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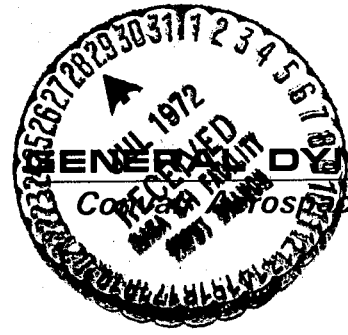
# LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY

## VOLUME II ✦ REQUIREMENTS AND DESIGN STUDIES




GENERAL DYNAMICS
Convair Aerospace Division



239

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# LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY

## VOLUME II ✦ REQUIREMENTS AND DESIGN STUDIES

March 1972

Submitted to
National Aeronautics and Space Administration
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# SECTION 1

# INTRODUCTION

## 1.1 OBJECTIVES

The "Life Sciences Payload Definition and Integration Study" is an integral part of the overall space experiment payload definition activity of NASA. The primary goal of this activity is to develop the program plans of the various scientific disciplines scheduled for space research. In pursuit of this goal, the Life Sciences Payload Definition and Integration Study evolved a series of preliminary conceptual laboratory designs. These designs provide the first step toward detailed definition of potential life sciences laboratory requirements that can, in turn, be used for detailed NASA planning activities. Such activities would include scheduling, SRT funding, overall cost planning, and requirements definition of launch and support vehicles such as RAM and space station.

The primary objectives of the Life Sciences Payload Definition and Integration Study were to:

a. Identify the research functions which must be performed aboard potential Life Sciences spacecraft laboratories and the equipment needed to support these functions.

b. Develop layouts and preliminary conceptual designs of several potential baseline payloads for the accomplishment of life sciences research in space.

The preliminary conceptual designs were to consider initial integration factors such as potential supporting mission guidelines on launch weight and module diameters. However, detailed integration studies were not to be included. These were to be the subject of further studies on the baseline payloads leading to RDT&E plans for life sciences research in space. The major tasks of the overall program are diagrammed in Figure 1-1. The subject of this study is the "preliminary concept phase."

## 1.2 CONDUCT OF THE STUDY

The study was divided into two major tasks. The research requirements were determined first and then the layouts and preliminary design studies were conducted (Tasks A and B in Figure 1-1).

The basic research requirements were obtained from various sources of information, including NASA documents and direct contact with pertinent life scientists. This information was then used to develop inventories of functions (activities) and equipment

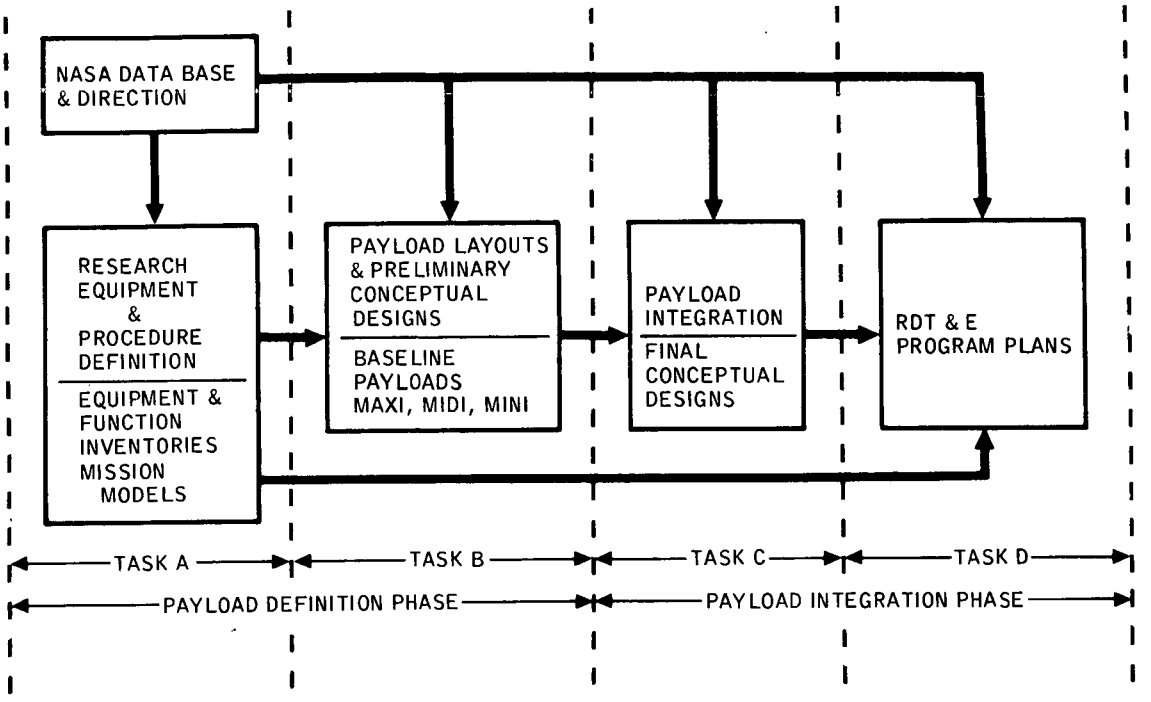


Figure 1-1. Program Overview

necessary to conduct life sciences research in space. This effort was purposely kept unlimited and unconstrained by mission parameters and other factors to obtain comprehensive inventories. These could later be screened, and the rationale for the elimination of functions and equipment could be preserved for future scrutiny.

The inventories were used as the basis for the conceptual design studies, including research operations analysis, design layouts, preliminary cost analysis, and supporting subsystem studies. Again, these studies were performed for maximum capability payloads which were then used as the basis for estimating the properties of more limited payloads. The final output of Task B was a set of four baseline payload layouts and the related preliminary design data. These payloads range from one that provides comprehensive research capability to one with early/limited capability.

## 1.3 SPACE BIOLOGY PAYLOAD DEFINITION

The present Life Sciences Payload Definition and Integration study was originally funded as the Space Biology Payload Definition (SBPD) study and was to cover Tasks A, B, C, and D as shown in Figure 1-1. After about 4-1/2 months of activity (midpoint of Task B), the program scope was expanded to include all of the life sciences disciplines. The added disciplines of biomedicine, life support/protective systems, and man system integration were then made a part of a redefined program called the Life Sciences Payload Definition and Integration. The LSPD study was then structured to perform only Task A and Task B (payload definition phase) with the funds that were originally provided to do the entire program (Tasks A, B, C, and D) for space biology.

## 1.4 DEFINITIONS

A term used throughout this report that reflects the general philosophy used in the study is "facility approach." This term refers to the fact that life sciences laboratory facility payloads were developed as opposed to laboratories designed to perform specific experiments. The reasons for using this approach are discussed further in Section 2.

The following paragraphs describe other important definitions used in the performance of the study.

1.4.1 LIFE SCIENCES. Life Sciences research includes biology, biomedicine, man-system integration, and life support/protective systems:

a. Space Biology is devoted to understanding the role of gravity and time in the maintenance of dysfunction of earth organisms and determining potential applications of this knowledge to earth surface problems.

b. Biomedicine is devoted to the medical qualification of man for long-term space flight by evaluation and understanding of changes in human functions and capabilities that may be induced by long duration space flight.

c. Man System Integration is devoted to providing qualitative and quantitative data relative to crew performance, crew operations, and equipment designs; effects of prolonged exposure to the space flight environment on man's individual and group behavior was also studied.

d. Life Support and Protective Systems is devoted to the acquisition of engineering data for advanced design of components and subsystems, the establishment of design criteria, and development of the technology that will enable man to perform space missions effectively and in safety.

1.4.2 LABORATORY EQUIPMENT ELEMENTS

a. Common Operational Research Equipment (CORE) is bench test or analysis equipment such as spectrophotometers, gas chromatographs, centrifuges, microscopes, specimen preparation facilities, or sample preservation facilities.

b. FPE-peculiar equipment (general purpose experiment hardware) is that hardware which can support a variety of experiments on a reusable basis such as a lower body negative pressure device, an MSI task board, a small vertebrate holding facility or a plant holding unit.

c. Experiment-peculiar equipment (special purpose experiment hardware) is that hardware designed specifically to implement and support a single experiment not reusable for another without modification.

d. Bioresearch centrifuge is an artificial gravity facility for biological research on both control and test organisms.

### 1.4.3 LABORATORY PAYLOADS DEFINED

a. Maxi Max Laboratory provides complete Blue Book payload capability (time period 1980 and beyond, five-year mission).

b. Maxi Nom Laboratory is the growth Space Station payload capability (time period 1980, two-year mission).

c. Mini-30 Laboratory is the initial Space Station payload or the extended sortie payload capability (time period 1978-1980, 30-day mission).

d. Mini-7 Laboratory is the early initial sortie payload capability (time period 1978-1980, seven-day mission).

e. A payload is any research or research related equipment that is emplaced within the structural and supporting elements of the spacecraft.

f. A laboratory is the total housing and contents making up any spacecraft area devoted to research in any science. The term is used to differentiate between separate supporting spacecraft areas and the spacecraft areas housing research equipment and operations. (Laboratory = Research Applications Module (RAM).

## 1.5 MISSION MODEL GUIDELINES

During the definition of requirements in Task A, candidates mission model guidelines were also determined for the payloads. These guidelines were used in Task B preliminary design studies, and are summarized in Table 1-1.

The maximum payloads will be supported by a RAM/space station complex to become operational beyond 1980. The planned mission duration of the life sciences laboratory is two-to-five years (90-day resupply), the atmospheric pressure is one atmosphere, and the space station crew is 6 to 12 men. The RAM diameter is 4.16 m (13.7 ft) and can be up to 17.7 m (58 ft) long.

The smaller payloads will also be supported by the RAM but operating with the RAM Support Module (RSM) and the shuttle in a sortie mode. The time period is 1977 to 1980, the mission duration is 7 to 30 days, and the research crew is 4 men.

The Skylab flights were also considered as possible supporting missions, but were dropped during the course of the study by NASA direction.

# Table 1-1. Mission Model Parameters

| PARAMETER | SKYLAB* | RAM[1]/RSM[2]/SHUTTLE | RAM/SPACE STATION |
|---|---|---|---|
| Operational Time Period | Flights of Opportunity | 1977 - 1980 | 1980 - Beyond |
| Payload Capacity | To Be Determined | 20,900 kg (46 k lbs) Total<br>RSM 16 k lbs<br>RAM 17 k lbs<br>Life Scien. Payload 13 k lbs | 11,360 - 13,600 (25k - 30k) Total<br>RAM 17 k lbs<br>Life Scien.<br>Payload 13 k lbs |
| Orbit: Altitude<br>Inclination | 407 km (220 n. m.)<br>0.611 rad (35°) | 185 km (100 n. m.)<br>0.497 rad (28.5°) | 500 km (270 n. m.)<br>0.96 rad (55°) |
| Mission Duration | 1 year | 7 - 30 Days | 2 - 5 years |
| Spacecraft: Diameter<br>Length | 6.7 m (22 ft)<br>13.4 m (44 ft) | 4.16 m (13.67 ft)<br>Approx. 10.7 m (35 ft) | 4.16 m (13.67 ft)<br>Up to 17.7 m (58 ft) |
| Cabin Atmospheric Pressures | Gas / $n/m^2$ / mm Hg / psia<br>Total 34,475 258.5 5.0<br>$O_2$ 25,511 191.0 3.7<br>$N_2$ 8,964 67.0 1.3<br>$CO_2$ 1,014 7.6 0.147 | Gas / $n/m^2$ / mm Hg / psia<br>Total 101,360 760 14.7<br>$O_2$ 21,340 160 3.09<br>$N_2$ 80,020 600 11.6<br>$CO_2$ 400 3 0.058 | → Same<br>→ "<br>→ "<br>→ " |
| Crew Numbers | 3 - 6 | 4 (30 Days) | 6 in 1980 12 in 1984 |
| Skills | Astronaut - Scientist | Scientist | Astronaut - Scientist |

* Skylab considerations used only for first generation layouts.

[1] RAM - Research Applications Module.

[2] RSM - RAM Support Module.

# SECTION 2

# PAYLOAD RESEARCH REQUIREMENTS DEFINITION

The definition of research requirements is based on a general laboratory facility approach rather than a specific experiment approach. The experiments that will be accomplished in the time frame of the candidate payloads cannot be accurately defined at present. The kind of experiments that will be selected are highly dependent on the experimental results of earlier flights. If physiological questions arise regarding man's ability in space, the emphasis for all Life Sciences will be toward physiological research. However, if man proves adaptable to zero gravity and can readapt to the earth environment, the research emphasis may include a variety of major areas, such as behavior, crew operations, circadian rhythms, zero-gravity physiology, host parasite relationship, exobiology, and radiation biology. Some of the experiments may be a continuation of Skylab experiments but many will be new. Also, the long mission duration of the advanced research laboratories requires that they be capable of accommodating unknown experiments.

The approach to defining the facility's research capability emphasized earth-based-laboratory functional requirements and the related equipment to perform these functions. This approach is described in this section along with the research capability of the baseline payloads.

## 2.1 SUMMARY OF BASELINE PAYLOAD RESEARCH CAPABILITY

A summary of the capability of the baseline payloads is shown in Table 2-1 in terms of the research test subjects that can be supported. Also indicated, where applicable, are the resulting number of cage modules required. A cage module is a basic holding unit used in all the payloads to house small vertebrates, plants, invertebrates, cells, and tissues. It is basically a sealed (but ventilated) cabinet approximately 0.5 m by 0.5 m by 0.65 m. See Section 4.2 for further details.

The capability of the Maxi Max payload is basically the entire contents of the Blue Book as modified slightly by NASA during the program. The number of primates was increased to six, to include two five-foot primate spheres and four primate cylinders. These were to be divided equally between the main zero-g lab and the centrifuge module. The radiobiology room was reduced, because of the elimination of the X-ray requirement, to make the facility approximately one-quarter that listed in the Blue Book. The resulting facility is pie shaped with an exposure area of approximately 1.5 m by 1.5 m and a 1-meter source-to-subject distance.

Table 2-1. Summary of Baseline Payload Test Subject Capacity

| Blue Book FPE and Test Subjects | Number of Test Subjects Aboard Baseline Payloads | | | |
|---|---|---|---|---|
| | Mini-7 | Mini-30 | Maxi Nom | Maxi Max |
| Vertebrates: | | | | |
| Chimpanzees | 0 | 0 | 0 | 2 |
| Macaques | 0 | 2 | 2 | 4 |
| Rats | 0 | 16 (2 cm) | 128 (16 cm) | 512 (64 cm) |
| Plants: | | | | |
| Marigolds | 16 (1 cm)* | 16 (1 cm) | 128 (8 cm) | 288 (18 cm) |
| Invertebrates | (1 cm) | (1 cm) | (2 cm) | (6 cm) |
| Cells and Tissues | (2 cm) | (2 cm) | (2 cm) | (8 cm) |
| Biomedicine: | | | | |
| Human Subjects | 0 | 4 | 12 | 12 |
| Life Support and Protective Systems: | | | | |
| Hardware Test Units | 1 | 1 | 1 | 2 |
| Manned System Integration: | | | | |
| Human Test Subjects | 4 | 4 | 12 | 12 |
| Centrifuge | None | None | Internal | Separate Module |

*Indicates the number of cage modules (cm) to support the organism.

The Maxi Max with full Blue Book capability requires two zero-g modules (RAMs) for the containment of the entire facility in addition to the third research centrifuge module. Generally, one zero-g module is devoted to biology research, and the other is primarily devoted to biomedical, life support, and manned system integration research. The Common Operational Research Equipment (CORE), which is specified in the Blue Book and contains some equipment to support all life sciences research, is placed partly in each of the two zero-g modules. The placement is according to usage of the individual CORE items, and some of the CORE equipment units are divided between the two laboratories. An example is the CORE unit for visual records and microscopy, which is generally required by all the FPEs. The biomedical recorder, an item within this equipment unit, is placed in the module containing biomedical research. On the other hand, microscopes are placed in the biology module. For complete information on the CORE and other equipment placement, see Section 3.

The Maxi Nom baseline payload is contained in a single RAM module with two chambers — one for biology and one for manned research consisting of biomedicine, life support and protective systems, and manned systems integration. The distribution of CORE in the Maxi Nom is also divided between the two compartments. The manned research capability for Maxi Nom is basically the same as that of Maxi Max or Blue Book where 12 men are assumed available as subjects. In the biology area, the large research centrifuge has been eliminated and a small internal biology centrifuge is substituted. The centrifuge can accommodate eight cage modules that house vertebrates: however, the mix of organisms on the centrifuge can be anything that is required by the research experiments. Preliminary considerations have been given to utilization of this internal centrifuge for the accommodation of some of the manned research centrifuge requirements. Indications are that some of the manned requirements can be met if the centrifuge were so outfitted. The number of primates in the Maxi Nom is two macaque-type primates, no chimpanzees. The macaque holding units will be two cylinders (no spheres). The number of vertebrates that can be accommodated in Maxi Nom is one-quarter that of Maxi Max or 128 rats or rat equivalents divided equally between the zero-g laboratory and the centrifuge. Similarly, the plant facility will accommodate 128 marigolds or marigold-equivalent plants. Two cage modules are allocated for invertebrate research — providing incubator volume of approximately 0.34 $m^3$ (12 cu ft). Two cage modules of similar volume are allocated for cells and tissues.

The Mini-30 payload capability is much smaller than the Maxi Nom. The number of primates, however, is the same — two macaques or their equivalent. There are two cage modules allocated for 16 rats or rat-equivalent organisms, one cage module that can contain 16 marigolds or their equivalent, one cage module allocated for invertebrates, and two cage modules for cells and tissues. Cell and tissue research in both of the Mini payloads is emphasized due to the limitations of volume and also the high reproductive rate inherent in these organisms, providing generations of these organisms that have been reared in the weightless state. The number of men available as test subjects for biomedicine and manned systems integration is four. The life support and protective systems capability is based on the requirement to accomplish one experiment at a time.

The Mini-7 payload does not contain any vertebrates as it is felt that a five-day on-orbit mission is inadequate time for the experiment effects to be manifested in these organisms. Also, the elimination of vertebrates in this payload significantly reduces the weight, power, and volume requirements. One cage module is allocated for plants, one cage module is available for invertebrates, and two cage modules are included for cells and tissues. The emphasis is on cells and tissues for the reasons previously stated for the Mini-30 payload. Biomedical research in the Mini-7 payload is also eliminated for the same reasons that the vertebrate research is eliminated. It is felt that the knowledge gained regarding man's physiology by the time the Mini-7 becomes operational will be much greater than can be obtained in the five-day missions of this payload. In life support/protective systems, only one piece of hardware need be

evaluated during each flight. Manned systems integration has a minimal capability to do only the most critical things that have been found to be problems in previous flights.

## 2.2 SOURCES USED IN DETERMINING RESEARCH REQUIREMENTS

The study team for the Task A effort (definition of requirements) was comprised of members of various disciplines and working environments. The team members included biologists and engineers at the Ames Research Center (ARC) and the Marshall Space Flight Center (MSFC) representing NASA, University of California at San Diego biologists representing the academic community, and Convair personnel representing industry. Study expansion from Space Biology to Life Sciences required additional inputs from other NASA centers — primarily the Manned Spacecraft Center (MSC) for Biomedicine. MSFC and ARC also provided personnel to assist and critique the total program effort.

The literature data sources consisted of documents, working papers, vendor data, equipment specifications. Table 2-2 lists the more significant documents of this data base. The Blue Book was the primary source of data used, and, this data was generally given precedence over other conflicting data. The major sources of data shown in Table 2-2 are included in the reference section of this report.

Table 2-2. Program Data Base

| Documents | Publisher |
|---|---|
| Blue Book | NASA/Convair |
| Earth Orbital Exp. Study | MDAC |
| Biotechnology Study | MDAC |
| IMBLMS | |
| B-3 Functional BB | LMSC/GE |
| Functional BB Performance Review | LMSC/GE |
| B-4 Statement of Work | NASA |
| Phase B Final Report | LMSC/GE |
| MSC End Item Specification for Inflight Medical Support System | NASA |
| Experiment Module Concepts | Convair |
| Space Station/Base | MDAC/Martin and NR/GE |
| Orbital Workshop | Martin |
| Space Shuttle | Convair/NR |
| Human Performance Prediction | Bunker-Ramo |
| Advanced Integrated Life Support Systems | HSD |
| Communications and Working Papers | |
| Ames Experiments and Common Use Equipment | |
| MSFC Communications and Working Papers | |
| Vendor/Mfg Specifications and Communications | |
| Ames Direct Communications | |
| MSC IMBLMS Review Meeting | |

## 2.3 FUNCTIONS AND EQUIPMENT INVENTORIES

The approach to defining payload research requirements utilized both a functions and equipment inventory.

The functions inventory is a list of possible research functions (activities), some of which will have to be performed aboard any given spacecraft laboratory. Similarly, the equipment inventory is a list of the possible equipment that might be needed in a given laboratory to support the research.

The functions were developed from the data base and form an inventory of about 445 reasonable activities required for space research. The equipment inventory contains approximately 380 items. Due to the size of these inventories, and the requirement to periodically accept new data, a computerized listing (and processing program) was developed. These listings can be updated as required to provide support for future life sciences payload studies. The present life sciences function and equipment inventories plus the computer output data on the four selected baseline payload functions and equipment require more than 25,000 lines of computer printout. The printouts, because of their size, are not a part of this final report but are available upon request of the NASA/MSFC computer center.

An overview of the functions/equipment inventory and its relation to the computer program is shown in Figure 2-1. As indicated, the program data sources provided

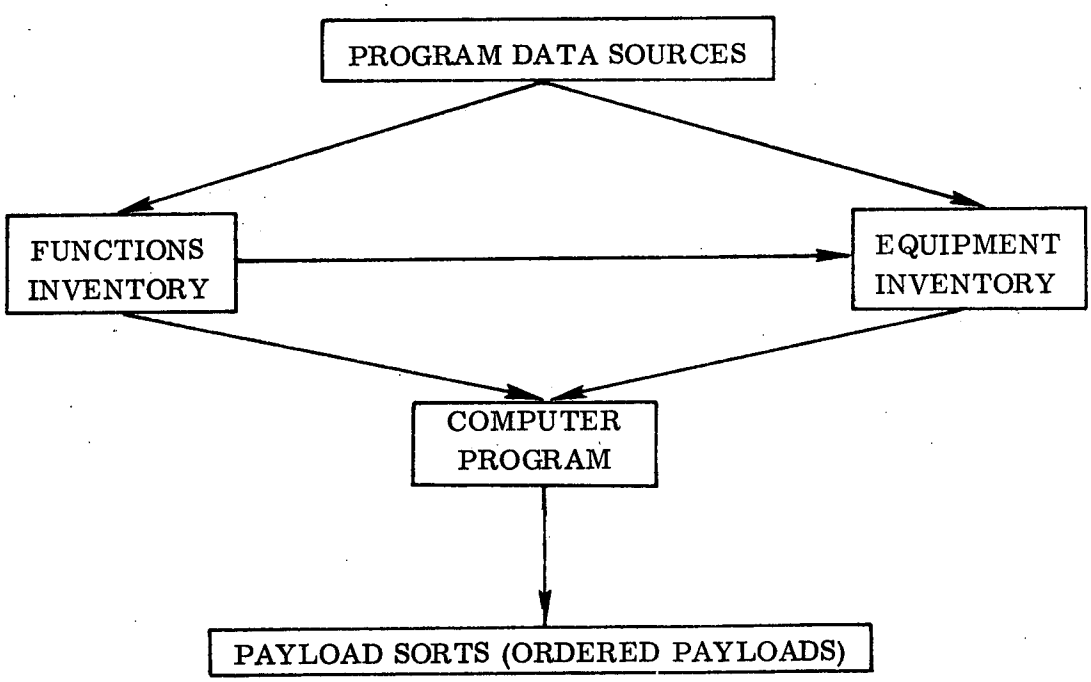


Figure 2-1. Overview of Program Activities in Establishing the Functions and Equipment Required for Life Science Payloads

information relative to the development of the functions and equipment inventories. In addition, the definition of the functions led to additional equipment items as well as better understanding of equipment requirements. As indicated in Figure 2-1, these two inventories were used as input to a digital computer program that was written to sort out and list the functions and equipment in an ordered payload. The ordered payload is one resulting from instructions to the computer on the specific functions desired as well as the number and type of equipment desired. These instructions result from various payload and mission guidelines that are used to manually screen the inventories and select appropriate functions and equipment. The specific procedures for obtaining ordered payloads are discussed in Section 2.4. The functions and equipment inventories are described in the following two sections.

2.3.1 FUNCTIONS INVENTORY DESCRIPTION. To summarize the information on all of the functions and make it usable for payload designs and decisions, it was placed on computer cards in code or abbreviated form. In the process, information about the functions was estimated and also included on cards. A sample portion of the functions inventory is shown in Figure 2-2 and a complete list of all the functions titles is contained in Figure 2-3.

```
C     CARD NUMBER 1 - FUNCTION TITLE AND DESCRIPTION
C
C        CARD NUMBER 2      *          CARD NUMBER 3     *    4
C
C F M C  C P  U       T E M*       E M S T   T   C  C  H*R C L M H
C U L A  R A  S       A N O*       N O C IF  IE  RS RS A*E R O A AI
C N T R  I Y   E      S V D*       V D I MII MAA EK EK Z*D E G I RNR
C C H D  T L     R    K  E*         E  ERT ECD WI WI A*U W I N DVE
C T O    I O  F         D  *      A   R  SE  HD  L  L R*N   S I WNF
C I D N  C A  P       T E D*      C A E  TM   I  L  L D*D I T B ATR
C O   O  A D   E      Y S E*      T C S       T          *N N I L RON
C R   .  L            P R S*      U T P       N          *C F C T ERC
C        Y  MVPICBLH   . D .*      L L N       L          *Y C S Y  YE
C
  39  1 THYROID FUNCTION TESTS-SERUM STABLE WHEN IF ALL CELLS REMOVED
  39  2  3 3 MV   B     1 1 M* PROCESS AND STORE FOR GROUND ANALYSIS
 39A 3 PROCESS AND STORE                1 M 2  20   2  3  1 1*
 39A14 CLOT TUBES                                              *1 2 2 1 105
 39A24 CENTRIFUGE                                              *1 3 1 2 041
 39A34 FREEZER                                                 *1 3 1 1 080

  40  1 BLOOD MORPHOLOGY AND CELL COUNTS
  40  2  1 1 MV   B     1 1 M*WRIGHTS STAIN AND METHYLENE BLUE STAINS
 40A 3 SMEAR,STAIN,AND READ             1 M 2  20   8  1  4 0*
 40A14 CELL COUNTER DIFFERENTIAL MANUAL OPS                    *0 3 0 1 106
 40A24 WRIGHT STAIN APPARATUS                                  *0 3 2 3 156A
 40A34 METHYLENE BLUE CAPILLARY SYSTEM STAINING KIT            *0 3 2 2 106
 40A44 MICROSCOPE LIGHT OIL IMMERSION 2000X                    *1 4 1 4 126
 40A54 MICROSLIDE AND MICROSLIDE CATALOGUE                     *1 2 2 1 106
 40B 3 SMEAR,STAIN AND XMIT DATA-GR  1 S 2  20   4  1  4 1*
 40B14 WRIGHTS STAIN APPARATUS                                 *0 3 2 3 156A
 40B24 MICROSLIDE AND MICROSLIDE CATALOGUE                     *1 3 2 1 106
 40B34 METHYLENE BLUE CAPILLARY SYSTEM STAINING KIT            *1 3 2 2 106
 40B44 MICROSCOPE LIGHT OIL IMM WITH VIDEO CAMERA ADAPTOR      *1 4 1 4 126
 40B54 VIDEO COLOR CAMERA AND DATA MGMT                        *0 4 1 4 038
 40C 3 SMEAR,STAINCOMPUTER READOUT   1 S 2  12   4  1  4 1*
 40C14 WRIGHTS STAIN APPARATUS                                 *0 3 2 3 156A
 40C24 MICROSLIDE AND MICROSLIDE CATALOGUE                     *1 3 2 1 106
```

