and Cabinet System	X	X	X	X
L098	Growth and Support Containers	X	X	X	X
L099	Miscellaneous Tools and Hardware	X	X	X	X
L100	Plant Holding Unit	X	X	X	X
L101	Rack and Manifold System	X	X	X	X
L102	Experiment Package			X	X
L103	Plate Film Camera			X	X
L105	Voice Recorder			X	X
L108	Radiobiological Unit			X	X
L109	Clinostats			X	X
L110	Freeze-Drying Apparatus			X	X
L111	Gas Analysis Equipment			X	X
L112	Standard Holding Units	X	X	X	X
L113	Holding Unit Lighting	X	X	X	X
L114	Rack and Cabinet System (lab)	X	X	X	X
L115	Rack and Cabinet System (centrifuge)	X	X	X	X
	Total Weight (lb)		13,594	15,362	16,385

Table A-20B. Levels II, IIA, and III Operational Concepts, Biosciences Research Laboratory (FPE's LS-2, 3, 4, 5)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
270 days	GPL	The major activity is in the cells and tissues experimental area; thus, isolation provisions are required. A portable-type clean room is feasible. Experiments requiring radiobiological and bio-centrifuge capability are deferred.
OPERATIONAL CONCEPT - LEVEL IIA		
Duration	Mode	Special Physical Requirements
540 days	RAM	A variety of activities will require isolation from station atmosphere. Because an increase of personnel is required, a more permanent room isolation is necessary. The vertebrates for this phase are all one type (rats). They may be stacked in their containers, but access to the containers must be preserved. Up to 160 rats will be involved and will require an area 5 feet x 1 foot x 77 inches high. The plant experiments will require a location that will allow controlled lighting without interference from the station lighting. An enclosure 4 feet x 3 feet x 3 feet high is required. The invertebrates will be stored in colony-type containers and will require a stacked volume 1 foot deep, 4 feet wide, and 80 inches high.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
6 years	RAM	The bioscience centrifuge will be required for this phase. One Blue Book concept presents the centrifuge as a module 60 feet long and 14 feet in diameter.

Table A-20B. Levels II, IIA, and III Operational Concepts, Biosciences Research Laborabory (FPE's LS-2, 3, 4, 5)(Cont)

OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
		The radiobiological equipment must be used within a specially constructed area to control the additional radiation exposure to the crew. Six additional animal types will be evaluated in this phase and will require another stacked animal container volume. The primate experiment will require a larger space for both the cages and the extra equipment—e. g., an animal ergometer will require temporary installation capability (when not in use it may be stored). This area is estimated to be 6 feet x 5 feet x the height of the station (82 inches). The primate and vertebrate areas may be combined into one general section.

Table A-20C. Levels II, IIA, and III Subsystems and Logistics Support, Bioscience Research Laboratory (FPE LS-2, 3, 4, 5)

PARAMETER	LEVEL II	LEVEL III
ELECTRICAL POWER	24 HOUR ENERGY: 3.0 kw-hr MAXIMUM SUSTAINED POWER: .050 kw PEAK POWER: .050 kw	24 HOUR ENERGY: 13.5 kw-hr (2) MAXIMUM SUSTAINED POWER: .160 kw PEAK POWER: .160 kw
CREW SUPPORT	SKILL 1, TIME 2.5 SKILL 2, TIME 4.0 (3 mo), .5 (6 mo) SKILL 3, TIME .5 SKILL 4, TIME -	SKILL (1) 1, TIME 6.5 SKILL 2, TIME 2.0 SKILL 3, TIME .5 SKILL 4, TIME 4.0
DATA OUTPUT	24 HOUR QUANTITY: 2.0×10^7; Film/mo 300 frames 10 reels MAX. SUST. RATE: 200 bps	24 HOUR QUANTITY: 2.1×10^8; Film/mo 850 frames 30 reels MAX. SUST. RATE: 1200 bps
DATA DISPOSITION	25% display, 75% store	15% display, 85% store
DATA INPUT	None	None
LOGISTICS INPUT/OUTPUT	INPUT: 75 lb/mo OUTPUT: 75 lb/mo	INPUT: 795 lb/mo OUTPUT: 795 lb/mo
GUIDANCE AND CONTROL/ OPERATIONS	10^{-5}g 81 D 10^{-4}g 30 D 10^{-3}g 140 D 10^{-2}g 15 D	10^{-5}g 180 D 10^{-4}g 360 D 10^{-3}g 180 D 10^{-2}g -- Avoid cues of time 720 Days .1 to 1.0 g

Notes: (1) Daily crew times are to be doubled for the centrifuge use for growth phase
(2) Electrical power requirements are to be doubled for centrifuge use.