Figure 2-2. Functions Inventory Printout

```
 1   1 ORGANISM RECVNG - SHIPPING ORGS IN CAGE VS SHIPPING CONTAINR. IF
 2   1 MATERIAL RECVNG- SAME TECHNIQUE AND TRADEOFF AS FUNC NO.1
 3   1 VERTEBRATE FEEDING- SOLID PELLETS ARE SUPPLIED ADLIB OR REGULATD
 4   1 VERTEBRATE WATERING- REQ DRIPLESS ANIMAL ACTUATED DISPENSOR TIPS
 5  11 URINE MGMT AT CAGE- URINE MUST BE REMOVED QUICKLY (MINUTES)
 6   1 URINE MGMT FROM CAGE COLLECTOR TO STORAGE OR DISPOSAL
 7   1 FECES MGMT AT CAGE -FECES MUST BE MOVED FROM ANIMAL AND COLLECTD
 8   1 FECES MGMT-CAGE TO DISPOSAL   LIQUID TO SOLID CONSISTANCY
 9   1 ORGANISM MASS MEASUREMENTS
10   1 HOLDING PRIMATES MMR -MEASURES BASIC METABOLISM AT WORK/REST
11   1 HOLDING RAT AND RAT SIZE ANIMALS FOR METABOLIC MSMTS
12   1 HOLDING MOUSE MMR-SAME AS FOR RAT
13   1 HOLDING CAGE MMR-RABBITS/MARMOTS ETC
14   1 BIOELECTIC XDCR INSTALLATION AND SETUP- REWARE EMI-
15   1 CAMERA SETUP
16   1 SETUP CAMERA OPTICAL COMMUTATION-ORGANISM TO ORGANISM
17  11 MONITOR ECG (FOR BIORESEARCH - ECG SIGNAL MGMT FROM CAGE TO CAGE
18  11 MONITOR EEG (FOR BIORESEARCH - EEG SIGNAL MGMT FROM CAGE TO CAGE
19   1 MONITOR EMG-EMG SIGNAL MGMT CAGE TO CAGE MOD TO DATA MGMT
20   1 RESPIRATORY  RATE MONITORING- DOES NOT INCLUDE RESP VOLUME
21   1 CARDIAC OUTPUT- IMPLANTED FLOW XDCR-SIGNAL XFR TO DM AS FUNC 17
22   1 TEMPERATURE MSMTS
23   1 NUTRIENT CONSUMPTION- A COUNT OF THE NUMBER OF PELLETS CONSUMED
24   1 WATER CONSUMPTION -WATER CONSUMED OR WATER DELIVERD
25   1 MUSCULOSKELETAL TONUS
26   1 LIQUID VOLUME MSMTS- MICRO VOLUMES  .001 ML TO 1 ML
27   1 LIQUID VOLUME MSMTS- MACRO  1 ML TO 1000 ML
28   1 MASS MEASUREMENTS OF CONTAINED LIQUIDS AND SOLIDS
29   1 MASS MEASUREMENTS- CONTAINED LIQUIDS AND SOLIDS
30   1 GROSS ANATOMIES-ASSESSMENT OF MAJOR ORGANS-SIZE SHAPE MASS COLOR
31   1 BIOSAMPLING-OBTAINING BLOOD WHOLE ORGANSM LEAVES ETC FOR ANALYS.
32   1 SPECIMEN STATUS OBSERVATION-PERIODIC LOOK AT ORGANISMS IN CAGES
33   1 BLOOD PREPARATION-SYRINGE-TUBE/CAPILLARY WITH NAF EDTA ETC
34   1 BLOOD ELECTROLYTES
35   1 BLOOD PH PCO2 O2    MSUR CONC OF DISSOLVED GS IN BLOOD
36   1 BLOOD TOTAL PROTEIN  MSUR CONC IN SERUM OR WHOLE BLOOD
39   1 THYROID FUNCTION TESTS-SERUM STABLE WHEN IF ALL CELLS REMOVED
40   1 BLOOD MORPHOLOGY AND CELL COUNTS
41   1 HEMATOCRIT  MSUR OF PACKED CELL VOL TO TOTAL VOL
42   1 HEMOGLOBIN-MSUR CONC OXYHGB OR CARBOXYHGB
43   1 DIGITAL RECORDS-RECORDING OF INSTRUMENT DATA
44   1 ANALOG RECORDS- RECORDING OF INST DATA
45   1 RBC OMOTIC FRAGILITY-MSUR RUPTURE PRESSURE OF RBC
47   1 IMMUNOGLOBIN ASSAY- MSUR ANTIBODY FORMATION
48   1 ANTIBODY TITRATION-DETERMINE ANTIBODY CONC TO SPECIFIC DISEASE
49   1 PRESSURE MONITORING
50   1 GAS SAMPLING- OBTAIN GAS FROM SITE XFER TO INSTMT
51   1 TRACE GAS ANALYSIS HYDROCARBONS-SPECIFIC COMPOUND/PREDETERM LIST
52   1 TRACE GAS ANALYSIS INORGANICS
53   1 OXYGEN MONITORING
54   1 CARBON DIOXIDE MONITORING
55   1 NITROGEN MONITORING
56   1 CARBON MONOXIDE MONITORING
57   1 WATER VAPOR MONITORING
58   1 AMMONIA MONITORING
59   1 ATMOSPHERIC ETHYLENE MONITORING  SENS TO 50PER
61   1 VIBRATION MONITORING
62   1 ACCELERATION MONITORING 10-5 TO 1G  0-100HZ
63   1 RADIATION MONITORING AT ORGNSM HOLDNG AND THROUGHOUT LAB
64   1 NOISE MONITORING
65   1 PLANT ACTIVITY-MSUR GROWTH AND MOVEMENT OF PLANTS
66   1 ANIMAL ACTIVITY- MSUR ANIMAL ACTIVITY IN STD AND MMR CAGES
67   1 LIPID ANALYSIS IN BIOLOGICAL SYSTEMS
68   1 ORGANISM IDENTIFICATION FILM
69   1 CARBOHYDRATE ANALYSIS-SOLUABLE/INSOLUABLE
70   1 AIR MOVEMENT
71   1 LIGHT MONITORING-ON/OFF AND INTENSITY -ASSUME NO FREQ DATA REQ
72   1 ORGANISM IDENTIFICATION VIDEO RECORDS
73   1 DATA STORAGE
75   1 CREW GUIDANCE - PROVIDE DESIRED INFORMATION TO CREW ON DEMAND
76   1 EXPERIMENT MANAGEMENT SYSTEM
77   1 MICROSCOPY GENERAL
78   1 INVERTEBRATE COUNTING AND SORTING  (INSECTS)
79   1 ORGANISM SUBCULTURE-SUBSTRATE PREPARATION
80   1 ORGANISM SUBCULTURE-PLANTS
81   1 MEDIA PREPARATION-CELLS AND TISSUE
82  11 WORK BENCH CLEANUP - DEACTIVAT EQUIP, RECAGE OR DISPOSE OF SPEC-
83   1 WORKBENCH STERILIZATION
84   1 ORGANISM SUBCULTURING-CELLS AND TISSUE
85   1 STARCH GRANULE ASSAY
86   1 BACTERIAL COLONY COUNTING
87   1 MICROORGANISM IDENTIFICATION
88   1 BACTERIAL SMEAR STAINING
89   1 HISTOLOGICAL SECTIONING-WAX AND PLASTIC EMPEDMENT
90   1 HISTOLOGICAL STAINING
91   1 PLANT RADIOCHEMISTRIES
92   1 VERTEBRATE RADIOCHEMISTRIES
93   1 INVERTEBRATE RADIOCHEMISTRIES
94   1 CELLS AND TISSUE RADIOCHEMISTRIES
95   1 RADIO ISOTOPE METHODOLOGY-PREPARATION AND MGMT
96   1 RADIOCHEM WASTE MGMT- RADIOCHEMS,ORGNSMS,AND PARTS
97   1 EXPERIMENT WASTE MGMT
98   1 DISTILLED/STERILE WATER PREPARATION
99   1 STERILIZATION OF TOOL/EQUIP
100   1 STERILIZN OF MEDIA  -NOT REQD IF PREPKGD
101   1 STERILZN OF HOLDNG UNITS
102   1 STERILIZN OF ATM GASES
103   1 ORGANSM HOLDING UNIT CLEANUP
104   1 HOLDING UNIT MANIFOLD CLEANUP
105   1 ORGANISM OR SAMPLE PRESVN WITH GAS OR LIQUID CHEMICALS
106   1 ORGANISM/SAMPLE PRES THERMAL
107   1 ORGANISM/SAMPLE PRESVN LYOPHIL
108   1 BACTERIAL CELL COUNTING
109   1 PLANT LIGNIN ASSAY
110   1 PLANT CELLULOSE ASSAY
112   1 OXYGEN MSMTS MMR
113   1 CARBON DIOXIDE MSMTS MMR
114   1 CYTOPLASMIC STREAMING-PLANTS
124   1 CREW/ORGANISM ISOLATION- REQMT TBD
125   1 CREW/CHEMICAL ISOLATION
126   1 CREW RADIATION ISOLATION
127   1 CREW MOBILITY/TRANSFER - CREW ACCESS TO ANY LAB AREA, WALLS, ETC
128   1 MATERIALS TRANSFER - MOVE CARGO,TOOLS,SPECIMEN IN/OUT AROUND LAB
129   1 HOLDING-PRIMATES- LARGE MACAQUE TO CHIMPANZEES
130   1 HOLDNG-MICE AND MICE SIZE ANIMALS
131   1 HOLDING,RATS QUAIL ETC
132   1 HOUSING-PLANT SEEDLINGS
133   1 HOLDING UNIT PLANTS
134   1 HOLDING-RABBITS CATS MARMOTS ETC
135   1 HOLDING-CELLS AND TISSUE
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Figure 2-3. Functions Inventory (Sheet 1)

136 1 HOLDING INVERTEBRATES
137 1 HOLDING-COLONY MICE HAMSTERS ETC
138 1 HOLDING COLONY RATS
139 1 HOLDING COLONY MARMOTS/RABBITS
141 1 AIRPARTICULATE SAMPLING AND ANALYSIS
142 1 MICRORIOLOGICAL SAMPLING, AIR, SURFACES AND LARGE ORGANISMS
143 1 PLANT HOMOGENATION
145 1 CENTRIFUGATION
148 1 THERMAL CONTROL OF CHEMICAL PREPARATIONS-WATER BATH SUBSTITUTE
149 1 URINE ANALYSIS
155 1 URINARY PHOSPHATES
156 1 URINE CREATININE AND CREATINE
161 1 ARTERIAL BLOOD PRESSURE
162 1 X-RAY DIAGNOSTIC
163 1 RADIATION EXPOSURE
164 1 PERIPHERAL VENOUS BLOOD PRESSURE
165 1 EVENT MONITORING
166 1 LINEAR MEASUREMENTS
167 1 ANAESTHESIOLOGY-VERTEBRATES
168 1 ANAESTHESIOLOGY-INVERTEBRATES
169 1 TELEVISION MONITORING ROUTINE AND FOR DATA B/W HIGH RESOLUTION
170 1 TV MONITORING AD HOC -COMMERCIAL GRADE COLOR
173 1 PLANT LIPIDS
174 11 ENZYME ASSAY-RECOMMEND ASSAYS POSSIBLE ON CRUDE HEMOGENATES AND
175 1 AMINO ACIDS ASSAY
177 1 PROTEIN ASSAY
180 1 PLANT HORMONES
181 1 PLANT ION TRANSPORT SYSTEM
184 1 CLINOSTAT ENVIRONMENT
185 1 CYTOCHEMICAL STAINING PLANTS
186 1 CYTOCHEMICAL STAINING -ANIMAL SYSTEMS - HEMATOXALIN/EOSIN
187 1 NUCLEIC ACID ASSAY
195 1 ARTIFICIAL GRAVITY -APPROX 50 PERCENT OF HOLDING CAPACITY
196 1 PRIMATE CAGE PREPARATION- INSTALL INSERTS,FEEDERS,EXPMT EQUIP---
197 1 VERTEBRATE CAGE PREPARATION-SETUP CAGES AND HOLDING UNIT
198 1 PLANT HOLDING UNIT PREPARATION-INSTALL LITES,WATER,EXPT EQUIP---
199 1 INVERTEBRATE CAGE AND HOLDING UNIT SETUP
200 1 CELLS AND TISSUE HOLDING UNIT SETUP/PREPARATION
201 1 CREW RESTRAINT - STABILIZE THE CREW FOR MAX SAFTY AND EFFICIENCY
206 1 VERTEBRATE BEHAVIOR STUDY
207 1 EXPERIMENT TERMINATION-PRIMATES-
208 1 EXPERIMENT TERMINATION-SMALL VERTEBRATES
209 1 EXPERIMENT TERMINATION-PLANTS
210 1 EXPERIMENT TERMINATION-CELLS AND TISSUE
211 1 EXPERIMENT TERMINATION-INVERTEBRATES
212 1 PREPARATION FOR XFER TO RECOVERY VEHICLE-PRIMATES
213 1 PREPARATION FOR XFER TO RECOVERY VEHICLE-VERTS
214 1 PREPARATION FOR XFER TO RECOVERY VEHICLE-PLANTS
215 1 PREPARATION FOR XFER TO RECOVERY VEHICLE-CELLS/TISSUE
216 1 PREPARATION FOR XFER TO RECOVERY VEHICLE- INVERTEBRATES
218 1 DEEP BODY TEMPERATURE- IMPLANTABLE SENSOR
222 1 VERTEBRATE EXPERIMENT INITTATION
223 1 PLANT EXPERIMENT INITIATION
224 1 INVERTEBRATE EXPERIMENT INITIATION
225 1 CELLS AND TISSURE EXPERIMENT SETUP.
226 1 CELLS AND TISSUE POPULATION DENSITY
227 1 ORGANISM EXPOSURE TO SPACE RADIATION
300 1 VOMITUS COLLECTION
301 1 VOMITUS PRESERVATION AND STORAGE
302 1 SWEAT SAMPLE COLLECTION
303 1 SWEAT PRESERVATION AND STORAGE
304 1 LOWER BODY NEGATIVE PRESSURE (LBNP)
305 1 SPACE SUIT SUPPLY AND CONTROL FOR EXPERIMENTAL SETUPS
306 1 EAR CANAL CALORIC STIMULATION
307 1 SPATIAL LOCALIZATION
308 1 ELECTRO-OCULOGRAM (EOG) 0.14-100HZ A-D AT LEAST 500 SAMP/SEC
309 1 ROUTINE METABOLIC GAS MONITORING
310 1 BICYCLE ERGOMETRY
312 1 ELECTRONIC EQUIPMENT CALIBRATION
313 1 ATMOSPHERIC MONITOR CALIPRATION
314 1 BIOCHEMANALYTICAL EQUIPMENT CALIBRATION
315 1 TOTAL BODY WATER
316 1 AGRAVIC PERCEPTION
317 1 OCULAR COUNTER-ROLLING
318 1 OCULOGYRAL ILLUSION
319 1 VECTORCARDIOGRAM (VCG) 0.05-500HZ A-D AT LEAST 2500 SAMP/SEC
320 11 PHONO/VIBROCARDIOGRAM (PCG/VBCG) 0.1-20HZ 10-30HZ 30-500HZ AND
321 1 IMPEDANCE CARDIOGRAPHY (ZCG) A-D 100 SAMPLES/SEC
322 1 VENOUS BLOOD PRESSURE -INVASIVE DURING VENIPUNCTURE
324 1 PULSE WAVE VELOCITY
325 1 PULSE WAVE CONTOUR
326 1 BALLISTOCARDIOGRAPHY (BCG) AT LEAST 800 SAMPLES PER SEC
327 11 RESPIRATORY VITAL CAPACITY (VC),TIMED VITAL CAPACITY (VC1,VC3)
330 1 RESPIRATORY DEAD SPACE (VD) ALVEOLAR VENTILATION (VA) RESIDUAL VOL (VR)
331 1 RESPIRATORY AIRWAY RESISTANCE (RA)
332 1 LUNG COMPLIANCE A-D AT LEAST 100 SAMP/SEC
333 1 BLEEDING TIME
334 1 CLOTTING TIME
335 1 ERYTHROCYTE SURVIVAL
336 1 PLASMA GLUCOSE
337 1 PLASMA PHOSPHATE
338 1 PLASMA ALKALINE PHOSPHATASE
339 1 PLASMA BILIRUBIN
340 1 PLASMA GLOBULINS
341 1 PLASMA IMMUNOGLOBINS
342 1 PLASMA COAGULATION
343 1 BODY MASS MEASUREMENT DEVICE (BMMD) FOR MAN
344 1 ELECTRONYSTAGMOGRAM (ENG)
345 1 ANGULAR ACCELERATION THRESHOLD
346 1 SUBJECT HISTORIES
347 1 INTRAOCULAR PRESSURES
348 1 GONAD HISTOPATHOLOGY
350 1 CREW METABOLIC RECORDS -FOOD/WATER CONSUMPTION-URINE/FECES PRODUCTION
351 1 BONE DENSITOMETRY- PHOTON ABSORPTION
352 1 RADIOISOTOPE COUNTING-WHOLE BODY
353 11 CULTURE/SENSITIVITY- MICROORGANISM GROWTH CAPABILITY IN PRESENCE
354 1 EAR CANAL TEMPERATURE
355 1 MUSCLE STRENGTH AND SIZE
356 1 SUBJECT INSTRUMENTATION AND CLEANUP
357 1 GASTRIC PRESSURE AND PH
358 1 BIOMEDICAL EQUIPMENT CLEANUP/DISPOSAL
359 1 HEART RATE
360 1 RENAL CLEARANCE PAH
361 1 WBC PHAGOCYTOSIS
364 1 VISUAL TASK WITH HEAD ROTATION
365 1 VENOUS COMPLIANCE (LVMS)
366 1 ARTERIOLAR REACTIVITY
368 1 STOOL PRESERVATION
369 1 URINE PRESERVATION
370 1 VIRAL CULTURING

**Figure 2-3. Functions Inventory (Sheet 2)**

371 1 VIRAL IDENTIFICATION
372 1 FUNGAL CULTURING
373 1 FUNGAL IDENTIFICATION
400 1 GALAVANIC SKIN RESPONSE (GSR)
401 1 ALVEOLAR VENTILATION
402 1 LUNG DIFFUSION CAPACITY
403 1 AVERAGE SKIN TEMPERATURE
404 1 RED BLOOD CELL MASS (RBC MASS)
405 1 BLOOD PLASMA VOLUME
406 1 URINE, MICROSCOPIC ANALYSIS
407 1 URINE CHEMICAL ANALYSIS (BILE,ACETONE,CA,NA,K,CL AND BLOOD)
408 1 SGOT (SERUM GLUTAMIC OXALACETIC TRANSMAMINASE)
409 1 SGPT (SERUM GLUTAMIC-PYRUVIC TRANSAMINASE)
410 1 BODY WATER BALANCE (WATER INTAKE/OUTPUT INCLUDING SWEAT)
411 1 MINERAL BALANCE
412 1 FECAL MASS/NET WEIGHT MEASUREMENT
413 1 LEAN BODY MASS
414 1 IMPEDANCE PNEUMOGRAM FOR MAN
415 1 LUNG VOLUMES
416 1 TRACKING MEASUREMENTS
417 1 PLASMA CHOLESTEROL
418 1 URINE VOLUME
419 1 NITROGEN BALANCE
420 1 CALORIC INTAKE
421 1 WATER CONSUMPTION FOR MAN
422 1 CORIOLIS SICKNESS SUSCEPTIBILITY
423 1 REGIONAL BLOOD FLOW MEASUREMENT
424 1 CAROTID BODY STIMULATION RESPONSE MEASUREMENT
425 1 BLOOD RHEOLOGY/ENCEPHARORHEOGRAMM (ERG)
426 1 PROTHROMBIN CONSUMPTION
427 1 PLATELET ADHESIVENESS
428 1 FIBRINOLYTIC ACTIVITY
429 1 SERUM ANTIDIURETIC HORMONE (ADH)
430 1 BLOOD, 17 HYDROXYCORTICOSTEROIDS
431 1 BLOOD UREA NITROGEN (BUN)
432 1 BLOOD URIC ACID
433 1 BLOOD BICARBONATE
434 1 CREATININE PHOSPHOKINASE (CPK) BLOOD
435 1 SERUM LACTIC ACID DEHYDROGENASE (LDH) AND LDH ISOENZYMES
436 1 BLOOD ADRENOCORTICOTROPIC HORMONE (ACTH)
437 1 BLOOD TBPA
438 1 BLOOD HISTAMIN
439 1 LYMPHOCYTE KARIOTYPING
440 1 TRANSFERRINS, BLOOD
441 1 WHOLE BLOOD METHOMEGLOBIN
442 1 RBC ENZYME MEASUREMENT
443 1 COMPLEMENT TITRATION, BLOOD
444 1 THYROID STIMULATING HORMONE
445 1 BLOOD GROWTH HORMONE
446 1 SERUM PARATHYROID HORMONE
447 1 SERUM CALCITONIN
448 1 INSULIN ASSAY
449 1 GLUCAGON ASSAY
450 1 BLOOD SEROTONIN (5HIAA)
451 1 ANGIOTENSION II
452 1 MEMBRANE ASSAY AND CYTOGENIC ANALYSIS, BLOOD CELLS
453 1 URINE, CALCIUM
454 1 URINE, MUCOPROTEINS
455 1 URINE, PYROPHOSPHATES
456 1 URINE, HYDROXYPROLINES
457 1 URINE, TOTAL AMINO ACID
458 1 URINE, ALDOSTERONE
459 1 URINE, ANTIDIURETIC HORMONE (ADH)
460 1 URINE, 17, HYDROXYCORTICOSTEROIDS
461 1 URINE, 17, KETOSTEROIDS
462 1 URINE, VINYL MENDELIC ACID (VMA)
463 1 URINE, METANEPHRINES
464 1 URINE, CATACHOLOAMINES
465 1 URINE, HISTAMINES
466 1 URINE, SEROTONINE (5HIAA)
467 1 URINE, SULFATE
468 1 ELECTROMAGNETTIC FIELD MONITORING
469 1 ROTATING LITTER CHAIR (RLC)
500 1 CONTROL OF EXPER PARAMETERS - T,P,FLOW,POWER,ETC.
501 1 ANALYSIS OF GAS MIXTURES FOR O2,N2,CO2,CO,CH4,H2O,H2,NH3,ETC
502 1 MAKE AND BREAK FLUID CONNECTIONS - LIQUID AND GAS
503 1 WATER ANALYSIS -CONDUCTIVITY MEASUREMENT
504 1 WATER ANALYSIS - PH MEASUREMENT (H2 ION CONCENTRATION)
505 1 WATER ANALYSIS - TOTAL SOLIDS CONTENT
506 1 WATER ANALYSIS - BACTERIOLOGICAL ASSAY
507 1 LIQUID TRANSFER
508 1 VACUUM SUPPLY
509 1 GAS MANAGEMENT SYSTEM FOR EXPERIMENT SUPPORT
510 1 ELECTRICAL POWER SYSTEM FOR EXPERIMENT SUPPORT
511 1 ELECTRICAL CONTINUITY AND VOLTAGE MEASUREMENTS
512 1 ELECTRICAL AMPERAGE MEASURMENTS
513 1 ELECTRICAL MAINTENANCE
514 1 MECHANICAL MAINTENANCE
515 1 SUPPLY OF COOLANT
516 1 ATMOSPHERIC GAS ISOLATION
517 1 CLEAN-UP, LIQUID AND SOLID
518 1 TRASH DISPOSAL
519 1 LEAK DETECTION/LOCATION (GAS)
520 1 PRESSURE SUIT DONNING AND DOFFING (EXPERIMENTAL)
521 1 PRESSURE SUIT VENTILATION AND COOLING (EXPERIMENTAL)
522 1 VARIATION AND MEASUREMENT OF METABOLIC RATE OF SUITED CREWMAN
523 1 INGRESS/EGRESS (LABORATORY TO EVA)
524 1 EVA MAINTENANCE TASK SIMULATION
525 1 DATA MANAGEMENT
700 1 VISUAL - ACUITY, STATIC - NEAR AND FAR
701 1 VISUAL - ACUITY, DYNAMIC
702 1 VISUAL - STEREOPSIS (DEPTH PERCEPTION), STATIC
703 1 VISUAL - STEREOPSIS (DEPTH PERCEPTION), DYNAMIC
704 1 VISUAL - BRIGHTNESS THRESHOLD, ABSOLUTE
705 1 VISUAL - BRIGHTNESS DISCRIMINATION
706 1 VISUAL - COLOR PERCEPTION
707 1 VISUAL - CRITICAL FLICKER FUSION FREQUENCY
708 1 VISUAL - PHORIAS, LATERAL AND VERTICAL - NEAR AND FAR
709 1 VISUAL - GLARE RECOVERY (PHOTO STRESS)
710 1 VISUAL - DARK ADAPTATION
713 1 VISUAL - PERIPHERAL FIELD
714 1 VISUAL - ACCOMMODATION RANGE
715 1 AUDITORY - ABSOLUTE THRESHOLD
716 1 AUDITORY - PITCH DISCRIMINATION
717 1 AUDITORY - TEMPORAL ACUITY
719 1 AUDITORY - SOUND LOCALIZATION
720 1 AUDITORY - DETECTION OF MOTION
721 1 CUTANEOUS - PRESSURE THRESHOLD
722 1 KINESTHETIC - SENSING LIMB MOVEMENT
723 1 KINESTHETIC - SENSING LIMB POSITION





Figure 2-3. Functions Inventory (Sheet 3)

730 1 COGNITIVE/COMPLEX PERCEPTUAL - SPEECH INTELLIGIBILITY
731 1 COGNITIVE/COMPLEX PERCEPTUAL - READING
734 1 COGNITIVE/COMPLEX PERCEPTUAL - PERCEPTUAL SPEED
735 1 COGNITIVE/COMPLEX PERCEPTUAL - TIME SHARING
736 1 COGNITIVE/COMPLEX PERCEPTUAL - SPATIAL ORIENTATION
737 1 COGNITIVE/COMPLEX PERCEPTUAL - SPATIAL VISUALIZATION
740 11 COGNITIVE/CONCEPTUAL AND THINKING ABIL.-VERBAL KNOWLEDGE,
750 1 COGNITIVE/MEMORY - ROTE MEMORY
751 1 COGNITIVE/MEMORY - MEANINGFUL MEMORY
752 1 COGNITIVE/MEMORY - MEMORY SPAN-IMMEDIATE RECALL
758 1 FINE PSYCHOMOTOR - WRITING ABILITY
759 1 FINE PSYCHOMOTOR - SPEAKING ABILITY
760 1 FINE PSYCHOMOTOR - MANIPULATIVE ABILITY-ARM/HAND STEADINESS
761 1 FINE PSYCHOMOTOR - MANIPULATIVE ABILITY-WRIST/FINGER SPEED
762 1 FINE PSYCHOMOTOR - MANIPULATIVE ABILITY-FINGER DEXTERITY
763 1 FINE PSYCHOMOTOR - MANIPULATIVE ABILITY-MANUAL DEXTERITY
764 1 FINE PSYCHOMOTOR - GROSS POSITIONG ABILTY-POSITION ESTIMATN*
766 1 FINE PSYCHOMOTOR - GROSS POSITIONG ABILTY-CONTROL PREC(TPK)
767 1 FINE PSYCHOMOTOR - GROSS POSITIONG ABILTY-ARM MOVEMNT SPEED
768 1 FINE PSYCHOMOTOR - GROSS POSITIONG ABILTY-MULTILIMB COORD.
769 1 FINE PSYCHOMOTOR - GROSS POSITIONG ABILTY-POSITION REPRODCT*
770 1 FINE PSYCHOMOTOR - REACTION TIME - SIMPLE
771 1 FINE PSYCHOMOTOR - REACTION TIME - COMPLEX(RESP ORIENTATN)
776 1 GROSS PSYCHOMOTOR - MUSCLE STRENGTH-IMPULSIVE-HAND/SHLDR
777 1 GROSS PSYCHOMOTOR - MUSCLE STRENGTH- SUSTAINED/REPETITIVE
779 1 GROSS PSYCHOMOTOR - GROSS BODY EQUILIBRIUM
780 1 GROSS PSYCHOMOTOR - GROSS BODY COORDINATION
782 1 GROSS PSYCHOMOTOR - SPEED OF LIMB MOVEMENT - LEGS
790 1 SLEEP BEHAVIOR - LENGTH AND DEPTH OF SLEEP
791 1 SLEEP BEHAVIOR - ABILITY TO AWAKEN AND RESPOND TO EMERGENCY
792 11 INDIVIDUAL BEHAVIOR - CLOSENESS OF INTERACTIONS(FRIENDLINESS,
793 11 INDIVIDUAL BEHAVIOR - AMOUNT OF INTERACTION(INTRO-VS EXTROVERSON
794 1 INDIVIDUAL BEHAVIOR - STRENGTH OF INTERACTION (ASSERTIVENESS)
795 1 INDIVIDUAL BEHAVIOR - AGGRESSION REACTION
796 11 INDIVIDUAL BEHAVIOR - CONFORMITY AND/OR CONTROL REACTION (DEPEN-
797 1 INDIVIDUAL BEHAVIOR - FLEXIBILITY/RIGIDITY REACTION
798 1 INDIVIDUAL BEHAVIOR - SELF CONTROL REACTION
799 11 INDIVIDUAL BEHAVIOR - SUBJECTIVITY/OBJECTIVITY REACTION (SELF
800 11 INDIVIDUAL BEHAVIOR - EMOTIONALITY,SENSITIVITY OF REACTION
801 1 INDIVIDUAL BEHAVIOR - DESIRED OUTPUT LEVEL(MOTIVATION,ASPIRATN)
802 11 INDIVIDUAL BEHAVIOR - DESIRED OUTPUT TYPE(CONSCIENTIOUS VS EXPED
805 1 GROUP BEHAVIOR - GROUP COMPATIBILITY
806 1 GROUP BEHAVIOR - GROUP COHESIVENESS
807 1 GROUP BEHAVIOR - GROUP LEADERSHIP
808 1 GROUP BEHAVIOR - GROUP SIMILARITY, PERCEIVED
820 11 TASK COMPLETION TIMES (E.G. TIME TO COMPLETE A SPECIFIED MAINTEN
821 1 TASK ACCURACY AND ERRORS
822 1 CREW BODY POSITION MEASUREMENTS
823 1 CREW BODY MOTION MEASUREMENTS
824 1 FORCES,PRESSURES AND TORQUES EXERTED ON EQUIPMENT
825 1 EYE MOVEMENT MEASUREMENTS - OPTICAL
830 1 FREQUENCY OF EQUIPMENT/FACILITY UTILIZATION
831 1 LENGTH OF USE OF EQUIPMENT/FACILITY
832 1 SEQUENCE OF USE OF EQUIPMENT/FACILITIES
833 1 CREW SUBJECTIVE COMMENTS ON EQUIPMENT/FACILITY/PROCEDURES/SCHED.
834 1 FACILITY TRAFFIC PATTERNS

840 1 MAX MASS TRANSPORTABLE - FUNCTION OF TYPE OF MOBILITY AID. ONE
841 1 MAX VOLUME TRANSPORTABLE - FUNCTION OF TYPE OF MOBILITY AID. ONE
842 1 MAX TRANSPORTABLE MOI ABOUT CARRYING HANDLE-FUNCT OF MOB.AID.ONE
843 1 MAX MASS ALIGNABLE - FUNTION OF TYPE OF RESTRAINT. ONE
844 1 MAX VOLUME ALIGNABLE - FUNCTION OF TYPE OF RESTRAINT. ONE
845 1 MAX ALIGNABLE MOI ABOUT CARRYING HANDLE-FUNCTION OF RESTRNT. ONE
846 1 REMOTE MANIPULATION
950 1 ROUTINE EQUIPMENT MAINTENANCE



Figure 2-3. Functions Inventory (Sheet 4)

The functions inventory includes three basic types of information for each function listed. These are:

a. Function Data — the title of the function and data that describes some of the characteristics of the function.

b. Methods Data — information on one or more methods and associated procedures for performing the function.

c. Equipment Data — preliminary information on the equipment required for each of the methods listed.

2.3.1.1 Function Data. The function data contained in the inventory includes information about the function as generally assessed from a life science research point of view. The type of information contained is shown in Figure 2-4. It includes a criticality rating, which is a general assessment of the importance of the function to successful research.

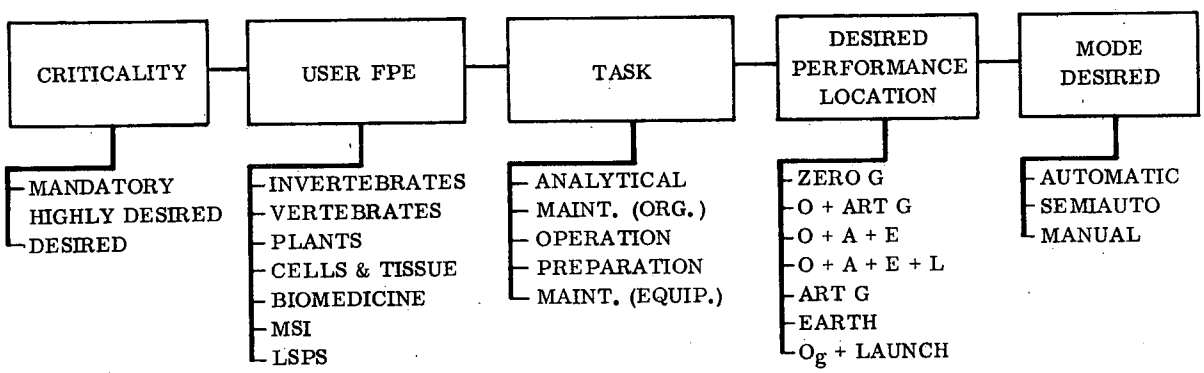



Figure 2-4. Function Data Included in the Function Inventory

A "mandatory" function (denoted by 1 in the inventory) such as vertebrate watering, obviously must be done in space. A "highly desirable" function (2) must be done for valid research but could partially be performed (usually the analysis) on the ground. The third classification is "desirable" (3), which applies to functions that add depth to the research results but are not essential.

Another classification included in the function data indicates the Blue Book FPE disciplines that require (use) the function. The disciplines covered are: Vertebrate Biology (MV), Plant Biology (P), Cells and Tissues (C), Invertebrate Biology (I), Biomedicine (B), Manned Systems Integration (H), and Life Support and Protective Systems (L). Vertebrate biology is divided into Large Primates (M) and Small Vertebrates (V) because of the special holding and management equipment required for large primates.

The task code indicates the nature of the function, and the desired performance location indicates which environment the function must be performed within (e.g., zero-g plus artificial-g plus the launch environment). Mode desired refers to that desired by the scientist from the standpoint of scientific responsiveness. A general guide to meaning of "mode desired" is:

a. An automatic mode (denoted by the letter A) refers to no manned involvement except for repairs.

b. Semiautomatic (S) refers to manual setup, functional checks, termination and repair, while the measurements and analysis are performed automatically.

c. Manual functions (M) refer to those where it is desirable for man to perform all the activities just mentioned.

2.3.1.2 Methods Data. The second type of information contained in the functions inventory is information on various methods of accomplishing each function. An illustration of the methods content of the inventory is shown in Figure 2-5, which also indicates the steps in defining equipment to accomplish the given function. For each function required aboard a laboratory payload, a preferred method is selected from the list of possible alternatives. Any given method selected carries the requirement for specific equipment that is also listed in the inventory. This selection process is described further in Section 2.4.

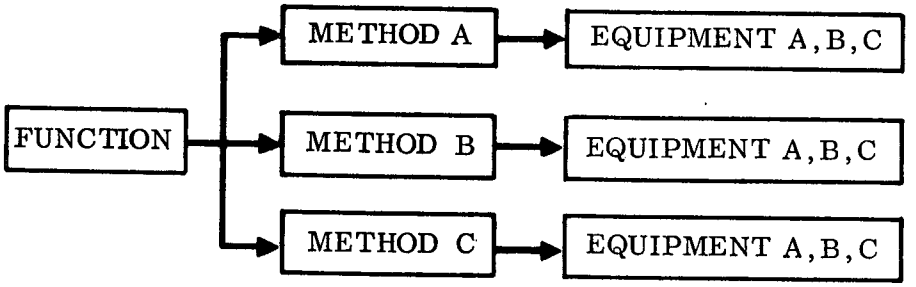



Figure 2-5. Functions Inventory Methods and Equipment Relationship

An attempt was made to include several pertinent methods for each function when reasonable for good research. These included methods for automatic operation, semiautomatic operation, and manual operation as well as methods utilizing various types of scientific instruments. Information contained in the inventory about the method included: scientific response, crew time, crew skill required, and inherent hazards.

The scientific response is a judgement indicating how well the candidate method meets the functional requirements. Category 1 (superfluously) indicates that the method accommodates the functional requirements easily and has greater precision and

accuracy than required. Category 2 indicates that the method adequately satisfies the functional requirement. Category 3 indicates a marginal method with possible problems. The crew time is listed in two categories: Time First Item is the time required to set up, perform, clean up, and restow the equipment. Time Each Additional is the time required to repeat the function — assuming everything is set up and cleanup time is charged to the first operation. Crew skills are specified by a number corresponding to a particular skill, such as biotechnician (1). Both a primary skill and a secondary skill are specified. The primary skill is that most suited to the performance of the function by the method selected. The secondary skill is that which could acceptably perform the same function by that method. The rating of hazard for each method is qualitative and serves to flag out possible unsafe methods.

2.3.1.3 Equipment Data. The equipment required for each method is listed in the functions inventory and has the following information pertaining to its use:

a. Redundancy — is the number of backup instruments of this or similar capability desired by the scientific investigators, based on experience with off-the-shelf equipment.

b. Crew Interface — is a judgement of the frequency and time crew members address that equipment item.

c. Logistics — is a judgement of the amount of supplies consumed or waste produced.

d. Maintainability — is a judgement of the amount of calibration, sterilization, and cleanup required for that equipment item.

Further information on each equipment item listed in the functions inventory is contained in the equipment inventory discussed in Section 2.3.2.

2.3.1.4 Inventory Changes Resulting From Study Expansion. As discussed in Section 1, the life sciences payload definition and integration study started out to define biology requirements and then was expanded to include biomedicine, life support and protective systems (LSPS), and manned system integration (MSI). The effects of this expansion on the number of functions and equipment in the inventories is shown in Figure 2-6, and demonstrates the commonality in the various life sciences disciplines. Many of the functions and equipment required to do biology research were also found to be applicable for research in the other FPEs. The resulting increase in functions and equipment was 62% and 49% respectively. Also indicated in Figure 2-6 is the increase in the CORE (common operational research equipment) and the supporting equipment units.

Subsequent to the study expansion, the functions inventory was reviewed by NASA personnel and 70 new functions were added in the biomedicine area. This 16% increase in functions resulted in less than a 1% increase in equipment items, demonstrating the completeness of the equipment inventory.

| BIOLOGY | + | BIOMED, LSPS, MSI | = | LIFE SCIENCES |
|---|---|---|---|---|
| 275 Functions | + | 170 New Functions | = | 445 Functions |
| 255 Equipment Items | + | 125 New Items | = | 380 Equipment Items |
| CORE | + | Increase Numbers, Some New Equipment | = | Increase Size |
| 12 Support Equipment Units | + | 8 New Support Equipment Units | = | 20 Equipment Units |

Organism Holding
Support E. U.
Radiobiology
Bioresearch Centrifuge, Etc.

+

Biomed Measurements Unit
Biomed Research Support Unit
Biomed/MSI Research Support Unit
Airlock/EVA Capability
LSPS Test Unit
Behavioral Measurements Unit
Human Research Centrifuge
Mobility Unit

Figure 2-6. Study Expansion Results

2.3.2 EQUIPMENT INVENTORY. This inventory is a list of approximately 380 equipment items that are relevant to a comprehensive life sciences research laboratory. The inventory was compiled by reviewing the various data sources, and also as a result of the functions and method definitions activities of this program.

The equipment inventory is similar to the functions inventory in that coded information was punched on computer cards that were used to print the inventory listing. Each equipment item has about 10 lines of information and the resulting inventory is too large for inclusion in this report. A list of the equipment item names, however, is shown in Figure 2-7. A sample portion of the actual inventory is shown in Figure 2-8.

The information contained in the equipment inventory for each equipment item includes:

a. A code indicating the data source where the item was recommended. (Where several sources referenced the equipment, generally the most complete source was listed.)

b. The name of the item.

c. An equipment unit number which indicates a functional group of equipment into which the equipment item has been assigned (e.g., preservation and preparation equipment unit).

d. Weight, power and volume. (As many as three values of weight, power, and volume may be listed in the inventory. These are, data from the reference source, the off-the-shelf catalog data, and space flight hardware estimates.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ACCELEROMTR (ACTIVITY) | 3 | 001 | ACCELEROMTR COUPLER | 3 | 001A | ACCOMMODTN RANGE TESTER | 91 | 002B |
| AIR LOCK, EVA | 11 | 003B | ADAPTERS,TV-MICROSCOPE | 1 | 003C | ACTIVITY MTR E/M CPLR | 42 | 003D |
| AUTOANALYZER,MULTIPLE | 5 | 007 | ANLZR, AMINO ACID | 5 | 008 | ANLZR, CARBOHYDRATE | 5 | 008B |
| ANLZR, GENL, IR SPECPH | 5 | 010 | ANLZR SPECTROPHOTOFLUOROMTR | 5 | 010A | ANLZR, MICRORG AUTO ID | 4 | 011A |
| ANLZR, PROTEIN | 5 | 011B | ANLZR, CONDUCTIVITY | 5 | 012A | ANLZR, URNF, AUTO | 5 | 013 |
| ANIMAL MAZE, RAT | 42 | 014A | ANTENNAS, ASSORTED | 2 | 014B | ANOMALOSCOPE | 91 | 014C |
| ANTHROPOMETRIC GRID | 93 | 015 | ATMOS SAMPLNG-MNFD SYS | 5 | 015A | ATTACHMT,SPECTPH THERM | 5 | 015B |
| AUDIO STEREO HEADSET | 91 | 015D | AUDIO TONE SOURCE,PORTABLE | 91 | 015E | AUDIO-VIS TACTL STIM | 42 | 016A |
| BEHAVIOR UNIT, PRIM | 42 | 016C | BADGES-RAD, STD FILM | 25 | 016D | BAGS-PLASTIC, PERMEABL | 6 | 016E |
| COUPLER BALLISTOCARDIOGRAM | 30 | 016F | BENCH, ELCT/MECH | 6 | 017 | BENCH, LAM FLO | 4 | 018 |
| BENCH LINERS,LFB | 4 | 018A | BNCH INSERT LFB,RADIOC | 4 | 018B | BICYCLE ERGOMETER | 30 | 018C |
| CUSTOM BITE BOARDS | 12 | 018D | BENCH, GENL EXPER | 5 | 019 | BIOBACKPACK, MICRO | 42 | 019A |
| BURNER, CATALYTIC | 3 | 019B | BOTL C/T CULT OPT FLTS | 51 | 019C | BODY MASS MEASUREMENT | 12 | 019D |
| CAGE INSRT, MICE | 42 | 024 | COLONY CHMBR,SEALBL,IV | 70 | 025A | COLONY CHMBR,SEALBL,CT | 60 | 025B |
| CAGE, LAUNCH/RE≠ENTRY | 40 | 026 | CAGE MMB, C/T | 60 | 026A | CAGE MMB, PLNT | 50 | 026B |
| CAGE, MMB, RAB | 40 | 027 | CAGE,MPMT/RAB C,SPECIF | 40 | 027A | CAGE, MONK, MACAC | 41 | 028A |
| CAGE, PRIMATE SPHERE | 41 | 029A | CAGE,RABBIT,SPECIFIC | 40 | 029B | CAGE SHELF, PLNT SEEDL | 51 | 030B |
| CAMERA CONTROLLER | 1 | 032A | CAMERA-IRIS 35MM SPECIAL | 31 | 036 | CAMRA, VIDEO B/W | 1 | 037 |
| CAMRA,VIDEO/COLOR | 1 | 038 | CAMERA X-Y DRIVE | 1 | 038A | CHROMATOGRAPH,LIQUID COLUMN | 4 | 039 |
| CHROMATOGRAPHY,THIN LAYER | 5 | 040 | CNTRIF MICRO | 4 | 042 | CENTR, ULTRA | 4 | 042A |
| CNTRIFG, BIORES MAXI | 20 | 042C | CNTRIFG SLIP RING SY | 21 | 042D | CNTRIFG REMOT MANIP/TV | 21 | 042E |
| CENTRIFUGE-COMMON USE RC | 20 | 042F | CNTRIF, SPECIMN | 23 | 043 | CHEMICALS | 4 | 044 |
| CHEMICALS-RADIOACTIVE | 4 | 044A | CHEM STOR CABINET | 7 | 045 | CLEANR, ULTRSNC | 6 | 047 |
| CLEANR, VACUUM | 4 | 048 | CLEANR, INSTRMNT/APPAR | 6 | 049 | CLINOSTAT | 51 | 050 |
| COMMUTATOR,GAS MANIFLD | 5 | 050A | COMPACTOR (SOLIDS) | 6 | 050B | CONSOLE,BEHAV MSMTS-CRT+KEY | 91 | 050C |
| COMPUTER, DIGITAL | 2 | 051 | CONVERTER,A-D | 2 | 051A | COOLER, THERMOELECTRIC | 4 | 051B |
| CONTRL PANL, SHIELD RM | 25 | 051C | CONTROL CONSOLE,EXPMTR | 12 | 051D | COUNTR CELL | 5 | 052 |
| COUNTR, COLONY (AUTO) | 5 | 053 | COUNTR, COLONY, MANUL | 5 | 054 | DATA MS, SPEC PRIMATE | 42 | 054A |
| CRYO SYS | 4 | 056 | DATA MNGMT SYS, BUSES | 2 | 056A | DATA MNGMT SYST, RE- | 2 | 058A |
| DATA MNGMT SYS, | 2 | 058B | DATA MNGMT SYST, WIDE | 2 | 058C | DENSITOMTR, X-RAY | 1 | 061 |
| DEVELOPER, FILM | 25 | 062A | DIALYSIS EQUIP | 4 | 063A | DISPLAY-KEYBRD,INT,PRT | 2 | 063B |
| DIVIDERS, RABBIT CAGE | 42 | 063F | DEIONIZER FOR PURE WATER | 4 | 063G | DYNAMOMETER,GRIP,0-200 LBS | 91 | 063H |
| ECG COUPLR | 2 | 064 | ECS SYS, SPEC PRIMATE | 42 | 064A | EEG COUPLR | 2 | 065 |
| ELECTROPHYSIOLOGY MONITOR | 12 | 065B | ELECTROPHYSILOGY RECEIVER | 12 | 065C | ELECTROPHYSIOLOGY DISPLAY | 12 | 065D |
| ELECTROPHYSIOLOGY MONITOR, | 12 | 065E | ELECTROPHYSIOLOGY CONSOLE | 12 | 065F | COUPLER ELECTRO-OCULOGRAM | 12 | 065G |
| COUPLER ELECTRONYSTAGMOGRM | 30 | 065H | EMG COUPLR | 2 | 066 | ELECTROPHRSIS APPAR | 4 | 070 |
| EVAPORATOR, ROTARY | 4 | 070A | EXRCISR/ERGOMTR (PRIM) | 42 | 071 | EXRCISR, RAT | 42 | 072 |
| FECES COLLECTOR SYS | 40 | 072A | FECES STORAGE SYS | 42 | 072B | FECES VACUUM SYS-CAGE | 40 | 072C |
| FEEDR, PEL DISPNSR | 40 | 074 | FEEDR,EDIBLE FD BLT SY | 40 | 074A | FEEDR, PASTE | 40 | 074B |
| FEEDR, PLNT, AUTO | 51 | 075 | FIBER OPTIC MOUNTS | 1 | 076A | FIBER OPTICS | 1 | 076B |
| FILM | 1 | 076C | FILM TABLE, X-RAYS | 26 | 076D | FILTERS, VIDEO | 1 | 076E |
| FLOWMETER,WATER MANFLD | 6 | 076F | FLOWMETER, ULTRASONIC | 42 | 076G | FLOWMETER COUPLER | 3 | 076H |
| FLOWMETER COUPLER | 42 | 076I | FLOWMETER -GAS | 3 | 076J | FLOWMETER,DOPPLER | 31 | 076K |
| FIBROMETER-BLOOD CLOT | 5 | 076L | FILTR, CHEMCLS | 4 | 077 | FLICKER FUSION APPAR | 12 | 077A |
| FRAGILIGRAPH | 4 | 077C | GAS ANLZR, AUTO PHYSIO | 5 | 085 | GAS ANLZR, CO2 | 5 | 086 |
| GAS ANLZR, MASS SPEC | 5 | 090 | GAS ANLZR, POLAR, O2 | 5 | 092 | GAS ANLZR, RH | 5 | 093 |
| GAS SUPPLY, ASSORTED | 3 | 093A | GAS METRING/CALIB UNIT | 3 | 093B | GENRTR, SIGNL(.01-20K) | 6 | 095 |
| GLV BX | 4 | 096 | GLOVE SHROUD, GAS STER | 4 | 096A | GLV BX, RAD TRACR CAP | 4 | 097 |
| HEMATOCRT, ELECTRNIC | 4 | 097A | HARNESS, SMALL WIRE | 42 | 097B | HOLD UNIT INCBTR-INVRTS3 | 70 | 098C |
| HOLD UNIT, MMB, PRIMTE | 41 | 100 | HOLD UNIT MOUSE HOUSE | 40 | 100A | HOLD UNIT, PLNT | 50 | 101 |
| HOLD UNIT, PLANT GR HS | 50 | 101A | INDICATR-ATMOS O2 | 5 | 104B | INDICATOR, LABSTIX | 4 | 104C |
| IONIZATN DETECTR-FLAME | 5 | 104D | COUPLER IMPEDANCE CARDIGRM | 30 | 104E | IMPEDANCE PNEUMOGRAPH | 30 | 104F |
| KIT, BENCH CHEM ANAL | 4 | 105 | KIT,BEHAVIORAL MSUREMTS | 91 | 105A | KIT,BEHAVIORAL MSRMTS II | 91 | 105B |
| KIT, HEMATOLOGY | 4 | 106 | KIT, CLEAN-UP | 6 | 106A | KIT, HIST | 4 | 108 |
| KIT, LINEAR MEAS | 6 | 109 | KIT, MICROBIOLOGY | 4 | 110 | KIT ORG HLDG/MGMT | 6 | 110B |
| KIT PHYSIOLOGY | 31 | 110C | KIT SUBJECT PREP/CLEANU | 12 | 111A | KIT, MEDICAL SURGICAL | 42 | 112 |
| KIT, TOOL, GENL | 6 | 113 | KIT,TOOL-INSECT MANIP. | 51 | 113A | KIT MICRODISSECTION | 4 | 114A |
| KIT, VETERNRY | 42 | 115 | LGT DISCRIM APPRTUS | 42 | 115A | LAMPS,UV | 6 | 115B |
| LEAK DETECTOR | 81 | 115C | LIMB BOARD,MTR OR MANL ROTN | 91 | 115D | LIFE SCIENCES SUPPORT CONTROL | | 115E |
| LSPS TEST UNIT | 80 | 115F | LOG BOOKS FOR DAILY RECORDS | 1 | 116 | LOWER BODY NEGATIVE PRESS | 30 | 117 |



Figure 2-7. Equipment Item Names (Sheet 1)

| | | |
|---|---|---|
| LYPHILZR (SPACE VAC) | 4 | 118 |
| MANIFLD, SAMPLE PRESVN | 4 | 118C |
| MANIFLD,SPECL-PLANTS | 51 | 118F |
| MANIFOLD, VACUUM | 80 | 118I |
| MASK,RESPIRATRY-PRIMTE | 42 | 120A |
| MASS, TEST-VAR.SIZE,WT,SHAP | 93 | 122A |
| MEDIUM SUBSTRATE PLANT | 51 | 125A |
| METABOLIC ANALYZER FIXED | 31 | 125D |
| MICRSCP, DISECTNG | 4 | 126A |
| MICROWAVE SOURCE | 6 | 126D |
| MONITOR, VIDEO | 1 | 126G |
| MICROTME,AUTO, FREZNG | 4 | 127 |
| MORTAR PESTLE AND SAND | 4 | 131B |
| ORTHORATER | 91 | 131F |
| OSCILSCPE (DC-5MHZ) | 2 | 132 |
| OTOLITH TEST GOGGLE | 12 | 133 |
| PEGBOARD,PURDUE(OG MOD) | 91 | 135A |
| PH COUPLER | 5 | 137 |
| PHOTOTRANSISTOR (CPLR) | 6 | 138B |
| PNEUMOTACHOGRAPH | 31 | 139A |
| PORTABLE LSS (PLSS) | 80 | 142 |
| PREPARATIONS, AGAR GEL | 4 | 143G |
| PRESSURECUFF W/XDCR | 42 | 143E |
| PRESSURE SUIT CONNECTR | 11 | 143H |
| PSYCHOMTR ROTATING DISKS | 91 | 144A |
| RADIATN DETECTR,GENERAL | 25 | 145 |
| RADIATN, ROOM | 25 | 147B |
| RADIATN WASTE SYS | 25 | 149A |
| RADIATN SRCE, ISOTOPE | 26 | 149F |
| RADIATN, SOURCE STOR | 25 | 150 |
| RCRDR, ELECTM,100-5MHZ | 2 | 150F |
| ROOM,PRIVATE GRND COMMUNCTN | 91 | 152A |
| SAMPLE CHANGR,SPECTRPH | 5 | 153C |
| SHROUD, ENVIRONMENTAL | 81 | 155B |
| SQUIB FIRING APPARATUS | 51 | 156C |
| SPACE SUIT SUPPLY CONSOL | 80 | 158A |
| STAIN SYS, (EMBD/RINS) | 4 | 160 |
| STERLZR, TOOL | 6 | 165 |
| TAGS, ID, ORGANISM | 6 | 168A |
| STRAIN GAGE, RESPIR | 42 | 171 |
| TARGET,LANDOLT RING APPART | 91 | 176A |
| TASK BOARD,VISUAL REACT TIM | 91 | 176E |
| TASKBOARD,FORCE/TORQUE | 91 | 176H |
| THERMOCOUPLES | 5 | 179A |
| TIMER, EVENT | 2 | 180 |
| XDCR BLOOD FLOW | 42 | 181A |
| TRANSDUCER, PRESSURE | 6 | 181D |
| TRANSMITTER, MICRO | 42 | 182 |
| URINE PADS | 40 | 182G |
| COUPLER, VECTORCARDIOGRAM | 31 | 182J |
| VISION TESTER-AMER OPT BROM | 91 | 182M |
| VOLMTRC MEAS, LIQ | 4 | 186 |
| EXPERIMENT SPECIFIC | 99 | 999 |
| MANIFLD FLUSH SY,HLD U | 6 | 118A |
| MANIFLD,ORGANISM,WATER | 40 | 118D |
| MANIFLD,SPEC-RABBT SUP | 42 | 118G |
| MAINTENANCE TASK SIMU- | 11 | 119 |
| MASS MEAS, MACRO | 4 | 121 |
| MEDIA, PREPRED | 61 | 124 |
| METERS, ASSORTED | 5 | 125B |
| METABOLIC ANALYZER BACKPACK | 12 | 125E |
| MICROPHONE | 5 | 126B |
| MIRROR MOUNT-COMMUTATR | 1 | 126E |
| MIRROR,REVOLVING | 91 | 126H |
| MILLIPORE FILTER APPARATUS | 4 | 128 |
| MOTOR,PLNT GRWTH MNTR | 51 | 131D |
| OCULOMETER, REMOTE | 91 | 131G |
| OSCILLATOR VCO | 42 | 132A |
| PATCHBOARD SYSTEM | 2 | 134A |
| PEGBOARD,SANTA ANA(OG MOD) | 91 | 135B |
| PH MTR | 5 | 138 |
| PHOTO ID DATE-TIME SYS | 1 | 138C |
| COUPLER PHONO/VIDEOCARDGRM | 30 | 140 |
| POSITION ESTIMATION CONTRL | 91 | 142A |
| PUMP,GAS CIRCULATNG | 51 | 143C |
| PRESSURECUFF PUMP | 42 | 143F |
| PRESSURE SUIT MANIFU- | 11 | 143I |
| PSYCHOGALVANOMTR GSR | 12 | 144B |
| RADIATION EXPOSURE AIRLOCK | 25 | 146 |
| RADIATN ROOM RACK SYS | 26 | 147C |
| RADIATN SRCE,XRAY ELEC | 26 | 149D |
| RADIATN SOURCE,PREPKGD | 26 | 149G |
| RECEIVER-EXG, CAGE MOD | 42 | 150B |
| RCRDR, ELECTM, 0-100HZ | 2 | 150G |
| ROTATING LITTER CHAIR (RLC) | 12 | 153A |
| RESTRAINT CHAIR-PRIMTE | 42 | 154A |
| STAIN APPARTUS,WRIGHTS | 4 | 156A |
| SIGNL COND RACK | 41 | 156E |
| EMERGENCY SPACE SUIT SUPPLY | 3 | 158B |
| STAINING SYS, PLANTS | 4 | 161A |
| STORAGE, GENL | 7 | 167B |
| STRAIN GAGE, MUS SKEL | 42 | 170 |
| SPACESUIT + 50 FT UMBILICAL | 11 | 172 |
| TARGET CONSOLE,SPD OF ARM | 91 | 176C |
| TASK BOARD,RESP ORIENTATION | 91 | 176F |
| T SENS, BODY | 42 | 177 |
| THERMOMETER | 5 | 179B |
| TRACE GAS CONCENTRATOR | 5 | 180A |
| TRANSDUCER-PLYTHESMGPH | 42 | 181B |
| VIDEO ID DATE-TIME SYS | 1 | 181E |
| URINE COLLECTOR SYS | 40 | 182A |
| VALVES, ASSORTED | 80 | 182H |
| VISION TESTR- | 91 | 182K |
| VISUAL CLIFF | 42 | 183A |
| VOMITUS BAGS AND HOLDERS | 31 | 186A |
| MANIFLD, O2/CO2 MSMTS | 5 | 118B |
| MANIFLD,SPEC-PLNT SEED | 50 | 118E |
| MANIFLD,SPEC-MARMT CLY | 42 | 118H |
| MANIPULATOR, REMOTE | 11 | 119A |
| MASS MEAS, MICRO | 4 | 122 |
| MEDIA POURING TBLE, AG | 4 | 124A |
| METER, AO TS | 5 | 125C |
| MICROSCOPE-HOLOGRAPHIC | 1 | 125F |
| MICROPHONE AMPLIFIER | 5 | 126C |
| MIRRORS, ASSORTED | 1 | 126F |
| MOBILITY UNIT-PROTCT CORRD | 93 | 126I |
| MXER, CHEMCLS | 4 | 131 |
| NON-VISUAL DIRCTN INDICATR | 12 | 131E |
| OPTISCAN-FIELD AND FIXT | T91 | 131H |
| OVEN, VACUUM 40-80 C | 6 | 132B |
| PAPER, RECORDING | 1 | 134B |
| PERCEPTUAL MTR PERF TESTER | 91 | 136 |
| PHOTOCELLS | 6 | 138A |
| PLETHYSMOGRAPH, LIMB | 31 | 139 |
| PLASTIC BAG DISPNSE/SEALER | | 141 |
| POWER SUPPLY | 3 | 143A |
| PURGE SYS, CAT BURN | 4 | 143D |
| COUPLER-PRESSURE TRANSDUCR | 5 | 143G |
| PSYCHOMTR PERF CONSOLE | 91 | 144 |
| RADIATN DETCTR, DOSMTR | 25 | 144C |
| RADIATN DETECTR,SCINT | 5 | 147 |
| RADIATION SYSTEM,PHOTON | 25 | 149 |
| RADIATN SRCE,ELECTRNIC | 26 | 149E |
| RADIATION WHOLE BODY SCAN | 26 | 149H |
| RECEIVERS DC-5MHZ | 3 | 150D |
| RESPONSE ANALYSIS TESTER | 31 | 151 |
| SENSORS,ASSORTED | 6 | 153B |
| SENSOR, IMPLNTD, | 42 | 155A |
| SQUIBS, FIXATIVE | 51 | 156B |
| SPACE SUIT SUPPLY CONTROL | 11 | 158 |
| STAING SYS, BACTERLGCL | 4 | 159 |
| STEADINESS TREMOR APPARTUS | 91 | 161B |
| STORAGE, FILM | 7 | 167C |
| STRAIN GAGE, PLNT GRTH | 51 | 170A |
| TAPE, VIDEO | 2 | 176 |
| TASK BOARD,POSITION REPRO | 91 | 176D |
| TASKBOARD,MAINT/GROSS COORD | 91 | 176G |
| TEMP SENSOR IR | 61 | 178 |
| TIMER, INTEGRAL EQUIPMENT | 91 | 179C |
| TXIC FLUID HNDLNG SYS | 4 | 181 |
| XDCR BLOOD PRESSURE | 42 | 181C |
| TRASH CAN | 6 | 181G |
| URINE PAD HOLDER | 40 | 182D |
| SPACE VACUUM XTRAVEH TUBE | 5 | 182I |
| VISION TESTR-HOWARD DOLMAN | 91 | 182L |
| VOLTMTR (VOM) | 6 | 185 |
| WASTE MNGMT SYS. | 3 | 187 |

**Figure 2-7. Equipment Item Names (Sheet 2)**

```
C
 M499 AIR PARTCL SMPL COLECT      61      6.      0      .03  3   REYNEIR      1X006
      ER CU                    2 2                                            2X006
                               1 1        6.      0      .03                   3 006
      4 8 1 1    28      4                          *                          4 006
            MINI  7          1          1    1                                1A7 006
            MINI 30          1          1    1                                1B7 006
            MIDI 30          1          1    1                                2B7 006
            MAXI NOM         1          1    1                                3A7 006
            MAXI MAX         1          1    1                                3B7 006
      FUNCTIONS 141A,142A                                                       9 006
C
 DV   AUTOANALYZER,MULTIPLE       5   100.    150     3.0   1   AUTOMATIC     1 007
                                                                 CLINICAL     2 007
                                      100.    150     3.0       ANALYZER     3 007
      4 0 1 1   700   100                                                       4 007
            MINI  7          1          1    1                                1A7 007
            MINI 30          1          1    1                                1B7 007
            MIDI 30          1          1    1                                2B7 007
            MAXI NOM         1          1    1                                3A7 007
            MAXI MAX         1          1    1                                3B7 007
      FUNCTIONS 155A,156C,174C,177D,336A,337A,338A,339A,360B,                   91007
      FUNCTIONS 38C,67C,155D,156D,429B                                          92007
C
 M497 ANLZR, AMINO ACID       1 3  5    75    400     2.    3   NS 4 REQ,HVY1 008
      RH CU                   1 2      100.   1000    5.83                    2X008
                              1 1       88.    700    3.9                     3 008
      2 0 4 2  2000   100                          *                          4 008
            MINI  7          1          1    1                                1A7 008
            MINI 30          1          1    1                                1B7 008
            MIDI 30          1          1    1                                2B7 008
            MAXI NOM         1          1    1                                3A7 008
            MAXI MAX         1          1    1                                3B7 008
      FUNCTIONS 175A                                                            9 008
C
 DV   ANLZR, ATOM ADS SPTRPH      5    60.    100     2.    1   INCL FLME    1X008A
      RH CU                   2 2      100.   120     6.25      AND EMISSION2X008A
                              1 1       80.   110     4.        CAPABILITY  3 008A
      2 3 3 2  1200    60                          *                          4 008A
            MINI  7          1          1    1                                1A7 008A
            MINI 30          1          1    1                                1B7 008A
            MIDI 30          1          1    1                                2B7 008A
            MAXI NOM         1          1    1                                3A7 008A
            MAXI MAX         1          1    1                                3B7 008A
      FUNCTIONS 34A,34B,52B,303B,407C                                           9 008A
```

Figure 2-8. Equipment Inventory Printout

e. Comments about the equipment item regarding candidate commercial models, operational volumes, etc.

f. An equipment item number which is used to cross reference the item in the functions inventory.

g. A code number indicating the amount of development required to obtain a flight qualified item. Categories include: (1) Research and Development; (2) Re-design; (3) Re-manufacture; (4) Repackage; and (5) Minimal effort.

h. A general classification that best describes the equipment item, such as electro-mechanical, electronic, optical, structural, pneumatic.

i. An estimated development time in years.

j. A development risk rating (low, medium, high).

k. An estimated development cost including flight qualification costs.

l. An estimated unit cost.

m. Data on the number of items required for each candidate payload. (For each equipment item, there is one line for each payload candidate, such as Mini 30. It also contains the name of the candidate payload and the number of equipment items required for that payload.

n. A functions cross reference consisting of all the reference numbers of the functions that call for this equipment item. (This provides for the capability to scan the functions inventory and determine which functions require the equipment item being reviewed.)

2.3.2.1 Equipment Specification Work Sheets. For selected equipment items, the data on the inventory listing was supplemented with additional information intended for the designer. This information was typed on work sheets using the format shown below:

EQUIPMENT ITEM NO. & TITLE

PURPOSE OF EQUIPMENT ITEM

REQUIREMENTS

HARDWARE STATUS

TECHNICAL DESCRIPTION

(OF MOST APPLICABLE CONFIGURATION)

COST

DEVELOPMENT TIME

SKETCH, CATALOG SHEETS, CONCEPTUAL

DESIGN DRAWINGS, ETC.

Following the item number and name, the purpose of the equipment is stated. Next, any specific technical requirements of the equipment necessary to accomplish the biolaboratory objectives are included. The status of applicable hardware is stated. These comments generally apply to an equipment item similar, or most applicable to the required item. The important design parameters including weight, power, and volume, are contained in the section of this report on technical description. Pertinent sketches, catalog sheets, or drawings of applicable equipment are also attached to the Specification Work Sheet.

Two sample pages from the equipment specification work book are shown in Figure 2-9. Similar information was compiled on 135 equipment items and is contained in Reference 16.

#41 CENTRIFUGE, REFRIGERATED, HIGH SPEED (LO, MIN - MOD, MID - HI, MAX)

Purpose

Separation equipment to support medical and biological research. This unit includes both high speed and standard speeds.

Requirements

Refrigeration

High separation forces (40,000 G)

Gravity independence

Minimum weight, power and volume

Hardware Status

Commercial designs include both vapor compression refrigeration unit and centrifuge. Use of a centralized refrigeration unit should be considered. Also weight and power should be reduced and drive motors replaced.

Technical Description

Catalog descriptions of models from A. R. Thomas Co. 68 P.237 and Braun Chemical Co. No. 63 P. 210-211 are attached. For this unit (International Centrifuge, Model PR-2).

| | |
|---|---|
| Weight: | 750 lbs. |
| Power | Centrifuge, 70 watts |
| | Refrigerator, 500 watts |
| Size: | 28 x 38 x 42" (25.9 cu. ft.) |
| | Centrifuge portion approximately half of the size |
| | of this unit. |
| Speed: | 0-20,000 rpm |

Cost

Commercial Model PR-2 $2.5K

Development Time - 2 - 3 years

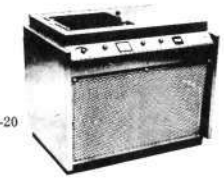




## HIGH SPEED REFRIGERATED CENTRIFUGES AND ULTRACENTRIFUGES

The centrifuges described on this page are all stocked by us. All feature: built-in refrigeration unit, controllable over −30° to +30° C, within ±1° C (lowest temperature attainable depends on running speed); solid state speed control; continuously indicating electric tachometer; electric brake; programmed sequential cooling, vacuum (in ultracentrifuges), and acceleration and deceleration within spin time selected. The drives of B-35 and B-60 ultracentrifuges are water cooled. All operate on 208-230 volts, 60 cycles; 50-cycle models are also available.

Performance specifications are shown for each model. Further details will be furnished on request.



Model B-20

Model B-35

Model B-60

Model PR-6

### Model B-20 High-Speed Refrigerated Centrifuge

**Maximum Speeds and Forces**

| Load | Head Angle | Speed | Force (rcf) |
|---|---|---|---|
| 24 × 13 ml | 33° | 19,500 rpm | 46,320 G |
| 12 × 14 ml | 40° | 20,000 rpm | 40,000 G |
| 8 × 50 ml | 33° | 19,500 rpm | 45,100 G |
| 6 × 250 ml | 20° | 14,500 rpm | 28,850 G |

### Model B-35 Ultracentrifuge

Includes vacuum pump producing operational vacuum below 50 microns.

**Maximum Speeds and Forces**

| Load | Rotor | Speed | Force (rcf) |
|---|---|---|---|
| 6 × 14 ml | 90° | 35,000 rpm | 206,200 G |
| 6 × 40 ml | 90° | 25,000 rpm | 110,000 G |
| 8 × 55 ml | 33° | 35,000 rpm | 147,100 G |
| 16 × 55 ml | 31° | 25,000 rpm | 90,100 G |
| 6 × 90 ml | 20° | 35,000 rpm | 130,400 G |
| 6 × 280 ml | 33° | 19,000 rpm | 57,000 G |
| 4 × 500 ml | 20° | 14,000 rpm | 28,500 G |

### Model B-60 Ultracentrifuge

Includes forepump and oil diffusion pump, to produce 0.3 micron vacuum.

**Maximum Speeds and Forces**

| Load | Rotor | Speed | Force (rcf) |
|---|---|---|---|
| 6 × 4.2 ml | 90° | 60,000 rpm | 405,900 G |
| 6 × 14 ml | 90° | 41,000 rpm | 283,200 G |
| 8 × 14 ml | 35° | 60,000 rpm | 321,400 G |
| 6 × 40 ml | 90° | 25,000 rpm | 110,000 G |
| 8 × 40 ml | 30° | 45,000 rpm | 211,200 G |
| 8 × 55 ml | 33° | 35,000 rpm | 147,100 G |
| 6 × 90 ml | 20° | 40,000 rpm | 170,300 G |
| 4 × 500 ml | 20° | 14,000 rpm | 28,500 G |

### Model PR-6 Refrigerated Centrifuge

Takes same heads and accessories as the Model PR-2 (see 2966-C10, ff.) but provides significantly higher speeds and forces. A 4-place windshielded head for 600 ml blood bags is available.

**Maximum Speeds and Forces**

| Load | Head | Speed | Force (rcf) |
|---|---|---|---|
| 4 × 600 ml | angle | 6000 rpm | 7900 G |
| 6 × 250 ml | angle | 5800 rpm | 7000 G |
| 4 × 600 ml | horizontal | 5500 rpm | 7000 G |
| 4 × 1000 ml | horizontal | 3000 rpm | 2250 G |
| 36 × 15 ml | angle | 5000 rpm | 4880 G |
| 20 × 15 ml | angle | 6000 rpm | 5620 G |
| 12 × 50 ml | angle | 6000 rpm | 5880 G |
| 14 × 100 ml | angle | 4300 rpm | 4100 G |

Figure 2-9. Sample Specification Sheets for an Equipment Item

## 2.4 DETERMINATION OF ORDERED PAYLOAD REQUIREMENTS

The functions and equipment inventories previously described contain various parameters and information that can be used in sorting processes to select functions and equipment for inclusion in specific payloads. An example would be to select only functions containing a (P) in their function data description, indicating that they apply to plant research. For such a list of functions, methods and equipment could be selected and would apply to a payload required to support only plant research. A payload such as this is called an ordered payload, which is one resulting from a specific (ordered) set of parameters. The process of obtaining ordered payloads is partially done manually and partially done by a digital computer program operating on the inventories. The guidelines used to establish the manual inputs are discussed in the following paragraphs.

2.4.1 GUIDELINES AND RATIONALE. In order to establish payload sizing and selection guidelines several factors were qualitatively considered. They are:

a. The research areas that would benefit most from experiments in the space environment (e.g., radiation biology, physiology, behavior, man-machine interface problems, etc.)

b. The kinds of experiments and experiment procedures which would produce valid results.

c. The number of organisms required to obtain the desired statistical validity.

d. The interelationship of all the individual life sciences FPE requirements.

e. The general mission model characteristics; such as supporting spacecraft, mission duration, operational time period, crew availability, and volume available.

Consideration of these factors along with NASA guidance led to the characteristics shown in Table 2-3 for each of the baseline payloads. This table was previously presented in summary form and discussed in Section 2.1. The mission data shown includes mission duration, a designation of the supporting spacecraft, and an approximate volume fraction of a RAM which was used as a guideline in the selection of the quantity, and type functions and equipment for each payload. For each mission in Table 2-3, the individual FPEs are listed, and several types of information are indicated. This includes: (1) the criticality of the functions selected for the payload; (2) the mode of operation desired for the methods and equipment selected; (3) the number of typical test subjects to be accommodated; and (4) the number of test subjects to be housed on a research centrifuge (if available).

As an example of the above items for Mini-30, the laboratory is part of a general purpose laboratory supported by shuttle sortie flights. The mission duration is 30 days, and 1/3 to 1/2 of a RAM was used as a guideline in selecting the functional

## Table 2-3. Payload Functional Capability

| Mission | FPE | Crit | Mode | Test Subject: Type or Equivalent | Test Subject: No. | Location: Zero g | Location: Art. g | Comments |
|---|---|---|---|---|---|---|---|---|
| **Mini Labs (General Purpose Labs)** | | | | | | | | |
| 7 Day (5 days on-orbit) 1/6-1/3 RAM | M | | | Primates | 0 | | | Deemphasize man as subject |
| | V | | | Rats | 0 | | | Maintain man as test conductor |
| | P } F | 2 | A | Marigolds | 16 | 1 cm | | Emphasize research operations and procedures |
| | I | 2 | A | Invertebrates | 1 cm | 1 cm | | |
| | C | 2 | S | Cells & Tissues | 2 cm | 2 cm | | |
| | B | - | - | Man | 0 | 0 | | |
| | L | 2 | S | Hardware | 1 | 1 | | |
| | H | 1 | M | Man | 4 | 4 | | |
| 30 Day 1/3-1/2 RAM | M | 2 | S | Primates | 2 | 2 Mac | | |
| | V | 2 | S | Rats | 16 | 2 cm | | |
| | P } F | 2 | S | Marigolds | 16 | 1 cm | | |
| | I | 2 | S | Invertebrates | 1 cm | 1 cm | | |
| | C | 2 | S | Cells & Tissues | 2 cm | 2 cm | | |
| | B | 2 | S | Man | 4 | 4 | | |
| | L | 2 | S | Hardware | 1 | 1 | | |
| | H | 1 | M | Man | 4 | 4 | | |
| **Station Oriented** | | | | | | | | |
| Nominal 2 year mission. Devoted RAM (Maxi-Nom) | M | 2 | M | Primates | 2 | 2 Mac | 0 | Includes internal centrifuge |
| | V | 2 | M | Rats | 128 | 8 cm | 8 cm | |
| | P } F | 2 | S | Marigolds | 128 | 8 cm | | |
| | I | 2 | S | Invertebrates | 2 cm | 2 cm | | |
| | C | 2 | S | Cells & Tissues | 2 cm | 2 cm | | |
| | B | 3 | M | Man | 12 | 12 | | |
| | L | 2 | S | Hardware | 1 | 1 | | |
| | H | 2 | M | Man | 12 | 12 | | |
| 5 Year Mission (Maxi-Max) | M | 3 | M | Primates | 6 | 1 Pan 2 Mac | 1 Pan 2 Mac | |
| | V | 3 | M | Rats | 512 | 32 cm | 32 cm | |
| | P } F | 3 | M | Marigolds | 288 | 9 cm | 9 cm | |
| | I | 3 | M | Invertebrates | 6 cm | 3 cm | 3 cm | |
| | C | 3 | M | Cells & Tissues | 8 cm | 4 cm | 4 cm | |
| | B | 3 | M | Man | 12 | 12 | 0-2 | |
| | L | 3 | M | Hardware | 2 | 2 | | |
| | H | 3 | M | Man | 12 | 12 | 0-2 | |

**Code**

FPE — M = Primates; V = Vertebrates; P = Plants; I = Invertebrates; B = Biomedicine; L = LSPS; H = Man System Integration; C = Cells & Tissues

Criticality — 1 = Mandatory; 2 = Highly Desirable; 3 = Desired (3 = 3 + 2 + 1 2 = 2 + 1)

Mode — M = Manual; S = Semiautomatic; A = Automatic (M = M + S + A S = S + A)

cm — Cage Modules

capability of the payload. Research to be supported in all but one of the FPEs is of criticality 2. This means that both mandatory and highly desirable functions were considered for inclusion, but that no desired functions were included. For the Mini-30, the desired mode of accomplishing the functions was generally semiautomatic. The typical test subjects which can be supported include 2 macaques, 16 rats, 16 marigolds, invertebrates, cells/tissues, biomedical experiments on 4 men, a single LSPS hardware test item, and MSI experiments using 4 men.

During this study, the first payload to be defined was the Maxi-Max, which includes functions and equipment to support the full content of the Blue Book. This was done to establish the maximum laboratory characteristics in terms of size, power consumables, and weight.

In the biology area, the Maxi-Max is capable of supporting all the biology FPEs including those concerned with research on primates, small vertebrates, plants, cells/tissues, and invertebrates. The payload size was set at six primates and two simultaneous experiments in each of the other disciplines consisting of four groups in variables of 30 organisms or samples each plus 2 contingency organisms per group. This resulted in a requirement for 256 organisms or samples per FPE or discipline. Any number of experiments can be conducted in the facility as long as the equivalent number of organisms or samples does not exceed this number. The sizing was based on using rats for the vertebrate organisms and marigolds for the plants. The following approximate equivalents were determined for one rat: 4 mice, 1/2 rabbit or guinea pig, 1/4 rat colony cage, and 1/8 small monkey or dog. For the payloads other than Maxi-Max, the number of organisms was obtained first by reducing the number of simultaneous experiments, and second by reducing the number of organisms in a statistical group. The total number of each organism that can be supported is listed in Table 2-3. Various combinations of colony sizes and numbers of colonies may be desired by the biologists depending upon the specific experiment being conducted.

In the area of biology, additional preliminary guidelines were used in the selection of functions, methods, and equipment to be incorporated in the payloads. These resulted from preliminary trade-off studies and discussions with NASA scientific personnel during the program. The first such guideline was that organisms would be carried in their normal cages during the launch and re-entry phases of all missions. An alternate approach would be to house the organisms in special restraining containers during these operations and transfer them to their cages during the orbital research period. However, many biological organisms will be fully instrumented on the ground, checked out with baseline data, and require data collection throughout launch, rendezvous, and docking. Many hours of crew time could be required to transfer the organisms to the standard cages, and then to connect, calibrate, and check-out the electronics instrumentation. Also, special EC/LSS provisions would have to be supplied for the transport containers. Thus, the current guideline is to use the standard enclosures, possibly with restraint fixtures, during the launch and re-entry periods.

A second guideline was the use of disposable rather than reusable equipment, such as syringes, needles, knives, surgical instruments, and laboratory glassware. The latter will require washing, and in some cases, sterilization before reuse. This would be difficult in the zero-g environment, and the size and weight of the related equipment would be large (estimated at approximately 0.31 $m^3$ (11 cubic feet), 68 kg (150 lb), and 500 watts during operation). It was concluded that this volume could be better allocated for the storage of disposable equipment. The penalty for waste management of this disposable equipment appeared to be less than that for the washing equipment.

A third guideline was concerned with the requirement for biochemical analysis in space. Although it is felt that emphasis should be placed on preparation and preservation in space with subsequent ground analysis, some analysis in space will be required to confirm the validity of the results obtained on the ground. Thus, space flight analysis should be performed on the earliest flights to (a) verify space analytical capability, and (b) identify any variations between space and ground results. This will allow principal investigators to more accurately plan detailed future experiment programs. Also, the requirements for the crew to manually perform such analysis should be minimized, with automatic analyzers used wherever possible.

The study change from space biology to life sciences resulted in little change to biology. Biomedicine (B), man-systems integration (H) and Life support and protective systems (L) were added. Biomedicine and man-system integration present different problems and considerations. Here man is both a subject and investigator, and the number of crew available to fill both roles is a prime consideration and is determined by the mission model. Four subjects (maximum) were assumed available on the Mini shuttle sortie missions, and 12 men were assumed available on the Space Station attached missions. Section 3.3 (Manning Analysis) is a detailed discussion on the requirements of crew subjects and investigators for biomedicine and man-system integration as well as other FPEs.

Life support and protective systems consists primarily of the test and evaluation of life support systems hardware. The LSPS capability for payloads other than Maxi Max was set at testing one equipment item at a time, such as a $CO_2$ processing unit or a trace contaminant removal device. Areas were also provided for such tests as those on protective equipment, advanced suits, and back-packs.

2.4.2 SORTING PROCEDURES AND ORDERED PAYLOAD SAMPLES. The over-all procedure for obtaining ordered payloads is diagrammed in Figure 2-10. Using a set of payload guidelines, the functions inventory is screened manually or by digital computer to obtain the functions required to satisfy these particular guidelines. Next, this list is reviewed and appropriate methods are manually selected, again considering the set of guidelines being used. The selection of methods automatically carries the requirement of specific equipment. By preparing card inputs to the computer, that designate which equipment is required and the quantity, the program sorts out the

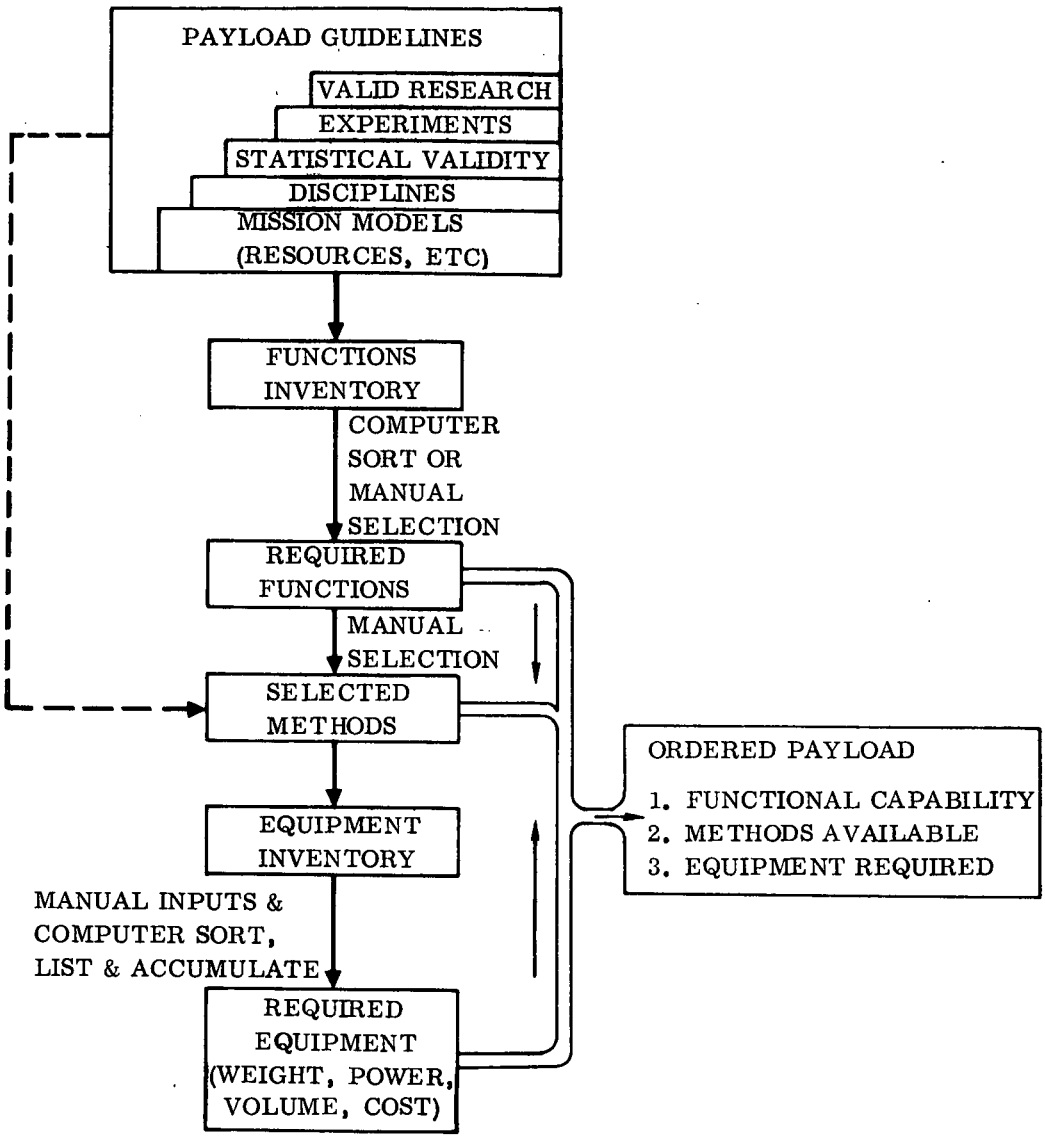



Figure 2-10. Diagram of Procedures for Obtaining Ordered Payloads

required equipment, lists it in summary form, and calculates weight, power, volume and cost values for that equipment. If the resulting ordered payloads are not consistent with the original guidelines used or other criteria such as layout configurations, the inputs to the computer are readily changed, and a new sort listed. Iterations are often necessary to define the payloads.

The printout of the ordered payloads sort is in two basic sections, the functional capability and the equipment list. A sample of the functions capability listing for the Mini-7 payload is shown in Figure 2-11. Only the selected methods of performing the required functions are listed. The lists of functions required for the ordered payloads, as well as the over-all functions inventory, were reviewed by various NASA centers. The

```
16  1 SETUP CAMERA OPTICAL COMMUTATION-ORGANISM TO ORGANISM
16  2  1 1 MVPIC8    2 4 S*1- 2 CAMERAS/CAGE MOD-MANUAL SETUP AUTO OPS
160 3 GROUND SETUP                          2   0   0  0  0 1*
16014 X-Y DRIVE                                                *0 2 1 3 038A

17 11 MONITOR ECG (FOR BIORESEARCH - ECG SIGNAL MGMT FROM CAGE TO CAGE
17 21  MOD TO DATA MGMT.)
17  2  1 1 MV   8 H  1 4 S*COUPLER SYS BUILT INTO CAGE MOD
17F 3 ELECTROPHYSIOLOGY BACKPACK -MAN-  2   U   U  4 12 1*
17F14 ELECTROPHYSIOLOGY PACKPACK                               *1 5 1 1 065B
17F24 ELECTROPHYSIOLOGY RECEIVER                               *0 4 1 1 065C
17F34 ELECTROPHYSIOLOGY DISPLAY                                *0 5 1 1 065D
17F44 COUPLER ELECTROCARDIOGRAM                                *1 2 1 2 064

22  1 TEMPERATURE MSMTS
22  2  1 1 MVPIC8LH  1 3 A*IN SOME CASES THIS IS A MAINT. FUNCTION
22A 3 THERMOCOUPLES-                    3 S 2   5   0  1    1*
22A14 THERMOCOUPLES    REQ STABLE POWER                        *1 4 1 1
22A24 THERMOCOUPLE COUPLER                                     *1 3
228 3 THERMISTERS                       3 S 2   5   0  1    1*
22814 THERMISTERS
22824 THERMISTER COUPLERS
C     CARD NUMBER 1 - FUNCTION TITLE AND DESCRIPTION
C
C        CARD NUMBER 2        *          CARD NUMBER 3
C
C F M C  C P  U        T E M*        E M S T   T   C
C U E A  R A   S       A N O*        N O C TE  IE  RS
C N T R  T Y    E      S V D*        V D I MII MAA EK
C C H D  T L     R     K   E*          E   ERT ECO WI
C T O    I O F         D   *        A   P  SE  HD
C I O N  C A  P        T E O*        C A E  TM
C O   O  A D   E       Y S E*        T C S
C N   .  L             P R S*        U T
C        Y   MVPIC8LH  . D .*        I
C

24  1 WATER CONSUMPTION -WATER
24  2  2 2 MVP  8L   1 3 A*
24A 3 FLOWMTR IN MANIFOLD
24A14 POSITIVE DISPLACE
24A24 FLOWMETER COU
24A34 FLOWME
```

Figure 2-11. Sample of Mini-7 Ordered Payload Functions Listing

methods to accomplish the functions were also reviewed, but will require continued updating by the principal research investigators to insure validity of the methods selected. The definition of functions and methods are the basis of the facility approach to laboratory design. If the functions and/or methods are correct, the resulting equipment in an ordered payload and payload layout will also be valid.

The second section of the sort is the equipment listing. Several sample pages from a Mini-7 payload sort list are shown in Figure 2-12. The equipment list contains all the research equipment required for the selected payload. Supporting subsystem equipment, such as that for environmental control, and thermal control, is generally not included. Also, structural components such as floors, bulkheads,

SORT OF EQUIPMENT INVENTORY LIST BY PAYLOAD OF CODE TYPE 1A7

NOTE - DEVELOPMENT COST IS A ONE-TIME EXPENSE PER ARTICLE.
UNIT COST UNDER SUB-TOTAL IS SIZING NUMBER TIMES COST PER ARTICLE.

| | | | TOTALS BY EQUIPMENT NUMBER | | | | |
|---|---|---|---|---|---|---|---|
| | | | WEIGHT (LBS.) | POWER (WATTS) | VOLUME (CU.FT.) | UNIT COST ( K $ ) | DEVELOPMENT COST ( K $ ) |
| AR 7 | CAMRA, CINE<br>MINI 7 = 4 X 2 1 | 1 1 8. 10 0.3 1 1HR-1T020 1X032<br>1 1A7 032 | 32.0 | 40 | | 80 | 150 |
| DV | CAMERA CONTROLLER<br>MINI 7 = 1 1 1 | 1 1 10. 200 .5 1 1 032A<br>1 1A7 032A | 10.0 | 200 | .500 | 50 | 5000 |
| CR 1 | CAMRA, STIL, (PLATE,#<br>MINI 7 = 2 1 1 1 | 1 1 25. 0 .1 1 INCL WORK 1X034<br>1 1A7 034 | 50.0 | 0 | .200 | 10 | 20 |
| CR 1 | CAMRA, VIDEO B/W 3 3<br>MINI 7 = 5 X 2 2 | 1 2 1.2 12 .1 2 40 RECD 1 037<br>1 1A7 037 | 6.0 | 60 | | 5 | 2 |
| CR 1 | CAMRA,VIDEO/COLOR 3 3<br>MINI 7 = 1 1 1 | 1 1 65. 125 1.8 2 COMML 1 038<br>1 1A7 038 | 65.0 | 125 | 1.800 | 100 | 300 |
| DV | CAMERA X-Y DRIVE<br>MINI 7 1 X 1 | 1 1 5. 20 .4 3FOR CAGE MOD 1 038A<br>1A7 038A | 5.0 | 20 | | 1 | 100 |
| DV | FILTERS, VIDEO<br>MINI 7 = 1 1 1 | 1 1 1. 0 .1 1 PART OF 037 1 076E<br>1 1A7 076E | 1.0 | 0 | .100 | 1 | -0 |
| 84 | LOG BOOKS FOR DAILY RECORDS 1<br>MINI 7 = 11 4 2 1 4 | 1 1. 0 .05 1 1 116<br>1A7 116 | 11.0 | 0 | .550 | 0 | 0 |
| M-98 | MICRSCP, COMPND<br>MINI 7 = 1 1 1 | 1 12.5 25 .8 1 10X-1000X 1X126<br>1A7 126 | 12.5 | 25 | .800 | 12 | 20 |
| DV | MIRROR MOUNT-COMMUTATR<br>MINI 7 = 1 X 1 | 1 .2 5 .01 3 1 126E<br>1A7 126E | .2 | 5 | | 1 | 100 |
| DV | MONITOR, VIDEO<br>MINI 7 = 1 1 1 | 1 1 20. 50 2. 1 PART OF 032A1 126G<br>1 1A7 126G | 20.0 | 50 | 2.000 | 5 | -0 |
| DV | PAPER, RECORDING<br>MINI 7 = 3 1 1 | 1 50. 3. 1 P/D SENSITIV1 134B<br>1A7 134B | 150.0 | 0 | 9.000 | 0 | 0 |
| E 65 | RCRDR MULTICHN BIOMED<br>MINI 7 = 1 1 1 | 1 150. 230 2.0 1 22X65X30 IN 1X150A<br>1A7 150A | 150.0 | 230 | 2.000 | 100 | 500 |
| DV | VIDEO ID DATE-TIME SYS<br>MINI 7 = 1 X 1 1 | 1 . . 1 1 181E<br>1 1A7 181E | ( DESIGN / LAYOUT SENSITIVE ) | | | | |
| DV | COMPUTER, DIGITAL<br>MINI 7 = 1 | 2 . . 1 PAYLD SENS 11051<br>W253. P V 8.95 1A7 0F1 | ( DESIGN / LAYOUT SENSITIVE ) | | | | |
| | DATA MNGMT SYS, BUSES<br>MINI 7= 1 | 2 . . 2 PAYLD SENS 1 056A<br>W 46.6P V 1.9 1A7 056A | ( DESIGN / LAYOUT SENSITIVE ) | | | | |

Figure 2-12. Sample of Mini-7 Ordered Payload Equipment List (Sheet 1)

- - - - SUB - TOTALS - - - -

| EQUIPMENT UNIT NUMBER | WEIGHT (LBS.) | POWER (WATTS) | VOLUME (CU.FT.) | UNIT COST ('K $) | DEVELOPMENT COST ( K $ ) |
|---|---|---|---|---|---|
| 1 | 512.7 | 755 | 16.950 | 365 | 6192 |
| 2 | 205.0 | 348 | 4.650 | 460 | 652 |
| 3 | 311.4 | 54 | 10.000 | 33 | 241 |
| 4 | 947.5 | 611 | 60.570 | 310 | 8998 |
| 5 | 459.8 | 899 | 25.820 | 717 | 6276 |
| 6 | 387.1 | 2146 | 25.260 | 186 | 11343 |
| 7 | 120.4 | 0 | 13.000 | 17 | 22 |
| 11 | 562.0 | 40 | 59.100 | 70 | 1225 |
| 12 | 65.0 | 25 | 4.500 | 75 | 300 |
| 25 | 111.6 | 11 | 1.450 | 102 | 715 |
| 42 | 16.6 | 46 | 1.000 | 56 | 121 |
| 50 | 95.0 | 10 | 6.640 | 25 | 5250 |
| 51 | 75.6 | 70 | 8.500 | 22 | 128 |
| 60 | 141.0 | 100 | 13.280 | 20 | 0 |
| 61 | 46.0 | 0 | 2.030 | 6 | 28 |
| 70 | 85.0 | 30 | 6.640 | 11 | 50 |
| 80 | 97.0 | 100 | 6.800 | 2000 | 257 |
| 91 | 105.0 | 105 | 4.700 | 93 | 371 |
| 93 | 4.0 | 0 | | 1 | 10 |
| 99 | 0.0 | 0 | | 0 | 0 |

Figure 2-12. Sample of Mini-7 Ordered Payload Equipment List (Sheet 2)

- - - - - TOTALS - - - - -

| WEIGHT (LBS.) | POWER (SEE NOTE) (WATTS) | VOLUME (CU.FT.) | UNIT COST ( K $ ) | DEVELOPMENT COST ( K $ ) |
|---|---|---|---|---|
| 4347 | 5379 | 270 | 12701 | 77248 |

* NOTE =

POWER TOTAL ASSUMES ALL EQUIPMENT IN INVENTORY IS ON CONTINUOUSLY. EXPERIMENT TIME LINES AND INSTRUMENT REQUIREMENTS, WHEN DETERMINED, WILL PROVIDE THE TRUE POWER PROFILE. PRELIMINARY STUDIES SHOW AVERAGE POWER TO BE APPROXIMATELY ONE TENTH OF TOTAL POWER.

THIS SORT CONTAINS THE RESEARCH EQUIPMENT REQUIRED TO ACCOMPLISH THE SELECTED FUNCTIONS LISTED. THE WEIGHT, POWER AND VOLUME STATEMENTS ARE FOR THE RESEARCH EQUIPMENT. THE SORT DOES NOT INCLUDE THE ENVIRONMENTAL CONTROL SYSTEM, THE SUPPORTING STRUCTURES (CONSOLES, RACK, ETC.) FOR THE HARDWARE OR THE HOUSING VEHICLE (RAM).

THE EQUIPMENT UNIT SUBTOTALS AND THE PAYLOAD TOTALS GIVEN DO NOT INCLUDE THE #DESIGN/LAYOUT SENSITIVE# ITEMS FLAGGED IN THE EQUIPMENT LIST. IN MOST CASES THE SPECIFIC PAYLOAD MUST BE ASSESSED AGAINST A DEFINED OR ASSUMED LAYOUT CONFIGURATION AND MODE OF CREW MOBILITY/RESTRAINT AND OPERATION.



Figure 2-12. Sample of Mini-7 Ordered Payload Equipment List (Sheet 3)

racks, and consoles for equipment installation are not included. The sorts contain some items flagged as "design/layout sensitive." These items are different for each payload and the weight, volume, power and cost data are generated manually. The power data for each equipment item is the power required when the item is "on." The daily average power for each item must be calculated based on its duty cycle. This was performed for the baseline payloads and is contained in Section 3.4.

Subtotals of weight, volume, power, and cost are contained in the sort for each group of equipment in an equipment unit. Following this, over-all totals for the ordered payload are given.

The functions inventory contains significantly more information than is presently being utilized by the existing sorting program. Data on crew skills and crew time required to accomplish the functions, safety, logistics and maintainability are available. These parameters could be analyzed in various ways to provide other significant results. For example, a program could be written which analyzes the equipment contained in a candidate payload to determine what additional functions might be accomplished with the equipment available. From the additional functions, it would be possible to determine what other experiments could possibly be considered without changing the equipment content of the payload. The equipment inventory also contains considerable data which is not used by the computer program.

2.4.3 PAYLOADS STUDIED DURING THE PROGRAM. During the course of the study, payload sorts were developed for the first generation and baseline payloads shown in the table in Figure 2-13. The table shows which payloads were dropped and indicates the reason.

First generation payload sorts were developed for:

a. Maxi Max. This is the complete Blue Book capability and was used as a reference capability. Other payloads were fractions of the Maxi Max with modifications.

b. Midi-90. This payload was based on a shuttle sortie mission of 30 days manned, 30 days unmanned (dormant) with select organisms maintained in the weightless state, and 30 days manned for analysis of the original experiments and the conduct of new experiments. This payload was deleted at the first NASA review.

c. Midi-30. This payload and the first 30 days of the Midi-90 are the same. It is a shuttle sortie type mission consisting of a dedicated life sciences payload. This payload was modified by NASA at the second generation payload review and became the Maxi-Nom payload supported by the Space Station.

d. Midi-56. This was a dedicated 56-day Skylab payload, and was deleted at the first generation payload review.

| | 1st Generation Payloads | 2nd Generation Payloads | Baseline Payloads | |
|---|---|---|---|---|
| Maxi Max Study Base | Fully developed as reference payload. | | | Complete Blue Book capability. Reference to measure loss of functional capability and equipment. |
| Maxi Nom | --- | Payload & Lay-out developed from Midi-30 | Payload & Lay-out refined | Space Station Life Sciences Candidate RAM |
| Midi-90 | Similar to Midi-30 except left un-manned for 30 days | Deleted | --- | No planned payload operated in the unmanned mode for Life Sciences. |
| Midi-30 | RAM payload & layout prelim. development | RAM payload & layout refined | Deleted | Deleted because of similarity to Maxi Nom. |
| Midi-56 Skylab Mission | Skylab payload & layout prelim. development | Deleted | --- | Delete as a candidate mission. |
| Mini-56 Skylab Mission | " | Deleted | --- | Deleted as a candidate mission. |
| Mini-30 | RAM payload & layout prelim. development | (RAM) Payload & layout refined. | (RAM or SS) Payload & layout refined | Shuttle sortie and a Space Station candidate payload. |
| Mini-7 | " | " | " | Shuttle sortie only. |

Figure 2-13. Study Chronology of Payload Development

e. Mini-56. This was the life sciences portion of a multipurpose Skylab payload with a 56 day mission duration. Both Skylab payloads were considered as "flights of opportunity" and were adaptable to any candidate vehicle.

f. Mini-30. This is the life sciences section of a general purpose laboratory (GPL). The primary mission is a 30-day shuttle sortie. It is also a candidate for a general purpose RAM attached to a space station complex.

g. Mini-7. This payload is similar to but smaller than the Mini-30 and has a 7-day duration. Due to the short on orbit period (5 days), the kinds of experiments are limited.

Second generation payload sorts were basically manual updates of the original sorts. A new Mini-7 payload sort was run, and the deletion of biomedicine and change in scope of cells/tissues was considered a major change. The two 56-day Skylab payloads were deleted as candidate missions, and the Midi-90 mission was deleted because no unmanned life sciences missions were being planned.

Baseline payload sorts were generated for Maxi Max, Maxi Nom, Mini-30, and Mini-7. The sorts were basically refinements of the original sorts employing updated and refined guidelines resulting from NASA inventory reviews, commonality studies of types and number of equipment required, design layout results, equipment item specification reviews, and manning requirements. These payloads are recommended for further design integration studies. The research capability of these payloads is described in Section 2.1 of this report.

# SECTION 3

# RESEARCH OPERATIONS ANALYSIS

The research operations required by the crew and/or their automatic equipment within the laboratory during the on-orbit phase of the mission were examined to develop initial estimates of required manning levels, skill requirements, equipment usage rates, and average power consumption levels, and to provide a basis for the initial human factors inputs to the candidate design layouts. The facilities approach guideline (Section 1) required the development of an operations model before the above estimates could be made. This model was used as the basis for the manning analysis and equipment operations analysis presented herein. Several unique aspects of the operations within the Life Sciences laboratory are reflected in this analysis, and are discussed in the following paragraphs.

## 3.1 UNIQUE ASPECTS OF THE LIFE SCIENCES PAYLOAD OPERATIONS

The normal operations within a space laboratory such as experiment installation, setup, initiation, conduction, termination, and refurbishment will be performed within the Life Sciences laboratory. The procedures and requirements of some of these operations are unique; however, the following discussion will serve to clarify their nature.

The Biology FPEs require living organisms for their experiments including vertebrates, invertebrates, plants, cells/tissues. A significant portion of the operations in support of these FPEs involves functions for specimen maintenance or housing, and sustaining living organisms in space. These specimen maintenance functions are unique to the Life Sciences payload and are an operational requirement in addition to the equipment maintenance and other normal functions.

The Biomedicine and Man-System Integration FPEs require man, not only as the experiment operator but as the test subject as well. Thus, the manning levels for most phases of the experiments are doubled, creating an unusually high demand on the crew. Parenthetically, the experimental apparatus should be designed to be self-administered wherever possible to alleviate this requirement. It is not just the life scientists assigned to the laboratory that serve as subjects for the experiments, but the entire crew available during the mission. The use of the entire crew increases the sample size and greatly enhances the possibility of obtaining statistically significant results. The operational impact of this requirement on crew scheduling affects not just the Life Sciences laboratory crew, but the entire available crew.

Another consideration that is unique to the Life Sciences laboratory and greatly influences the biological operations within the laboratory is the requirement for the use of a laminar flow bench (LFB).

The LFB, a modified portable glovebox, is used to provide an isolated operational interface between man and the biological organisms because of the effects of zero gravity and space radiation on the biologicals produced by the test organisms, as well as the effects these conditions will have on man's resistance, is unknown. The effect of chemical contamination is also of concern. A related requirement for isolation exists between experimental groups of organisms. Without isolation, any disease affecting an experimental group would most likely spread throughout the lab colony destroying the experiments. The LFB is intended to provide this isolation.

The LFB also performs the following functions:

a. The laminar flow system maintains clear vision to the subject as well as keeping debris such as urine, feces, water, and hair away from the subject.

b. It provides a portable workbench that can be appropriately outfitted for the desired task and taken to the organism. Moving a biological organism to the work area might exceed the allowable gravity levels established for the organism.

c. It provides an instrumentation complex (video display, CRT display) at the organism holding units, allowing setup and checkout of the experiment instrumentation (camera adjustments, bioelectronic calibration and adjustment, feed and water dispenser checkout, etc).

d. It provides a means of transporting samples from the holding units to the preservation and preparation unit while maintaining isolation.

Glove box operations are also required for many additional biological functions. Examples are toxic chemical management and radiobiological research. Toxic chemical management can be accomplished in the LFB by interfacing with an equipment rack containing the chemicals, the management equipment and measurement instruments. Radiochemistries can be performed in the LFB by using a liner fabricated from shielding fabric and a shielding glass. In this case the radiochemicals are contained in the portable LFB that can be moved throughout the laboratory as needed.

The requirement to use the LFB for so many functions within the biology laboratory imposes a significant constraint on the crew operations. The limited number of LFBs and their requirement for sterilization after use affects activity schedules, traffic patterns, and cargo handling systems. Its most advantageous operational impact, is that it allows free transfer for other members of the crew in and out of the laboratory without having to perform decontamination procedures.

## 3.2 OPERATIONS MODEL

The guideline, discussed in Section 1, requiring a facility approach to the design of the Life Sciences payload had a significant impact on the operations analyses conducted in support of that design. The guideline, which directs that specific experiments not be used as the basis for laboratory design, made it difficult to determine experiment dependent factors such as crew size and skill requirements, average power consumption levels, equipment usage rates, and workspace volume requirements. For preliminary estimates of these quantities, it was necessary to develop an operations model upon which the estimates could be based. This section discusses the development of that model.

The model is based on all the functions that are to be performed within the laboratory for a given payload. The functions, their specific methods, and the time required to perform each function were used. The model is completed, as illustrated by Table 3-1, by the addition of an assumed frequency for each method. In support of this approach, it may be noted that a set of functions, if placed in their proper sequence, would satisfy specific experiment requirements and constitute a standard timeline analysis format. The designation of frequencies eliminates the sequencing step and still makes possible estimates of crew size and skill requirements. The assumed frequencies were constrained by practical considerations for some functions. As an example, the frequency with which a sample of blood can be drawn from a rat is bounded by the need of the experimenter on one hand, and exsanguination of the rat on the other, and for others by intuitive estimate of the expected frequency of a particular function within the laboratory. The expected frequencies are considered to be reasonable estimates representative of the character of the operations within the laboratory.

The complete operations model tables are contained in the Appendix, Volume III. The functions are grouped in the model by the following categories:

a. Experiment measurements and analysis

b. Support operations

c. Specimen maintenance

d. Equipment maintenance.

and by the following type:

a. Manual and semiautomatic

b. Automatic.

Table 3-1. Excerpt from Operations Model, Maxi Max Payload

```
20   1 RESPIRATORY  RATE MONITORING- DOES NOT INCLUDE RESP VOLUME
20B       FREQ - 12/WK - PLYTHESMOGRAPH ON ORGANISM

21   1 CARDIAC OUTPUT- IMPLANTED FLOW XDCR-SIGNAL XFR TO DM AS FUNC 17
21A       FREQ -  3/WK - CATHETERIZED SEMIRESTRAINED
21B       FREQ -  2/WK - ULTRASONIC FLOWMETER

24   1 WATER CONSUMPTION -WATER CONSUMED OR WATER DELIVERD
24B       FREQ - 10/WK - VOL OR MASS OF WATER BAG/BOT

26   1 LIQUID VOLUME MSMTS- MICRO VOLUMES  .001 ML TO 1 ML
26A       FREQ -  3/DY - MICROPIPETTES
26B       FREQ -  4/DY - MICROSYRINGES

27   1 LIQUID VOLUME MSMTS- MACRO  1 ML TO 1000 ML
27        FREQ - 15/DY

28   1 MASS MEASUREMENTS OF CONTAINED LIQUIDS AND SOLIDS - .001-100 GRAMS
28        FREQ -  6/DY

29   1 MASS MEASUREMENTS- CONTAINED LIQUIDS AND SOLIDS   - 10-1000 GRAMS
29        FREQ -  9/DY

30   1 GROSS ANATOMIES-ASSESSMENT OF MAJOR ORGANS-SIZE SHAPE MASS COLO
30        FREQ -  3/WK

34   1 BLOOD ELECTROLYTES
34B       FREQ - 20/WK - ATOMIC ABSORPTION
34C       FREQ - 20/WK - PRESERVE FOR GROUND ANALYSIS

35   1 BLOOD PH PCO2 O2     MSUR CONC OF DISSOLVED GS IN BLOOD
35        FREQ - 20/WK

36   1 BLOOD TOTAL PROTEIN  MSUR CONC IN SERUM OR WHOLE BLOO
36C       FREQ - 10/WK - PRESERVE FOR GROUND ANALYSIS
36D       FREQ -  2/WK - ELECTROPHORESIS