Table A-20C. Levels II, IIA, and III Subsystem and Logistics Support, Bioscience Research Laboratory (FPE LS-2, 3, 4, 5) (Cont)

PARAMETER	LEVEL IIA			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 8.0 kw-hr	MAXIMUM SUSTAINED POWER: .150 kw	PEAK POWER: .150 kw	24 HOUR ENERGY	MAXIMUM SUSTAINED POWER	PEAK POWER
CREW SUPPORT	SKILL / TIME: 1 / 4.5; 2 / 2.0 (5 mo)		SKILL / TIME: 3 / .5; 4 / 2.0			
DATA OUTPUT	24 HOUR QUANTITY: 1.2×10^8	Film/mo 700 frames 20 reels	MAX. SUST. RATE: 1200 bps	24 HOUR QUANTITY		MAX. SUST. RATE
DATA DISPOSITION	20% display	80% store				
DATA INPUT	None					
LOGISTICS INPUT/OUTPUT	INPUT: 250 lb/mo	OUTPUT: 250 lb/mo		INPUT	OUTPUT	
GUIDANCE AND CONTROL/ OPERATIONS	10^{-5}g 270 D 10^{-4}g 160 D 10^{-3}g 125 D 10^{-2}g 15 D					

Table A-21A. Evolution Summary, Life Support and Protective Systems Laboratory (FPE LS-6)

OBJECTIVES		
Level I	Level II	Level III
Verify gravity-sensitive aspects of life support subsystems	Investigate gravity-sensitive elements of LSPS components Evaluate advanced LSPS components, subsystems, and systems Evaluate man's ability to maintain and repair equipment and perform operations in space	Same as those for Level II

SELECTED EXPERIMENTS				
Experiment		Level I	Level II	Level III
LS-6.1	Water Recovery Methods	X	X	X
LS-6.2	Waste Management Methods		X	X
LS-6.3	Advanced Cooling System Methods		X	X
LS-6.4	Zero-g Whole-Body Shower	X	X	X
LS-6.5	Advanced Two-Gas Atmosphere Supply and Control		X	X
LS-6.6	Atmosphere Supply Methods		X	X
LS-6.7	Oxygen Regeneration Methods		X	X
LS-6.8	Carbon Dioxide Collection Method		X	X
LS-6.9	Advanced Trace Contaminant Control	X	X	X
LS-6.10	Protective Clothing and Advanced Space Suit Assemblies		X	X
LS-6.11	EVA Suit and Biopack		X	X
LS-6.12	Food Storage and Preparation		X	X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Independent self-contained units Minimum interaction with shuttle subsystems Selected experiments contribute to station subsystem qualification and crew health	Support advanced missions, defer to Level III	Support advanced missions EVA experiment requires large airlock All subsystem tasks are in addition to station subsystem development High daily crew participation

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
L050	Movie Camera	X	X	X
L060	Roll-Film Camera	X	X	X
L105	Voice Recorder	X	X	X
L149	Life Support Subsystem Test Unit	X	X	X
L150	Water Recovery Subsystem	X	X	X
L151	Data Management and Display	X	X	X
L152	Biochemical and Microbial Analysis Equipment	X	X	X
L156	Waste Management System Test Specimen		X	X

Table A-21A. Evolution Summary, Life Support and Protective Systems Laboratory (FPE LS-6) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
L157	Advanced Cooling System Test Specimen		X	X
L158	Zero g Whole-Body Shower	X	X	X
L159	Advanced Gas Atmosphere Supply/Control Subsystem		X	X
L160	Atmosphere Supply System		X	X
L161	O_2 Regeneration System		X	X
L162	CO_2 Collection System		X	X
L163	Advanced Trace Contaminent Control Monitor	X	X	X
L164	Protective Clothing and Advanced Space Suit		X	X
L165	EVA Suit and Biopack		X	X
L166	Food Storage, Preparation, Feeding		X	X
	Total Weight (lb)		7360	7360

Table A-21B. Levels II and III Operational Concepts, Life Support and Protective Systems Laboratory (FPE LS-6)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Two 37-month cycles. The time required for the individual experiments varies from 30 to 450 days. All but three (3, 6, 7) can be performed in 30-day increments; these three require 90, 270, and 450 days, respectively.	GPL/RAM/airlock	The advanced cooling methods experiment requires the installation of externally mounted radiators, heat pipes, boilers. These items may be installed on a RAM. Experiments with the space suit and biopack require access to space for both men and equipment. Experiments with atmospheric storage systems require protected space outside the pressure volume. Access to electrical power, instrumentation, and control is required.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Same as that for Level II	Same as that for Level II	Same as those for Level II

Table A-21C. Levels II and III Subsystem and Logistics Support, Life Support and Protective Systems Laboratory (FPE LS-6)

PARAMETER	LEVEL II	LEVEL III
ELECTRICAL POWER	24 HOUR ENERGY / MAXIMUM SUSTAINED POWER / PEAK POWER SAME AS LEVEL III	24 HOUR ENERGY: 2.23 KW-Hr/Day MAXIMUM SUSTAINED POWER: 1.00 KW PEAK POWER: 1.00 KW
CREW SUPPORT		Skill / Man-Hr/Day: Test Subj (1) 7.75 2 2.0 11 7.0 12 6.0 Skill 22 / Man-Hr/Day 1.0 Avg - 300 Man-Hr/Mo
DATA OUTPUT	24 HOUR QUANTITY / MAX. SUST. RATE	24 HOUR QUANTITY: 2.8×10^8 Film - 18 Reels/Month (4) MAX. SUST. RATE: 1.3×10^5
DATA DISPOSITION		Digital - Display - 30% Store - 70% Film - Store
DATA INPUT		Station Atmosphere Composition Station Attitude (2) Station Overboard Dump
LOGISTICS INPUT/OUTPUT	INPUT / OUTPUT	INPUT: 13 lb/month OUTPUT: 63 lb/month
GUIDANCE AND CONTROL/ OPERATIONS		No Maneuvers During EVA (3)

NOTES:
(1) Test subject skill refers to crew man of any skill
(2) Station attitude required for thermal control systems evaluation
(3) EVA required for crew systems evaluation
(4) One reel of film, 200 feet, 16 mm

Table A-22A. Evolution Summary, Man-System Integration Laboratory (FPE LS-7)

OBJECTIVES		
Level I	Level II	Level III
Quantify man's capability to do physical work in space	Observe man in space to prepare for specific tasks at higher level	Determine man's behavior characteristics in space Quantify human capabilities for tasks in space Develop technology for crew and equipment for IVA and EVA Develop habitability criteria Develop crew selection criteria

SELECTED EXPERIMENTS				
	Experiment	Level I	Level II	Level III
LS-7.1	Behavioral Effects			
LS-7.1.1	Effects of Space Flight on Sensory Processes			X
LS-7.1.2	Effects of Space Flight on the Cognitive Process			X
LS-7.1.3	Effects of Space Flight Environment on Psychomotor Functions			X
LS-7.1.4	Effects of Space Flight Environment on Individual/ Group Dynamics			X
LS-7.2	Performance Capability Assessment			
LS-7.2.1	Cargo Handling Capabilities	X		X
LS-7.2.2	Assembly, Deployment, Maintenance, and Repair Capabilities			X
LS-7.2.3	Locomotion and Restraint Capabilities		Partial	X
LS-7.2.4	System Controller Capabilities		X	X
LS-7.3	Habitability and Proficiency			
LS-7.3.1	Interior Configurations, Environments and Decor			X
LS-7.3.2	Off-Duty Activities and Facilities			X
LS-7.3.3	Skill Retention and Assessment in Long-Duration Space Flight			X
LS-7.4	Behavioral Effects and Performance in Rotogravitation			
LS-7.4.1	Locomotion and Balancing Capabilities			X
LS-7.4.2	Fine Psychomotor Capabilities			X
LS-7.4.3	Cargo Handling and Gross Psychomotor Capabilities			X

COMMENTS AND RATIONALE		
Level I	Level II	Level III
Passive equipment will provide data for "station" operations Short, intermittent tests Portable metabolic analyzer (inexpensive)	Tasks performed within station airlock/EVA unit deferred (7.2.3) Will provide data useful to subsatellite operations	Supports advanced missions centrifuge—very expensive (7.4) Sensory/skill/behavioral assessment requires variety of equipment and frequent crew participation

Table A-22A. Evolution Summary, Man-System Integration Laboratory (FPE LS-7) (Cont)