39   1 THYROID FUNCTION TESTS-SERUM STABLE WHEN
39        FREQ -  6/WK

40   1 BLOOD MORPHOLOGY AND CELL CO
40        FREQ - 20/WK

41   1 HEMATOCRIT  MSUR OF
41        FREQ -  4/WK

42   1 HEMOGLOBIN-MS
42        FREQ -
```

The expected frequencies, as shown in Table 3-1,are stated as the number of repetitions of a given function or method. The time interval to perform each function or method is given in the functions inventory, and this is multiplied by the frequency to obtain the total time required for the crew to perform the function.

It should be recognized that functions frequently do not occur at regular intervals but are of a more sporadic nature. For example, a function might occur ten times one day and only twice the next, or every day for two weeks and then not at all for two months. Average frequencies have been assumed for these functions.

## 3.3 MANNING ANALYSIS

The operations model was used as the basis for estimating total crew time requirements (work load), and thus crew size. Along with the skill requirements of each function from the function inventory, the model was also used to estimate total skill requirements and potential mixtures of individuals which would satisfy these requirements. The distribution of the work load was constrained by the assumed duty cycle for each particular payload.

3.3.1 DUTY CYCLE. The basic duty cycle assumed for the crew was 12 hours on duty and 12 hours off duty, seven days a week with the entire crew on duty at the same time and sleeping at the same time. This cycle as based partly on the results of the space station crew's duty cycle. One space station configuration used a 12 hour on duty cycle followed by a 12 hour off duty cycle, but with the crew on-duty time staggered, so that half of the crew was on duty while the other half was off duty. This recommendation was qualified, however, by the suggestion that this duty cycle might be unrealistic. The other space station configuration placed all the crew on a simultaneous ten hour day, six days a week, and qualified their recommendation by saying the seventh day would be available for unscheduled maintenance, or other duties.

Other reasons for the selection of 12 hour duty cycle are based on the Life Sciences payload requirements. No experiment requirements for round-the-clock (RTC) operations have been identified for these payloads and the all on, all off operation was selected in order to:

a. Increase the availability of crew skills. When the crew is split in half with RTC operations, one of two procedures must be followed. First, to schedule all activities requiring a certain skill during one half of the day. This would result in grossly inefficient operations such as requiring crewmen to get up in the middle of their sleep period to serve as subjects on tests conducted by the specialist on the other shift. It would also limit life sciences research by reducing the number

of crew skills available at any particular time, thus reducing the overall versatility of the laboratory in applying all the skills available as the immediate situation demanded. Secondly, the alternative to splitting skills is cross-training crew members to an even greater degree than otherwise required. Some cross-training of crewmen to acquire the variety of skills demanded by the Life Sciences payload will be required even when all the crewmen are available at one time (see Section 3.3.3). This requirement would be further compounded by RTC operations.

b. Minimize noise during sleep periods. Recommendations from ground-based simulations of long-duration spaceflight and past space experience consistently contain references to continuing efforts to minimize noise during sleep periods. Noise can be a major irritant to the crew, and even with separated living quarters, as in the case of the RSM (RAM Support Module), the active crew would disturb the sleeping crew when they return to the RSM for meals, etc. This factor loses its relevance as the sleeping quarters become further separated from the Life Sciences laboratory, from galley areas, etc., as would be possible with a space station supported laboratory.

c. Maintain ground biorhythms. To maintain peak performance during the initial adjustment phases of the mission, the all on, all off schedule allows continuation of the crew's ground-based wake/sleep cycle and no readaptation of their biorhythms is required.

The assumed duty cycle for the Life Sciences payload crew is illustrated in Figure 3-1 for the selected payloads. The 12 hours of off-duty time for each crewman are divided into: 1) 8 hours of sleep; 2) 2.5 hours of food preparation, meals, and cleanup for three meals, or about 45 minutes for each of two meal periods, and an hour for the third; and 3) 90 minutes of exercise and personal hygiene activities. Periodic housekeeping of the living quarters is assumed to be completed during this latter time period as required.

The 12 hours of on-duty time are scheduled as shown depending on the payload. For Mini-7, eleven hours are completely scheduled with functions from the function inventory and one hour is left unscheduled as contingency time. This time is provided for handling of unscheduled activities such as emergency repair or replacement of equipment, extensions of scheduled activities beyond the baseline timeline, and unscheduled experimental activity selected by the on-board experimenter.

For the 30-day Mini-30, the scheduled activity is reduced to ten hours with a corresponding increase in contingency time to account for the greater probability of equipment breakdown on a longer mission, to provide for a larger margin of error in scheduling activities over the longer mission, and to provide the potential for crew personal or recreational time should circumstances warrant it, and the need arise.

Basic duty cycle - 12 hours on, 12 hours off, 7 days a week with the entire crew on-duty at the same time and sleeping at the same time.[1]

| ON-DUTY TIME | | | | OFF-DUTY TIME | |
|---|---|---|---|---|---|
| Payload | Crew Replacement Cycle | Scheduled Activity | Contingency Time[2] | | |
| Mini 7 (7 days) | 7 days | 11 hrs.[3] | 1 hr. | Sleep | 8.0 hrs. |
| Mini 30 (30 days) | 30 days | 10 hrs.[3] | 2 hrs. | Food prep., meals, and cleanup | 2.5 hrs. |
| Maxi Nom (2 yrs.) | 90-180 days | 10 hrs.[4] | 2 hrs.[4] | Exercise and personal hygiene | 1.5 hrs. |
| Maxi Max (5 yrs.) | 90-180 days | 10 hrs.[4] | 2 hrs.[4] | | 12.0 hrs. |

[1] Minimizes noise during sleep periods, increases crew skills availability, maintains ground biorhythms, etc.

[2] Contingency time provided for emergency repair/replacement and/or unscheduled experiment activity.

[3] General Purpose Laboratories. Assume 40% of scheduled activity is in support of the Life Sciences Payload.

[4] Except for every 7th day which is planned as follows: 6 hours of experiment evaluation (review experiments with ground-based P.I. and modify experiment procedures/hardware as appropriate) and 6 hours of contingency and/or off-duty time.

Figure 3-1. Duty Cycle

For the longer missions with 90 to 180 day crew replacement cycles, Maxi Nom and Maxi Max, the scheduled activity/contingency time ratio remains the same as Mini-30, with the exception of every seventh day. Once every week, a highly flexible day is provided with no scheduled activity from the functions inventory. This day is scheduled as an experiment evaluation and review time between the on-board experimenter and ground-based principal investigators to take full advantage of the research flexibility allowed by manned laboratories in space. The scheduled activity for the coming week would be thoroughly evaluated based on the experience of the past week and potential changes or repetition of measurements planned. In addition, this day would provide time for abnormally high maintenance and repair activity, and for crew personal and recreational time as required by the long duration mission.

3.3.2 MANNING LEVEL. The crew size for the Maxi Max payload was determined based on the required work load. This work load was calculated using the selected functions from the inventory, the crew task completion times for these functions, and the expected frequency of the function from the operations model. The crew requirement for each function was calculated in terms of man hours per time period (e.g., day, week, month, etc.), as specified for the function. This figure was then converted to the average number of men required per day for each function (e.g., 0.04 men per day). These values were tabulated by preferred skill type and are summarized in Table 3-2.

The average manning level required for the Maxi-Max payload is 8.75 men. This figure includes all 12 men participating as test subjects in the biomedical and MSI experiments. The actual life sciences research crew size for this laboratory is eight men with the other four Space Station crewmen serving only as test subjects 18% of their time. The current Space Station 12 man crew is organized into two groups: a 4 man operations group and an 8 man scientific group. Thus, the Maxi-Max Life Sciences laboratory utilizes the full scientific crew and cannot grow in size itself until the capacity of the supporting Space Station is increased from 12 men.

The Mini-7 and Mini-30 payloads will share the four man scientific complement of the space shuttle crew. This assumes a shuttle crew consisting of the pilot and co-pilot and four experimenters (two housed in the orbiter and two in the RSM). Based on the size of these two Life Sciences payloads, it is reasonable to expect that experiments in at least one or two disciplines besides life sciences will be conducted within one RAM. If this is an accurate assumption, the Mini-7 and Mini-30 Life Sciences payload crews will average slightly less than two men with a peak loading of four men.

Table 3-2. Manning Level by Skill Category - Maxi Max Payload

| SKILL | MANNING LEVEL REQUIRED |
|---|---|
| Biotechnician (1)* | 1.246 |
| Microbiotechnician (2) | 0.465 |
| Biochemist (3) | 0.636 |
| Physiologist (4) | 0.867 |
| Electromechanical Technician (12) | 0.177 |
| Medical Doctor (13) | 0.240 |
| Behavioral Scientist (21) | 0.485 |
| Chemical Technician (22) | 0.128 |
| General Skills (0) | 2.504 |
| Test Subjects** | 1.992 |
| TOTAL | 8.740 |

*Functions Inventory skill reference number.

**All crew members participating as subjects (12 men).

The Maxi Nom payload manning level lies in between the 2 and 8.75 man extremes, and is estimated at the present time to require 3 life scientists full time augmented by specialists from the Space Station. This estimate was based on the number of functions to be executed within the laboratory, the degree of automation of these functions, and the number of biological organisms compared to the other payloads.

The probable distribution of the Space Station crew in support of multiple RAMs docked to the Space Station was also taken into account. One man is assumed to be a specialist in F functions (biology), one in BLH functions (biomedicine, life support, and man-systems integration), and one in CORE operations. The average occupancy level is estimated to be four men. This includes using the full 12 man Space Station crew as test subjects on the biomedical and MSI experiments in order to maximize sample size.

3.3.3 SKILLS MIX. For the Maxi-Max, an analysis was performed to select a mixture of individuals with certain skills to satisfy the laboratory requirements. To provide the ten skills identified in Table 3-2 by the eight man crew, some cross-training will be necessary. The selected skills mix of minimal cross-training is indicated by Table 3-3. Only crewman number 1, a medical doctor cross-trained as a behavioral scientist, and crewman number 7, an electromechanical technician cross-trained as a chemical technician, possess more than one skill. This sample skills mix was developed by grouping the functions required for the Maxi-Max payload by their primary skill requirement. (For each function in the functions inventory, the preferred skill for performing that function is identified. In addition, a secondary skill is listed that would be an acceptable alternative should the primary skill be unavailable.) The time required for each function was summed to give the total crew time requirement by skill category, refer to Table 3-2.

Since each individual must perform certain functions that require only a general skill (e.g., crew restraint, crew mobility, etc.) and each individual must serve as a test subject, the time requirements for these functions were added to the time requirements for each primary skill category to get a more accurate estimate of the crew time requirement by the primary skill category.

These totals were then adjusted to evenly balance the work load by removing functions from overloaded crewmen and reassigning these functions by their secondary skill requirement to other crewmen.

The minimal substitution of the secondary skill for the primary can be seen in Table 3-4. This table illustrates the specific functions assigned to each crewman. The left-hand column indicates the primary skill required. This skill matches the skill of the crewman (or is "0" for general skills) except for one function for crewman 6, five functions for crewman 7, and one function for crewman 8. These instances reflect the use of the secondary skill for that function.

Table 3-3. Sample Crew Duties/Skills Mix (Maxi-Max Payload)

CREW SIZE - 8 (The 4 remaining crew members of the SS crew will be required to spend 18% of their scheduled on-duty time in the laboratory as test subjects.)

| ASSIGNMENT | PRIMARY DUTIES | PRIMARY SKILLS |
|---|---|---|
| Scientific Staff | | |
| 1. Laboratory Director | Responsible for the overall operation of the laboratory and selected experiment execution and analysis. | Medical Doctor (Skill 13) cross-trained as Behavioral Scientist (Skill 21) |
| 2. Physiologist | Responsible for selected experiment execution and analysis. | Physiologist (Skill 4) |
| 3. Biochemist | Responsible for selected experiment execution and analysis. | Biochemist (Skill 3) |
| Technical Staff | | |
| 4. Biotechnician | Contaminant control technician, sample preservation specialist. | Biotechnician (Skill 1) |
| 5. Senior Biotechnician | Sample - blood -etc. analyst, RLC technician. | Biotechnician (Skill 1) |
| 6. Microbiotechnician | Microbiological technician, biomedical assistant. | Microbiotechnician (Skill 2) |
| 7. Maintenance Technician | Equipment maintenance and calibration, electrical and chemical technician. | Electromechanical technician (Skill 12) cross-trained as chemical technician (Skill 22) |
| 8. Biological Specimen Caretaker | Cleaning and feeding of biological specimens. | General skills (Skill 0) |

The other data in Table 3-4 indicate: a grouping of each crewman's assigned functions by frequency of occurrence, identification of these functions and their selected method by identification number and title, a graphic comparison of the average time spent on each function on a daily base, and an approximation of the percentage of time a man spends on each of his functions.

## 3.4 EQUIPMENT OPERATIONS ANALYSIS

The operation of research equipment in the Maxi-Max Life Sciences payload was analyzed to determine average power consumption, equipment usage rates, the related workspace volume required, and to verify the initial estimates of the number of each equipment item required. The function and equipment inventories and the operations model were used as the basis for these analyses.

Table 3-5 is an excerpt from the documentation of the equipment operations analysis contained in Appendix , Volume III. The reference number for each equipment item is tabulated in the left hand column, followed by the name of the item, the equipment unit to which it belongs, and its weight, unit power, and volume. Beneath the name of each piece of equipment are the functions that use the equipment identified by reference number and title. Directly opposite each using function are the number of that equipment item required for the function, an estimate of the time that the crew spends using that equipment, an estimate of the length of time that the equipment is "on" (using power), and the power consumption based on a 24 hour average.

The number of items required for each function has been used as the basis for selecting the total number required for the payload. This number appears in the table under each number required column, and corresponds to the total used in the equipment inventory sorts to obtain the ordered payloads discussed in Section 2.4. The total number of items does not always equal the sum of its parts. Normally, a total less than the sum reflects sharing of the equipment item between several functions while a total greater than the sum reflects an allocation for spares or the replacement of consumable items. Other differences between the sum and the total are due to more specific reasons. For example, equipment item 018D, custom bite boards shows a sum of nine required for the using functions but a total of 12. This is due to the custom nature of the item. Each crewman uses his own bite board. While only nine are used for the specified functions during the indicated weekly repetition period, a total of 12 are needed by all the subjects who will eventually execute that function.

The total for the crew use time column has been adjusted to a daily base for comparative purposes. This total can be used in conjunction with design layouts for gross estimations of the workspace volumes required: whether single or multiple crew accessibility is desirable; whether crew occupation of the accessibility workspace to the item is so high that special provisions for passage by other crewmen or for access to adjacent items is necessary to minimize interference. This total can also be used if payload trimming of border line items is necessary to cut weight, or volume.



C.2.

## Table 3-4. Individual Crew Duties

### CREWMAN #1

LABORATORY DIRECTOR - Medical Doctor (Skill 13) cross-trained as a Behavioral Scientist (Skill 21)

| PSR* | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Twice Daily | | | |
| 0 | 144A | Experiment status monitoring | ——— | 2.2 |
| | Daily | | | |
| 0 | 75A | Crew guidance | —— | 1.3 |
| 0 | 127H | Crew mobility/transfer | ———— | 4.0 |
| 0 | 128H | Materials transfer | ————— | 6.0 |
| 0 | 201L | Crew restraint | —— | 1.0 |
| 21 | 820 | Task completion times | — | 0.4 |
| 21 | 822B | Crew body position measurements | ———— | 5.0 |
| 21 | 823B | Crew body motion measurements - cine | ———— | 5.0 |
| 21 | 823C | " " " " - body mntd. sensors | —— | 0.8 |
| 21 | 824A | Forces, pressures and torques exerted-man | —— | 0.8 |
| | Weekly | | | |
| 13 | 304A | Lower body negative pressure | ——————————— | 12.1 |
| 13 | 306A | Ear canal caloric stimulation | ——— | 2.5 |
| 13 | 311A | Body restraint, motion device | | 0.1 |
| 13 | 315A | Total body water | ——— | 1.7 |
| 13 | 357A | Gastric pressure and pH | ——— | 2.1 |
| 21 | 700A | Visual - acuity, static | - | 0.1 |
| 21 | 701A | " " , dynamic | - | 0.1 |
| 21 | 702A | " - stereopsis, static | - | 0.1 |
| 21 | 703A | " " , dynamic | - | 0.1 |
| 21 | 704A | " - brightness threshold, abs. | - | 0.1 |
| 21 | 705A | " " discrimination | - | 0.1 |
| 21 | 706A | " - color perception | - | 0.1 |

*Primary Skill Required (See Table 3-2 for skill reference numbers)

## Table 3-4. Individual Crew Duties, Contd

### CREWMAN #1 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weekly (continued) | | | | | | | | | | |
| 21 | 707A | Visual - CFFF | - | | | | | | | | 0.1 |
| 21 | 708A | " phorias | - | | | | | | | | 0.1 |
| 21 | 709A | " glare recovery | - | | | | | | | | 0.1 |
| 21 | 710A | " dark adaptation | — | | | | | | | | 0.8 |
| 21 | 713A | " peripheral field | — | | | | | | | | 0.3 |
| 21 | 714A | " accommodation range | - | | | | | | | | 0.1 |
| 21 | 715A | Auditory - absolute threshold | - | | | | | | | | 0.1 |
| 21 | 716A | " pitch discrimination | - | | | | | | | | 0.2 |
| 21 | 717A | " temporal acuity | - | | | | | | | | 0.2 |
| 21 | 719A | " sound localization | - | | | | | | | | 0.2 |
| 21 | 720A | " detection of motion | - | | | | | | | | 0.2 |
| 21 | 721A | Cutaneous - pressure threshold | — | | | | | | | | 0.4 |
| 21 | 722A | Kinesthetic - sensing limb movement | - | | | | | | | | 0.2 |
| 21 | 723A | " - " " position | - | | | | | | | | 0.2 |
| 21 | 730A | Cognitive/complx percptl - speech intell. | — | | | | | | | | 0.4 |
| 21 | 731A | " " " reading | — | | | | | | | | 0.5 |
| 21 | 734A | " " " perceptl speed | — | | | | | | | | 0.4 |
| 21 | 735A | " " " time sharing | — | | | | | | | | 0.3 |
| 21 | 736A | " " " spatial orient. | — | | | | | | | | 0.5 |
| 21 | 737A | " " " spatial visual. | — | | | | | | | | 0.4 |
| 21 | 740A | Cognitive/conceptual and thinking abilities | — | | | | | | | | 0.9 |
| 21 | 750A | Cognitive/memory - rote memory | — | | | | | | | | 0.4 |
| 21 | 751A | " " meaningful memory | — | | | | | | | | 0.4 |
| 21 | 752A | " " memory span.-imm. | — | | | | | | | | 0.4 |
| 21 | 758B | Fine psychomtr. - writing ability | — | | | | | | | | 0.4 |
| 21 | 759C | " " speaking ability | — | | | | | | | | 0.4 |
| 21 | 760A | " " manip. ability - stead. | — | | | | | | | | 0.4 |

## Table 3-4. Individual Crew Duties, Contd

### CREWMAN #1 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Weekly (continued) | | | |
| 21 | 761A | Fine psychomtr. - manip. abil. - finger speed | - | 0.1 |
| 21 | 762C | " " " " " dext. | — | 0.3 |
| 21 | 763C | " " " " manual dext. | - | 0.1 |
| 21 | 764C | " " gross positn. abil. - p. est. | - | 0.1 |
| 21 | 766A | " " " " " track. | - | 0.2 |
| 21 | 767C | " " " " " arm sp. | - | 0.1 |
| 21 | 768A | " " " " " coord. | — | 0.3 |
| 21 | 769C | " " " " " p. repro. | - | 0.1 |
| 21 | 770A | " " reaction time - simple | - | 0.2 |
| 21 | 771A | " " " " complex | - | 0.1 |
| 21 | 776B | Gross psychmtr - muscle strength - imp. | —— | 0.8 |
| 21 | 777B | " " " " sust. | —— | 0.8 |
| 21 | 779A | " " gross body equil. | — | 0.4 |
| 21 | 780A | " " " " coord. | — | 0.4 |
| 21 | 782A | " " spd of limb - legs | - | 0.1 |
| 21 | 792B | Individual behavior - closeness of inter. | — | 0.4 |
| 21 | 793B | " " amount of inter. | — | 0.4 |