EQUIPMENT				
ID Number	Item	Level I	Level II	Level III
L003	ECG (leads and preamp)			X
L017	Body Mass Measurement Device			X
L018	Rotating Litter Chair			X
L048	GSR (leads and preamp)			X
L049	Behavioral Measurement Unit			X
L050	Movie Camera		X	X
L060	Roll-Film Camera		X	X
L105	Voice Recorder	X	X	X
L151	Data Management and Display			X
L171	Video Camera (color)	X	X	X
L172	Video Tape Recorder	X	X	X
L173	Limb Strength/Force Control Measurement			X
L176	Mobility Unit			X
L177	Portable Metabolic Analyzer	X	X	X
L178	Impact Force Detector			X
L179	Portable Accelerometer	X	X	X
L180	Event Timer	X	X	X
L181	Selected Restraints and Locomotion Aids	X	X	X
L182	Transport Masses	X	X	X
L183	Mechanical Aids	X	X	X
L184	Experiment System for EVA Maintenance Repair			X
L185	EVA Camera/Recorder			X
L186	Tools for Experiments			X
L187	External Lights and Miscellaneous Support Equipment			X
L188	System Controller Capability Study Equipment		X	X
L192	Other Support Equipment			X
L193	Off-Duty Activities and Facilities Evaluation			X
L194	Trainer/Refresher Units and Skill Retention Devices			X
L195	Human Research Centrifuge Rotating Assembly Control Station, etc.			X
L196	Behavior/Performance in Rotogravitation			X
L197	Psychomotor Test Equipment (L-1)			X
L198	Experiment Equipment for Cargo Handling and Cross Psychomotor Capability			X
L199	Centrifuge Facility			X
L200	Work Table	X	X	X
L201	Man Translocater			X
L138	Laminar Flow Bench	X	X	X
	Total Weight (lb)		2900	5900

Table A-22B. Levels II and III Operational Concepts, Man-System Integration Laboratory (FPE LS-7)

OPERATIONAL CONCEPT - LEVEL II		
Duration	Mode	Special Physical Requirements
Three months (three cycles). The early experiments are independent of each other and may be interrupted—that is, the daily scheduling is flexible.	GPL or RAM	The system controller experiments require controlled noise level and isolation from auditory and visual distractions.
OPERATIONAL CONCEPT - LEVEL III		
Duration	Mode	Special Physical Requirements
Three months (eight cycles). The experiments may be performed in three-month segments.	GPL/airlock and RAM	Experiments require manned EVA capability for cargo handling and maintenance evaluations. One group of experiments requires a manned centrifuge and counterweight. A recommended radius (see Section 7 of Volume 8 of 1971 Blue Book) is 112 inches. The centrifuge requires a 3.5-hp ac motor, communications, water storage, life support, and an automatic counterweight adjusting system.

Table A-22C. Levels II and III Subsystem and Logistics Support, Man-System Integration Laboratory (FPE LS-7)

PARAMETER	LEVEL II			LEVEL III		
ELECTRICAL POWER	24 HOUR ENERGY: 0.1	MAXIMUM SUSTAINED POWER: 0.05	PEAK POWER: 0.2	24 HOUR ENERGY: 1.0 KW-Hr	MAXIMUM SUSTAINED POWER: 0.4 KW	PEAK POWER: 0.4 KW
CREW SUPPORT	Skill / Man-Hr/Day Subject 5.0 21 3.5	Avg - 15.0 Man-Hr/Month		Skill / Man-Hr/Day Subject 7.5 11 9.0 D/9* 12 11.0 D/10	Skill / Man-Hr/Day 13 5.0 D/3 21 1.5 D/5 (see Note)	
DATA OUTPUT	24 HOUR QUANTITY: $7.2x10^5$ Bits		MAX. SUST. RATE: 100 bps Analog-4MHz	24 HOUR QUANTITY: $3.0x10^7$ Bits		MAX. SUST. RATE: $2.55x10^3$ bps Analog-4MHz
DATA DISPOSITION	Digital - 10% Displays; 90% Store Analog - 100% Display			Digital - 10% Display; 90% Store Analog - 100% Display		
DATA INPUT	None			None		
LOGISTICS INPUT/OUTPUT	INPUT: 45 lb/month	OUTPUT: 45 lb/month		INPUT: 300 lb/month	OUTPUT: 300 lb/month	
GUIDANCE AND CONTROL/ OPERATIONS	No Maneuvers During Cargo Handling			H = 7225 ft-lb-sec (Man Centrifuge) No Maneuvers During Cargo Handling		

NOTE: *D/9 means every ninth day