| 21 | 794B | " " strength of inter. | — | 0.4 |
| 21 | 795B | " " aggression react. | — | 0.4 |
| 21 | 796B | " " conformity | — | 0.4 |
| 21 | 797B | " " flexibility react. | — | 0.4 |
| 21 | 798B | " " self control react. | — | 0.4 |
| 21 | 799B | " " subjectivity react. | — | 0.4 |
| 21 | 800B | " " emotionality | — | 0.4 |
| 21 | 801B | " " desired output lev. | — | 0.4 |
| 21 | 802B | " " desired output typ. | — | 0.4 |

Table 3-4. Individual Crew Duties, Contd

CREWMAN #1 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Weekly (continued) | | | |
| 21 | 805D | Group behavior - group compatibility | — | 0.4 |
| 21 | 806D | " " " cohesiveness | — | 0.4 |
| 21 | 807D | " " " leadership | — | 0.4 |
| 21 | 808D | " " " simil. perceiv. | — | 0.4 |
| 21 | 825A | Eye movement measurements - optical | — | 0.8 |
| 21 | 830A | Freq. of equip/facility util - video | - | 0.1 |
| 21 | 830C | " " " " " blt-in | - | 0.1 |
| 21 | 831A | Length of use of equip/facility - video | - | 0.1 |
| 21 | 831C | " " " " " " blt-in | - | 0.1 |
| 21 | 832A | Sequence of use of equip/facility | - | 0.1 |
| 21 | 834A | Facility traffic patterns | - | 0.1 |
| 21 | 840-2A | Max mass transportable - SS | ——— | 2.5 |
| 21 | 840-2B | " " " press. | ——— | 2.5 |
| 21 | 843-5A | " " alignable - SS | ——— | 2.5 |
| 21 | 843-5B | " " " press. | ——— | 2.5 |
| 21 | 846A | Remote manipulation | ——— | 5.0 |
| | Every two weeks | | | |
| 13 | 322A | Venous blood press. | —— | 1.3 |
| 13 | 333A | Bleeding time | - | 0.2 |
| 13 | 352A | Radioisotope counting | ——— | 2.1 |
| | Every month | | | |
| 13 | 335A | Erythrocyte survival | ——— | 1.9 |
| 21 | 791A | Sleep behavior - emer. response | — | 0.3 |
| | As scheduled | | | |
| S | | Test subject (includes preparing crew medical histories (346A&B), crew metabolic records (350A&B), and crew subjective comments (833A&B). | ——————————→ | 16.6 |
| | | | | 103.6 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #2

Physiologist (Skill 4)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | **Twice daily** | | | |
| 0 | 144A | Experiment status monitoring | ——— | 2.2 |
| | Daily | | | |
| 4 | 31B | Biosampling - obtaining blood, etc. | ——————————————— | 10.8 |
| 0 | 75A | Crew guidance | ——— | 1.3 |
| 0 | 124A | Crew/organism isolation | ——— | 1.4 |
| 0 | 127H | Crew mobility/transfer | ——————— | 4.0 |
| 0 | 128H | Materials transfer | ——————————— | 6.0 |
| 0 | 201L | Crew restraint | ——— | 1.0 |
| 4 | 308B | Electro-oculogram-backpack, man | ——— | 1.7 |
| | Every two days | | | |
| 4 | 162A | X-ray diagnostic | ——— | 2.1 |
| | Every three days | | | |
| 4 | 319A | Vectorcardiogram - discrete units | ——— | 2.8 |
| 4 | 319B | " backpack | ——— | 2.8 |
| 4 | 320A | Phono/vibrocardiogram - discrete units | ——— | 2.8 |
| 4 | 320B | " backpack | ——— | 2.8 |
| 4 | 321A | Impedance cardiography - disct. unt. | ——— | 2.8 |
| 4 | 321B | " " backpack | ——— | 2.8 |
| 4 | 344A | Electronystagmogram - discrete units | ——— | 1.7 |
| 4 | 344B | " backpack | ——— | 1.7 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #2 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Weekly | | | |
| 4 | 21B | Cardiac output - ultrasonic flowmeter | | 1.1 |
| 4 | 30A | Gross anatomies | | 2.5 |
| 4 | 63A | Radiation monitoring - film sensors | | 3.1 |
| 4 | 89A | Histological sectioning | | 1.4 |
| 4 | 164A | Peripheral venous blood pressure | | 1.7 |
| 4 | 167A | Anesthesiology - vertebrates | | 2.8 |
| 4 | 302A | Sweat sample collection | | 0.6 |
| 4 | 310A | Bicycle ergometry | | 15.0 |
| 4 | 326A | Ballistocardiography - discrete unit | | 1.1 |
| 4 | 326B | " backpack | | 1.1 |
| | Every 2 weeks | | | |
| 4 | 95C | Radio isotope methodology - prep & mgmt. | | 0.2 |
| 4 | 96A | Radiochem waste mgmt. | | 0.2 |
| 4 | 126A | Crew radiation isolation | | 1.8 |
| 4 | 327A | Respiratory vital capacity, etc. | | 0.5 |
| 4 | 330A | Respiratory dead space, etc. | | 0.5 |
| 4 | 331A | Respiratory airway resistance | | 0.5 |
| 4 | 332A | Lung compliance | | 0.2 |
| 4 | 351A | Bone densitometry | | 2.0 |
| | As scheduled | | | |
| S | | Test subject (see Crewman #1) | | 16.6 |
| | | | | 103.6 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #3

Biochemist (Skill 3)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Twice daily | | | |
| 0 | 144A | Experiment status monitoring | —— | 2.2 |
| | Daily | | | |
| 3 | 26A | Liquid vol. msmts, .001-1 ml - micropipettes | — | 1.0 |
| 3 | 26B | " " " " " - microsyringes | — | 1.3 |
| 3 | 27A | " " " 1-1000 ml | —— | 5.0 |
| 3 | 28A | Mass msmts of contained liq. & slds. - .001 - 100 gm | —— | 3.0 |
| 3 | 29A | Mass msmts of contained liq. & slds. - 10 - 1000 gm | —— | 4.5 |
| 0 | 75A | Crew guidance | — | 1.3 |
| 0 | 124A | Crew/organism isolation | — | 1.4 |
| 0 | 125A | Crew/chemical isolation - LFB | —— | 5.0 |
| 0 | 125B | " " " std glove box | —— | 3.3 |
| 0 | 127H | Crew mobility/transfer | —— | 4.0 |
| 0 | 128H | Materials transfer | —— | 6.0 |
| 0 | 201L | Crew restraint | — | 1.0 |
| | Weekly | | | |
| 3 | 34B | Blood electrolytes - atomic absorp. | — | 1.3 |
| 3 | 34C | " " preserve for grnd. | — | 1.2 |
| 3 | 35A | Blood pH, $pCO_2$, $O_2$ | — | 1.1 |
| 3 | 36C | Blood total protein - preserve for grnd. | - | 0.6 |
| 3 | 36D | " " " electrophoresis | - | 0.4 |
| 3 | 39A | Thyroid function tests | — | 0.8 |
| 3 | 47C | Immunoglobin assay - pres. for grnd. | - | 0.2 |
| 3 | 48B | Antibody titration - pres. for grnd. | - | 0.2 |
| 3 | 69B | Carbohydrate analysis | —— | 1.7 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #3 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | | Weekly (continued) | | |
| 3 | 90A | Histological staining | | 0.4 |
| 3 | 143A | Plant homogenation | | 1.3 |
| 3 | 145A | Centrifugation | | 5.0 |
| 3 | 149A | Urine analysis - auto urine anal. | | 0.6 |
| 3 | 149C | Urine analysis - pres.for grnd. | | 0.5 |
| 3 | 155A | Urinary phosphates | | 5.0 |
| 3 | 163A | Radiation exposure | | 3.3 |
| 3 | 177B | Protein assay - pres. for grnd. | | 0.8 |
| 3 | 340A | Plasma globulins | | 1.3 |
| 3 | 342A | " coagulation | | 1.0 |
| 3 | 365A | Venous compliance (LVMS) | | 1.0 |
| | | Every two weeks | | |
| 3 | 91A | Plant radiochemistries | | 4.4 |
| 3 | 92A | Vertebrate radiochemistries | | 4.4 |
| 3 | 93A | Invertebrate radiochemistries | | 4.4 |
| 3 | 94A | Cells and tissue radiochemistries | | 4.4 |
| 3 | 180A | Plant hormones - chromatogrph | | 1.1 |
| 3 | 180B | " " pres. for grnd. | | 0.4 |
| 3 | 348A | Gonad histopathology | | 1.3 |
| | | Every month | | |
| 3 | 173A | Plant lipids | | 0.4 |
| 3 | 175A | Amino acids assay - auto anal. | | 0.1 |
| 3 | 175B | " " " pres. for grnd. | | 0.2 |
| | | As scheduled | | |
| S | | Test subject (see Crewman #1) | | 16.6 |
| | | | | 104.4 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #4

BIOTECHNICIAN (Skill 1) - Contaminant control technician, sample preservation specialist

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Daily | | | |
| 1 | 14A | Bioelectric transducer installatn. & setup | | 3.3 |
| 0 | 75A | Crew guidance | | 1.3 |
| 1 | 78A | Invertebrate counting and sorting (insects) | | 5.0 |
| 1 | 80A | Organism subculture - plants | | 5.0 |
| 0 | 82A | Work bench cleanup | | 5.0 |
| 0 | 83A | Work bench sterilization - chem. wash | | 1.7 |
| 0 | 83C | " " " LFB liners | | 8.3 |
| 1 | 97A | Experiment waste management | | 5.0 |
| 1 | 105A | Organism or sample presvn. with chem. | | 1.3 |
| 1 | 106A | " " " " , thermal | | 2.6 |
| 1 | 107A | " " " " , lyophil. | | 7.5 |
| 0 | 124A | Crew/organism isolation | | 1.4 |
| 0 | 127H | Crew mobility/transfer | | 4.0 |
| 0 | 128H | Materials transfer | | 6.0 |
| 1 | 168A | Anesthesiology - invertebrates | | 5.0 |
| 0 | 201L | Crew restraint | | 1.0 |
| | Every two days | | | |
| 1 | 99A | Sterilization of tool/equip. - gas | | 1.7 |
| 1 | 99D | " " " " chem | | 4.2 |
| | Weekly | | | |
| 1 | 79A | Organism subculture - substrate prep | | 5.3 |
| 1 | 100A | Sterilization of media | | 1.1 |
| 1 | 303A | Sweat presvn. and storage | | 0.5 |
| 0 | 368A | Stool presvn. | | 1.0 |
| 0 | 369A | Urine presvn. | | 1.0 |

Table 3-4. Individual Crew Duties, Contd

CREWMAN #4 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Every 90 days | | | |
| 1 | 104A | Holding unit manifold cleanup | - | 0.1 |
| 1 | 196B | Primate cage preparation | — | 0.5 |
| 1 | 222B | Vertebrate experiment initiation | —— | 1.3 |
| 1 | 223B | Plant " " | — | 0.6 |
| 1 | 224B | Invertebrate " " | — | 0.6 |
| 1 | 225B | Cells and tissue experiment setup | — | 0.6 |
| | As scheduled | | | |
| S | | Test subject (includes preparing crew medical histories (346A&B), crew metabolic records (350A&B), and crew subjective comments (833A&B)). | ——→ | 16.6 |
| | | | | 98.5 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #5

SENIOR BIOTECHNICIAN (Skill 1) - Sample-blood analyst, RLC technician

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Daily | | | |
| 1 | 9A | Organism mass measurements | | 4.2 |
| 1 | 50A | Gas sampling | | 3.3 |
| 1 | 51A | Trace gas analysis hydrocarbons - gas chrom. | | 3.3 |
| 1 | 51B | " " " " mass spec. | | 1.7 |
| 1 | 51C | " " " " infrared ab. | | 1.7 |
| 0 | 75A | Crew guidance | | 1.3 |
| 0 | 124A | Crew/organism isolation | | 1.4 |
| 0 | 127H | Crew mobility transfer | | 4.0 |
| 0 | 128H | Materials transfer | | 6.0 |
| 0 | 201L | Crew restraint | | 1.0 |
| | Every three days | | | |
| 1 | 161A | Arterial blood pressure | | 4.2 |
| | Weekly | | | |
| 1 | 20B | Respiratory rate monitoring - plythesmograph | | 1.7 |
| 1 | 21A | Cardiac output | | 0.8 |
| 1 | 40A | Blood morphology and cell counts | | 4.8 |
| 1 | 41B | Hematocrit-msur of packed cell vol.-total vol. | | 0.1 |
| 1 | 42A | Hemoglobin | | 0.7 |
| 1 | 45A | RBC omotic fragility | | 1.3 |
| 1 | 47B | Immunoglobin assay-disc gel electrophor. | | 0.2 |
| 1 | 48A | Antibody titration - interfacial test in agar | | 0.6 |
| 1 | 85B | Starch granule assay | | 0.4 |
| 1 | 156C | Urine creatinine and creatine | | 0.6 |
| 1 | 177D | Protein assay - auto biochemical anlyzr. | | 0.3 |
| 1 | 185A | Cytochemical staining - plants | | 4.4 |
| 1 | 186A | " " animal sys | | 4.4 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #5 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Weekly (Continued) | | | |
| 1 | 307A | Spatial localization | | 4.2 |
| 1 | 316A | Agravic perception | | 2.9 |
| 1 | 317A | Ocular counter-rolling | | 5.0 |
| 1 | 318A | Oculogyral illusion | | 2.9 |
| 1 | 336A | Plasma glucose | | 0.3 |
| 1 | 337A | " phosphate | | 0.1 |
| 1 | 338A | " alkaline phosphatase | | 0.3 |
| 1 | 339A | " bilirubin | | 0.3 |
| 1 | 345A | Angular acceleration threshold | | 2.9 |
| 1 | 362B | Urine serotonin and aldosterone | | 1.2 |
| 1 | 364B | Visual task with head rotation | | 5.4 |
| | Every two weeks | | | |
| 1 | 324A | Pulse wave velocity | | 1.9 |
| 1 | 325A | Pulse wave contour | | 2.1 |
| 1 | 334A | Clotting time | | 0.2 |
| 1 | 347A | Intraocular pressures | | 0.9 |
| | Every three weeks | | | |
| 1 | 353A | Culture/sensitivity-microorgan. growth cap. | | 0.2 |
| | Every month | | | |
| 1 | 174C | Enzyme assay | | 0.3 |
| | As scheduled | | | |
| S | | Test subject (see Crewman #1) | → | 16.6 |
| | | | | 100.1 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #6

MICROBIOTECHNICIAN (Skill 2) - Biomedical Assistant

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Daily | | | |
| 4 | 33A | Blood preparation | | 5.3 |
| 0 | 75A | Crew guidance | | 1.3 |
| 0 | 82A | Workbench cleanup | | 2.5 |
| 2 | 84A | Organism subculturing - cells and tissues | | 11.2 |
| 0 | 124A | Crew/organism isolation | | 1.4 |
| 0 | 127H | Crew mobility/transfer | | 4.0 |
| 0 | 128H | Materials transfer | | 6.0 |
| 2 | 141A | Airparticulate sampling and analysis | | 4.2 |
| 0 | 142A | Microbiological sampling - air | | 0.8 |
| 0 | 142B | " " - surface & wound | | 2.5 |
| 0 | 201L | Crew restraint | | 1.0 |
| 2 | 226B | Cells and tissue population density | | 5.0 |
| 0 | 343A | Body mass measurement (man) | | 2.0 |
| 0 | 356B | Subject instrumentation and cleanup | | 5.0 |
| 0 | 358B | Biomedical equipment cleanup/disp. | | 2.5 |
| 0 | 359A | Heart rate | | 0.9 |
| 2 | 506A | Water analysis - bacteriological assay | | 3.3 |
| | Weekly | | | |
| 2 | 24B | Water consumption - vol. or mass of water bag | | 1.3 |
| 2 | 86A | Bacterial colony counting | | 0.8 |
| 2 | 87A | Microorganism identification | | 4.2 |
| 2 | 88A | Bacterial smear staining | | 6.9 |
| 2 | 100C | Sterilization of media - filtration | | 0.4 |
| 2 | 108A | Bacterial cell counting - auto cell cntrs. | | 0.4 |
| 2 | 108B | " " " hematocrit | | 0.3 |
| 0 | 366A | Arteriolar reactivity | | 0.9 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #6 (Continued)

| PSR | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|
| | Every two weeks | | |
| 2 | 370A Viral culturing | ——— | 2.9 |
| 2 | 371A " identification | ——— | 1.8 |
| 2 | 372A Fungal culturing | ——— | 1.8 |
| 2 | 373A " identification | ——— | 1.8 |
| | Every three weeks | | |
| 0 | 354A Ear canal temperature | – | 0.3 |
| 0 | 355A Muscle strength and size | — | 0.9 |
| | Every month | | |
| 2 | 108C Bacterial cell counting - vital staining | – | 0.2 |
| | As scheduled | | |
| S | Test subject (see Crewman #1) | ——————————→ | 16.6 |
| | | | 100.4 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #7

MAINTENANCE TECHNICIAN (Skill 12 - electromechanical technician and Skill 22 - chemical technician)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Hourly | | | |
| 12 | 512A | Electrical amperage measurements | | 3.3 |
| | Every four hours | | | |
| 22 | 503A | Water analysis - conductivity msrmt | | 2.5 |
| 22 | 504A | " " pH measurement | | 2.5 |
| | Daily | | | |
| 12 | 15A | Camera setup (BLH) | | 5.0 |
| 4 | 18G | Monitor EEG - discrete units - man | | 3.3 |
| 0 | 49A | Pressure monitoring - visual meters | | 0.8 |
| 22 | 53A | Oxygen monitoring - polarographic snsr. | | 1.7 |
| 22 | 57C | Atmos. water monitoring - spec sensrs. | | 1.7 |
| 0 | 75A | Crew guidance | | 1.3 |
| 0 | 127H | Crew mobility/transfer | | 4.0 |
| 0 | 128H | Materials transfer | | 6.0 |
| 0 | 148B | Thermal control of chemical preparations | | 0.8 |
| 0 | 170A | TV monitoring ad hoc - color | | 5.0 |
| 0 | 201L | Crew restraint | | 1.0 |
| 22 | 501A | Analysis of gas mixtures - gas chrom. | | 1.7 |
| 22 | 501B | " " " " mass spec | | 0.7 |
| 22 | 501C | " " " " IR absorp | | 0.7 |
| 0 | 501E | " " " " ind. sensrs | | 0.7 |
| 22 | 505A | Water analysis - total solids content | | 0.8 |
| 0 | 507A | Liquid transfer - syringe | | 2.5 |
| 0 | 507C | " " collapsible bladder | | 2.5 |
| 0 | 517A | Cleanup, liquid and solid | | 0.8 |
| 0 | 518A | Trash disposal | | 0.3 |
| 0 | 950A | Routine equipment maintenance | | 2.5 |

## Table 3-4. Individual Crew Duties, Contd

CREWMAN #7 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Weekly | | | |
| 4 | 14B | Bioelectric xdcr installation and setup | ——— | 1.6 |
| 12 | 17B | Monitor ECG - hardwire data to DM | – | 0.3 |
| 12 | 17C | " " xmtr on organism/rec at CM | — | 0.6 |
| 12 | 18B | " EEG - hardwire data to DM | – | 0.3 |
| 12 | 18C | " " xmtr on organism/rec at CM | — | 0.6 |
| 4 | 18F | " " electrophys. bkpk. man | ———— | 2.5 |
| 4 | 18H | " " " consol " | — | 0.4 |
| 12 | 19B | " EMG - hardwire data to DM | – | 0.3 |
| 12 | 19C | " " xmtr on organism/rec at CM | — | 0.6 |
| 4 | 19F | " " electrophys. bkpk. man | ———— | 2.5 |
| 0 | 166A | Linear measurements | — | 0.4 |
| 12 | 184A | Clinostat environment | ——— | 1.7 |
| 0 | 305A | Space suit supply and control | ——— | 1.7 |
| 0 | 312A | Electronic equip calibration - computer cal. | — | 0.8 |
| 0 | 312B | " " " in place | — | 0.8 |
| 0 | 313B | Atmos. monitor calibration | — | 0.8 |
| 0 | 314A | Biochem equipment calibration | ——— | 1.7 |
| 12 | 511A | Electrical continuity and voltage msmts | - | 0.1 |
| 12 | 513A | Electrical maintenance | — | 0.4 |
| 12 | 514A | Mechanical " | — | 0.4 |
| 0 | 516A | Atmos. gas isolation | - | 0.1 |
| 0 | 520A | Pressure suit donning and doffing | ———— | 2.5 |
| 0 | 522A | Measurement of metabolic rate of suited man | — | 0.4 |
| 0 | 523A | Ingress/egress (EVA) | — | 0.9 |
| | Every two weeks | | | |
| 22 | 328A | Alveolar $pO_2$ | - | 0.1 |
| 22 | 329A | " $pCO_2$ | — | 0.4 |

## Table 3-4. Individual Crew Duties , Contd

CREWMAN #7 (Continued)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Every two weeks (continued) | | | |
| 0 | 521A | Pressure suit ventilation & cooling - umb. | – | 0.1 |
| 0 | 521B | " " " " " PLSS | – | 0.3 |
| 0 | 524A | EVA maintenance task simulation | —— | 1.7 |
| | Every 90 days | | | |
| 0 | 2A | Material receiving - LFB | – | 0.2 |
| 0 | 2B | " " other | – | 0.2 |
| 12 | 15A | Camera setup (F) | —— | 1.2 |
| 12 | 16A | Setup camera optical commutation | ——— | 2.9 |
| | As scheduled | | | |
| S | | Test subject (see Crewman #1) | ——————→ | 16.6 |
| | | | | 98.2 |

## Table 3-4. Individual Crew Duties , Contd

CREWMAN #8

BIOLOGICAL SPECIMEN CARETAKER (Skill 0 - general)

| PSR | | Assigned Functions | Daily Average, Minutes/Day 0 10 20 30 40 50 60 70 | Approx. Percentage of Duty Time |
|---|---|---|---|---|
| | Daily | | | |
| 0 | 32A | Specimen status observation | | 17.0 |
| 0 | 75A | Crew guidance | | 1.3 |
| 0 | 124A | Crew/organism isolation | | 1.4 |
| 0 | 127H | Crew mobility/transfer | | 4.0 |
| 0 | 128H | Materials transfer | | 6.0 |
| 0 | 170A | TV monitoring ad hoc - color | | 5.0 |
| 0 | 201L | Crew restraint | | 1.0 |
| | Weekly | | | |
| 0 | 3A | Vertebrate feeding - pellets | | 7.2 |
| 1 | 3C | " " liquid | | 3.6 |
| 0 | 3E | " " paste | | 3.6 |
| 0 | 8B | Feces management | | 14.9 |
| 0 | 81B | Media preparation - cells & tissue | | 1.7 |
| 0 | 103A | Organism holding unit cleanup - vac. | | 12.5 |
| 0 | 103C | " " " " remov. | | 1.8 |
| | Every ninety days | | | |
| 0 | 1A | Organism receiving | | 0.2 |
| 0 | 197A | Vertebrate cage preparation | | 0.6 |
| 0 | 198A | Plant holding unit preparation | | 0.2 |
| 0 | 199A | Invertebrate cage and h.u. setup | | 0.1 |
| 0 | 200A | Cells and tissue h.u. setup/prep. | | 0.1 |
| | As scheduled | | | |
| S | | Test subject (see Crewman #1) | | 16.6 |
| | | | | 98.8 |

# Table 3-5. Excerpt from Equipment Operations Analysis

| REF. NO. | EQUIPMENT ITEM (EU)/ INVENTORY, WT., PWR., VOL. | NO. REQ. | CREW USE TIME, MIN/X | EQUIP "ON" TIME, MIN/X | AVE PWR, WATTS |
|---|---|---|---|---|---|
| 018B | Bench insert LFB, radioc (4)/50, 0, 2 | 2 | 15/2 wk | 0 | 0 |
| | 95C Radio isotope methodology - prep and mgmt. | 2 | 1/dy | | 0 |
| 018C | Bicycle ergometer (30)/150, 48, 12 | 1 | 538/wk | 538/wk | 3 |
| | 310A Bicycle ergometry | 1 | 90/dy | | 3 |
| 018D | Custom bite boards (12)/0.5, 0, .001 | 3 | 150/wk | 0 | 0 |
| | 307A Spatial localization | 3 | 180/wk | 0 | 0 |
| | 317A Ocular counter-rolling | 3 | 105/wk | 0 | 0 |
| | 345A Angular acceleration threshold | 12 | 73/dy | | 0 |
| 019 | Bench genl exper (5)/100, 50, 9 | 1 | 10/dy | 10/dy | 0 |
| | 14A Bioelectric Xdcr installation - mnl cal | 1 | 60/wk | 60/wk | 0 |
| | 14B Bioelectric Xdcr installation - precal | 1 | 30/dy | 30/dy | 1 |
| | 78A Invertebrate counting and sorting (insects) | 1 | 35/dy | 35/dy | 1 |
| | 82A Work bench cleanup | 1 | 320/2 wk | 320/2 wk | 1 |
| | 91A Plant radiochemistries | 1 | 320/2 wk | 320/2 wk | 1 |
| | 92A Vertebrate radiochemistries | 1 | 320/2 wk | 320/2 wk | 1 |
| | 93A Invertebrate radiochemistries | 1 | 320/2 wk | 320/2 wk | 1 |
| | 94A Cells and tissue reaiochemistries | 2 | 192/dy | | 6 |
| 019A | Biobackpack, micro (42)/0.1, 0, .05 | 16 | 20/wk | 0 | 0 |
| | 17C Monitor ECG - Xmtr on orgnsm, recvr at CM | 16 | 20/wk | 0 | 0 |
| | 18C Monitor EEG - " | 16 | 20/wk | 0 | 0 |
| | 19C Monitor EMG - " | 16 | 10/dy | | 0 |
| 019B | Burner, catalytic (3)/* | 1 | a | * | * |
| | 102A Sterilization of atm gases | 1 | a | | |
| 019C | Botl C/T cult opt flts (61)/0.3, 0,.02 | 10 | 5/dy | 0 | 0 |
| | 505A Water analysis - total solids content | 17 | 20/dy | 0 | 0 |
| | 506A Water analysis - bacteriolgcl assay | 5 | 15/dy | 0 | 0 |
| | 507C Liquid transfer - collapsible bladder | 32 | 40/dy | | 0 |
| 019D | Body mass measurement (12)/25, 2, 28 | 1 | 12/dy | 12/dy | 0 |
| | 343A Body mass measurement for man | 1 | 12/dy | | 0 |
| 022 | Cage, colny, rat (40)/4 20 2.2 | 8 | 10/wk | 0 | 0 |
| | 103C Organsm holding unit cleanup-at washer | 8 | a | 1/2 c | 80 |
| | 138B Holding colony rats | 8 | 2/dy | | 80 |
| 023 | Cage, colny, rab (40)/21, 10, 4.5 | 5 | a | 1/2 c | 25 |
| | 137A Holding colony-mice, hamsters, etc. | 3 | a | 1/2 c | 15 |
| | 139A Holding colny-marmots/rabbits | 8 | a | | 40 |
| 024 | Cage insrt, mice (42)/0.5, 0, 0.1 | 16 | a | 0 | 0 |
| | 130A Holding-mice | 16 | a | | 0 |
| 025A | Colony chmbr, sealbl, iv (70)/2, 0, 0.2 | 4 | 320/2 wk | 0 | 0 |
| | 93A Invertebrate radiochemistries | 4 | 27/dy | | 0 |
| 025B | Colony chmbr, sealbl, ct (60)/0.5, 0, 0.1 | 4 | 320/2 wk | 0 | 0 |
| | 94A Cells and tissue radiochemistries | 4 | 27/dy | | 0 |
| 026B | Cage MMB, plnt (50)/25, 0, 2.73 | 32 | 320/2 wk | 0 | 0 |
| | 91A Plant radiochemistries | 32 | 27/dy | | 0 |
| 027 | Cage, MMB, rab (40)/7, 20, 2.2 | 8 | a | 1/2 c | 80 |
| | 13A Holding cage MMB-rabbits/marmots | 8 | a | | 80 |
| 028 | Cage, MMB, rat (40)/5, 10, 0.5 | 17 | a | 1/2 c | 85 |
| | 11A Holding rat for metabolic msmts | 17 | a | 1/2 c | 85 |
| | 12A Holding mouse MMB | 34 | a | | 170 |
| 028A | Cage monk macac (41)/250, 50, 25 | 4 | a | 1/2 c | 100 |
| | 129C Holding, primates - cylinders | 4 | a | | 100 |

For example, equipment item 008 (not shown in Table 3-5) an amino acid analyzer, weighs 88 pounds but is used only 15 minutes each month or an average of less than one minute a day. If weight savings were desired, this item would be a candidate for a tradeoff between its in space usefulness and the weight saving obtained if this function were performed on the ground.

The equipment "on" time is an estimate of the power consuming time by each equipment item per function, and is the basis for the 24 hour average power figures in the final column. The inventory or unit power for selected items such as refrigerators that consume power in a cyclic pattern or those that have a standby or warmup power requirement is assumed to be an average value reflecting those requirements. The 24 hour average power has been rounded off to the nearest watt. In many cases, a zero appears in the last column where power is being consumed but only for a short time so that, on a 24 hour basis, it is nil.

3.4.1 AVERAGE POWER BY EQUIPMENT UNIT. The average power for the equipment items contained in each equipment unit has been totaled as shown in Table 3-6. The biological organism holding equipment units (EU's 40, 41, 50, 60, and 70) use the largest block of power, 2441 watts or 54% of the average power, while the core (EU's 1-7) use 1853 watts or 40% of the power.

The values in the table, as in Tables 3-7 and 3-8, must be adjusted for experiment/layout, specific items, and subsystem power requirements such as EC/LS and data management before total average power for the Life Sciences payload can be defined. (See Section 5.4, Electrical Power Systems.) The average power shown for EU 2, Data Management Unit, reflects the average power requirements for those individual equipment items in direct support of the scientific experiments and not the data management subsystem as a whole.

3.4.2 AVERAGE POWER BY LARGEST CONSUMERS. Those equipment items which draw the largest amount of power, on a 24 hour average basis, are listed in Table 3-7. These 36, out of a total of 303 equipment items in the Maxi Max payload, use 95% of the power. The inventory power (unit power) for each equipment item is shown along with the total number of each item that is required. The items are ranked by average power required for all units of one type. For example, the 262 rat cages draw an average power of 655 watts every 24 hours.

3.4.3 AVERAGE POWER FOR MAXI-NOM, MINI-30 AND MINI-7. The average power required for the smaller payloads has been approximated by factoring back the power for the Maxi Max payload. The 36 items which consume 95% of the power have been used as a basis for this approximation as shown in Table 3-8. For each of the big power consumers, the average power required has been reduced in direct proportion to the number of that item required in the given payload (the number required fraction in Table 3-8). For example, 262 rat cages on the Maxi Max payload draw 655 watts of power. On Maxi Nom only 128 rat cages are required or $\frac{128}{262} = 49\%$.

Table 3-6. Average Power Consumption* by Equipment Unit - Maxi Max Payload

| EU | Title | Power, 24 hr. Average Watts | |
|---|---|---|---|
| 1 | Visual records and microscopy unit | 252 | (6%) |
| 2 | Data management unit | 201 | (4%) |
| 3 | Life sciences experiment support unit | 266 | (5%) |
| 4 | Preparation, preservation and retrieval unit | 503 | (11%) |
| 5 | Biochemical/biophysical analysis unit | 467 | (10%) |
| 6 | Maintenance, repair and fabrication unit | 204 | (4%) |
| 7 | Ancillary storage unit | 0 | (0%) |
| 11 | Airlock/EVA capability unit | 1 | (0%) |
| 12 | Biomedical/man-system integration research support unit | 41 | (1%) |
| 20 | Research centrifuge | 0 | (0%) |
| 25 | Radiobiology unit | 59 | (1%) |
| 26 | Radiobiology support unit | 17 | (0%) |
| 30 | Biomedical measurements unit | 3 | (0%) |
| 31 | Biomedical research support unit | 2 | (0%) |
| 40 | Small vertebrate holding unit | 1361 | (30%) |
| 41 | Primate holding unit | 290 | (6%) |
| 42 | Vertebrate research support unit | 84 | (2%) |
| 50 | Plant holding unit | 90 | (2%) |
| 51 | Plant research support unit | 83 | (2%) |
| 60 | Cell and tissue holding unit | 400 | (9%) |
| 61 | Cell and tissue research support unit | 0 | (0%) |
| 70 | Invertebrate holding unit | 300 | (7%) |
| 80 | Invertebrate research support unit | 6 | (0%) |
| 81 | Life support subsystems test unit | 0 | (0%) |
| 91 | Behavioral measurements unit | 5 | (0%) |
| 93 | Mobility unit | 0 | (0%) |
| | | 4,595 | (100%) |

*Excludes experiment/layout specific items.

## Table 3-7. Biggest Power Consumers - Maxi Max Payload*

| Ref. No. | Equipment Item | Unit Power, watts | No. Req'd | Power, 24 hr. Average, watts |
|---|---|---|---|---|
| 030A | Cage, rat/hamp/quail | 5 | 262 | 655 |
| 098A | Holding unit incbtr, cells | 50 | 8 | 400 |
| 030 | Cage, rab/mar/g pg/chk | 10 | 66 | 330 |
| 091 | Gas anlzr, mass spec | 40 | 8 | 320 |
| 098C | Holding unit incbtr, inverts | 50 | 6 | 300 |
| 001A | Accelerometr coupler | 10 | 45 | 200 |
| 179 | Temp block | 100 | 4 | 200 |
| 028 | Cage, MMB, rat | 10 | 34 | 170 |
| 162 | Sterilzr, autoclave, stm | 300 | 1 | 150 |
| 080 | Freezer, genl | 35 | 4 | 140 |
| 100 | Holding unit, MMB primate | 70 | 2 | 140 |
| 064 | ECG couplr | 1 | 134 | 128 |
| 037 | Camera, video B/W | 12 | 93 | 110 |
| 028A | Cage, monk, macac | 50 | 4 | 100 |
| 101 | Holding unit, plant | 10 | 18 | 90 |
| 027 | Cage, MMB, rab | 20 | 8 | 80 |
| 022 | Cage, colny, rat | 20 | 8 | 80 |
| 143C | Pump, gas circulating | 5 | 16 | 80 |
| 089 | Gas anlzr, GC (complex) | 500 | 1 | 67 |
| 150B | Receiver - exg, cage mod | 10 | 32 | 60 |
| 083 | Refrigerator | 58 | 1 | 58 |
| 126E | Mirror mount - commutatr | 5 | 102 | 53 |
| 029A | Cage, primate sphere | 50 | 2 | 50 |
| 147 | Radiatn room | 1000 | 1 | 50 |
| 032A | Camera controller | 200 | 2 | 45 |
| 050A | Commutator, gas manifld | 20 | 6 | 40 |
| 023 | Cage, colny, rab | 10 | 8 | 40 |
| 065 | EEG couplr | 1 | 34 | 33 |
| 066 | EMG couplr | 1 | 32 | 32 |
| 081 | Freezer, lo-temp | 25 | 1 | 25 |
| 076H | Flowmeter coupler, water manifld | 1 | 24 | 24 |
| 153 | Recorder, voice | 50 | 10 | 22 |
| 165 | Sterlzr, tool | 500 | 1 | 22 |
| 181B | Transducer - plythesmgph | 1 | 22 | 22 |
| 010 | Anlzr, genl, IR specph | 250 | 1 | 21 |
| 168 | Stove | 1000 | 1 | 20 |
| | | | | 4,357 |

or 95 % of total aver. pwr.

*Excludes experiment/layout specific items.

Table 3-8. Approximation of Average Power Requirements* for Maxi Nom, Mini-30, and Mini-7 Payloads

| Ref. No. | Equipment Item | Maxi Max Average Power, Watts | Maxi Nom No.** Req'd Fraction | Maxi Nom Average Power, Watts | Mini 30 No.** Req'd Fraction | Mini 30 Average Power, Watts | Mini 7 No.** Req'd Fraction | Mini 7 Average Power, Watts |
|---|---|---|---|---|---|---|---|---|
| 030A | Cage, rat/hamp/quail | 655 | 128/262 | 320 | 16/262 | 40 | 8/262 | 20 |
| 098A | Holding unit incbtr, cells | 400 | 2/8 | 100 | 2/8 | 100 | 2/8 | 100 |
| 030 | Cage, rab/mar/g pg/chk | 330 | 8/66 | 40 | 2/66 | 10 | 2/66 | 10 |
| 091 | Gas anlzr, mass spec | 320 | 3/8 | 120 | 2/8 | 80 | 2/8 | 80 |
| 098C | Holding unit incbtr, inverts | 300 | 2/6 | 100 | 1/6 | 50 | 1/6 | 50 |
| 001A | Acceleromtr coupler | 200 | 17/45 | 76 | 7/45 | 31 | 5/45 | 22 |
| 179 | Temp block | 200 | 4/4 | 200 | 3/4 | 150 | 3/4 | 150 |
| 028 | Cage, MMB, rat | 170 | 8/34 | 40 | 2/34 | 10 | 2/34 | 10 |
| 162 | Sterilzr, autoclave, stm | 150 | 1/1 | 150 | 1/1 | 150 | 1/1 | 150 |
| 080 | Freezer, genl | 140 | 4/4 | 140 | 1/4 | 35 | 1/4 | 35 |
| 100 | Holding unit, MMB primate | 140 | 2/2 | 140 | 1/2 | 70 | 1/2 | 70 |
| 064 | ECG couplr | 128 | 36/134 | 34 | 12/134 | 11 | 12/134 | 11 |
| 037 | Camera, video B/W | 110 | 41/93 | 48 | 13/93 | 15 | 5/93 | 6 |
| 028A | Cage, monk, macac | 100 | 4/4 | 100 | 1/4 | 25 | 1/4 | 25 |
| 101 | Holding unit, plant | 90 | 8/18 | 40 | 2/18 | 10 | 1/18 | 5 |
| 027 | Cage, MMB, rab | 80 | 4/8 | 40 | 1/8 | 10 | 1/8 | 10 |
| 022 | Cage, colny, rat | 80 | 2/8 | 20 | 1/8 | 10 | 1/8 | 10 |
| 143C | Pump, gas circulating | 80 | 8/16 | 40 | 2/16 | 10 | 0/16 | 0 |
| 089 | Gas anlzr, GC (complex) | 67 | 1/1 | 67 | 1/1 | 67 | 1/1 | 67 |
| 150B | Receiver-exg, cage mod | 60 | 16/32 | 30 | 2/32 | 4 | 1/32 | 2 |
| 083 | Refrigerator | 58 | 1/1 | 58 | 1/1 | 58 | 1/1 | 58 |
| 126E | Mirror mount-commutatr | 53 | 28/102 | 15 | 4/102 | 2 | 1/102 | 1 |
| 029A | Cage, primate sphere | 50 | 2/2 | 50 | 1/2 | 25 | 1/2 | 25 |
| 147 | Radiatn room | 50 | 1/1 | 50 | 1/1 | 50 | 1/1 | 50 |

* Based on the 36 biggest power consumers (which use 95% of the power) for the maxi max payload.

** No. req'd for specified payload over no. req'd for the maxi max payload.

Table 3-8. Approximation of Average Power Requirements* for Maxi Nom, Mini-30, and Mini-7 Payloads, Cont.

| Ref. No. | Equipment Stem | Maxi Max Average Power, Watts | Maxi Nom No.** Req'd Fraction | Maxi Nom Average Power, Watts | Mini 30 No.** Req'd Fraction | Mini 30 Average Power, Watts | Mini 7 No.** Req'd Fraction | Mini 7 Average Power, Watts |
|---|---|---|---|---|---|---|---|---|
| 032A | Camera controller | 45 | 2/2 | 45 | 1/2 | 23 | 1/2 | 23 |
| 050A | Commutator, gas manifld | 40 | 4/6 | 27 | 1/6 | 7 | 1/6 | 7 |
| 023 | Cage, colny, rab | 40 | 2/8 | 10 | 1/8 | 5 | 1/8 | 5 |
| 065 | EEG couplr | 33 | 12/34 | 12 | 4/34 | 4 | 4/34 | 4 |
| 066 | EMG couplr | 32 | 32/32 | 32 | 6/32 | 6 | 6/32 | 6 |
| 081 | Freezer, lo-temp | 25 | 1/1 | 25 | 1/1 | 25 | 1/1 | 25 |
| 076H | Flowmeter coupler, water manifld | 24 | 8/24 | 8 | 4/24 | 4 | 4/24 | 4 |
| 153 | Recorder, voice | 22 | 5/10 | 11 | 1/10 | 2 | 0/10 | 0 |
| 165 | Sterlzr, tool | 22 | 1/1 | 22 | 1/1 | 22 | 1/1 | 22 |
| 181B | Transducer-plythesmgph | 22 | 10/22 | 10 | 6/22 | 6 | 6/22 | 6 |
| 010 | Anlzr, genl, IR specph | 21 | 1/1 | 21 | 1/1 | 21 | 1/1 | 21 |
| 168 | Stove | 20 | 1/1 | 20 | 1/1 | 20 | 1/1 | 20 |
| | 95% = | 4,357 | | 2,261 | | 1,168 | | 1,110 |
| | Ave. Pwr. (100%) = | 4,595 | | 2,384 | | 1,232 | | 1,171 |

Therefore, only 49% of 655 watts or 320 watts is assumed to be the average power requirement for Maxi Nom. This proportionment of the power for each of the big power items has been done for each of the smaller payloads and summed as shown in Table 3-8. Since the big power items represent 95% of the power required, the totals have been adjusted upward to 100% to reflect the average power required for each payload.

SECTION 4

CONFIGURATIONS

This section summarizes the design activity performed in evolving the five baseline Life Science payload layouts. The computer printouts of the functional capabilities and related equipment items as described in Section 2.4, were used as the starting point. Figure 4-1 outlines the steps in the layout evolution starting with: (1) Equipment Module Studies; (2) First Generation Layouts; (3) Second Generation Layouts; and (4) Baseline Payload Layouts.

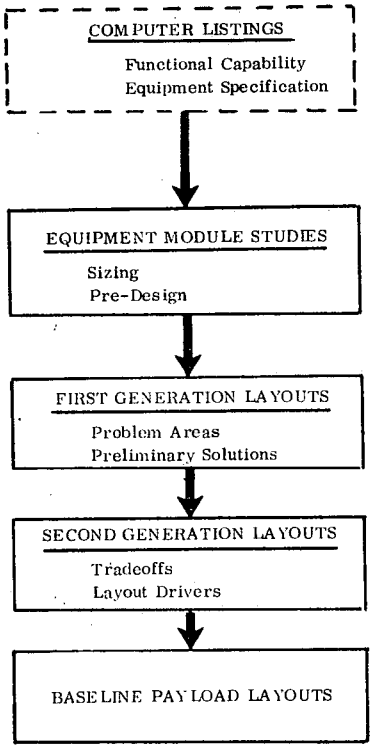



Figure 4-1. Layout Design Development

## 4.1 BASELINE PAYLOAD AND LAYOUTS SUMMARY

The initial group of payloads (computer listings) were the Maxi Max, Midi-30, Midi-56, Mini-56 and the Mini-7.

Layout designs which addressed these payload capabilities were developed using the guidelines presented in Section 1 of this report. These layouts were evaluated in terms of crew safety, scientific return, payload weight, and cost in a screening process conducted by NASA and General Dynamics Convair Aerospace Division. As a

result of this review a new group of payload capabilities were selected for use in the second generation layout development. The new group consisted of the Maxi Max, Maxi Nom, Midi-30, Mini-30, and the Mini-7. These second generation layouts were developed and subsequently reviewed by NASA and Convair. The results of the design review reduced the number of payloads to a third group. The third group was identified as Baseline Payloads. These baseline payloads (Maxi Max, Maxi Nom, Mini-30, and Mini-7) were then subjected to further refinement of the internal designs. A group of six layout designs representing the Baseline Layouts, was developed as shown below:

| | | |
|---|---|---|
| Maxi Max[1] | F Module[2] | No Floors[3] |
| Maxi Max[1] | BLH Module | No Floors & Long. Floors |
| Maxi Nom | FBLH Module | Long. Floors[4] |
| Maxi Nom | FBLH Module | No Floors - Wafer Floors |
| Mini-30 | FBLH Module | Long. Floors |
| Mini-7 | FBLH Module | Long. Floors |

1. The research Centrifuge (RC) Module is part of the Maxi Max payload (P/L). The RC Module is shown in Figure I-42, Volume III.
2. See Table 4-1 for definitions.
3. "NO FLOORS" designates a layout concept with wall mounted equipment, and man oriented basically parallel to the axis of the LS-RAM. Configurations of this type also include wafer floors (i.e., floors arranged at right angles to the axis of the LS-RAM).
4. "LONG FLOORS" designates basically linearily arranged equipment and man oriented basically normal to the axis of the LS-RAM with floors running longitudinally parallel to the axis of the LS-RAM.

Reference 24, (References noted in this report are listed in Section 7) NASA Guidelines for Task B, in part, called for: (1) the Maxi Max payload to be placed in three Life Sciences Research Application Modules (LS RAM) as shown in Figure 4-2; and (2) the Maxi Nom, Mini-30, and Mini-7 payloads in a single LS-RAM as shown in Figure 4-3.

The layout configurations were developed with regard to missions as shown in Figures 4-4 and 4-5. Note that the Mini-30 payload is designed for both Space Station and sortie missions. The layouts for the Mini-30 payload reflect this capability and show the space available for other disciplines.

4.1.1 EQUIPMENT MODULES AND 3 DIMENSIONAL LAYOUTS. As previously shown in Figure 4-1, the equipment modules were developed for each P/L using the computer listings. Approximately 70 equipment modules which house the scientifc equipment were pre-designed. They are shown in Volume III "Appendix", Figures I-1 through I-22. These 70 equipment modules are defined as: Equipment Racks (ER); Equipment Consoles (EC); and Special Equipment Modules (SEM). From these pre-designs, three-dimensional 1/20th scale models were made, representing the equipment modules.

Table 4-1. Basic Terminology

| CODE | | RESEARCH FACILITY MODULES | |
|---|---|---|---|
| B | BIOMEDICINE | BLH | MODULE CONTAINING BL&H SCIENTIFIC EQUIPMENT |
| F | BIOLOGY (MVPIC OR VPIC OR ETC.) | F | MODULE CONTAINING F SCIENTIFIC EQUIPMENT |
| L | LIFE SUPPORT & PROTECTIVE SYSTEMS | FC | BIOLOGY RESEARCH CENTRIFUGE |
| H | MAN SYSTEM INTEGRATION (MSI) | HC | HUMAN RESEARCH CENTRIFUGE |
| | | RC | RESEARCH CENTRIFUGE (BIOLOGY & HUMAN FACTORS) |

| | | OTHER | |
|---|---|---|---|
| C | CORE | AL | AIR LOCK |
| CORE | COMMON OPERATIONS RESEARCH EQUIPMENT | COMM S/S | COMMON SUBSYSTEMS |
| | | LS-RAM | LIFE SCIENCES RESEARCH APPLICATION MODULE |
| COG | CORE IN ZERO G | ECS | ENVIRONMENTAL CONTROL SYSTEM |
| CAG | CORE IN ARTIFICIAL G | MSS OR SS | MODULAR SPACE STATION |
| EU | EQUIPMENT UNIT | CM-4 | COMMON MODULE (LS-RAM)(EXPERIMENT MODULE) |
| EI | EQUIPMENT ITEM | RSM | RESEARCH SUPPORT MODULE (CREW LIVING QUARTERS FOR SHUTTLE SORTIE MISSIONS) |
| EM | EQUIPMENT MODULE | | |
| ER | EQUIPMENT RACK | | |
| EC | EQUIPMENT CONSOLE | | |
| SEM | SPECIAL EQUIPMENT MODULE | | |

Plexiglass shells were also made representing the LS-RAMs and layouts were made by manipulating the scale equipment modules within the 1/20th scale LS-RAMs to create Life Sciences Research Facility layouts.

Figures 4-6 through 4-13 show the four baseline payloads in the form of the individual three-dimensional (3D) equipment modules. The 3D layout approach was used to develop the second generation layouts.

## 4.1.2 BASELINE PAYLOADS

4.1.2.1 Maxi Max. Figure 4-6 and Figure 4-7 depict the Maxi Max payload in the form of 1/20th scale equipment modules for the zero-g laboratory (the F and BLH modules). There are additional equipment modules not shown which make up the full Maxi Max payload. They are installed in the Research Centrifuge (RC) module, and consist of 48 cage modules, holding unit support racks, and MSI habitability equipment. This equipment is shown on the drawing of the RC module in Volume III.

In Figures 4-6 and 4-7 CORE units are shown in the background. The transparent boxes represent a first approximation of space required for the performance and use of certain research equipment. These space allocations were later reduced as it became obvious in development of the actual layouts that these spaces could be shared.

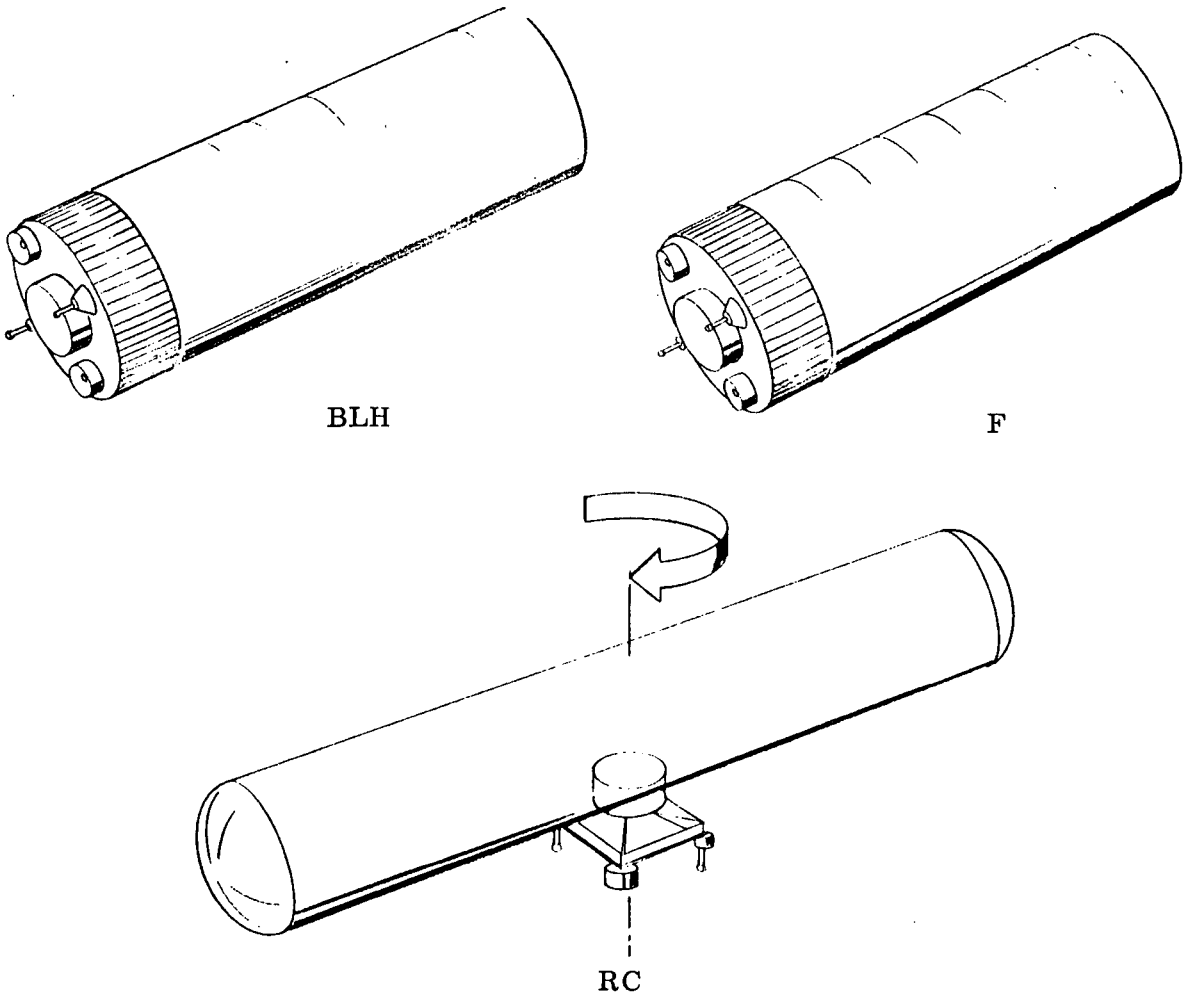



Figure 4-2. LS-RAMs for Maxi Max

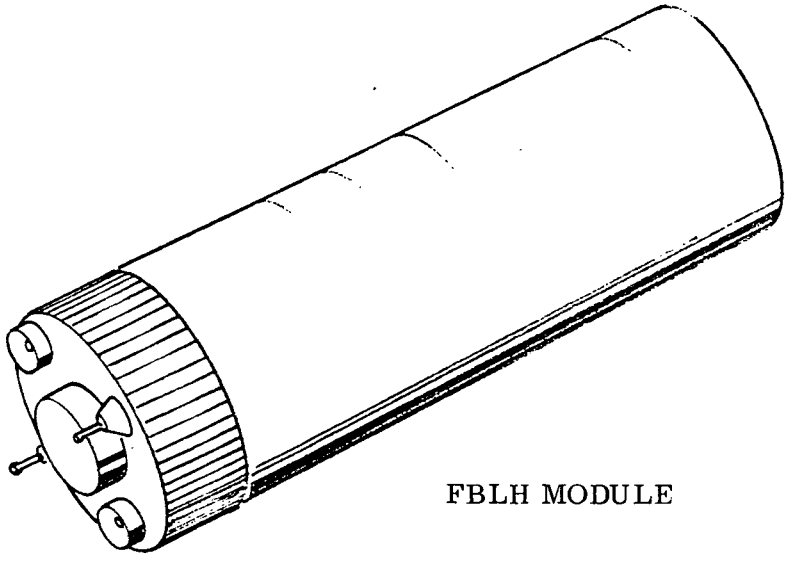



Figure 4-3. LS-RAM for Maxi Nom, Mini-30, and Mini-7

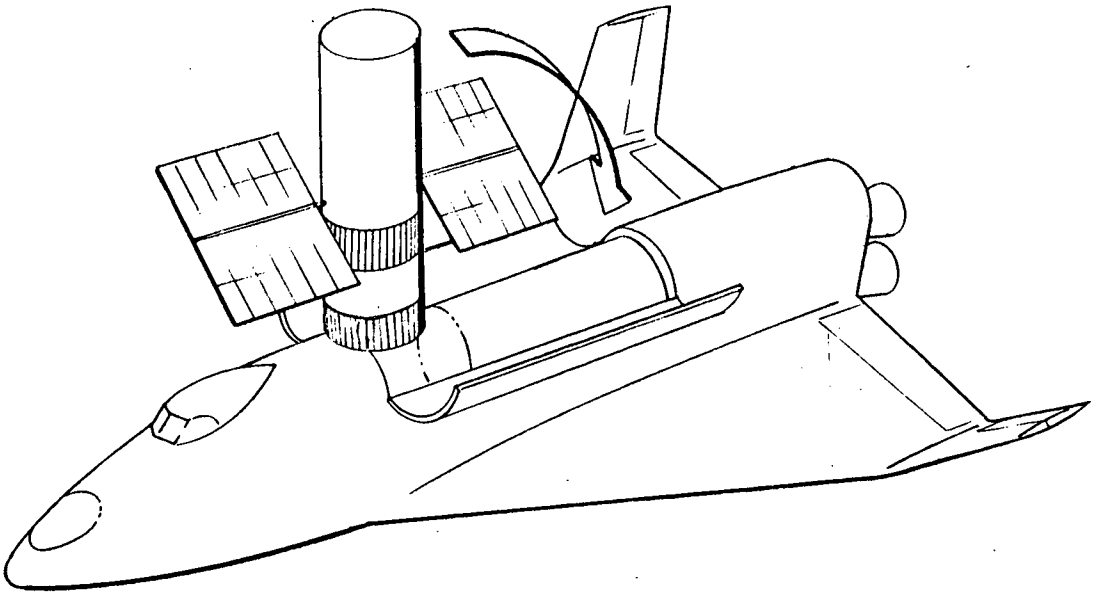


Figure 4-4. Mini-30 and Mini-7 Shuttle Sortie Payloads

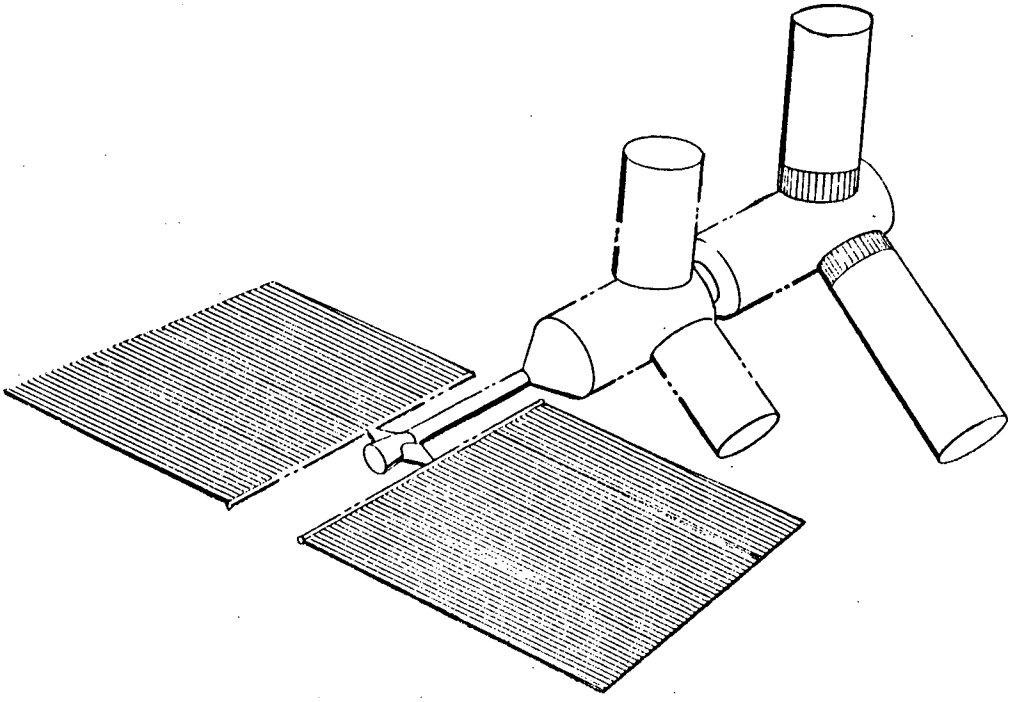


Figure 4-5. Maxi Nom, Mini-30 (Growth Version) Space Station Payloads

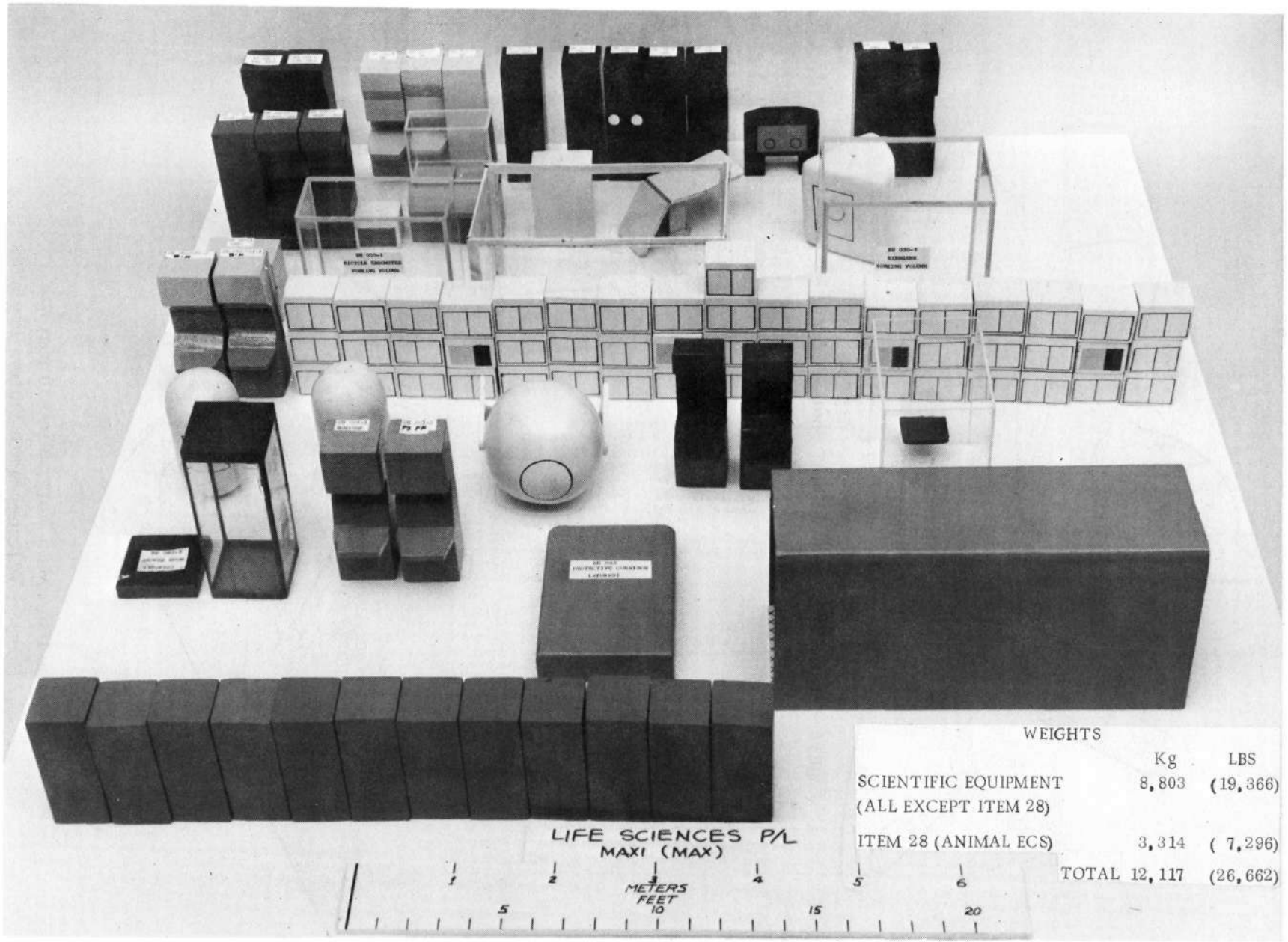
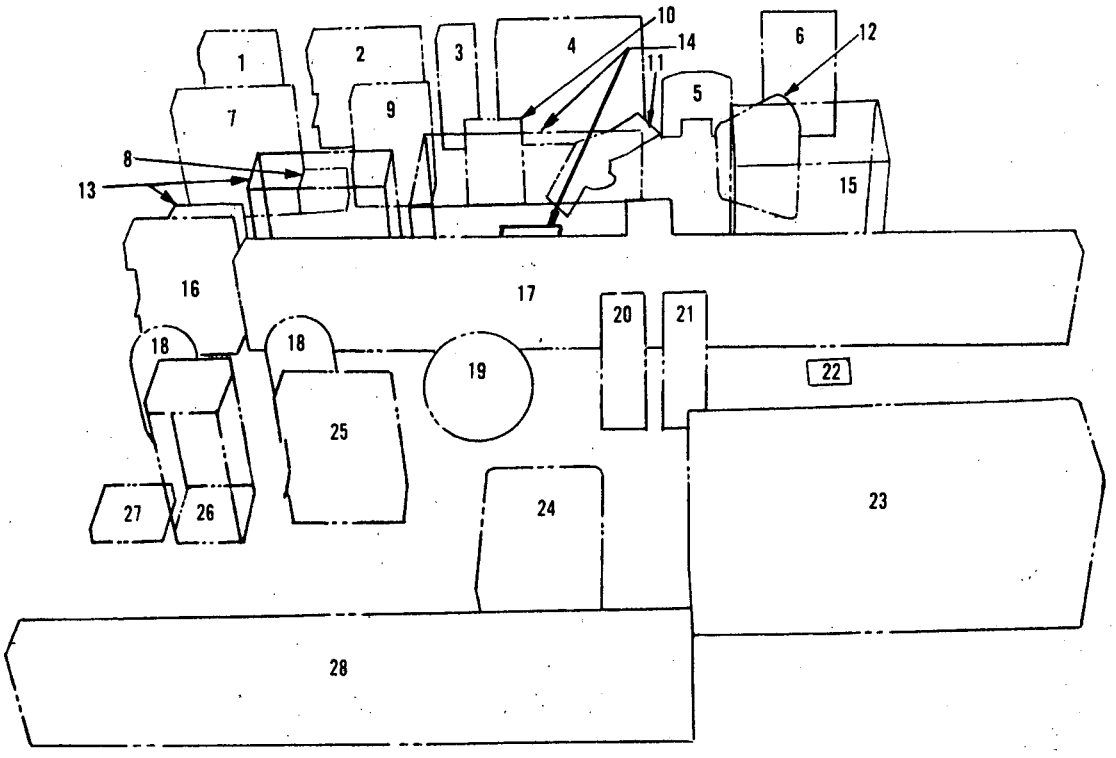



Figure 4-6. Maxi Max Three-Dimensional Equipment Payload




| | | |
|---|---|---|
| 1. | EU 001-1, -2 | VISUAL RECORDS AND MICROSCOPY UNIT |
| 2. | EU 002-1, -2, -4 | DATA MANAGEMENT UNIT |
| 3. | EU 003-1 | LIFE SCIENCES EXPERIMENT SUPPORT UNIT |
| 4. | EU 004-1, -2, -3, -4 | PREPARATION & PRESERVATION UNIT |
| 5. | EU 004-13 | PREPARATION & PRESERVATION UNIT |
| 6. | EU 005-1, -2 | BIOCHEMICAL AND BIOPHYSICS ANALYSIS UNIT |
| 7. | EU 006-1, -2, -3 | MAINTENANCE REPAIR & FABRICATION UNIT |
| 8. | EU 006 | SUPPORT UNIT |
| 9. | EU 011-1, -2 | REMOTE MANIPULATOR |
| 10. | EU 012-1 | BODY MASS MEASUREMENTS |
| 11. | EU 012-2 | ROTATING LITTER CHAIR |
| 12. | EU 025 | RADIATION EXPOSURE UNIT |
| 13. | EU 030-1 | BICYCLE ERGOMETER & WORKING VOLUME |
| 14. | EU 030-2 | LOWER BODY NEGATIVE PRESSURE |
| 15. | EU 030-3 | EXERGENIE |
| 16. | EU 012/031-1, -2 | BIO-MEDICAL MAN-SYSTEM INTEGRATION RESEARCH SUPPORT UNIT |
| 17. | | CAGE MODULES & SUPPORT UNIT. |
| 18. | EU 041-1 | PRIMATE HOLDING FACILITY |
| 19. | EU 041-2 | PRIMATE HOLDING FACILITY |
| 20. | EU 080-1 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 21. | EU 080-2 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 22. | EU 080-4 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 23. | EU 093 | MOBILITY UNIT - DAMAGE PROOF |
| 24. | EU 093 | STOWED |
| 25. | EU 091-1, -2 | BEHAVIORAL MEASUREMENTS UNIT |
| 26. | EU 080-5 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 27. | EU 080-5 | STOWED |
| 28. | EU 110-1 | ANIMAL ENVIRONMENTAL CONTROL SYSTEM |

Figure 4-7. Maxi Max Equipment Layout

4.1.2.2 Maxi Nom. Figure 4-8 and Figure 4-9 illustrate the Maxi Nom payload equipment modules. Note the high degree of commonality with the previously described Maxi Max payload.

The significant differences between Maxi Nom and Maxi Max are shown by these figures: (1) there is reduced CORE capability in Visual Records and Microscopy, and Data Management; (2) there are fewer cage modules 48 to 28, and therefore less organism ECS equipment; (3) the single 5 foot primate sphere and the radiation room have been eliminated; and (4) the Maxi Nom has an internal centrifuge.

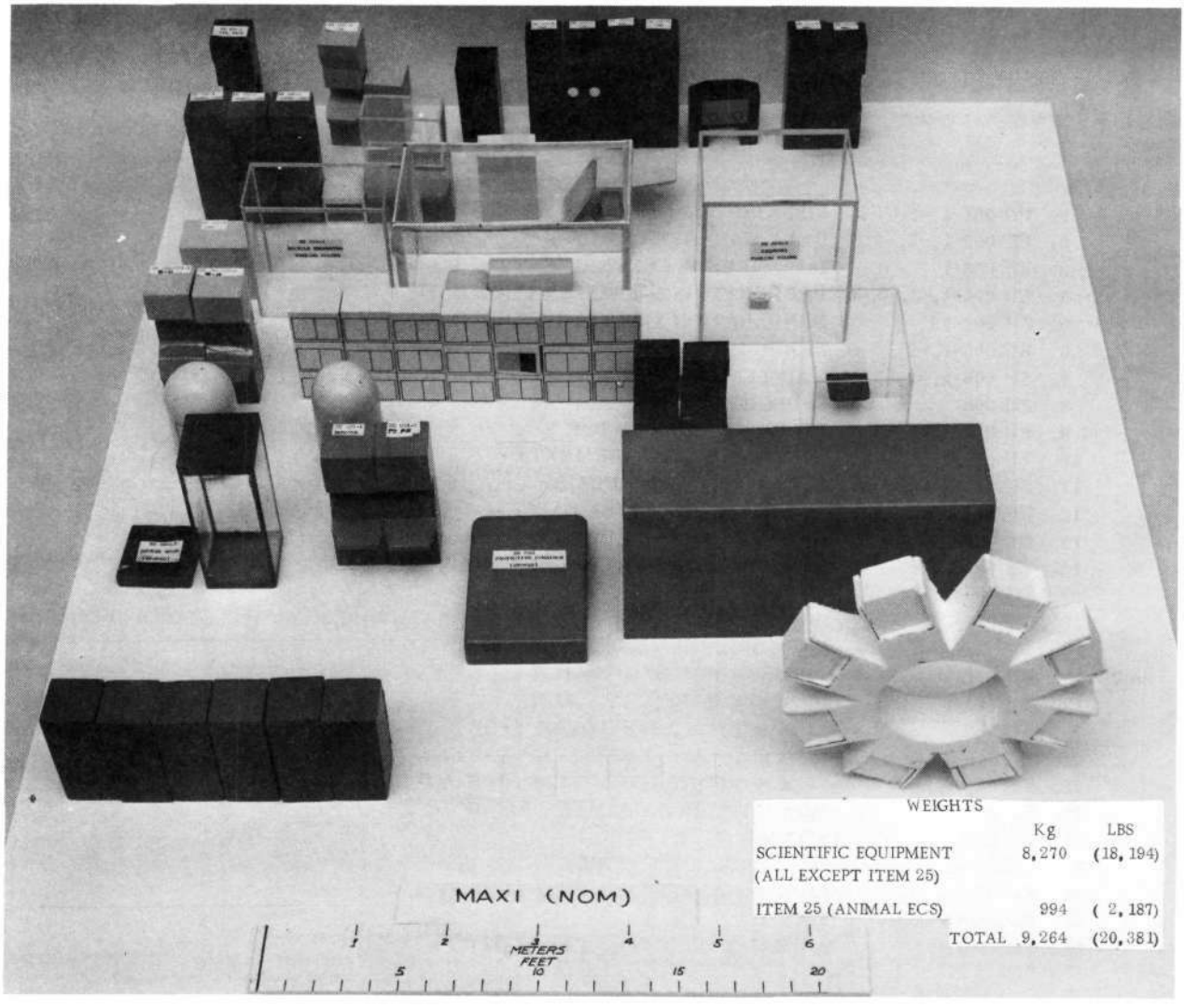
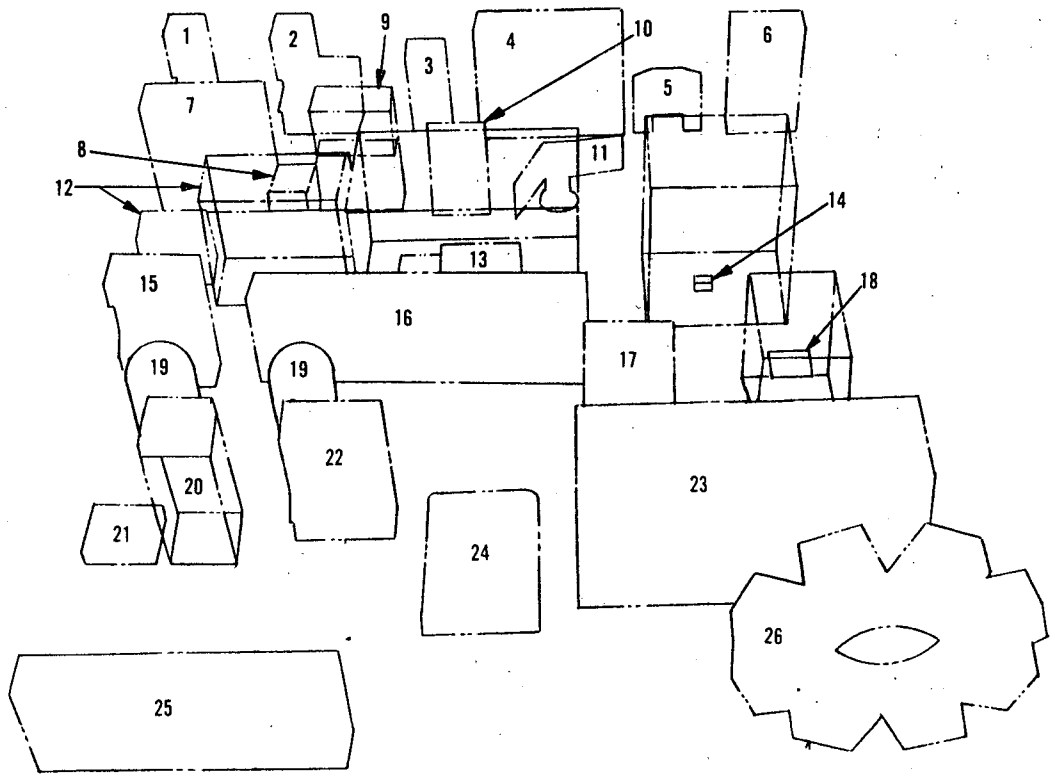


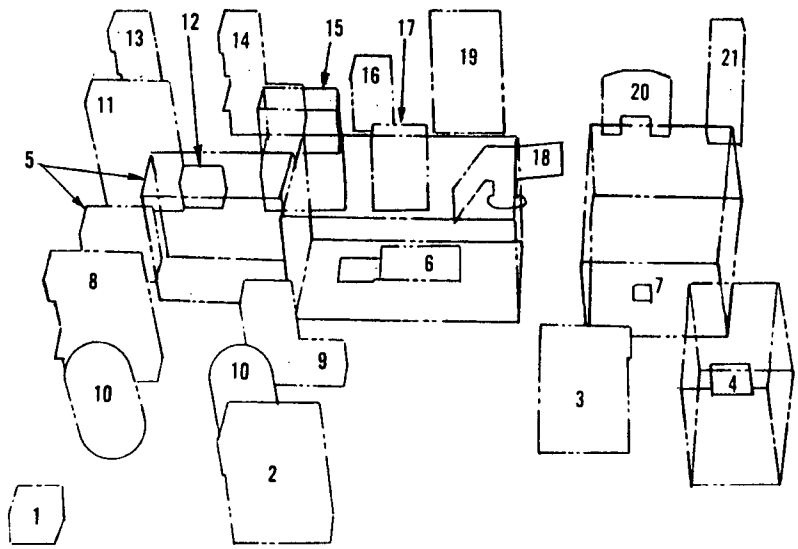

Figure 4-8. Maxi Nom Three-Dimensional Equipment Payload




| | | |
|---|---|---|
| 1. | EU 001-3 | VISUAL RECORDS & MICROSCOPY UNIT |
| 2. | EU 002-3, -5 | DATA MANAGEMENT UNIT |
| 3. | EU 003-2 | LIFE SCIENCES EXPERIMENT SUPPORT UNIT |
| 4. | EU 004-1, -2, -3, -4 | PREPARATION & PRESERVATION UNIT |
| 5. | EU 004-13 | PREPARATION & PRESERVATION UNIT |
| 6. | EU 005-1, -2 | BIOCHEMICAL & BIOPHYSICS ANALYSIS UNIT |
| 7. | EU 006-1, -2, -3 | MAINTENANCE REPAIR & FABRICATION UNIT |
| 8. | EU 006 | SUPPORT UNIT |
| 9. | EU 011-1, -2 | REMOTE MANIPULATOR |
| 10. | EU 012-1 | BODY MASS MEASUREMENT |
| 11. | EU 012-2 | ROTATING LITTER CHAIR |
| 12. | EU 030-1 | BICYCLE ERGOMETER & WORKING VOLUME |
| 13. | EU 030-2 | LOWER BODY NEGATIVE PRESSURE |
| 14. | EU 030-3 | EXERGENIE |
| 15. | EU 012/031-1, -2 | BIO-MEDICAL MAN-SYSTEM INTEGRATION RESEARCH SUPPORT UNIT |
| 16. | EU 040 | CAGE MODULE & SUPPORT UNIT |
| 17. | EU 080-1, -2 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 18. | EU 080-4 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 19. | EU 041-1 | PRIMATE HOLDING FACILITY |
| 20. | EU 080-5 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 21. | EU 080-5 | STOWED |
| 22. | EU 091-1, -2 | BEHAVIORAL MEASUREMENTS UNIT |
| 23. | EU 093-1 | MOBILITY UNIT - DAMAGE PROOF |
| 24. | EU 093-1 | STOWED |
| 25. | EU 110-1 | ANIMAL ENVIRONMENTAL CONTROL SYSTEM |
| 26. | EU 023 | INTERNAL CENTRIFUGE |

Figure 4-9. Maxi Nom Equipment Layout

4.1.2.3 Mini-30. Figure 4-10 and Figure 4-11 identify the Mini-30 payload equipment. Comparing Mini-30 with the Maxi Nom it is seen that the CORE equipment is reduced, and the number of cage modules are reduced to 6 (Photo shows 3 only). Biomedicine, MSI and LSPS equipment is about the same. ECS requirements are reduced based on the 30 day mission and smaller organism load.




| | | |
|---|---|---|
| 1. | EU 110-3 | ANIMAL ENVIRONMENTAL CONTROL SYSTEM |
| 2. | EU 091-1,-2 | BEHAVIORAL MEASUREMENTS UNIT |
| 3. | EU 080-1,-2 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 4. | EU 080-4 | LIFE SUPPORT SUBSYSTEM TEST UNIT |
| 5. | EU 030-1 | BICYCLE ERGOMETER & WORKING VOLUME |
| 6. | EU 030-2 | LOWER BODY NEGATIVE PRESSURE |
| 7. | EU 030-3 | EXERGENIE |
| 8. | EU 012/031-1,-2 | BIO-MEDICAL MAN-SYSTEM INTEGRATION RESEARCH SUPPORT UNIT |
| 9. | EU 040/050/070 | CAGE MODULE & SUPPORT UNIT |
| 10. | EU 041-1 | PRIMATE HOLDING UNIT |
| 11. | EU 006-5,-6 | MAINTENANCE REPAIR & FABRICATION UNIT |
| 12. | EU 006 | SUPPORT UNIT |
| 13. | EU 004-4 | VISUAL RECORDS & MICROSCOPY UNIT |
| 14. | EU 002-3,-6 | DATA MANAGEMENT UNIT |
| 15. | EU 011-1,-2 | REMOTE MANIPULATOR |
| 16. | EU 003-3 | LIFE SCIENCES EXPERIMENT SUPPORT LINK |
| 17. | EU 012-1 | BODY MASS MEASUREMENT |
| 18. | EU 012-2 | ROTATING LITTER CHAIR |
| 19. | EU 004-9,-10 | PREPARATION & PRESERVATION UNIT |
| 20. | EU 004-13 | PREPARATION & PRESERVATION UNIT |
| 21. | EU 005-4 | BIOCHEMICAL & BIOPHYSICS ANALYSIS UNIT |

Figure 4-10. Mini-30 Equipment Layout

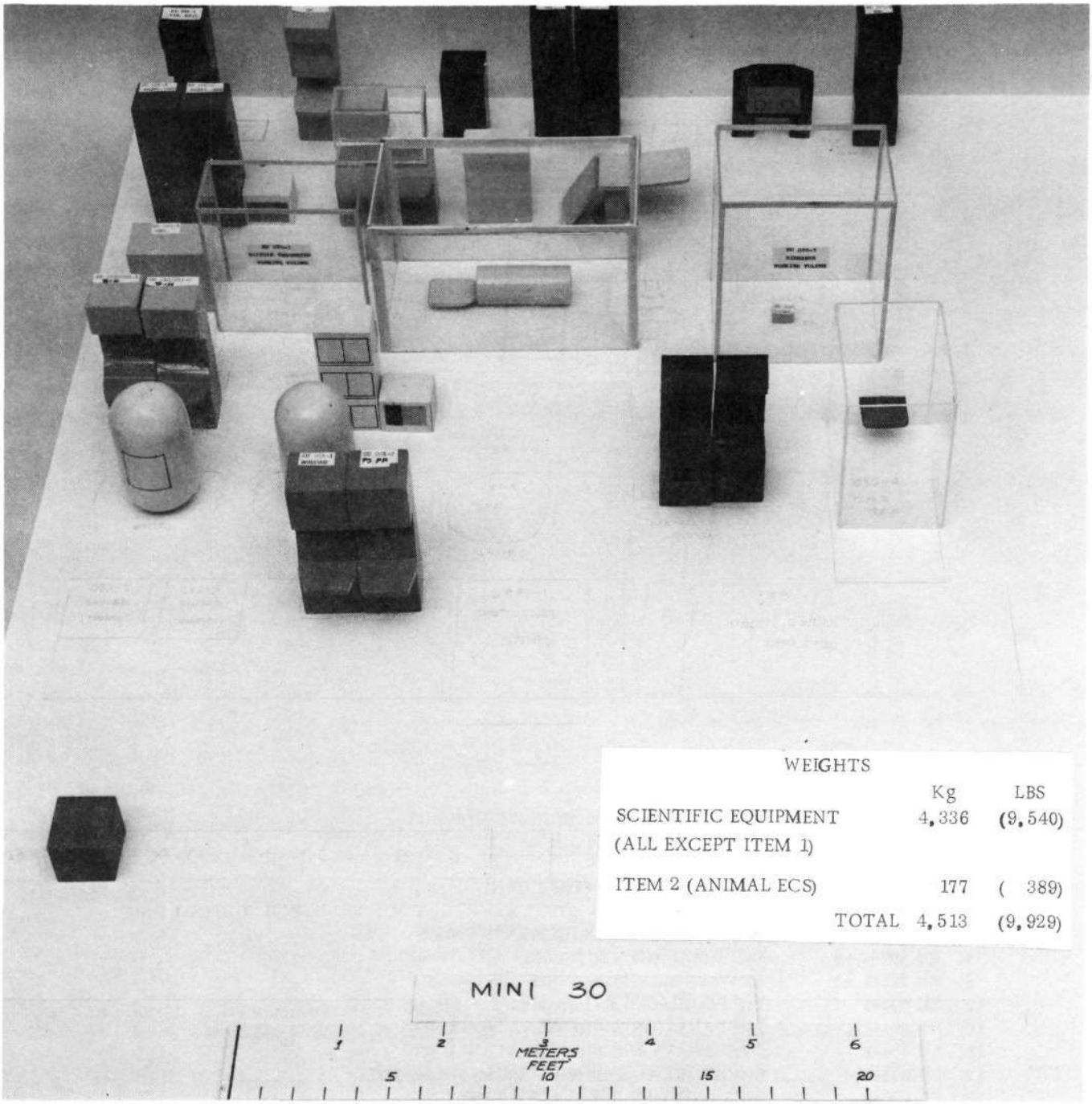
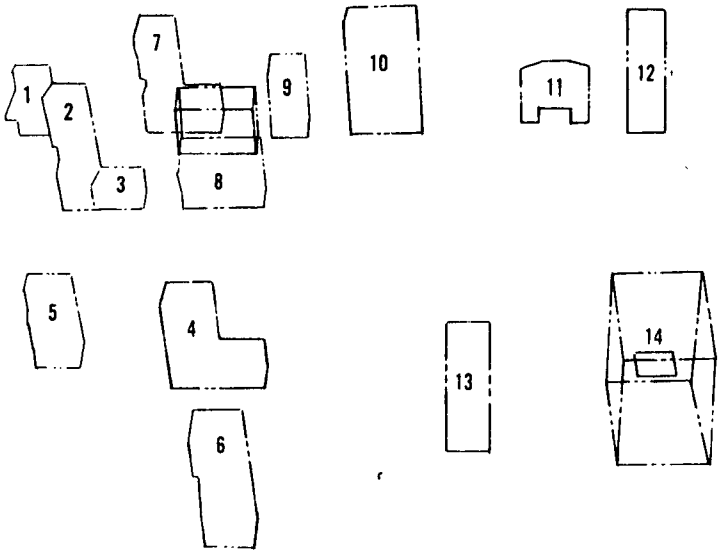



Figure 4-11. Mini-30 Three-Dimensional Equipment Payload

4.1.2.4 Mini-7. Figure 4-12 and Figure 4-13 identify the Mini-7 payload equipment requirements. The biomedicine equipment is eliminated, cage modules are reduced to 4, and MS1 and LSPS equipment is also reduced.




1. EU 001-5 VISUAL RECORDS & MICROSCOPY UNIT
2. EU 006-7 MAINTENANCE REPAIR AND FABRICATION UNIT
3. EU 006 SUPPORT UNIT
4. EU 040/050/070 CAGE MODULE & SUPPORT UNIT
5. EU 012/031-4 BIO-MEDICAL MAN-SYSTEM INTEGRATION RESEARCH SUPPORT UNIT
6. EU 091-2 BEHAVIORAL MEASUREMENTS UNIT
7. EU 002-3, -6 DATA MANAGEMENT UNIT
8. EU 011-1, -2 REMOTE MANIPULATORS
9. EU 003-3 LIFE SCIENCES EXPERIMENT SUPPORT UNIT
10. EU 004-11, -12 PREPARATION & PRESERVATION UNIT
11. EU 004-13 PREPARATION & PRESERVATION UNIT
12. EU 005-5 BIOCHEMICAL & BIOPHYSICS ANALYSIS UNIT
13. EU 080-3 LIFE SUPPORT SUBSYSTEM TEST UNIT
14. EU 080-4 LIFE SUPPORT SUBSYSTEM TEST UNIT

Figure 4-12. Mini-7 Equipment Layout

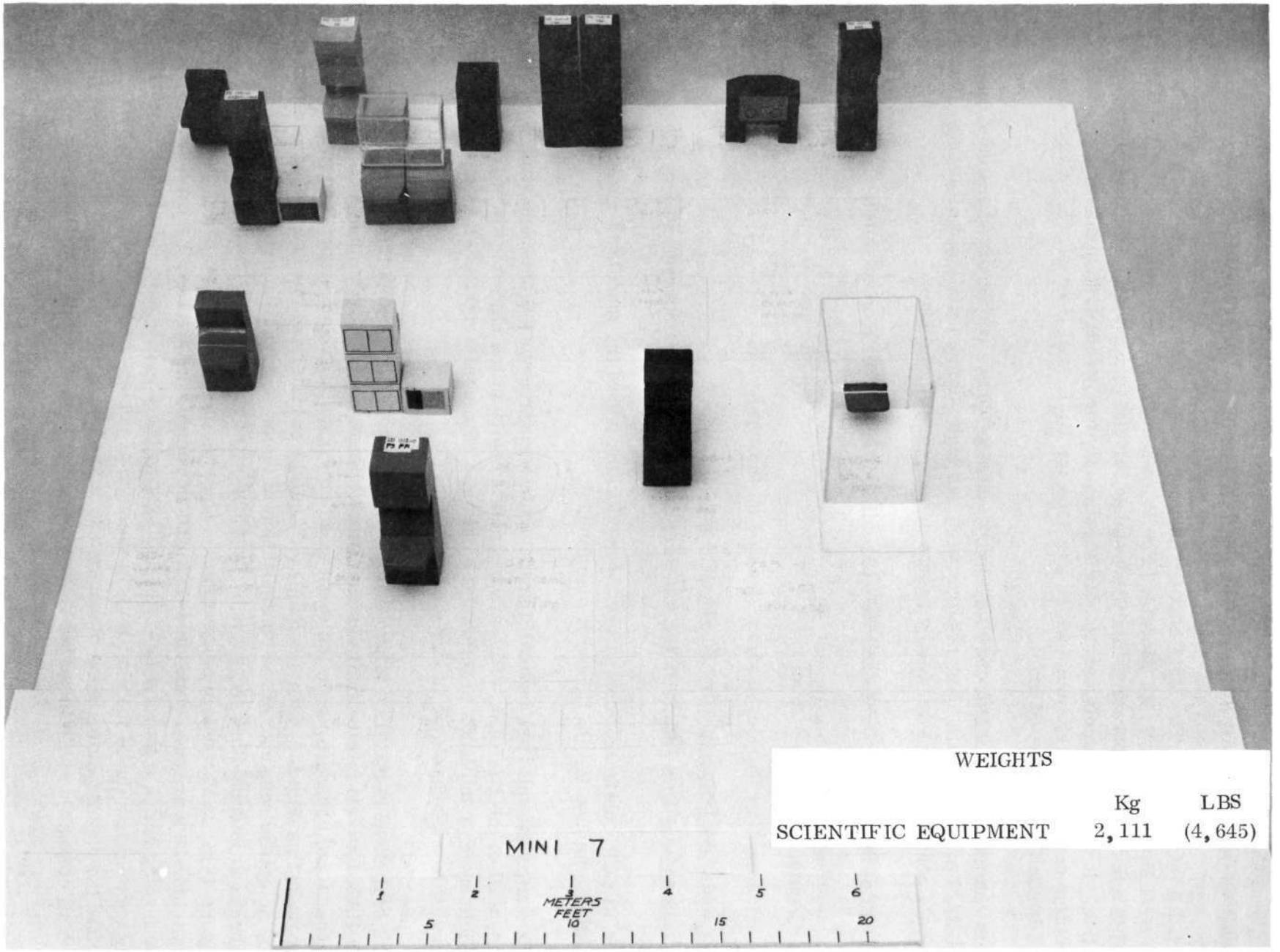



Figure 4-13. Mini-7 Three-Dimensional Equipment Payload

4.1.3 BASELINE LAYOUTS. The five baseline payload layouts, presented in the following figures, were selected from the second generation group of layouts.

4.1.3.1 Maxi Max. The Maxi Max payload consists of three modules: (1) F Module; (2) BLH Module, and (3) RC Module. The F module is shown in Figures 4-14 and 4-15 and is a dedicated laboratory facility designed for use in a modular space station application. It provides functional capability primarily for research in space biology, and contains some CORE elements which are used for B, L, and H research. CORE units are located on the second level.

This configuration features the "No Floors" concept where equipment is mounted on the LS-RAM pressure wall. The configuration has high volume utilization efficiency. The module contains basically biology research equipment as follows:

a. 12 of the 15 CORE ERs and ECs (the other 3 are in the BLH module).

b. Holding units (i.e., 48 cage modules, 2 Macaque cylinders, and 1 primate sphere) located on the first level.

c. Holding Unit Support Modules (located on the top level).

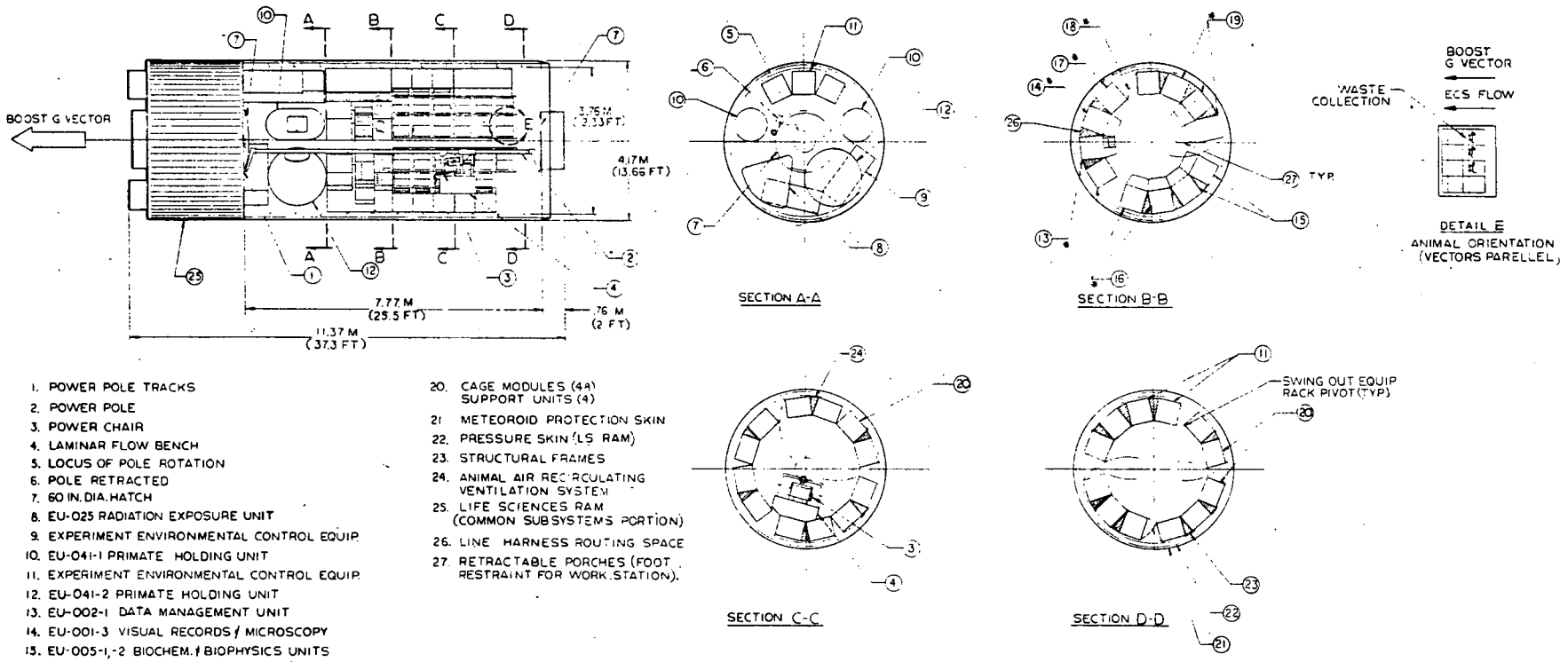
d. Radiation Room (located on the first level).

e. 12 Animal ECS ERs (7 in the top level and 5 in the lower level).

The 12 CORE units are located toward the docking end of the module to make them available for use for B, L, and H functions.

The equipment units are basically arranged in annular shaped clusters against the pressure wall of the LS-RAM. This arrangement results in the high volume utilization efficiency ($\epsilon_V$) and leads to minimum length and minimum weight LS-RAMs. There is very little unused volume in this configuration.

The equipment is installed to provide maximum open area through the center of the LS-RAM for: (1) full visibility of laboratory operations by a crew member; and (2) unrestricted escape route in the event of an emergency. The configuration provides for operation with the escape hatch(s) (60" hatch) in either the open or closed position. The scientific response of the configuration in terms of organism orientation and crew operations is considered very good. One feature of the design, shown in detail E on Figure 4-15, is "organism orientation". The cage modules are arranged such that organisms are oriented with the 4-1/2 g boost vector, and with the 1 g ground vector for loading animals into the LS-RAM and loading the LS-RAM into the shuttle (assuming vertical loading of the shuttle). In the case of vertebrates, the air flow vector within the cage module, feces management, urine management, and animal position are all compatible with these boost vectors and ground acceleration vectors.




1. POWER POLE TRACKS
2. POWER POLE
3. POWER CHAIR
4. LAMINAR FLOW BENCH
5. LOCUS OF POLE ROTATION
6. POLE RETRACTED
7. 60 IN. DIA. HATCH
8. EU-025 RADIATION EXPOSURE UNIT
9. EXPERIMENT ENVIRONMENTAL CONTROL EQUIP.
10. EU-041-1 PRIMATE HOLDING UNIT
11. EXPERIMENT ENVIRONMENTAL CONTROL EQUIP.
12. EU-041-2 PRIMATE HOLDING UNIT
13. EU-002-1 DATA MANAGEMENT UNIT
14. EU-001-3 VISUAL RECORDS / MICROSCOPY
15. EU-005-1,-2 BIOCHEM. / BIOPHYSICS UNITS
16. EU-006-1,-2,-3 MAINTENANCE REPAIR / FABRICATION UNITS
17. EU-003-1 LIFE SCIENCES SUPPORT UNIT
18. SWING OUT PATH
19. EU 004-1,-2,-3,-4 PRESERVATION / PREPARATION UNITS
20. CAGE MODULES (44) SUPPORT UNITS (4)
21. METEOROID PROTECTION SKIN
22. PRESSURE SKIN (LS RAM)
23. STRUCTURAL FRAMES
24. ANIMAL AIR RECIRCULATING VENTILATION SYSTEM
25. LIFE SCIENCES RAM (COMMON SUBSYSTEMS PORTION)
26. LINE HARNESS ROUTING SPACE
27. RETRACTABLE PORCHES (FOOT RESTRAINT FOR WORK STATION).

2) DEDICATED LABORATORY FOR MODULAR SPACE STATION

1) *DENOTES CORE UNIT

NOTE:





Figure 4-14. Maxi Max Payload (F Module)

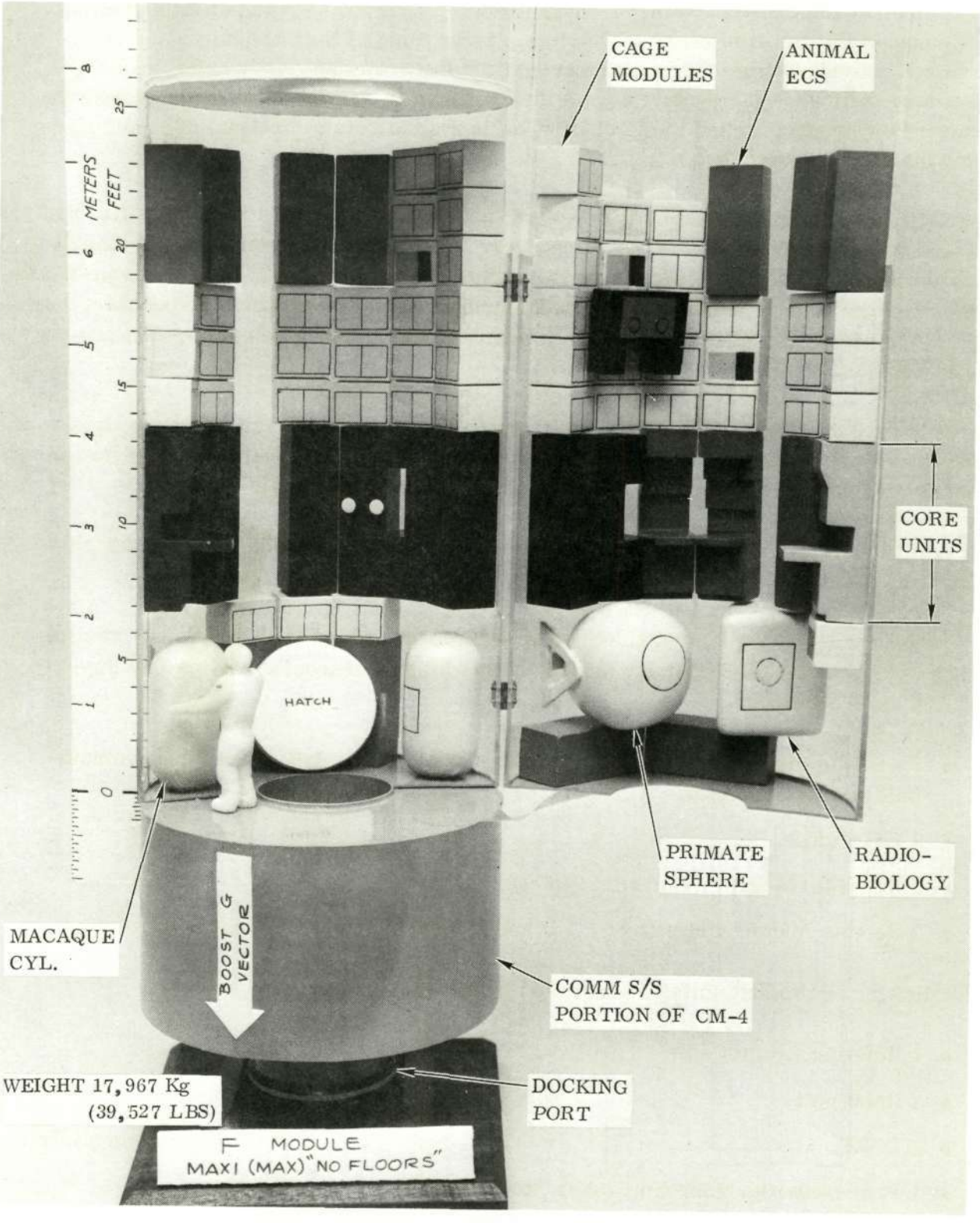



Figure 4-15. Maxi Max Baseline (F Module)

Crew operation provisions include two candidate concepts for crew mobility, restraints, and cargo handling: 1) the Powered Chair System; and 2) the X-Y plotter plus Guided Soaring. The Powered Chair (Item 3 on Figure 4-14) has a pole (Item 2) that supports the powered chair to which is attached the LFB or another piece of cargo. It provides three degrees of freedom for the crewman (i.e., axial, radial, and rotary motion). The system allows the crewman to service cage modules with the laminar flow bench attached to the chair. He is free to rotate through 360° and interface with any cage module.

The X-Y Plotter and Guided Soaring System (not illustrated) would have rails (tracks) between the cage modules at 90° to each other. The LFB can traverse to any module (like plotting X-Y coordinates) using a manual or powered system. In these same tracks, a crewman could move about in a "Guided Soaring" fashion. Retractable "porches" (item 27) are provided as foot restraints for crewmen working at a given station for prolonged periods.

The BLH module (Figures 4-16 and 4-17) represents a dedicated laboratory designed for use in a modular space station configuration and provides functional capability for research in biomedicine, life support, and man systems integration.

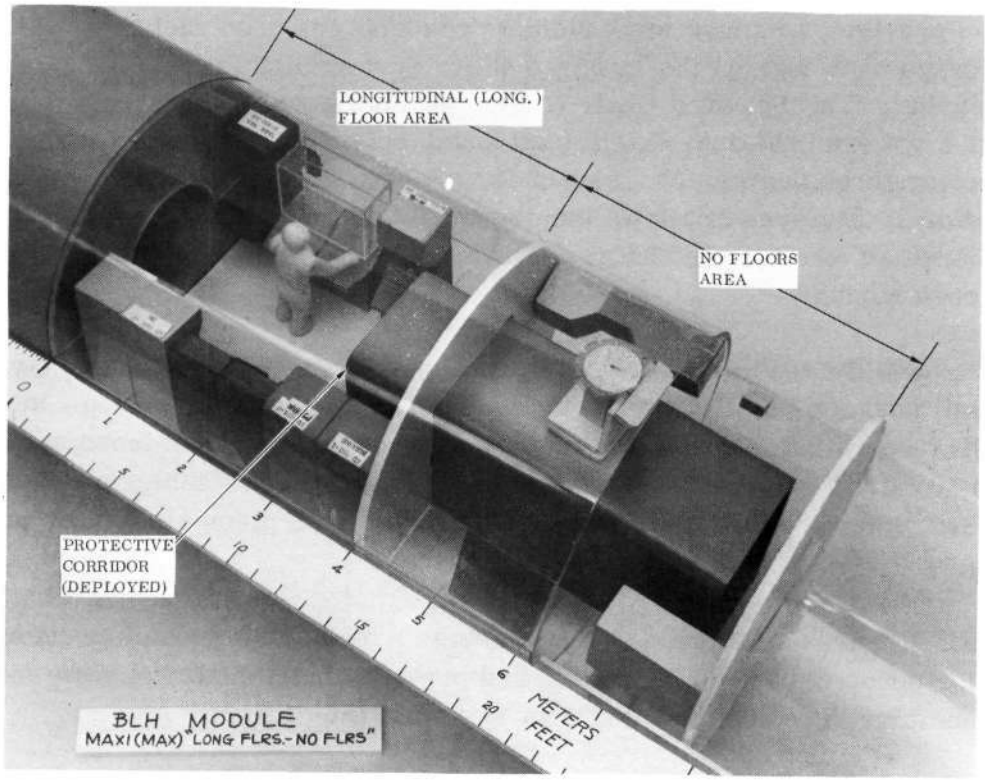
The design features no floors and longitudinal floors in combination with a bulkhead separating the laboratory into two areas.

The module contains B, L, and H scientific equipment and some CORE units. The following units are installed in the long floor area which is nearest the hatch leading to the modules space station.

- 3 CORE units (1 Vis. Rec. and Micro, 2 D.M. unit), 1 B and H Measurement Unit and 1 Ergometer
- 2 LSPS units
- 2 Behavior Measurement Units (MSI)
- 2 Remote Manip. Units (MSI), 1 B and H Measurement Unit and 1 Ergometer

The following equipment units are installed in the no floors area:

- 1 Rotating Litter Chair
- 1 BMM unit
- 1 LBNP
- 1 Protective Corridor Unit (show stowed)
- 1 Shower
- 1 Exegenie
- 1 B and H Measurement Unit



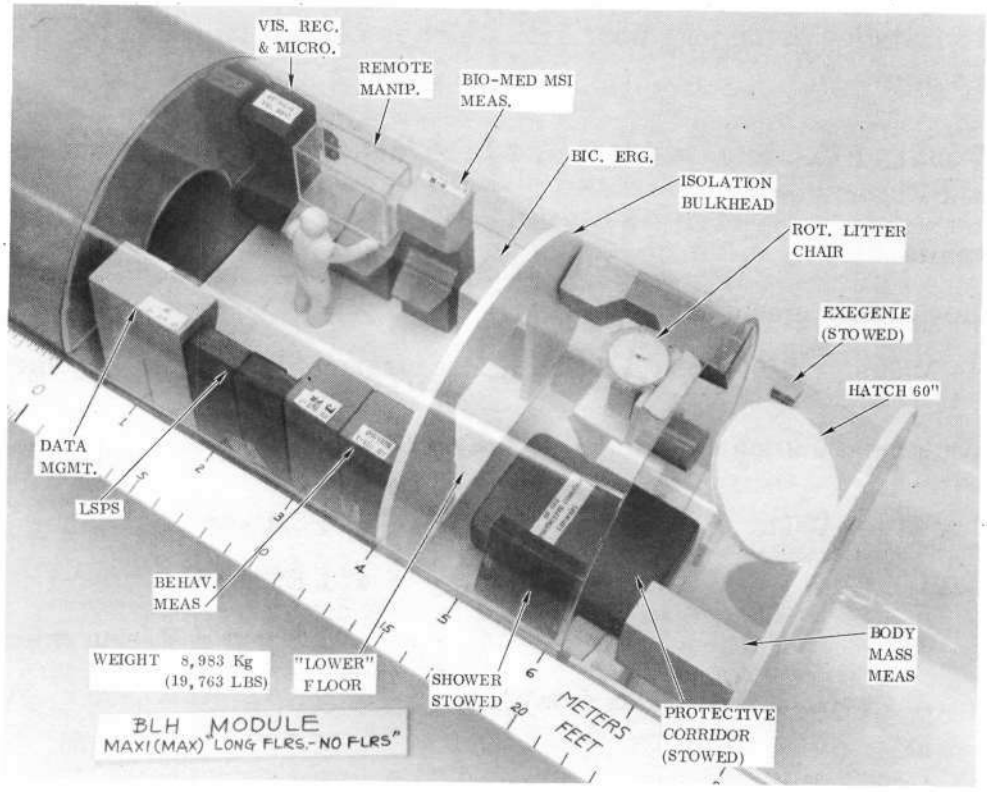
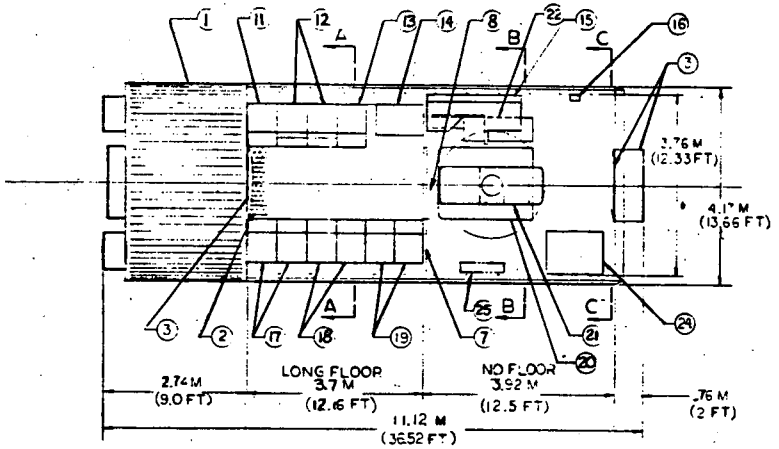
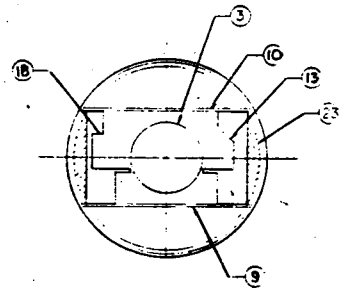
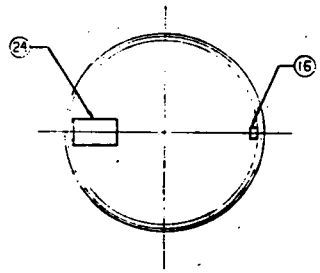
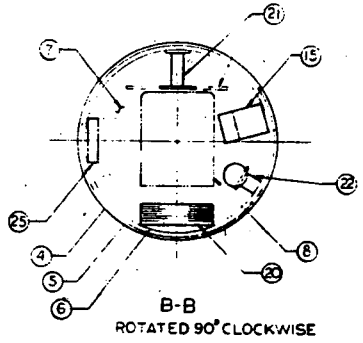




Figure 4-16. Maxi Max BLH Module




1. LIFE SCIENCES RAM COMMON SUBSYSTEMS PORTION.
2. CANDIDATE MOBILITY AID (ASTRO GRID).
3. 60 IN. DIA. HATCH AND TUNNEL
4. METEOROID PROTECTION SKIN
5. RAM MODULE PRESSURE SKIN
6. STRUCTURAL FRAME DEPTH
7. ISOLATION BULKHEAD
8. COMPARTMENT DOORS (DOUBLE FOLDING)
9. "LOWER" MOBILITY AID SURFACE (FLOOR)
10. "UPPER" MOBILITY AID SURFACE (CEILING)
11. EU-001-2 VISUAL RECORDS AND MICROSCOPY.
12. EU-011-1,-2. REMOTE MANIPULATOR UNIT
13. EU 012/031-1 BIOMEDICAL MSI SUPPORT UNIT
14. EU-030-1 BICYCLE ERGOMETER
15. EU-012/031-2 BIOMEDICAL MSI SUPPORT UNIT
16. EU-030-3 EXERGENE
17. EU-002-2,-4 DATA MANAGEMENT UNITS
18. EU-080-1-2 LIFE SUPPORT SUBSYSTEMS TEST UNITS.
19. EU-091-1,-2 BEHAVIORAL MEAS. UNITS
20. EU-093-1 MOBILITY UNIT (STOWED)
21. EU-012-2 ROTATING LITTER CHAIR
22. EU-030-1 LOWER BODY NEGATIVE PRESSURE
23. LINES & HARNESS ROUTING SPACE
24. EU-012-2 BODY MASS MEASUREMENTS UNIT
25. EU 080 LIFE SUPPORT SUB SYSTEMS TEST UNIT



Figure 4-17. Maxi Max BLH Baseline

Crew safety was given top priority. As shown, there is always a clear escape path for the crew. Both hatches may be open during operation (as far as internal clearance is concerned), which provides crew members with good visibility of the laboratory operations at all times.

Figure 4-16 shows two views of the protective corridor. In one case it is in the stowed position and in the other it is deployed. Operation of the protective corridor requires that activity in other areas be curtailed during tests involving the protective corridor unit.

The equipment units in the long floors areas are mounted on the floor on opposite sides of the LS-RAM as shown in Figure 4-17. Access for maintenance to the backside of the equipment racks and to the LS-RAM pressure wall is made possible by either a track that will allow the rack to roll out from the wall or a hinge mechanism that will allow the racks to swing upward. Equipment loads are reacted through the floor into the structural wall of the LS-RAM.

Equipment units in the no floors area are directly mounted to the LS-RAM pressure wall. This mounting allows for rack to swing out from the wall for maintenance.

These equipment arrangements result in high volume utilization efficiency, particularly in the no floors portion. The required module length is 7.6 meters (24.6 feet). A slight improvement in volume utilization could be obtained using no floors throughout; however, the configuration shown is considered good utilization of space and will result in a reasonable payload fraction. In the long floor area, there is unused storage volume available both above and below.

BLH equipment has a low density with the result that the above layout does not make full use of the shuttle boost payload weight because the volume limit is reached before the weight limit is reached.

The crew mobility restraint and cargo handling provisions potential for this design are as follows:

a. For the long floors area, candidate systems are floor and ceiling astro grid or mobility by pressure walking or guided soaring at the work station.

b. For the no floors area, concepts using guided soaring for mobility and local porch with astro grid for crewman at the work station.

The Research Centrifuge Module (RC) is shown in Figure 4-18. It is part of the Maxi Max payload. Design features of this module are discussed in Volume III. Equipment arrangement in the RC module was developed considering the other two modules (i.e., F and BLH). The total facility weight of the Maxi Max payload layout is shown in Table 4-2 in Section 4.1.4 of this report.

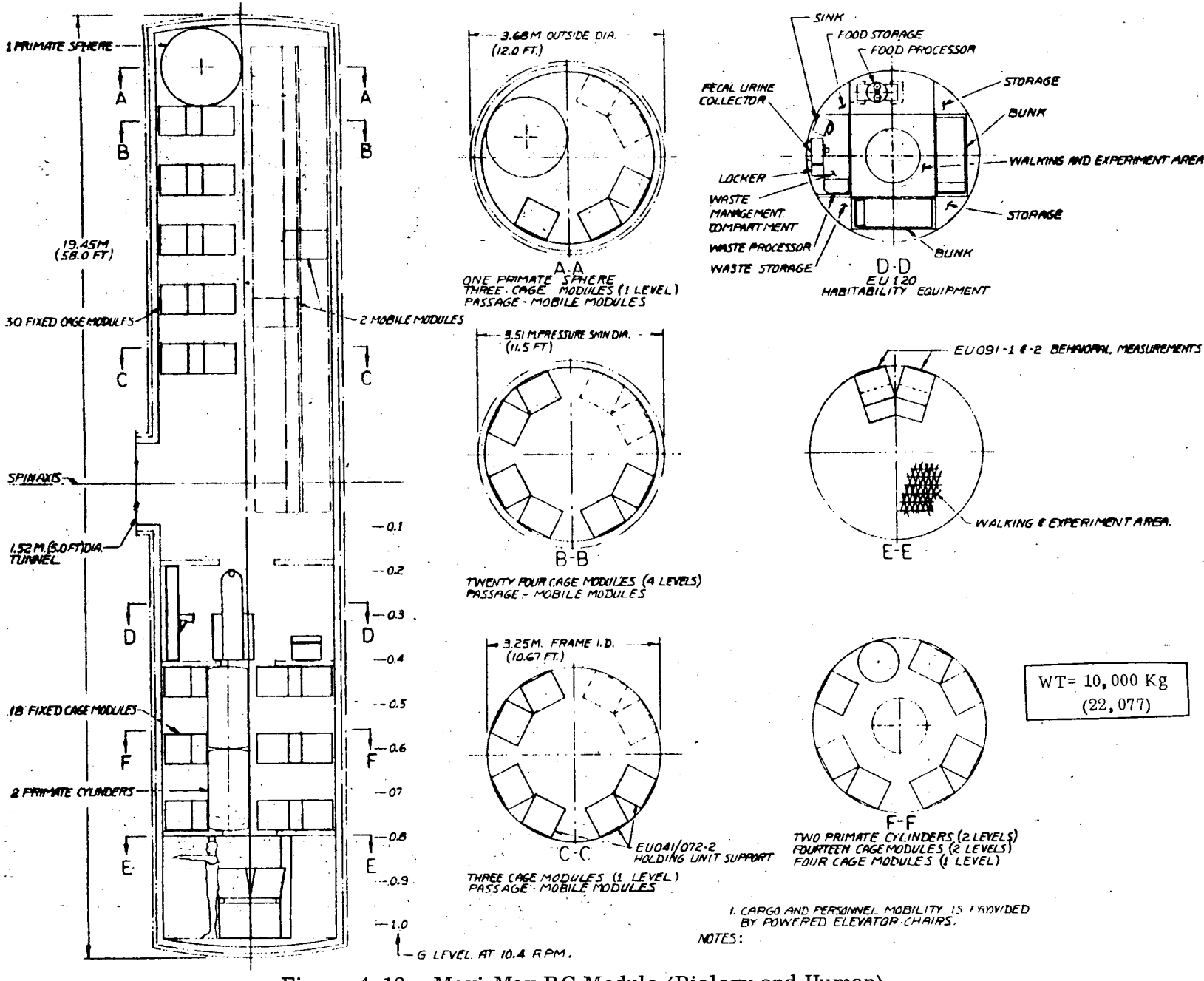



Figure 4-18. Maxi Max RC Module (Biology and Human)

4.1.3.2 Maxi Nom. The Maxi Nom payload was studied in two internal configuration designs; a long floor and a no floors design. In both these designs a Space Station based LS-RAM is used. All Life Sciences functions are contained within the single LS-RAM module.

In the Maxi Nom payload, the long foor configuration has two compartments. One compartment is dedicated to the F functions and the other serves the BLH functions. Figures 4-19 and 4-20 show the two compartments with the module open to illustrate the equipment mounted above and below the floor and ceiling. Here the internal centrifuge is located at the far end of the F compartment.

Figure 4-21 illustrates the above ceiling and under floor equipment relationships including the stowage space available in these areas. Figure 4-22 shows the experiment compartment length to be about 13.6 m (44.7 ft), and also shows the protecting corridor extended. Figure 4-23 illustrates the overall length of the module as about 16.6 m (54.7 ft). In this configuration locomotion is accomplished through the use of an astro grid floor or pressure walking, long distances may be covered by soaring. The drawing, Figure 4-24, correlates the equipment items to the photo illustrations.

Maxi Nom (no floors) wafer floors configuration is shown in Figures 4-25, 4-26, and 4-27. Figure 4-25 illustrates the no floors version with the protective corridor in its stowed position, Figure 4-26 shows the corridor extended. In this configuration the payload is divided into three basic compartments. The lower two compartments which are adjacent to the space station docking port are dedicated to the BLH functions while the third compartment with the internal centrifuge at the far end is dedicated to the F functions. The only exception to this division in disciplines is the location of the remote manipulator units in the F functions section. Figure 4-27 may be used to correlate equipment locations shown in the photographs.

The overall length of the experiment compartment is shown to be about 10.3 m (34 ft) or an overall module length of 13.5 m (44.2 ft) which is about 3 m (10 ft shorter than the long floor configuration.

With this version, several types of locomotion are possible in the lower two compartments; an astro grid floor or pressure walking may be used, while in the upper or F section a power pole or soaring may be used with fixed work station restraints provided.

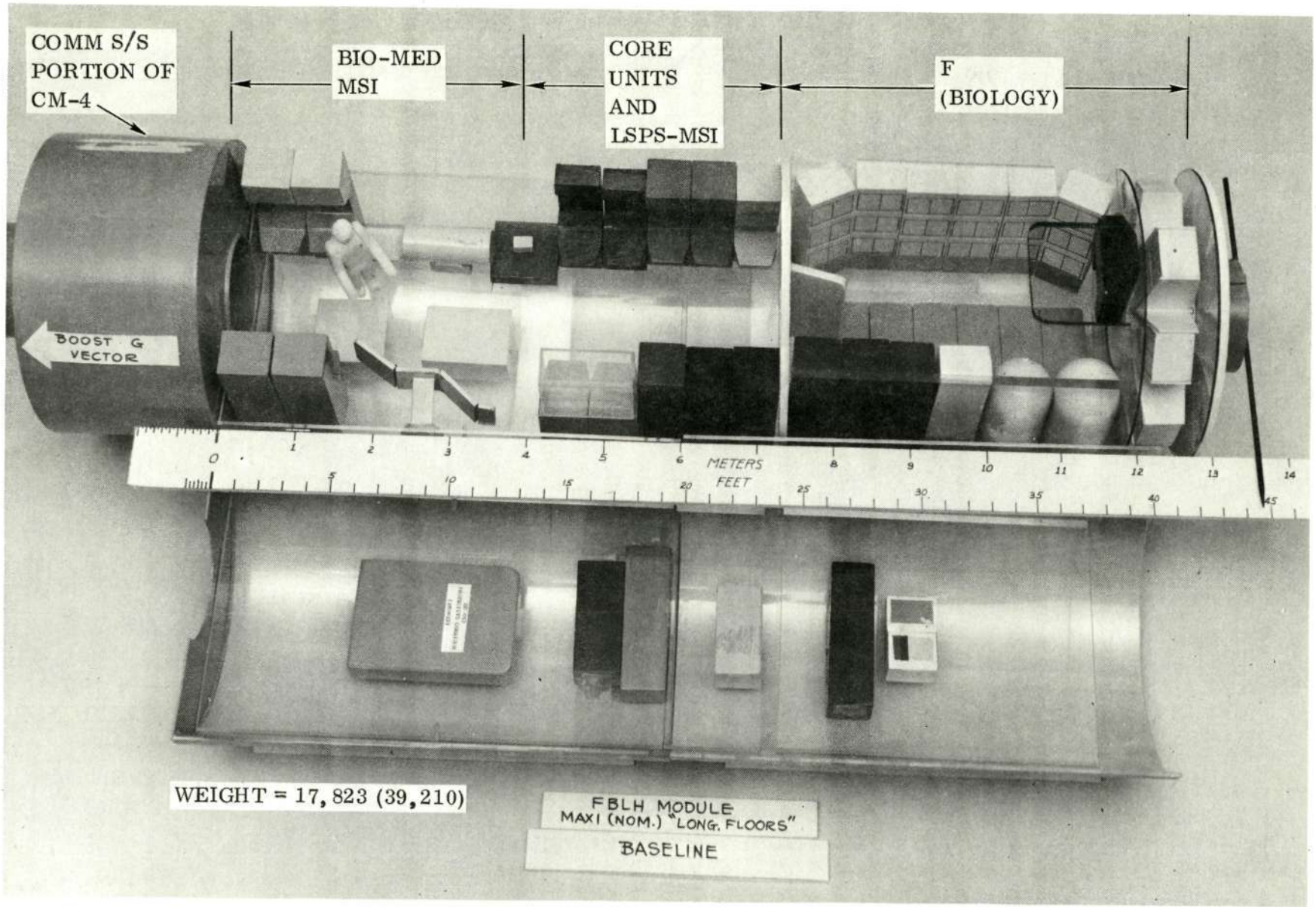



Figure 4-19. Maxi Nom Long Floors (F BLH Module)

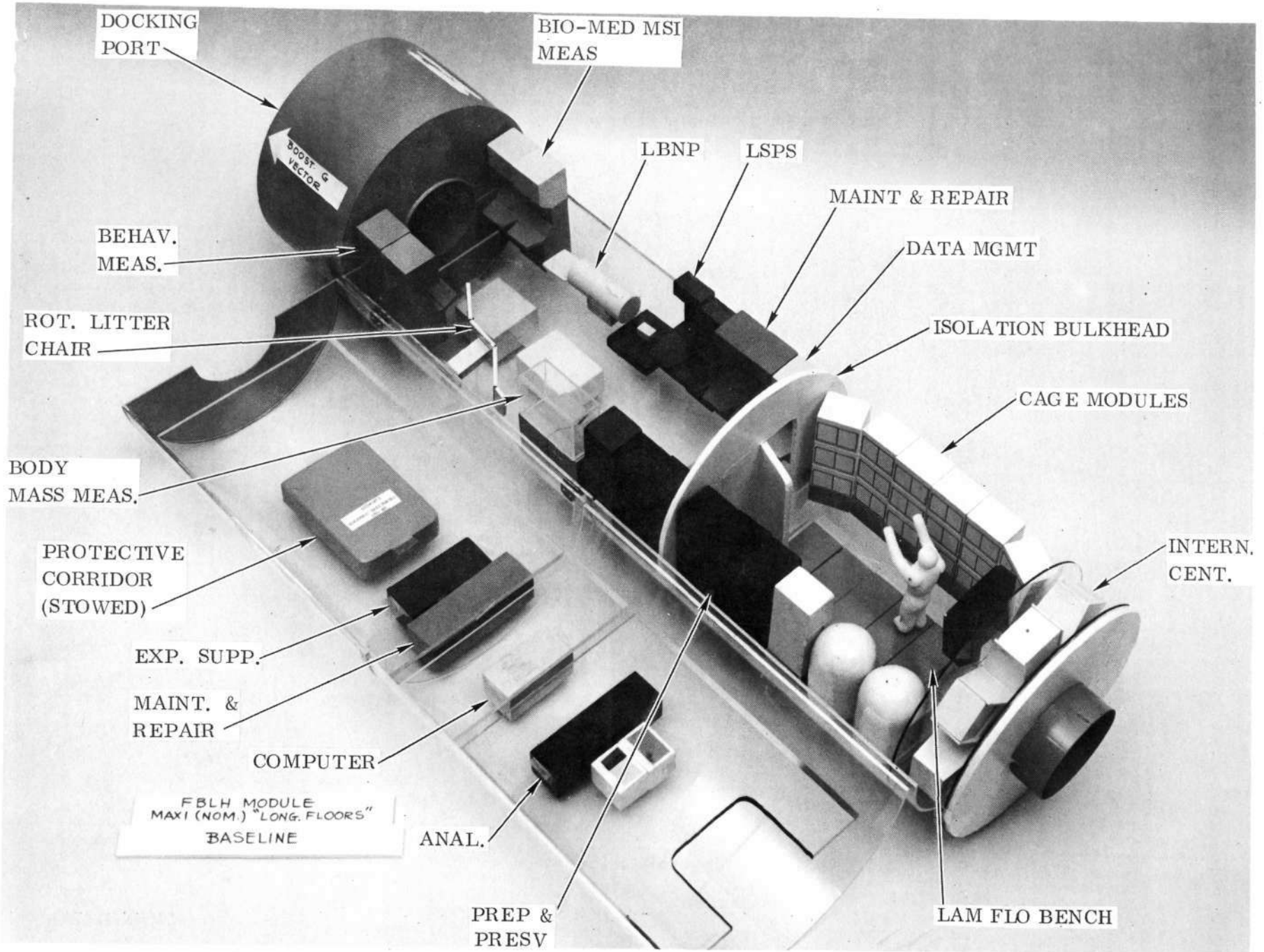



Figure 4-20. Maxi Nom. Long Floors (F BLH Module Equipment Layout)

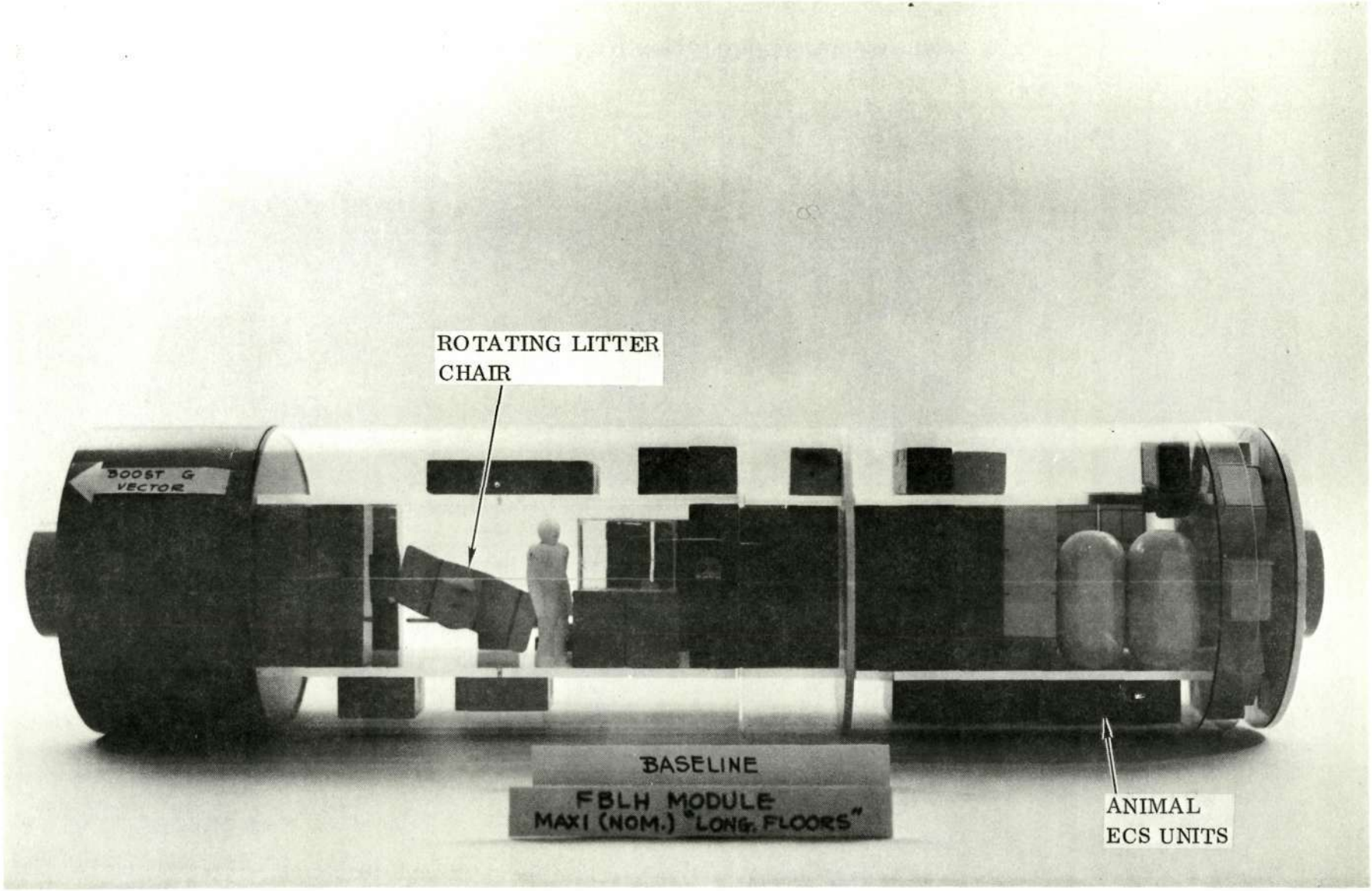



Figure 4-21. Maxi Nom Equipment Layout

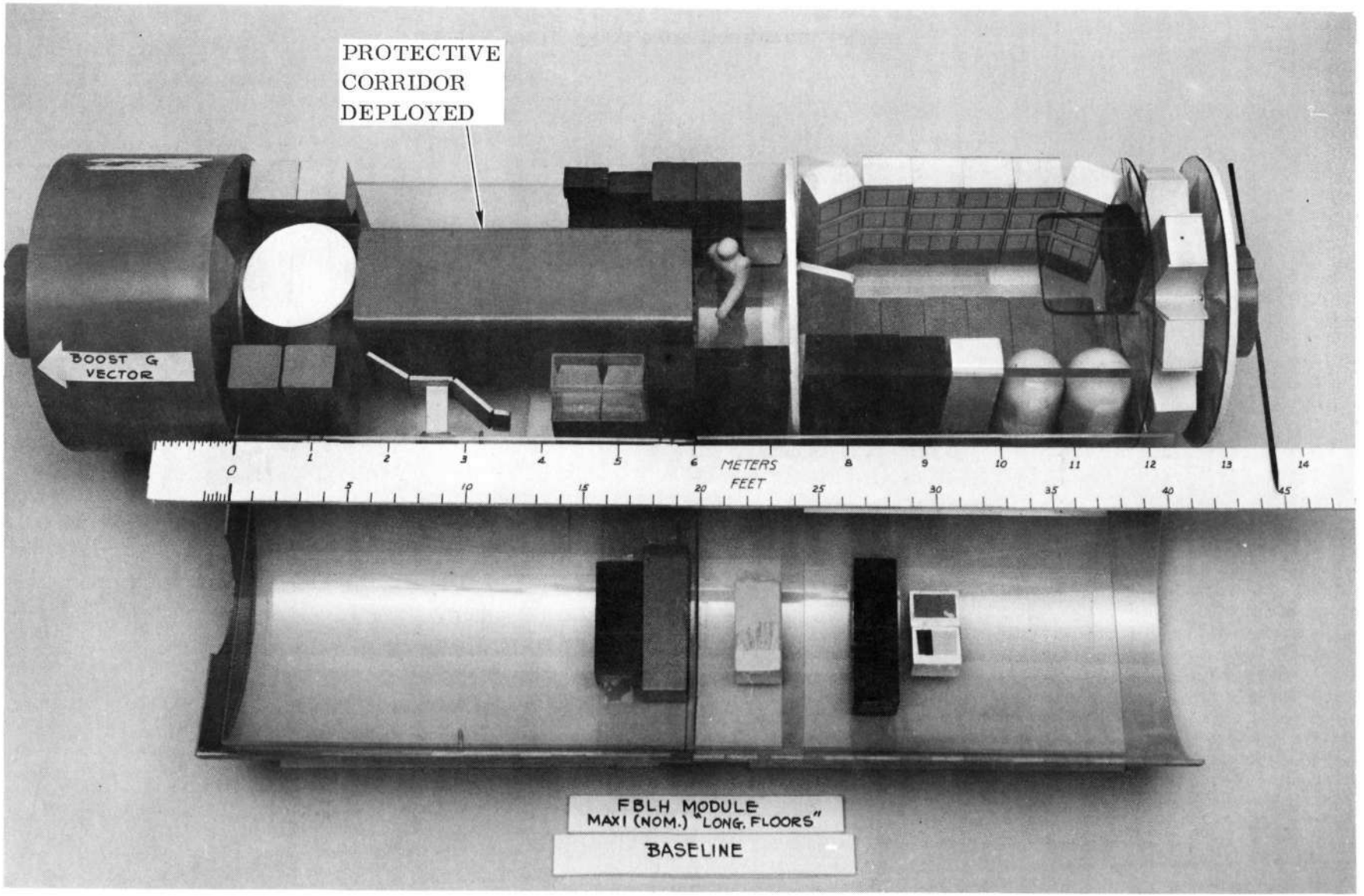



Figure 4-22. Maxi Nom F BLH Module Baseline

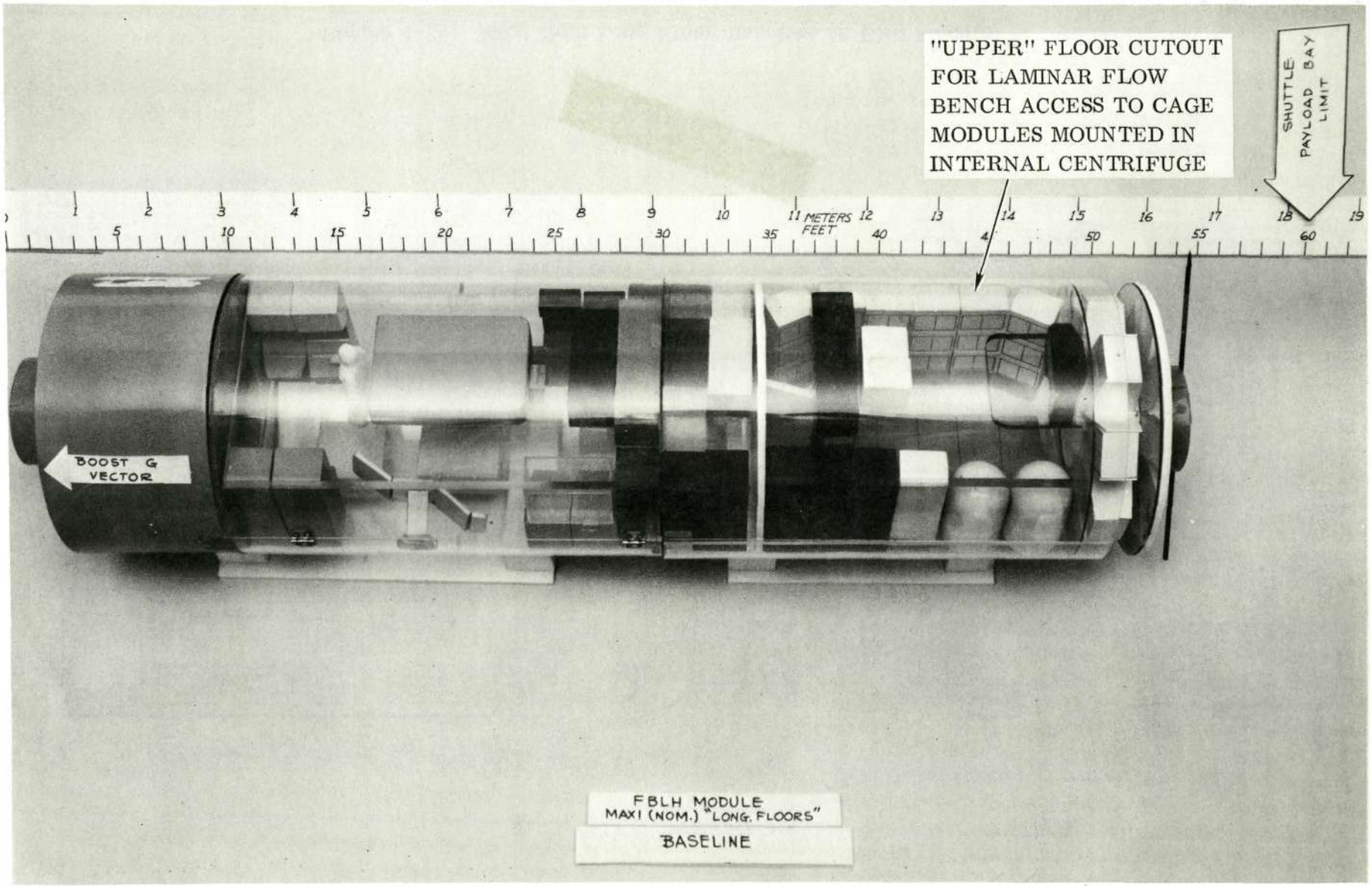
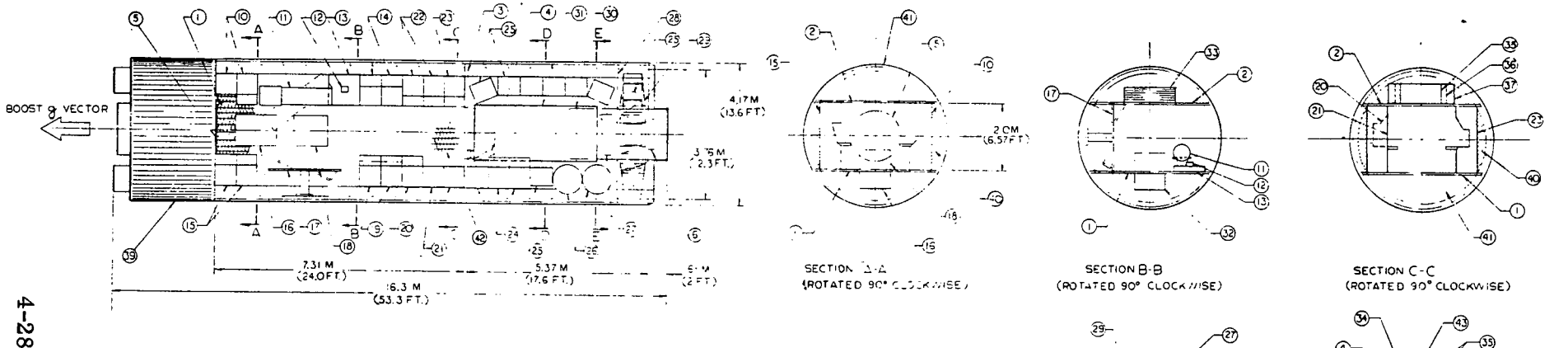



Figure 4-23. Maxi Nom Overall F BLH Module




1. LOWER MOBILITY AID SURFACE (FLOOR)
2. UPPER MOBILITY AID SURFACE (CEILING)
3. PARTITION(ISOLATION BULKHEAD)
4. DOUBLE DOORS
5. 60 IN. DIA. HATCH/TUNNEL
6. 36 IN. DIA. HATCH .9 M
7. METEOROID PROTECTION SKIN
8. PRESSURE SKIN
9. FRAME DEPTH
10. EU 012/031-1-2 BIOMEDICAL MSI RESEARCH SUPPORT UNIT
11. EU 030-2 LOWER BODY NEGATIVE PRESSURE UNIT
12. EU 030-3 EXERGENE
13. EU 080-5 LIFE SUPPOPT TEST UNIT(SHOWER OR EQUIV)
14. EU 080-1-2 LIFE SUPPORT SUB SYSTEM TEST UNIT
15. EU 091-1-2 BEHAVIORAL MEASUREMENTS UNIT
16. EU 012-1 BODY MASS MEASUREMENTS UNIT
17. EU 012-2 ROTATING LITTER CHAIR
18. EU 030-1 BICYCLE ERGOMETER
19. EU 011-1-2 REMOTE MANIPULATOR UNIT
20. EU 001-3 VISUAL RECORDS/MICROSCOPY UNIT
21. EU 005-1-2 BIOCHEM./BIOPHYSICAL ANALYSIS UNIT
22. EU 006-2-3 MAINTENANCE, REPAIR/FABRICATION UNIT
23. EU 002-3 DATA MANAGEMENT UNIT
24. EU 004-2-3-4 PREPARATION, PRESERVATION UNITS
25. CAGE MODULES (28)(6 IN CENTRIFUGE) SUPPORT UNITS (2)
26. EU 041-1 PRIMATE HOLDING UNITS (2)
27. EU 034-3 LAMINAR FLOW BENCH (SHOWN SERVICING CENTRIFUGE CAGE MODULE)
28. CENTRIFUGE PARTITION
29. EU 100 INTERNAL CENTRIFUGE
30. CEILING CUTOUT FOR LAMINAR FLOW BENCH
31. EU 110-1 ANIMAL ENVIRONMENTAL CONTROL SYSTEM (6)
32. BICYCLE ERGOMETER STOWED
33. EU 093-1 MOBILITY UNIT (STOWED)
34. EU 004-1 PREPARATION/PRESERVATION UNIT
35. EU 002-5 DATA MANAGEMENT UNIT
36. EU 003-2 LIFE SCIENCES SUPPORT UNIT
37. EU 007-1 MAINTENANCE, REPAIR/FABRICATION UNIT
38. ANIMAL AIR RECIRCULATING VENTILATION SYSTEM
39. COMMON SUBSYSTEMS PORTION OF LIFE SCIENCES RAM
40. LINE/HARNESS ROUTING SPACE
41. ADDITIONAL STORAGE SPACE AVAILABLE
42. CANDIDATE MOBILITY AID (ASTRO-GRID)
43. EU-042/071-3 HOLDING UNIT SUPPORT



Figure 4-24. Maxi Nom Long Floor Baseline (F BLH Module)

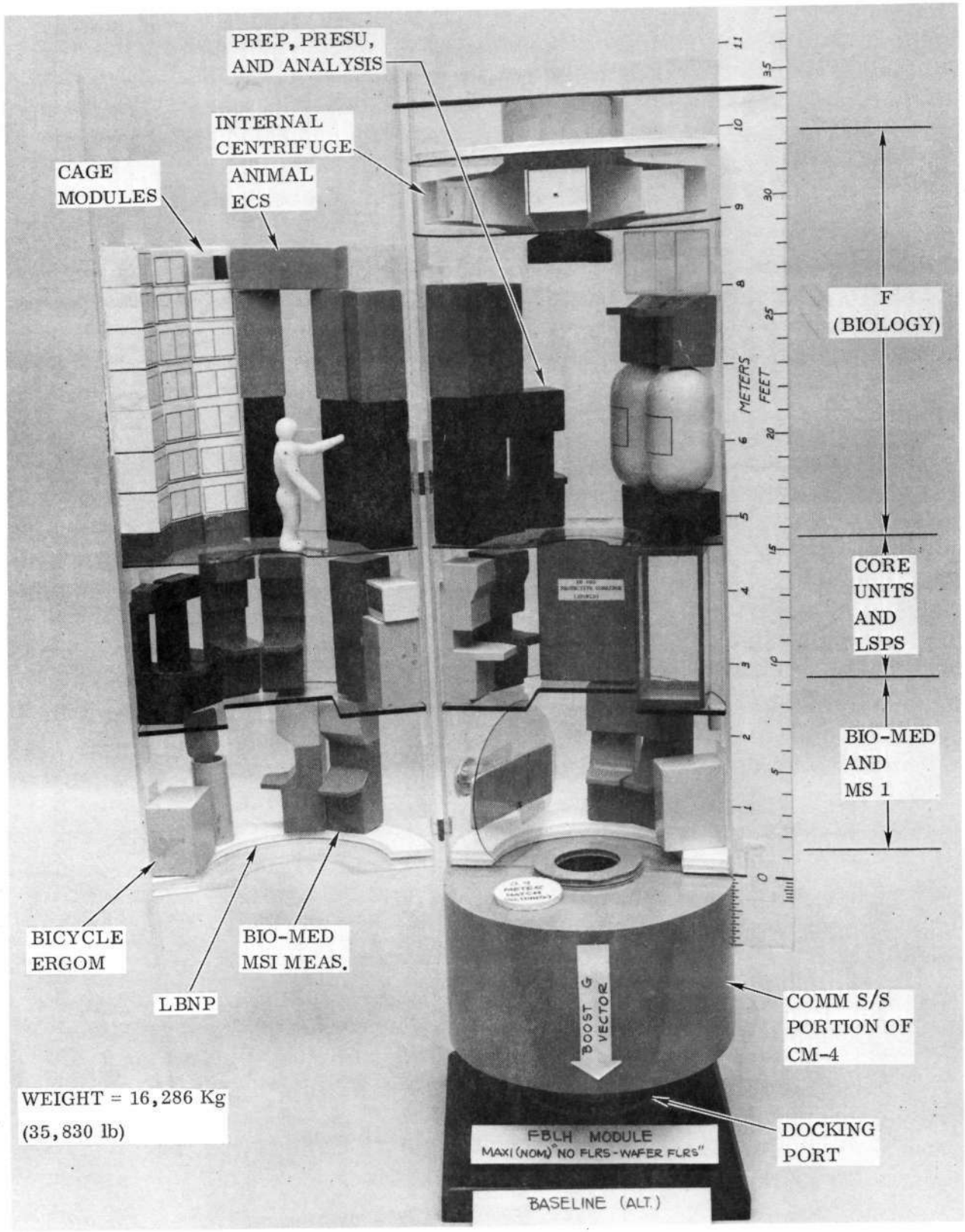



Figure 4-25. Maxi Nom No Floors Configuration (FBLH Module/Baseline Alternate)

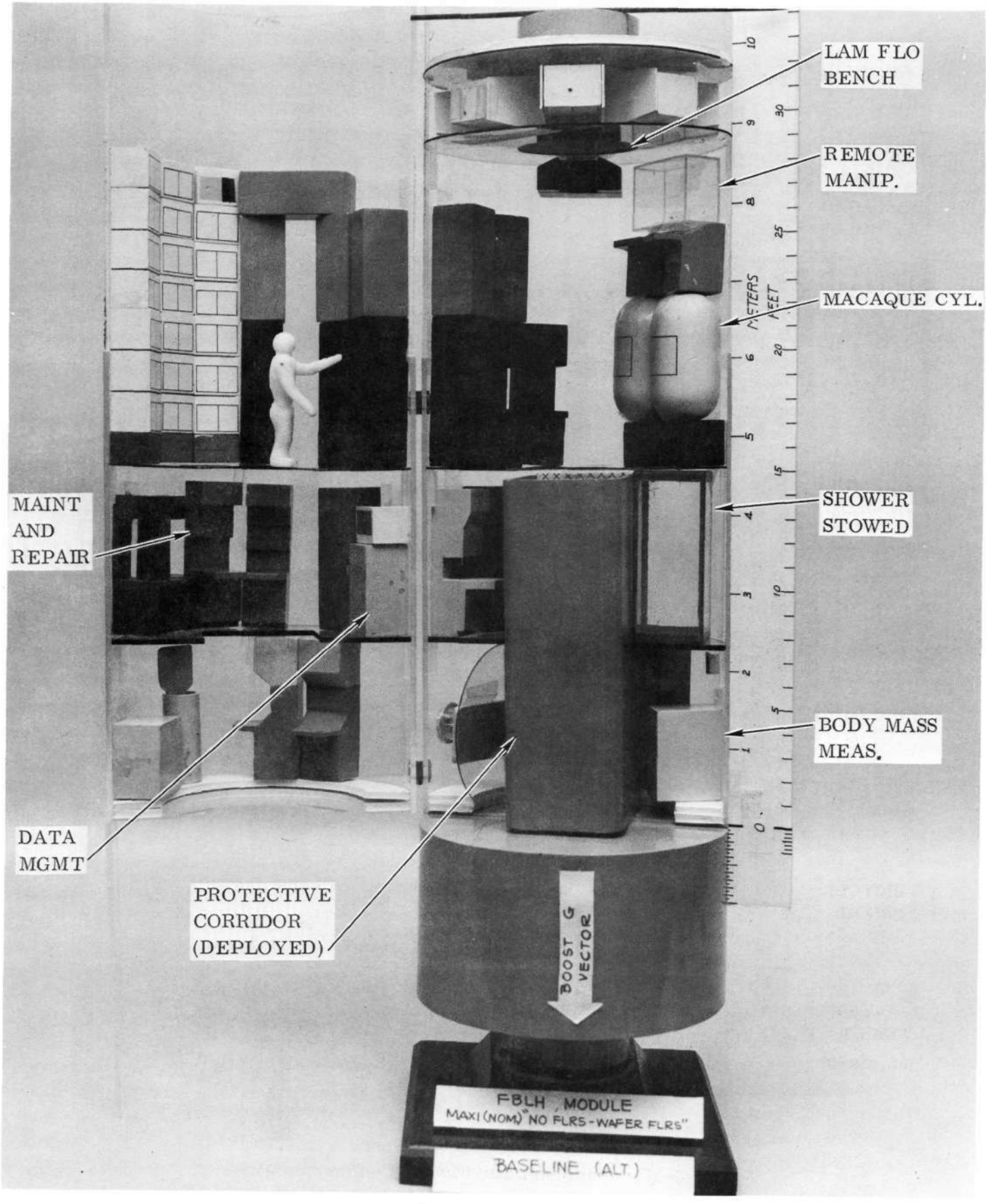
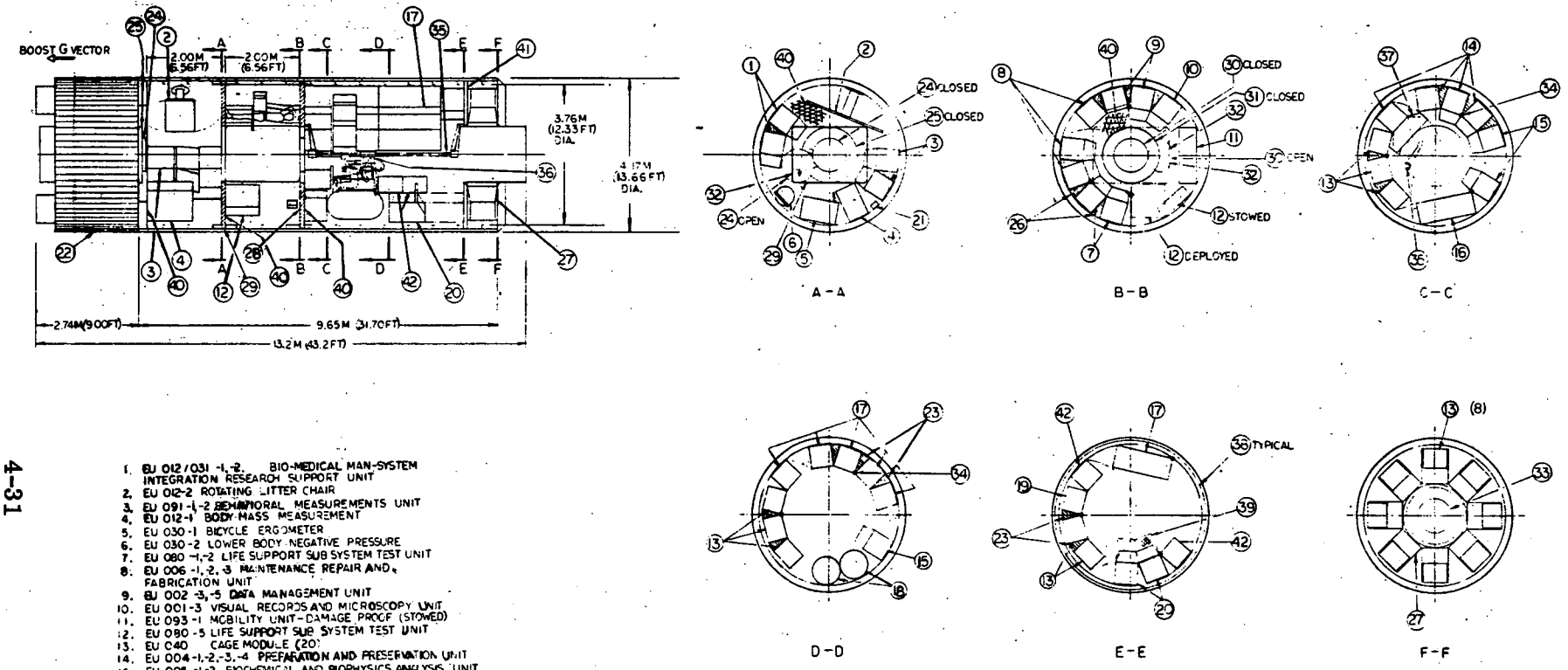



Figure 4-26. Maxi Nom No Floors Configuration
(Protecting Corridor Extended)




1. EU 012/031 -1,-2. BIO-MEDICAL MAN-SYSTEM INTEGRATION RESEARCH SUPPORT UNIT
2. EU 012-2 ROTATING LITTER CHAIR
3. EU 091 -1,-2 BEHAVIORAL MEASUREMENTS UNIT
4. EU 012-1 BODY MASS MEASUREMENT
5. EU 030-1 BICYCLE ERGOMETER
6. EU 030-2 LOWER BODY NEGATIVE PRESSURE
7. EU 080 -1,-2 LIFE SUPPORT SUB SYSTEM TEST UNIT
8. EU 006 -1, -2, -3 MAINTENANCE REPAIR AND FABRICATION UNIT
9. EU 002 -3,-5 DATA MANAGEMENT UNIT
10. EU 001-3 VISUAL RECORDS AND MICROSCOPY UNIT
11. EU 093 -1 MOBILITY UNIT-DAMAGE PROOF (STOWED)
12. EU 080 -5 LIFE SUPPORT SUB SYSTEM TEST UNIT
13. EU 040 CAGE MODULE (20)
14. EU 004 -1,-2,-3,-4 PREPARATION AND PRESERVATION UNIT
15. EU 005 -1,-2 BIOCHEMICAL AND BIOPHYSICS ANALYSIS UNIT
16. EU 003 2 LIFE SCIENCES EXPERIMENT SUPPORT UNIT
17. EU 110 -1 ANIMAL ENVIRONMENTAL CONTROL SYSTEM UNIT
18. EU 041 -1 PRIMATE HOLDING FACILITY
19. CAGE MODULE SUPPORT UNIT
20. EU 011 -1,-2 REMOTE MANIPULATOR
21. EU 030 -3 EXERGENE
22. COMMON SUBSYSTEM PORTION OF LIFE SCIENCES RAM
23. ANIMAL AIR RECIRCULATING VENTILATION EQUIPMENT
24. 0.9 METER SLIDING HATCH
25. 1.52 METER SWINGING HATCH
26. LINE AND HARNESS ROUTING SPACE
27. INTERNAL CENTRIFUGE
28. ISOLATION BULKHEAD AND MOBILITY SURFACE
29. WAFER FLOOR WITH RECTANGULAR DOUBLE DOOR (MOBILITY AID)
30. 0.9 METER ISOLATION BULKHEAD HATCH
31. 1.52 METER ISOLATION BULKHEAD HATCH
32. CLEARANCE FOR EU 093-1 WHEN DEPLOYED
33. 0.9 METER SWINGING HATCH
34. PIVOT POINT FOR SWINGOUT EQUIPMENT RACKS
35. POWER POLE
36. POWERED CHAIR
37. LAMINAR FLOW BENCH
38. LIFE SCIENCES RAM PRESSURE WALL
39. MOBILITY PORCH(FOLDABLE)
40. CANDIDATE MOBILITY AID SURFACE (ASTRO-GRID)
41. CENTRIFUGE BULKHEAD
42. EU 042/071-3 HOLDING UNIT SUPPORT



Figure 4-27. Maxi Nom (No Floors) Wafer Floors Baseline (F BLH Module)

4.1.3.3 Mini-30. The Mini-30 payload is shown in Figures 4-28, 4-29, and 4-30. Figure 4-30 shows two cases for Mini-30, (1) Initial Space Station payload, and (2) Extended Sortie payload.

As illustrated in Figure 4-28 the Mini-30 configuration is a long floors, single compartment configuration, which, when applied to a module of full shuttle bay length, leaves an undedicated length of 4.57 m (15.00 ft) for the Sortie and 6.40 m (21.00 ft) for the Space Station concept.

Figures 4-28 and 4-30 illustrate the single compartment configuration with the BLH functions located adjacent to the RSM. Also shown is the ceiling and floor equipment item storage concept. The method of locomotion here is pressure walking (astro grid) floor or soaring for longer distances.

Weight shown in Figure 4-28 is total facility weight but includes only the usable portion of the LS-RAM ($\approx$8.5 m) plus a portion of the RSM weight.

4.1.3.4 Mini-7. The shuttle based Mini-7 payload configuration is shown in Figures 4-31, 4-32, and 4-33.

Figure 4-31 illustrates the Mini-7 payload incorporated into a RAM of full shuttle bay length. As shown the compartment is a long floors configuration located at the opposite end of the module from the RSM module. In this case, the equipment is housed in a compartment which is 4 m (14 feet) long thus leaving 9 m (30 feet) available for use by other disciplines.

The drawing in Figure 4-33 may be used to correlate the equipment items to the photo illustrations.

The methods of locomotion in the Mini-7 compartments are pressure walking (astro grid) floor, or soaring for long distances.

Weight shown in Figure 4-31 is total facility weight but includes only the usable portion of the LS-RAM ($\approx$ 4 m) plus a portion of the RSM weight.

4.1.4 BASELINE PROPERTIES. Tables 4-2 through 4-6 summarize the analysis made of the baseline payload layouts. The characteristics of the baselines that can be of greatest value during Tasks C and D (Integrated Program Plan Phase) have been included. The more pertinent of these are: (1) size of the RAM; (2) scientific payload weight; (3) shuttle launches required; and (4) the costs.

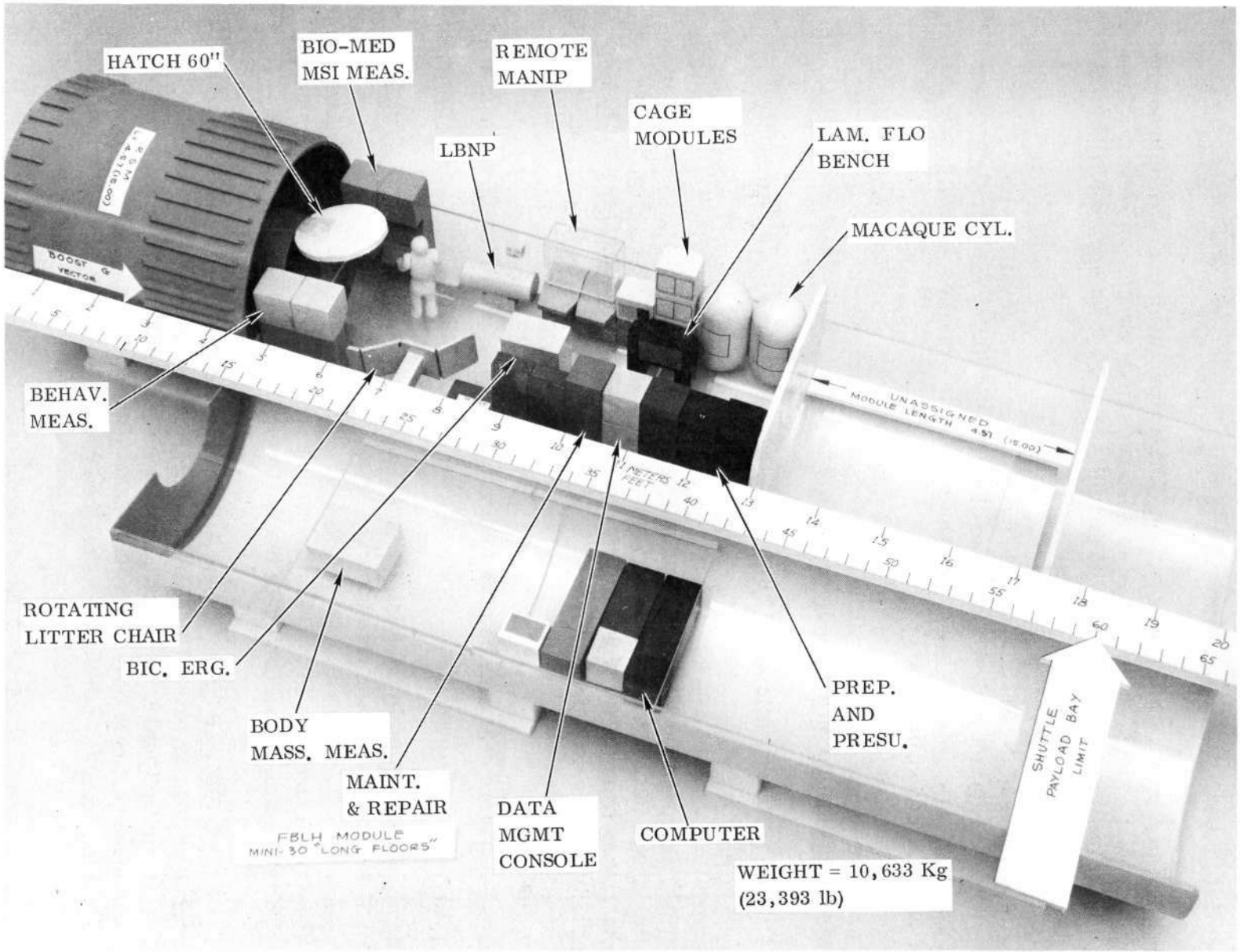



Figure 4-28. Mini-30 Long Floors, Single Compartment (F BLH Module)

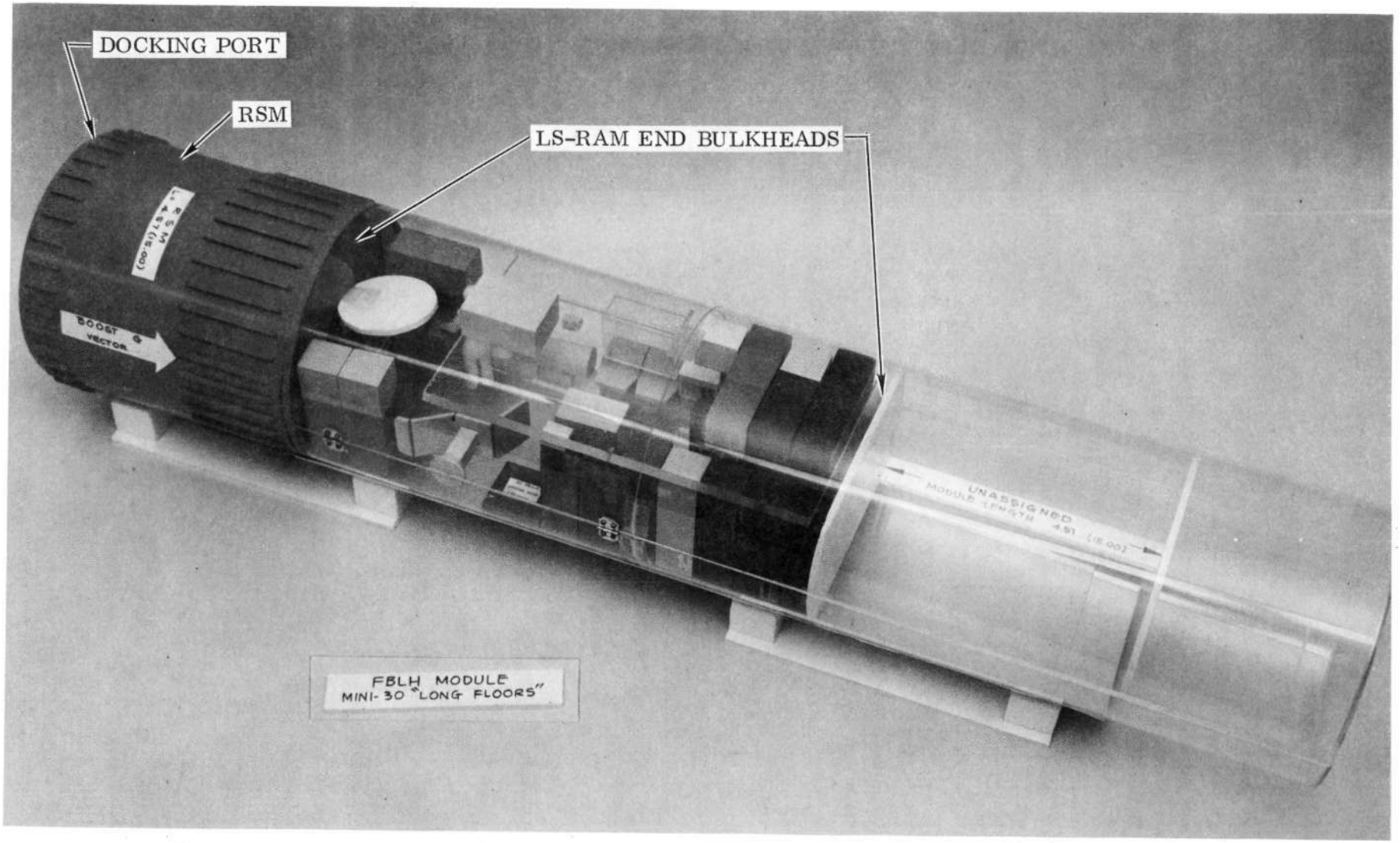
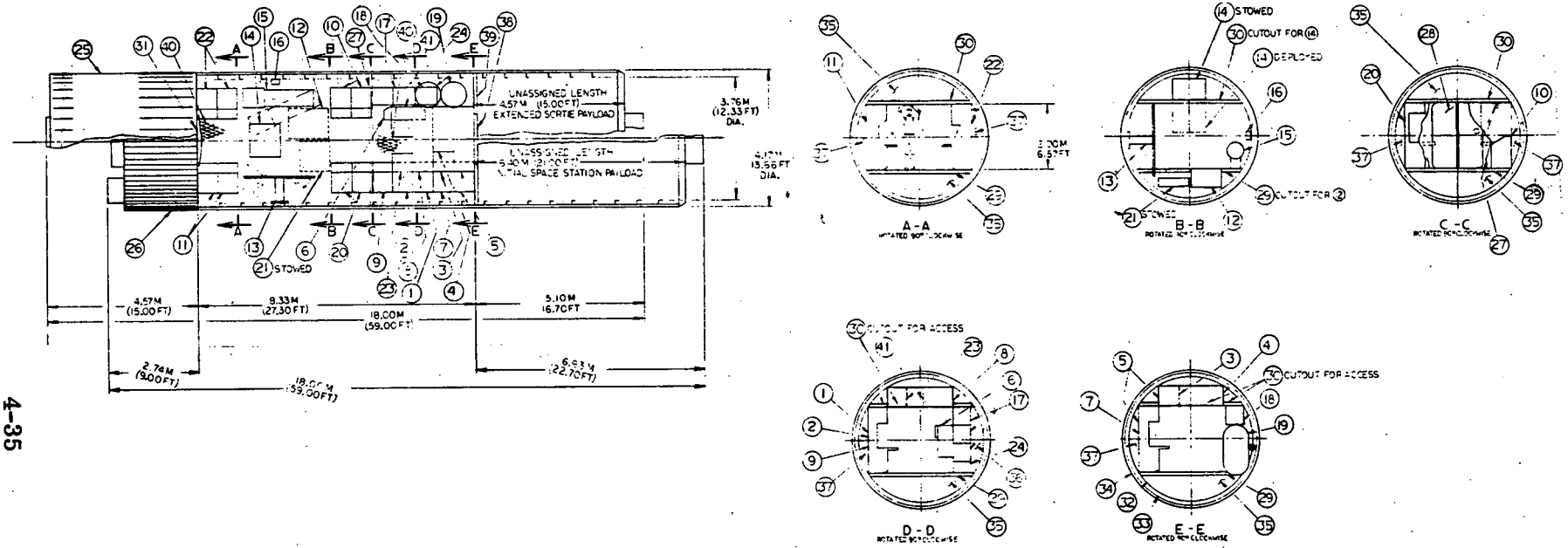



Figure 4-29. Mini-30 Long Floors (F BLH Module)




1. EU001-4 VISUAL RECORDS AND MICROSCOPY UNIT
2. EU002-3 DATA MANAGEMENT UNIT
3. EU002-6 DATA MANAGEMENT UNIT
4. EU003-3 LIFE SCIENCES EXPERIMENT SUPPORT UNIT
5. EU004-9,-10 PREPARATION AND PRESERVATION UNITS.
6. EU004-13 LAMINAR FLOW BENCH
7. EU005-4 BIOCHEMICAL AND BIOPHYSICS ANALYSIS UNIT
8. EU006-5 MAINTENANCE REPAIR AND FABRICATION UNIT
9. EU006-6 MAINTENANCE REPAIR AND FABRICATION UNIT
10. EU011-1,-2 REMOTE MANIPULATOR
11. EU 012/031-1,-2 BIOMEDICAL MAN-SYSTEM INTEGRATION RESEARCH SUPPORT UNIT
12. EU012-1 BODY MASS MEASUREMENTS UNIT
13. EU012-2 ROTATING LITTER CHAIR
14. EU030-1 BICYCLE ERGOMETER
15. EU030-2 LOWER BODY NEGATIVE PRESSURE
16. EU030-3 EXERGENIE
17. EU040-1 CAGE MODULES (6)
18. CAGE MODULE SUPPORT UNIT
19. EU041 PRIMATE HOLDING FACILITY
20. EU080-1,-2 LIFE SUPPORT SUBSYSTEM TEST UNITS
21. EU080-5 SHOWER
22. EU [illegible]-1,-2 BEHAVIORAL MEASUREMENTS UNITS
23. CHEMICAL STORAGE
24. EU110-3 ANIMAL ENVIRONMENTAL CONTROL SYSTEM
25. RESEARCH SUPPORT MODULE (FOR SORTIE PAYLOAD)
26. COMMON SUBSYSTEM PORTION OF LIFE SCIENCES RAM (FOR INITIAL SPACE STATION PAYLOAD)
27. ISOLATION BULKHEAD (PARTITION) (ALTERNATE PROVISION)
28. DOUBLE DOORS
29. MOBILITY AID SURFACE (FLOOR)
30. MOBILITY AID SURFACE (CEILING)
31. 1.52M DIA. HATCH
32. FRAME DEPTH
33. LIFE SCIENCES RAM PRESSURE WALL
34. METEOROID PROTECTION SKIN
35. ADDITIONAL STORAGE SPACE AVAILABLE
36. ANIMAL AIR RECIRCULATING VENTILATION EQUIPMENT
37. LIFE AND HARNESS ROUTING SPACE
38. HATCH (UNPRESSURIZED)
39. BULKHEAD (UNPRESSURIZED)
40. CANDIDATE MOBILITY AID - ASTRO GRID
41. EU042 [illegible]-4 HOLDING UNIT SUPPORT





**Figure 4-30. Mini-30 Longitudinal Floors Baseline (F BLH Module)**

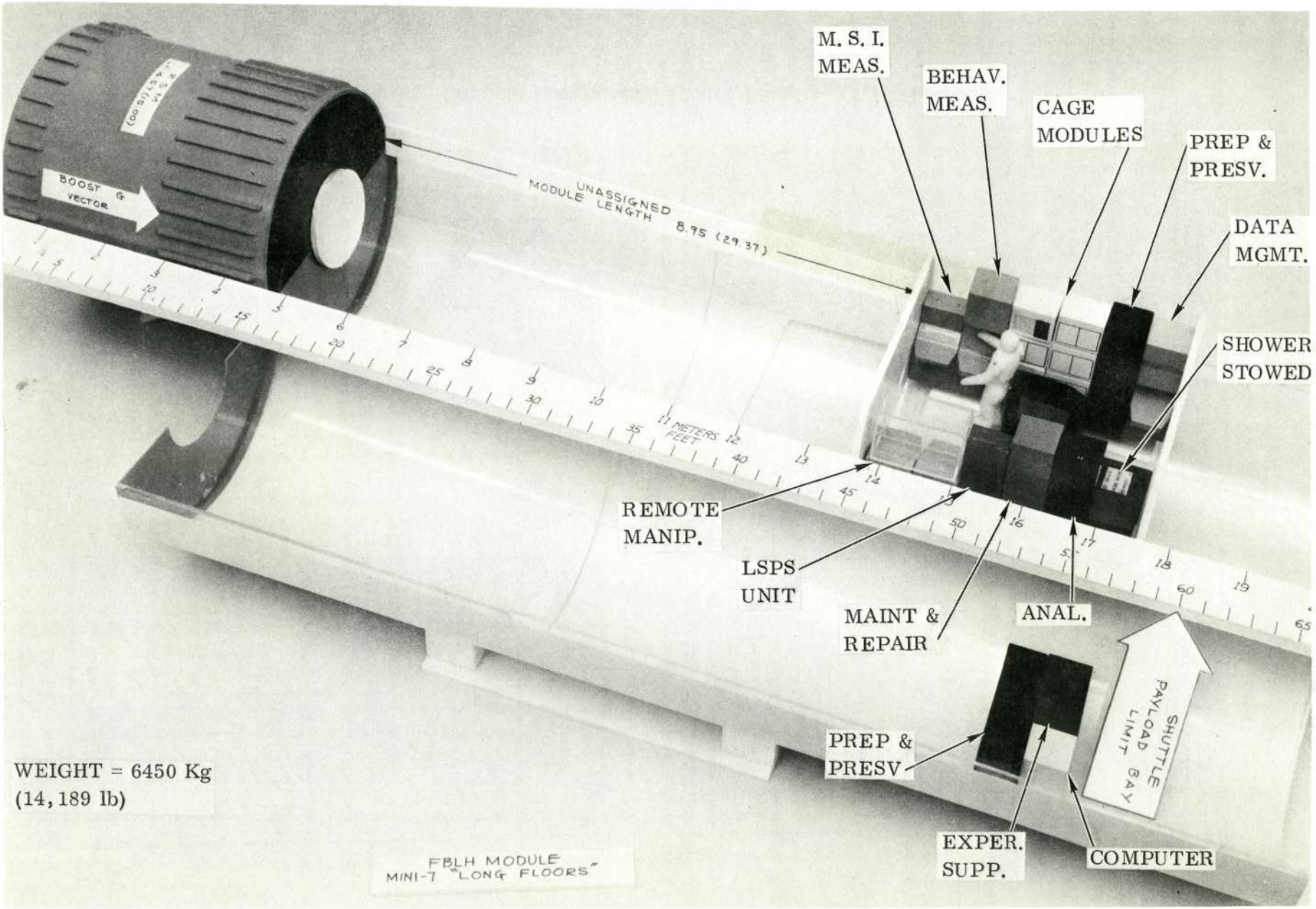



Figure 4-31. Mini-7 Long Floors Configuration (F BLH Module)

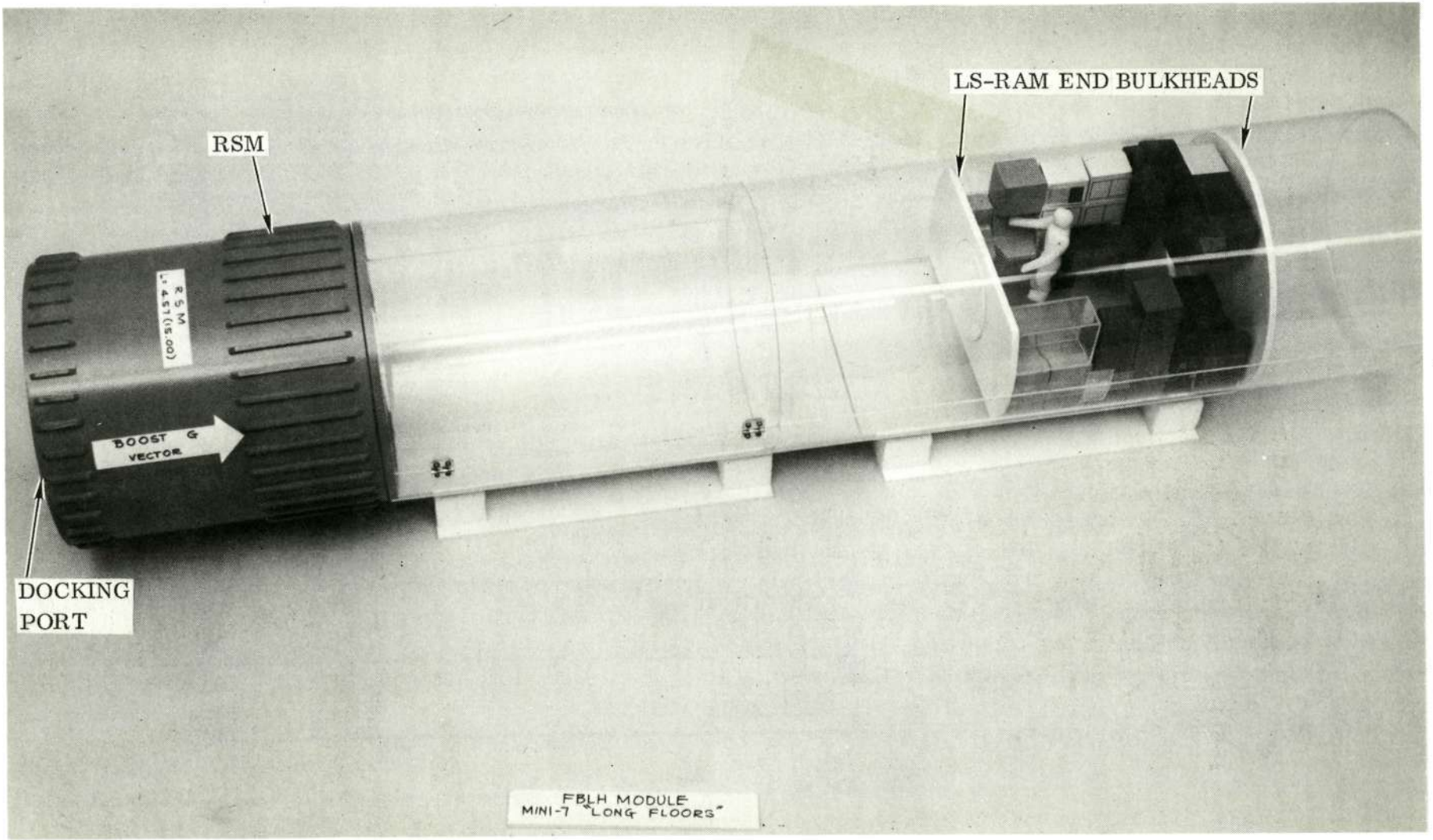
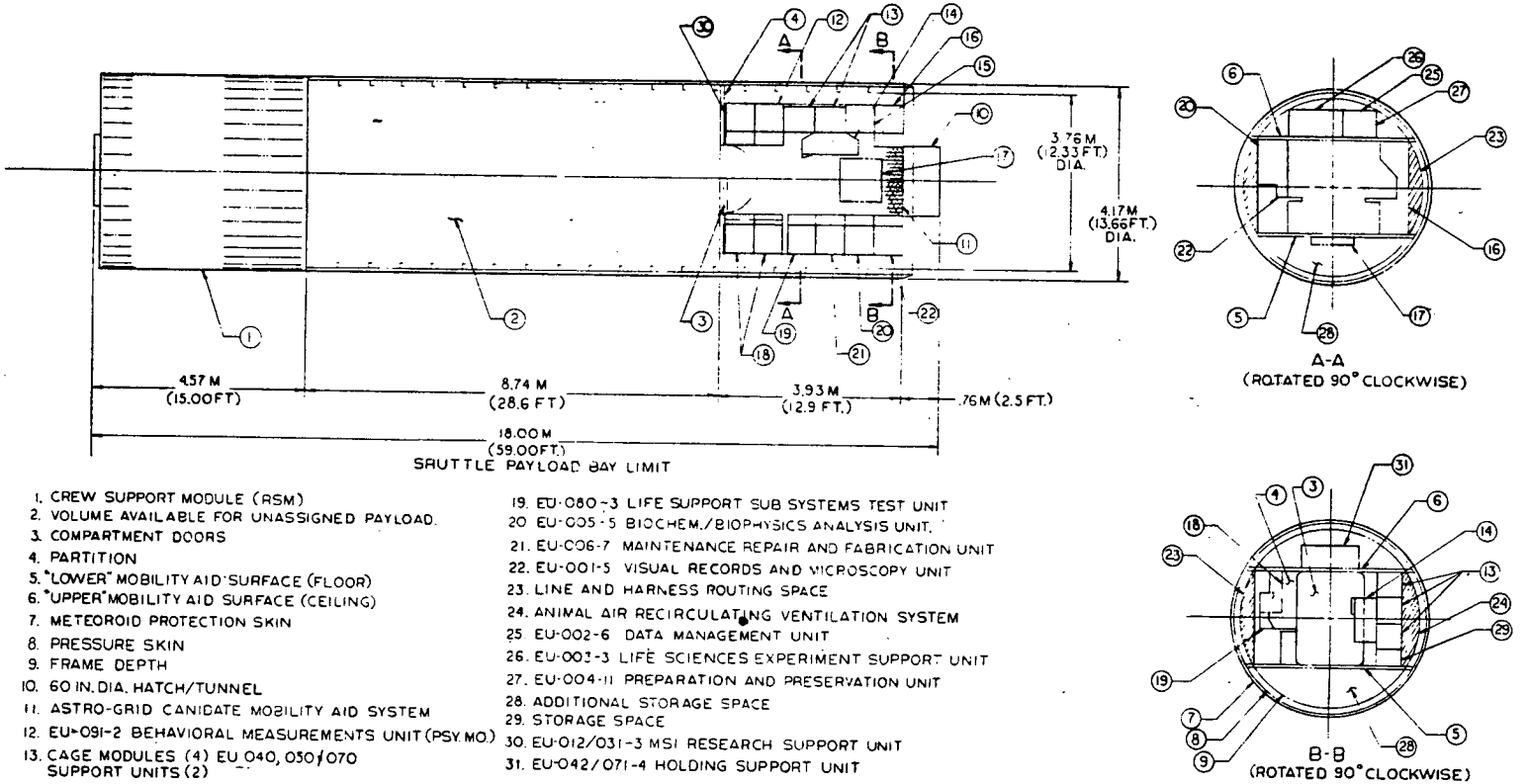



Figure 4-32. Mini-7 Long Floors (F BLH Module)




1. CREW SUPPORT MODULE (RSM)
2. VOLUME AVAILABLE FOR UNASSIGNED PAYLOAD.
3. COMPARTMENT DOORS
4. PARTITION
5. "LOWER" MOBILITY AID SURFACE (FLOOR)
6. "UPPER" MOBILITY AID SURFACE (CEILING)
7. METEOROID PROTECTION SKIN
8. PRESSURE SKIN
9. FRAME DEPTH
10. 60 IN. DIA. HATCH/TUNNEL
11. ASTRO-GRID CANIDATE MOBILITY AID SYSTEM
12. EU-091-2 BEHAVIORAL MEASUREMENTS UNIT (PSY. MO.)
13. CAGE MODULES (4) EU 040, 050/070 SUPPORT UNITS (2)
14. EU-004-13 LAMINAR FLOW BENCH
15. EU-004-12 PREPARATION AND PRESERVATION UNIT
16. EU 002-3 DATA MANAGEMENT UNIT.
17. EU-080 LIFE SUPPORT SUB SYSTEMS TEST UNIT (DEDICATED SPACE)
18. EU 011-1,-2 REMOTE MANIPULATOR
19. EU-080-3 LIFE SUPPORT SUB SYSTEMS TEST UNIT
20. EU-005-5 BIOCHEM./BIOPHYSICS ANALYSIS UNIT.
21. EU-006-7 MAINTENANCE REPAIR AND FABRICATION UNIT
22. EU-001-5 VISUAL RECORDS AND MICROSCOPY UNIT
23. LINE AND HARNESS ROUTING SPACE
24. ANIMAL AIR RECIRCULATING VENTILATION SYSTEM
25. EU-002-6 DATA MANAGEMENT UNIT
26. EU-003-3 LIFE SCIENCES EXPERIMENT SUPPORT UNIT
27. EU-004-11 PREPARATION AND PRESERVATION UNIT
28. ADDITIONAL STORAGE SPACE
29. STORAGE SPACE
30. EU-012/031-3 MSI RESEARCH SUPPORT UNIT
31. EU-042/071-4 HOLDING SUPPORT UNIT



Figure 4-33. Mini-7 Long Floors Baseline (F BLH Module)

# Table 4-2. Maxi Max — Baseline Design Concept Analysis

| DESIGN CONFIGURATION | | | Item No. | No Floors | Longitudinal Floors and No Floors | No Floors Wafer Floors |
|---|---|---|---|---|---|---|
| MODULE TYPE | | | 1 | F | BLH | Research Centrifuge |
| SIZE OF LIFE SCIENCE RAM REQUIRED | Number of Modules | | 2 | 1 | 1 | 1 |
| | Total Length - M (ft) | | 3 | 11.27 (36.5) | 11.12 (36.52) | 17.7 (58.0) |
| | Usable Volume - $M^3$ ($ft^3$) | | 4 | 86.5 (3,050) | 83.4 (2,940) | 142.0 (5,000) |
| | WEIGHT | MODULE STRUCTURE Kg (lb) | 5 | 4,080 (9,019) | 4,040 (8,909) | 4,580 (10,100) |
| | | INTERFACE STRUCTURE Kg (lb) | 6 | 761 (1,675) | 793 (1,746) | 672 (1,478) |
| | | COMMON SUBSYSTEMS Kg (lb) | 7 | 987 (2,171) | 987 (2,171) | 987 (2,171) |
| | | ORGANISM ENVIRONMENTAL CONTROL SYSTEM Kg (lb) | 8 | 1949 (4288) | 0 | |
| | | CONSUMABLES Kg (lb) | 9 | 1365 (3008) | 0 | |
| | | TOTAL Kg (lb) | 10 | 9,164 (20,161) | 5,830 (12,826) | 6,240 (13,749) |
| SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | VOLUME - $M^3$ ($ft^3$) | | 11 | 28.0 (988) | 29.9 (1,056) | 24.5 (863) |
| | WEIGHT - Kg (lb) | | 12 | 8,803 (19,366) | 3,153 (6,936) | 3,780 (8,328) |

| | | | | | |
|---|---|---|---|---|---|
| SHUTTLE LAUNCHES REQUIRED | WEIGHT OF DEDICATED LAUNCHES Kg (lb) | | 11,400 (25,000) | 8,983 (19,762 | 10,020 (22,027) |
| | WEIGHT OF CARGO LAUNCHES Kg (lb) | 14 | 6,567 (14,527) | --- | |
| | TOTAL NUMBER OF LAUNCHES | 15 | 1.9 | 1.0 | 1.0 |
| COST ($\$ \times 10^{-6}$) | MODULE & COMMON SUBSYSTEMS | 16 | 12.43 | 12.43 | 155.36 |
| | SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | 17 | 110.82 | 47.95 | 4.99 |
| | ORGANISM ECS | | 42.50 | --- | --- |
| | LAUNCH MODULE | 18 | 4.50 | 4.50 | 4.50 |
| | LAUNCH CARGO | 19 | 4.18 | --- | |
| | TOTAL | 20 | 174.43 | 64.85 | 164.85 |
| TOTAL FACILITY | | | | | |
| | WEIGHT Kg (lb) (ITEM 10 + ITEM 12) | 22 | 17,967 (39,527) | 8,983 (19,762) | 10,020 (22,077) |
| EFFICIENCY | PAYLOAD VOLUME / USEABLE VOLUME (ITEM 11 — ITEM 4) | 23 | 0.323 | .359 | .173 |
| | PAYLOAD WEIGHT / TOTAL WEIGHT (ITEM 12 — ITEM 22) | 24 | 0.490 | 0.351 | 0.312 |

# Table 4-3. Maxi Nom Baseline Design Concept Analysis

| DESIGN CONFIGURATION | | | Item No. | Longitudinal Floors |
|---|---|---|---|---|
| MODULE TYPE | | | 1 | FBLH |
| SIZE OF LIFE SCIENCE RAM REQUIRED | Number of Modules | | 2 | 1 |
| | Total Length - M (ft) | | 3 | 16.3 (53.3) |
| | Useable Volume - $M^3$ ($ft^3$) | | 4 | 140.3 (5,050) |
| | WEIGHT | MODULE STRUCTURE Kg (lb) | 5 | 5,070 (11,139) |
| | | INTERFACE STRUCTURE Kg (lb) | 6 | 2,060 (4,582) |
| | | COMMON SUBSYSTEMS Kg (lb) | 7 | 1,413 (3,108) |
| | | ORGANISM ENVIRONMENTAL CONTROL SYSTEM Kg (lb) | 8 | 660 (1,453) |
| | | CONSUMABLES Kg (lb) | 9 | 334 (734) |
| | | TOTAL Kg (lb) | 10 | 9,553 (21,016) |
| SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | VOLUME - $M^3$ ($ft^3$) | | 11 | 55.2 (1,945) |
| | WEIGHT - Kg (lb) | | 12 | 8,270 (18,194) |

| | | | |
|---|---|---|---|
| SHUTTLE LAUNCHES REQUIRED | WEIGHT OF DEDICATED LAUNCHES Kg (lb) | 13 | 11,400 (25,000) |
| | WEIGHT OF CARGO LAUNCHES Kg (lb) | 14 | 6,423 (14,210) |
| | TOTAL NUMBER OF LAUNCHES | 15 | 1.9 |
| COST ($ x $10^{-6}$) | MODULE & COMMON SUBSYSTEMS | 16 | 14.78 |
| | SCIENTIFIC & SUPPORT EQUIPMENT PAYLOAD | 17 | 113.30 |
| | ORGANISM ECS | | 28.10 |
| | LAUNCH — MODULE | 18 | 4.50 |
| | LAUNCH — CARGO | 19 | 4.09 |
| | TOTAL | 20 | 164.77 |
| TOTAL FACILITY | WEIGHT Kg (lb) (ITEM 10 + ITEM 12) | 22 | 17,823 (39,210) |
| EFFICIENCY | PAYLOAD VOLUME / USABLE VOLUME (ITEM 11 ÷ ITEM 4) | 23 | 0.385 |
| | PAYLOAD WEIGHT / TOTAL WEIGHT (ITEM 12 ÷ ITEM 22) | 24 | 0.464 |

## Table 4-4. Maxi Nom Baseline Alternate Design Concept Analysis

| DESIGN CONFIGURATION | | | | Item No. | No Floors and Wafer Floors |
|---|---|---|---|---|---|
| MODULE TYPE | | | | 1 | FBLH |
| SIZE OF LIFE SCIENCE RAM REQUIRED | Number of Modules | | | 2 | 1 |
| | Total Length - M (ft) | | | 3 | 13.2 (43.2) |
| | Usable Volume - $M^3$ ($ft^3$) | | | 4 | 107.0 (3,780) |
| | WEIGHT | MODULE STRUCTURE | Kg (lb) | 5 | 4,450 (9,779) |
| | | INTERFACE STRUCTURE | Kg (lb) | 6 | 1,165 (2,562) |
| | | COMMON SUBSYSTEMS | Kg (lb) | 7 | 1,413 (3,108) |
| | | ORGANISM ENVIRONMENTAL CONTROL SYSTEM | Kg (lb) | 8 | 660 (1,453) |
| | | CONSUMABLES | Kg (lb) | 9 | 334 (734) |
| | | TOTAL | Kg (lb) | 10 | 8,016 (17,636) |
| SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | VOLUME - $M^3$ ($ft^3$) | | | 11 | 55.2 (1,945) |
| | WEIGHT - Kg (lb) | | | 12 | 8,270 (18,194) |

| | | | | | |
|---|---|---|---|---|---|
| SHUTTLE LAUNCHES REQUIRED | WEIGHT OF DEDICATED LAUNCHES | | Kg (lb) | 13 | 11,400 (25,000) |
| | WEIGHT OF CARGO LAUNCHES | | Kg (lb) | 14 | 4,886 (10,830) |
| | TOTAL NUMBER OF LAUNCHES | | | 15 | 1.7 |
| COST ($\$ \times 10^{-6}$) | MODULES & COMMON SUBSYSTEMS | | | 16 | 14.08 |
| | SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | | | 17 | 113.30 |
| | ORGANISM ECS | | | | 28.10 |
| | LAUNCH | MODULE | | 18 | 4.50 |
| | | CARGO | | 19 | 3.12 |
| | TOTAL | | | 20 | 163.10 |
| TOTAL FACILITY | | | | | |
| | WEIGHT Kg (lb) (ITEM 10 + ITEM 12) | | | 22 | 16,286 (35,830) |
| EFFICIENCY | PAYLOAD VOLUME / USEABLE VOLUME (ITEM 11 ÷ ITEM 4) | | | 23 | 0.514 |
| | PAYLOAD WEIGHT / TOTAL WEIGHT (ITEM 12 ÷ ITEM 22) | | | 24 | 0.508 |

# Table 4-5. Mini-30 Design Concept Analysis

| DESIGN CONFIGURATION | | | | Item No. | Longitudinal Floors |
|---|---|---|---|---|---|
| MODULE TYPE | | | | 1 | FBLH |
| SIZE OF LIFE SCIENCE RAM REQUIRED | Number of Modules | | | 2 | 1 |
| | Total Length M (ft) | | | 3 | 11.07 (1) (36.30) |
| | Usable Volume $M^3$ ($ft^3$) | | | 4 | 92.3 (2) (3,260) |
| | WEIGHT | MODULE STRUCTURE Kg (lb) | | 5 | 4,200 (3) (9,249) |
| | | INTERFACE STRUCTURE Kg (lb) | | 6 | 1,360 (2,998) |
| | | COMMON SUBSYSTEMS Kg (lb) | | 7 | 553 (4) (1,217) |
| | | ORGANISM ENVIRONMENTAL CONTROL SYSTEM Kg (lb) | | 8 | 177 (389) |
| | | CONSUMABLES Kg (lb) | | 9 | In Cage Module |
| | | TOTAL Kg (lb) | | 10 | 6,297 (13,853) |
| SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | VOLUME - $M^3$ ($ft^3$) | | | 11 | 24.8 (876) |
| | WEIGHT - Kg (lb) | | | 12 | 4,336 (9,540) |

| | | | |
|---|---|---|---|
| SHUTTLE LAUNCHES REQUIRED | WEIGHT OF DEDICATED LAUNCHES Kg (lb) | 13 | 10.633 (23,393) |
| | WEIGHT OF CARGO LAUNCHES Kg (lb) | 14 | -- |
| | TOTAL NUMBER OF LAUNCHES | 15 | 1 |
| COST ($ x $10^{-6}$) | MODULE & COMMON SUBSYSTEMS | 16 | 8.29 (5) |
| | SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | 17 | 98.01 |
| | ORGANISM ECS | | 12.90 |
| | LAUNCH MODULE | 18 | 3.40 (5) |
| | LAUNCH CARGO | 19 | -- |
| | TOTAL | 20 | 122.60 |
| TOTAL FACILITY | | | |
| | WEIGHT Kg (lb) (ITEM 10 + ITEM 12) | 22 | 10,633 (23,393) |
| EFFICIENCY | PAYLOAD VOLUME / USABLE VOLUME (ITEM 11 ÷ ITEM 4) | 23 | 0.268 |
| | PAYLOAD WEIGHT / TOTAL WEIGHT (ITEM 12 ÷ ITEM 22) | 24 | 0.408 |

1. Length of common subsystem and FBLH section only
2. Volume in FBLH section only
3. Includes 2,640 Kg (5,819 lb) which will be shared with other scientific disciplines
4. This weight will be shared with the other scientific disciplines
5. Pro-rated Cost

## Table 4-6. Mini-7 Design Concept Analysis

| | | | Item No. | Longitudinal Floors |
|---|---|---|---|---|
| DESIGN CONFIGURATION | | | | |
| MODULE TYPE | | | 1 | FBLH |
| SIZE OF LIFE SCIENCE RAM REQUIRED | Number of Modules | | 2 | 1 |
| | Total Length - M (ft) | | 3 | 6.67 (21.9) (1) |
| | Usable Volume - $M^3$ ($ft^3$) | | 4 | 43.7 (1,540) (2) |
| | WEIGHT | MODULE STRUCTURE Kg (lb) | 5 | 3,380 (7,439) (3) |
| | | INTERFACE STRUCTURE Kg (lb) | 6 | 512 (1,126) |
| | | COMMON SUBSYSTEMS Kg (lb) | 7 | 428 (941) (4) |
| | | ORGANISM ENVIRONMENTAL CONTROL SYSTEM Kg (lb) | 8 | 17 (38) |
| | | CONSUMABLES Kg (lb) | 9 | In Cage Module |
| | | TOTAL Kg (lb) | 10 | 4,338 (9,544) |
| SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | VOLUME - $M^3$ ($ft^3$) | | 11 | 11 (388) |
| | WEIGHT - Kg (lb) | | 12 | 2,111 (4,645) |

| | | | Item No. | |
|---|---|---|---|---|
| SHUTTLE LAUNCHES REQUIRED | WEIGHT OF DEDICATED LAUNCHES Kg (lb) | | 13 | 6,450 (14,189) |
| | WEIGHT OF CARGO LAUNCHES Kg (lb) | | 14 | -- |
| | TOTAL NUMBER OF LAUNCHES | | 15 | 1 |
| COST ($ x $10^{-6}$) | MODULE & COMMON SUBSYSTEMS | | 16 | 3.81 (5) |
| | SCIENTIFIC AND SUPPORT EQUIPMENT PAYLOAD | | 17 | 71.61 |
| | ORGANISM ECS | | | 4.28 |
| | LAUNCH | MODULE | 18 | 1.40 (5) |
| | | CARGO | 19 | -- |
| | TOTAL | | 20 | 81.10 |
| TOTAL FACILITY | | | | |
| | WEIGHT (ITEM 10 + ITEM 12) Kg (lb) | | 22 | 6,450 (14,189) |
| EFFICIENCY | PAYLOAD VOLUME / USABLE VOLUME (ITEM 11 ÷ ITEM 4) | | 23 | 0.252 |
| | PAYLOAD WEIGHT / TOTAL WEIGHT (ITEM 12 ÷ ITEM 22) | | 24 | 0.327 |

1. Length of common subsystem and FBLH section only
2. Volume in FBLH section only
3. Includes 2,640 Kg (5,819 lb) which will be shared with other scientific disciplines.
4. This weight will be shared with the other scientific disciplines.
5. Pro-rated Cost

## 4.2 CONFIGURATION STUDIES

This section describes the approach used to generate the Life Sciences laboratory designs. The evolution of the designs are covered from the broad first generation layouts, to the more specific second generation layouts. Included are the equipment unit module configuration studies.

Several Life Sciences laboratory design concepts were identified. Each of the concepts had different levels of design credibility. Before detailed studies were conducted, these design concepts received cursory evaluation in the form of a screening process. This identification and screening process ensured that the detailed studies were conducted on valid concepts. Equipment modules and payload layouts were developed, and detailed studies were conducted which resulted in baseline layouts.

The CM-4 Experiment Module, as shown in Figure 4-34, was used as the housing vehicle for all payloads supported by the modular Space Station. Skylab was used to house the payloads for Midi-56 and Mini-56. The CM-4 type module is 4.1 meters (13.67 ft) in diameter. The length was determined based on the payload being developed and the

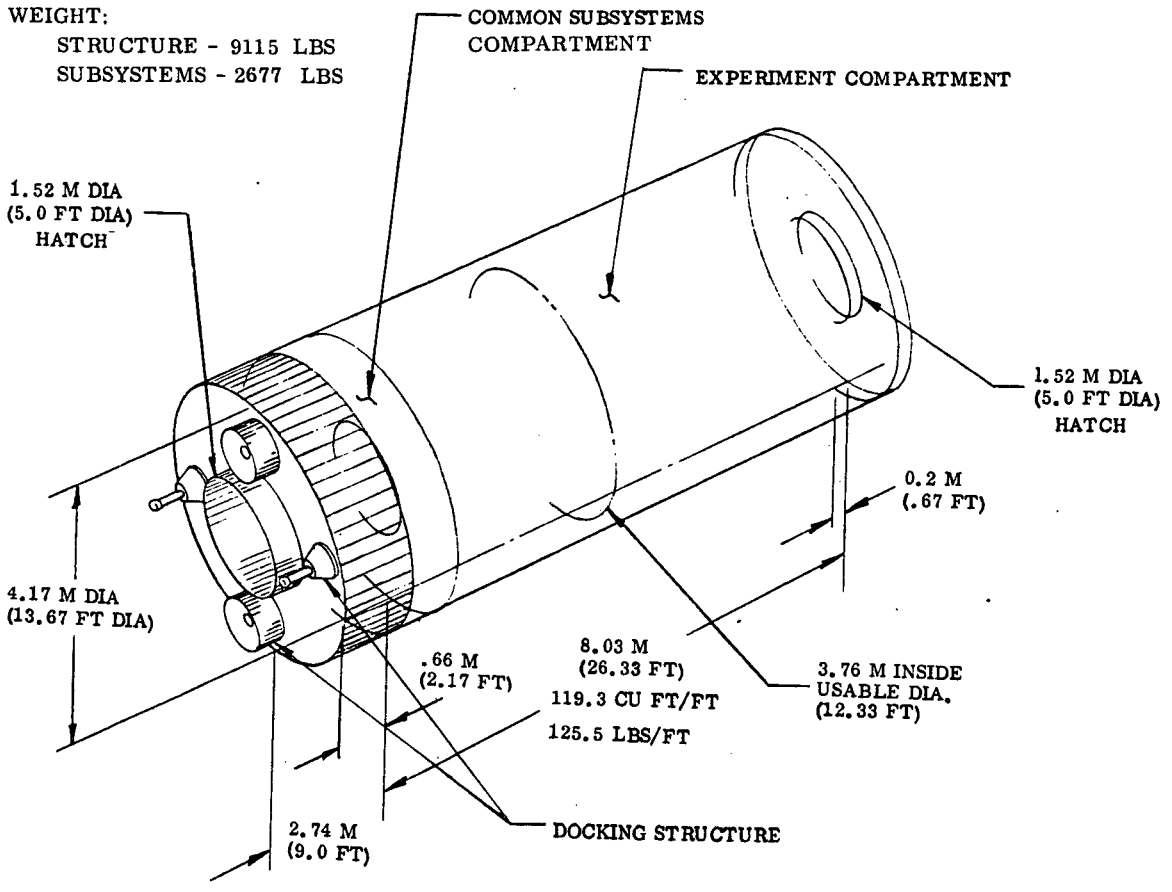



Figure 4-34. The CM-4 Common Module

layout concept being considered. The common subsystem portion includes electrical power distribution, thermal control, and docking and guidance systems. A Shuttle payload bay of 4.94 m (15 ft) in diameter by 19.75 m (60 ft) long, and boost capability of 11,350 kg (25,000 lbs) and 18,100 kg (40,000 lbs) was assumed. For Shuttle sortie missions, the common subsystem portion of the CM-4 was replaced with a Research Support Module (RSM) that provided living quarters for the crew.

4.2.1 FIRST GENERATION LAYOUTS. First generation layouts were developed for six payloads. The Maxi Max payload was developed for application to a modular Space Station mission. The Midi-30, Mini-30, and Mini-7 payloads were developed for application to Shuttle Sortie flights, and Midi-56 and Mini-56 were considered for Skylab. Figure 4-35 shows the various modules and space vehicles used for Maxi Max payload definition. Figure 4-36 shows the vehicles used for the Midi and Mini payloads. The major emphasis in first generation layout development was placed on the Maxi Max payload, the rationale being that insights gained in this development would apply to the lesser payloads.

Ten conceptual layouts were prepared for the Maxi Max payload and five layouts were made for the Midi and Mini payloads. Analysis of all layouts were made to determine weight, volume, cost and other characteristics.

4.2.1.1 Rack and Console Module Designs. The initial task in support of the first generation layouts was to obtain the scientific equipment items from the computer printout, determine the approximate size and shape of each item, and arrange them in racks or consoles so that crew members could perform the required functions. Early designs led to consoles and racks of the type shown in Figures 4-37 and 4-38. These equipment racks and consoles were used in the development of first generation layouts. These designs became somehwat difficult to handle when many different arrangements of laboratory facilities were considered because of the dissimilarity of sizes and shapes. Since the same problem will be encountered with modification of the actual space hardware, one of the outputs of the first generation layout studies was that equipment racks and consoles should be designed using the modular approach wherever possible.

4.2.1.2 Layout Concepts. The method used for identifying potential concepts, was to define the major factors which characterize a layout and combine these factors in various combinations. The following characteristics were considered and are shown in Figure 4-39.

a. Physical entities (groups of scientific equipment installed in the LS-RAM)

b. Laboratory environments (zero-g or artificial-g)

c. Degrees of commonality of functions and Equipment (Figure 4-40)

d. Crew operations modes

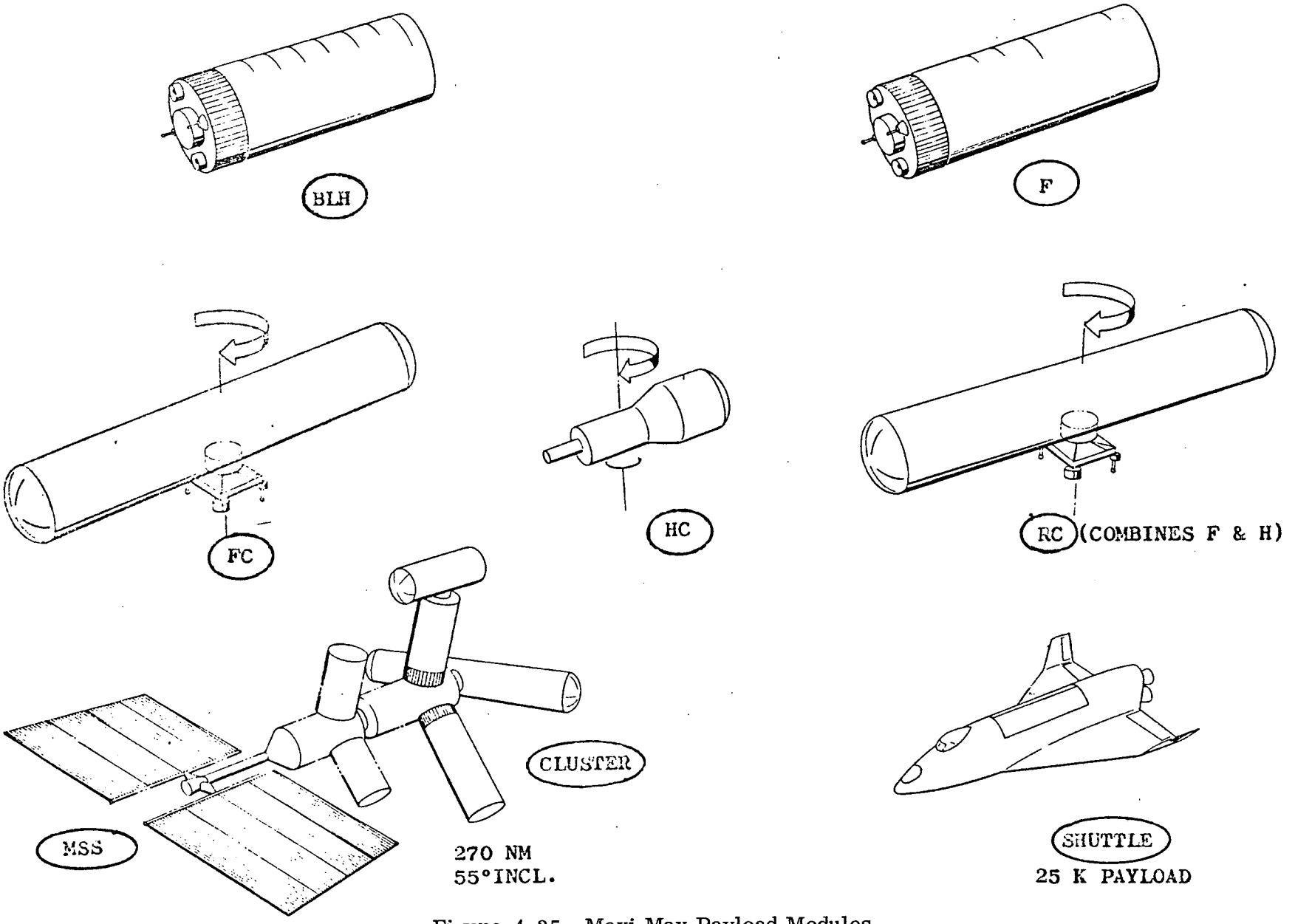



Figure 4-35. Maxi Max Payload Modules

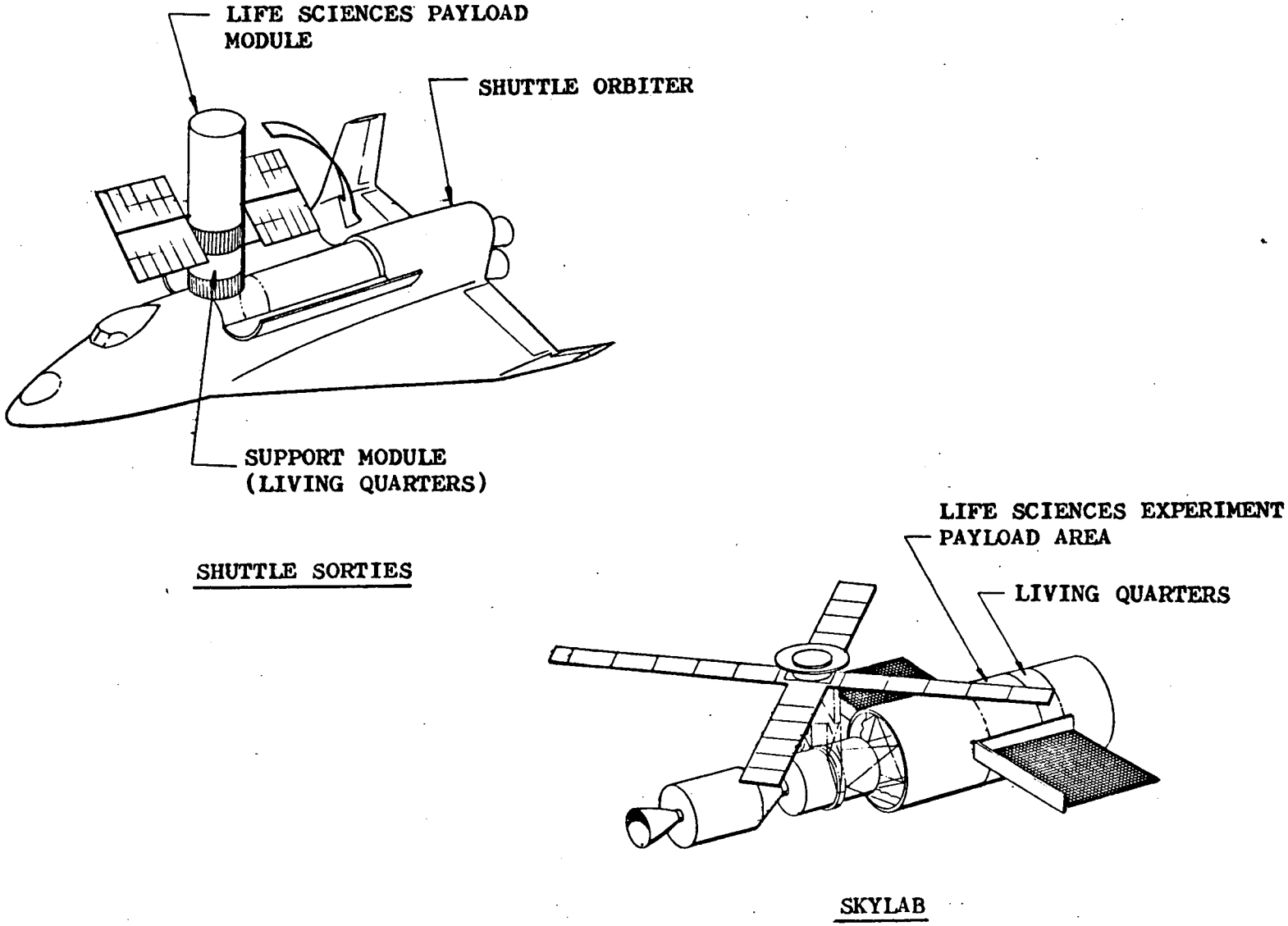
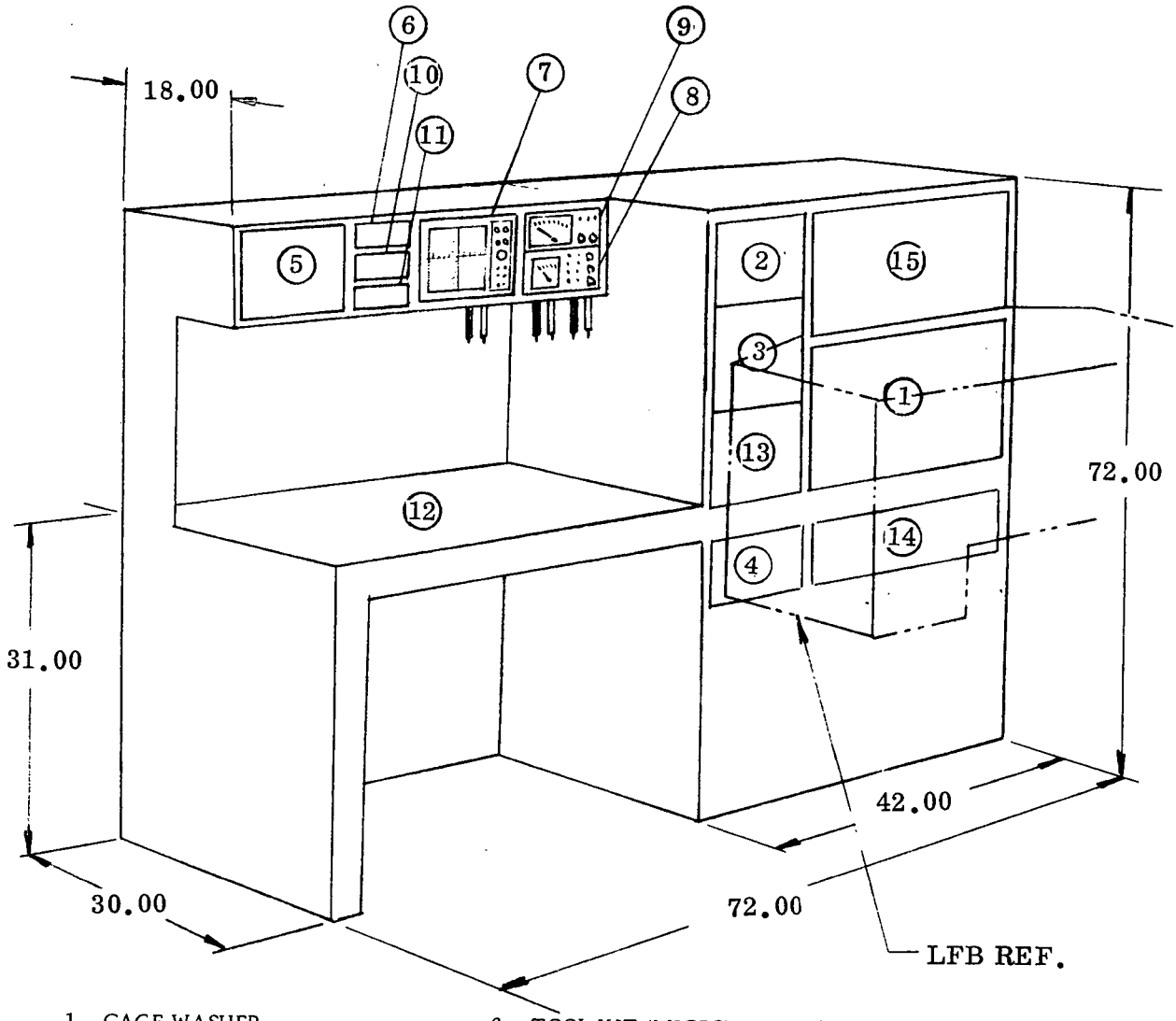



Figure 4-36. Midi and Mini Payload Modules



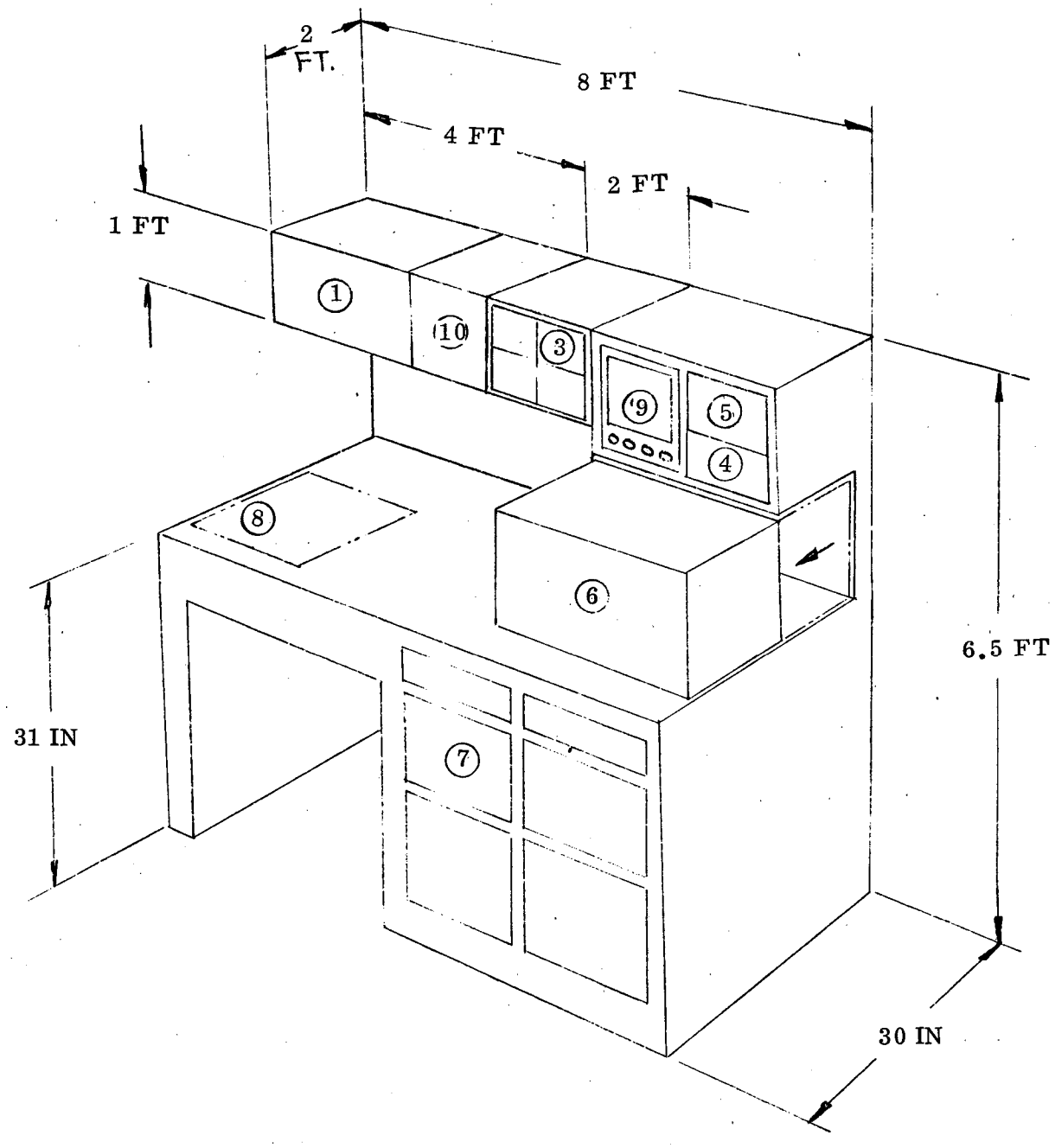

1. CAGE WASHER
2. DRYING OVEN
3. ULTRASONIC CLEANER
4. INSTR. & APPAR. WASH.
5. TOOL KIT
6. TOOL KIT (MICRO)
7. OSCILLOSCOPE
8. VOLT OHMMETER
9. SIG. GENERATOR
10. ELEC. TOOLS
11. ELEC. HARDWARE
12. WORK AREA
13. HANDCLEANER
14. MEAS. KIT
15. AUTOCLAVE

Figure 4-37. Maintenance Repair and Fabrication Unit

e. Geometric configurations (Figure 4-41)

f. Space Station cluster arrangements (4-42)

A typical design concept would be a laboratory that grouped the biomedical, man-system integration; and life support scientific equipment in one area, and the biology equipment in another; had the CORE in zero gravity; shared all common equipment; provided the crew with a self-mobility system; had wall mounted equipment and no floors; and used clustered modules.




1. VIDEO CAMERA, COLOR
2. VIDEO CAM. (BW IN LAB)
3. POLOROID CAMERA (4)
4. MOVIE CAMERA, 35 mm
5. VOICE RECORDING
6. HOLOGRAPH
7. STORAGE
8. PLUG IN INSTR. AREA
9. VIDEO MONITOR
10. COMPOUND MICROSCOPE

Figure 4-38. Visual Records and Microscopy Unit

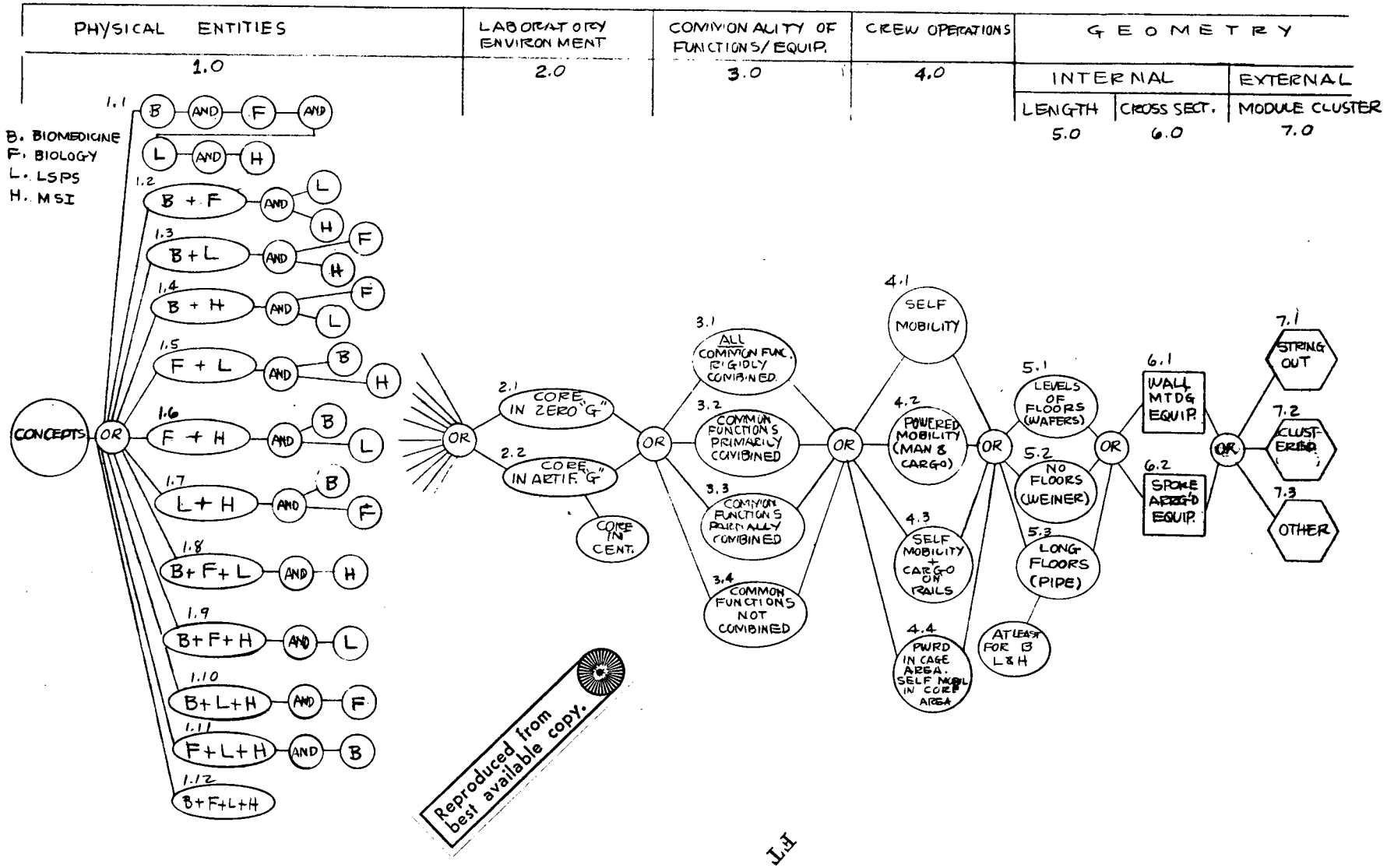



Figure 4-39. Design Concepts Methodology

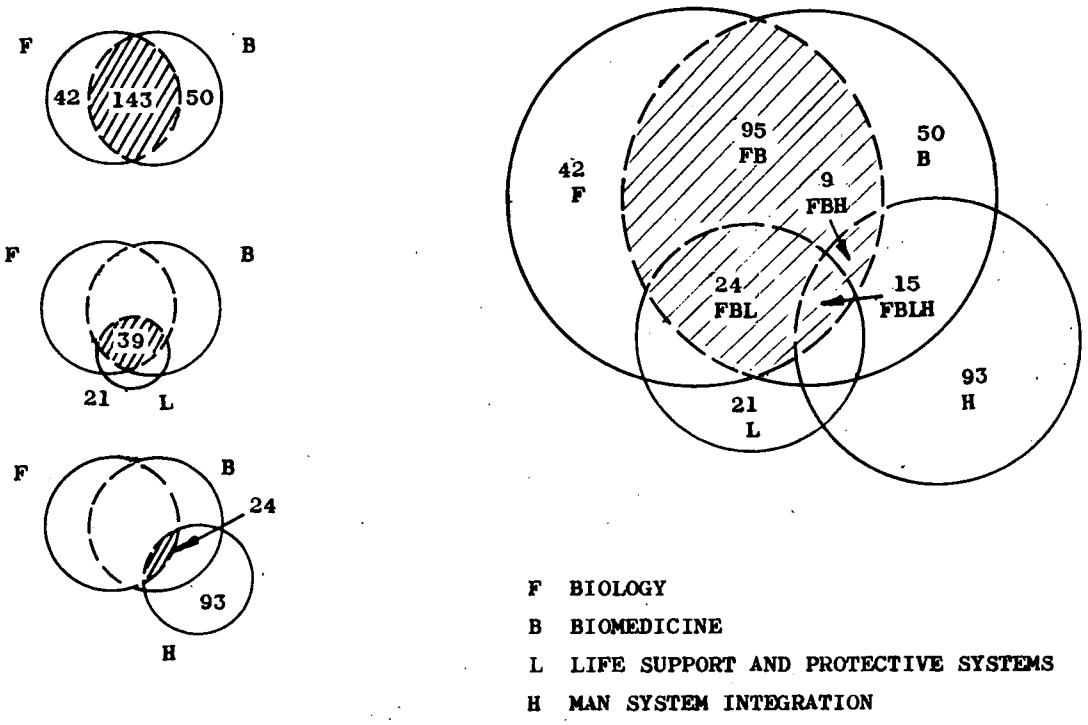



Figure 4-40. Function Commonality (Maxi Max Payload)

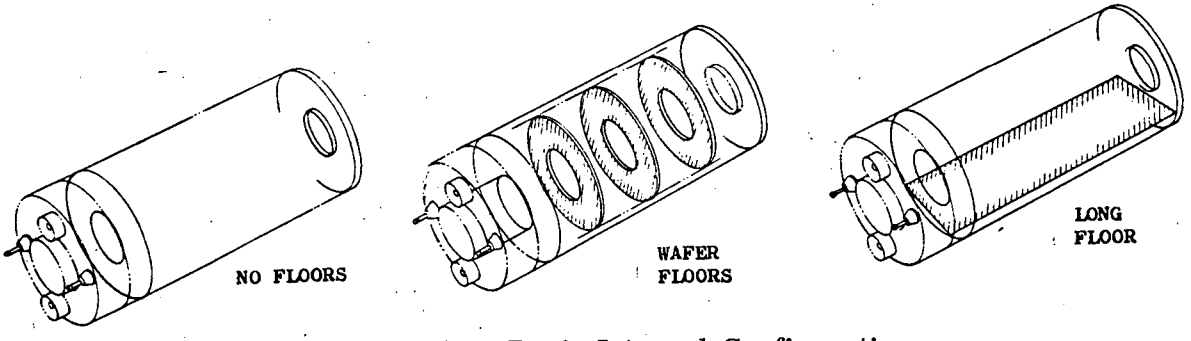



Figure 4-41. Basic Internal Configurations

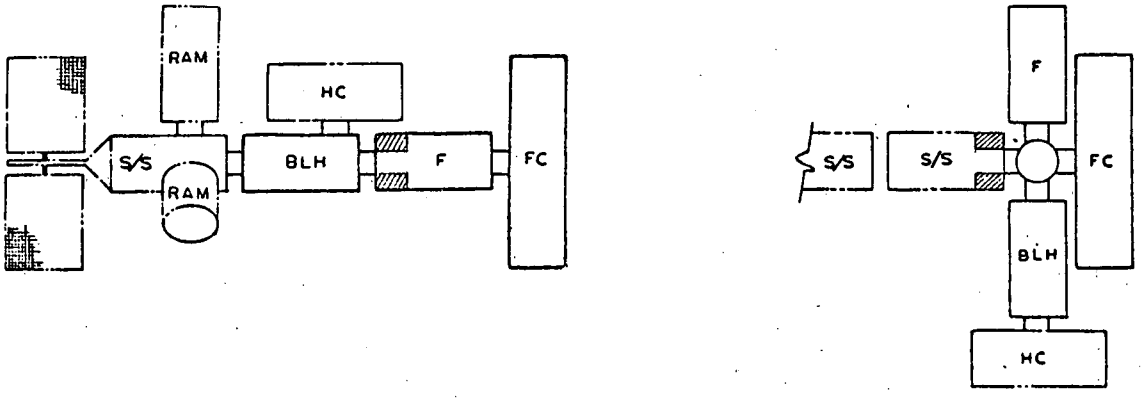



Figure 4-42. Module Clusters

During the screening process, a gross evaluation of each concept characteristic with respect to crew safety, scientific response, volume utilization, crew efficiency, weight utilization, complexity, mobility and restraint system potential, maintainability, and logistics was made. The screening process identified the characteristics which resulted in the most promising layout concepts, and the others were dropped. The process terminated with identification of a manageable number of the more creditable concepts which then received further design investigation.

Table 4-7 illustrates the features selected as desirable and the rational behind their selection. The layout concepts composed of the desirable features were retained and the other concepts deleted. These layouts are summarized in Table 4-8. Conventional two-dimensional drawings were made for the ten layout concepts; these drawings are contained in Volume III. Two examples showing the types of drawing made are shown in Figures 4-43 and 4-44.

Table 4-7. Summary of the Desirable Features of Each Characteristic and the Rationale Behind its Selection

| Concept Characteristic | | Selected Features | Rationale for Selection |
|---|---|---|---|
| 1.0 | Physical Entity (Modules) | B + L + H and F | Separate man and animal environment. Use of CORE by F, approaches common module which lowers cost. |
| 2.0 | CORE in Zero or Artificial "G" | Both carried through 1st general L. O. phase | Merits of each required evaluation. |
| 3.0 | Commonality of Functions Equipment | Invariant | Functions printout showed high commonality which relates to lower cost. L. O. design can achieve commonality with small penalty. |
| 4.0 | Crew Mobility | Powered mobility, self mobility + rails | As a minimum, rails are required for cargo transfer of large masses. |
| 5.0 | Floors | No floors, wafer floors, long floors | Floor configurations are design drivers. |
| 6.0 | Equipment Mounting | Wall mount basically, some consideration for spoke mounting | Wall mount gives increase volume utilization |
| 7.0 | Clusters | Cruciform | Provides maximum safety and flexibility for cluster buildup and modification. |

Table 4-8. Maxi Max Payload Design Concepts

| NO. | BASIC MODULES | CORE LOCATION | | | CREW OPS. | | | FLOORS | | | EQUIP. MTG | | REF. FIG. NO. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | F MOD (COG) | FC (CAG) | SEP MOD (ZERO G) | PWRD MAN CARGO | SELF + CARGO RAILS | PWRD + SELF CORE | NONE | WAFER | LONG | WALL | SPOKE (OTHER) | |
| 1 | BLH + F | X | | | | BLHX | FX | X | | | X | | 1 |
| 2 | " | | X | (OR X) | | X | | | FX | BLHX | X | | 2 |
| 3 | " | X | | | | BLHX | FX | | FX | BLHX | X | | 3 |
| 4 | " | X | | | | X | | X | | | BLHX | FX | 4 |
| 5 | " | X | | | | BLHX | FX | FX | BLHX | | X | | 5 |
| 6 | " | | X | (OR X) | | X | (OR FX) | FX | | BLHX | BLHX | FX | 6 |
| 7 | " | X | | | (OR FX) | FX BLHX | | X | | | X | | 7 |
| 8 | " | | X | (OR X) | | X | | | | X | X | | 8 |
| 9 | " | X | | | | X | | | X | | X | | 9 |
| 10 | " | | | X | FX | (OR FX) BLHX | | X | | | | | 10 |

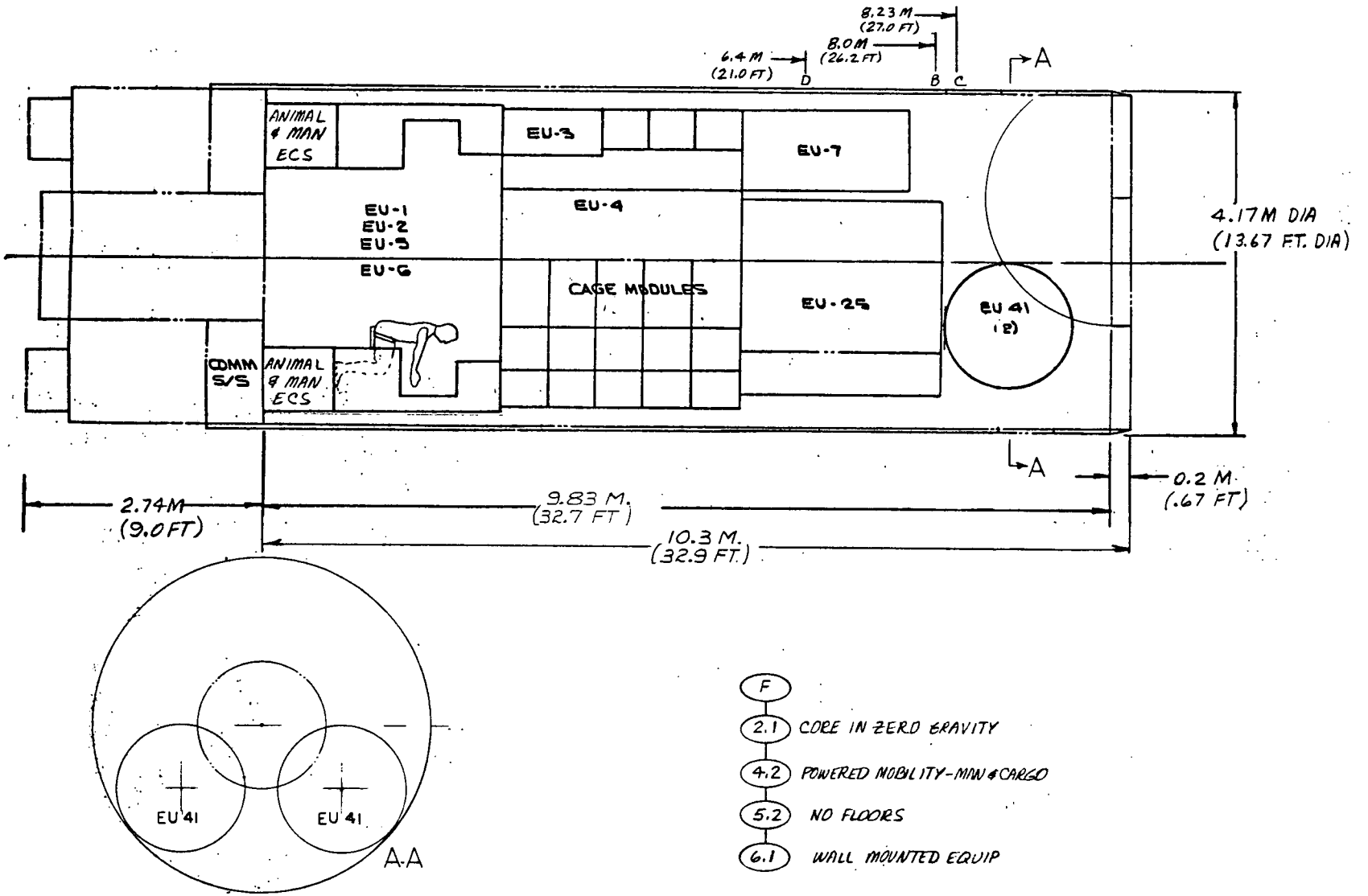



Figure 4-43. F Module for Space Station Operation

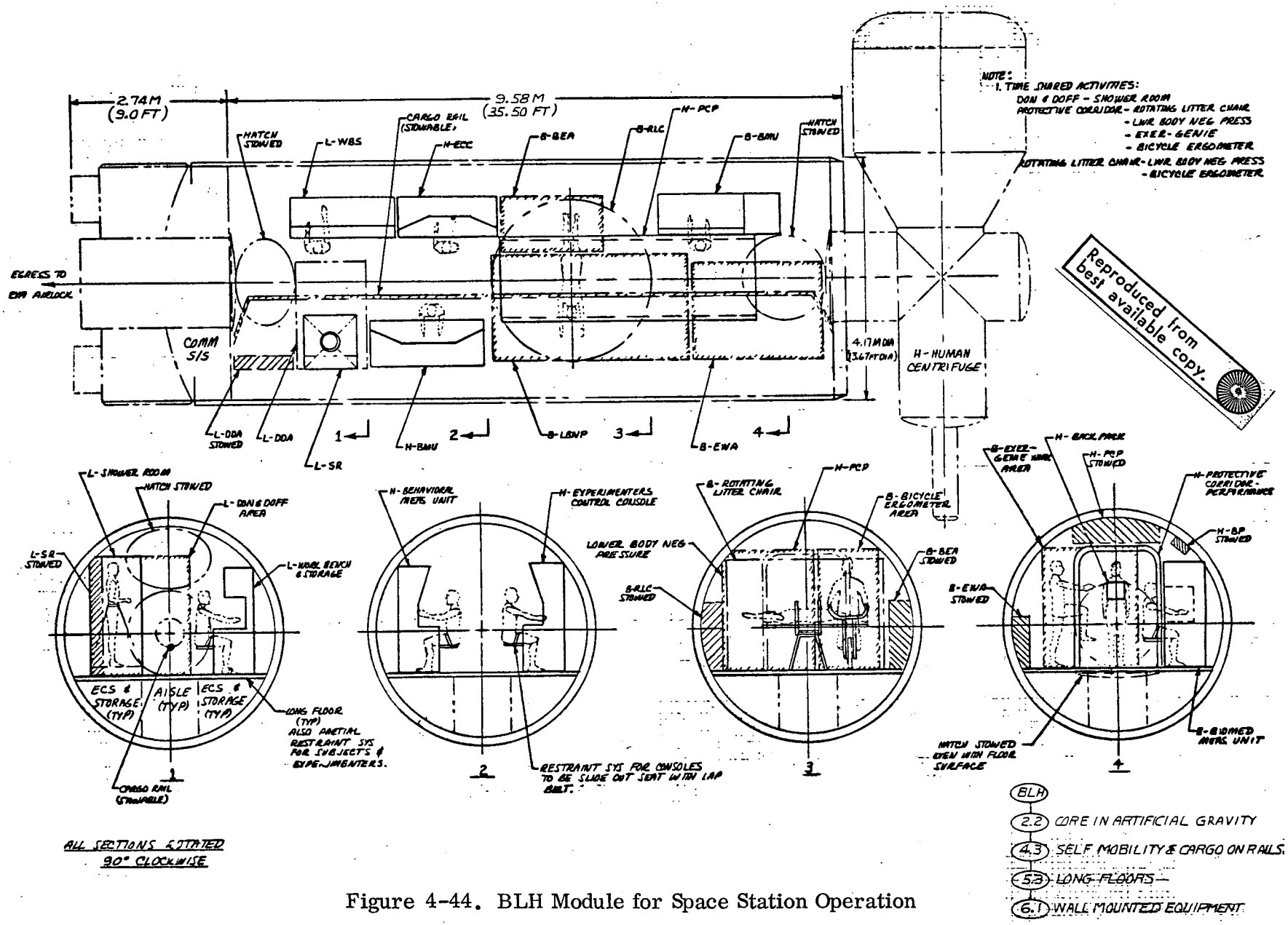



Figure 4-44. BLH Module for Space Station Operation

4.2.1.3 Layout Results. A layout analysis of the scientific responsiveness was made for the Maxi Max payload. Four equipment perturbations were made as shown below:

| Change / Perturbation | Combines Human Centrifuge (HC) and Bioresearch Center (FC) into Common Research Centrifuge (RC) | Eliminate Radiobiology Room (EU 25) | Reduce Organism Holding Capacity in Zero "G" Lab |
|---|---|---|---|
| A | X | | |
| B | X | X | |
| C | X | | X |
| D | X | X | X |

Major results of the changes are:

a. Combined Human and Bioresearch Centrifuge into Research Centrifuge:

1. Organism cage modules are reduced from 62 to 48.
2. Primate spheres are reduced from 1 sphere and 3 cylinders to 1 sphere and 2 cylinders.
3. Stop/start frequency. RC is basically continuous, (i.e. one stop each 1-2 mo). HC made frequent stops.
4. Hypogravity manned tolerance studies must precede organism occupancy due to the lower RPM and incremental rate change requirement.

b. Eliminate Radiobiology Room:

1. No radiation.
2. Radiochemistry capability maintained.
3. No clinical X-ray or photon densiometry.

c. Reduced Organism Holding = 50% cage module reduction in zero gravity laboratory.

These design/cost impacting perturbations of the Maxi Max payload scientific capability were made to demonstrate their effects on candidate designs. In particular, these four perturbations were assessed against the complete payloads in terms of weight, volume, cost, and number of Shuttle launches.

For the Midi and Mini payloads (which are payloads with incremental decreases in scientific responsiveness), weight, volume, and cost were analyzed and compared. This approach illustrated the effects of changes in scientific responsiveness.

For the Maxi Max payload, the first generation layout results are summarized in Figure 4-45, Concept Data Summary. The Midi and Mini payload variations of weight volume, and cost are shown in Table 4-9. The four bar charts shown in Figure 4-45 present weight, volume, cost and number of launches versus the ten Maxi Max design concepts. For any horizontal cut through the four plots (i.e., when one layout design concept is compared with another), only minor differences are noted. However, if the perturbations are examined within a concept (a vertical cut through any given design concept, for example , A versus D, A versus C, or A versus B), greater differences can be observed.

From this layout analysis, certain conclusions were drawn to guide the second generation designs. They are: for Maxi Max payloads, future design compromises should favor safety, scientific responsiveness, modularity, and maximum organism holding capability. The reason for this is that there is very little difference in the weight, volume, number of launches or cost for the ten layout concepts studied.

Table 4-9. Midi and Mini L. O. Analysis Results

| Payload | Weight (lb) | Volume (cu. ft.) | Cost ($) |
|---|---|---|---|
| Midi-30 | 40.1 K | 4056 | 134.3 M |
| Mini-30 | 20.2 K | 2708 | 94.6 M |
| Mini-7 | 17.4 K | 1992 | 62.5 M |

Additional data developed during the first generation layout studies showed that the number of equipment items sharing space within the laboratory has a significant impact on its length. Figure 4-46 indicates that, for the BLH module, if the rotating litter chair, body mass measurement device, bicycle ergometer, and other equipment were to be used without space sharing, a module length of approximately 42 feet would be required (see Figure I-16, Volume III). If some of these activities could share space, then the module length could be reduced to approximately 28 feet.

Weight and volume sensitivity of BLH and F modules for the Maxi Max payload is shown in Figure 4-47. Parameters shown are the weight increase of the CM-4 as volume increases, and the weights and volumes of selected BLH and F modules taken from the group of ten concepts. The figure also shows: (1) the Shuttle payload weight capability; (2) Shuttle payload volume limits; and (3) maximum desired on orbit module weight taken from the RAM program guidelines data. As the CM-4 usable volume is increased from 0 to 6000 $ft^3$, its weight increases from 800 to 1400 lbs. If equipment is added to the F module for concept Number 1, total module weight reaches 57,800 lbs well before the volume limit of 6000 $ft^3$ is reached. The module has a high density payload. The BLH companion module for concept Number 1 has a

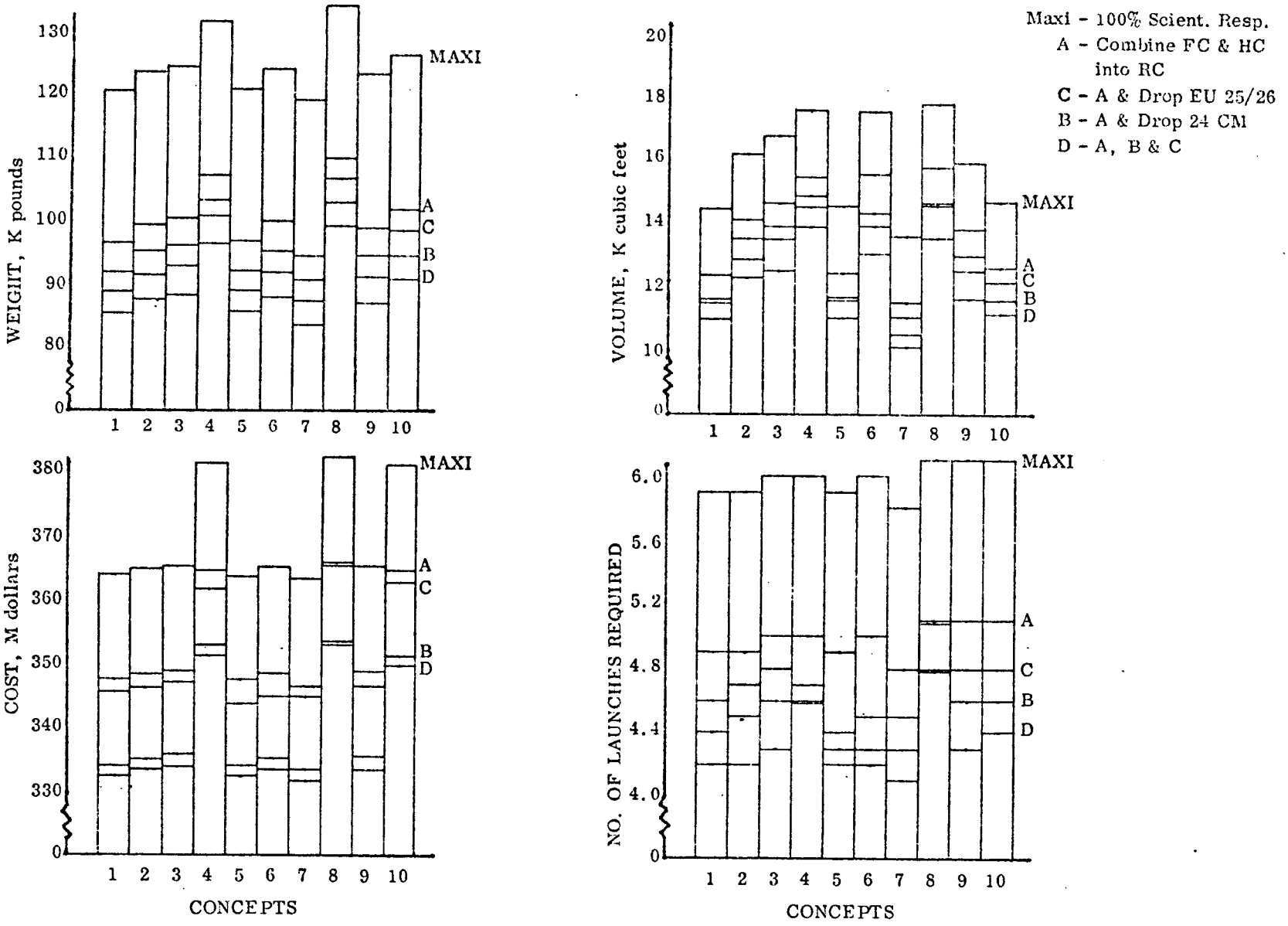



Figure 4-45. Concept Data Summary

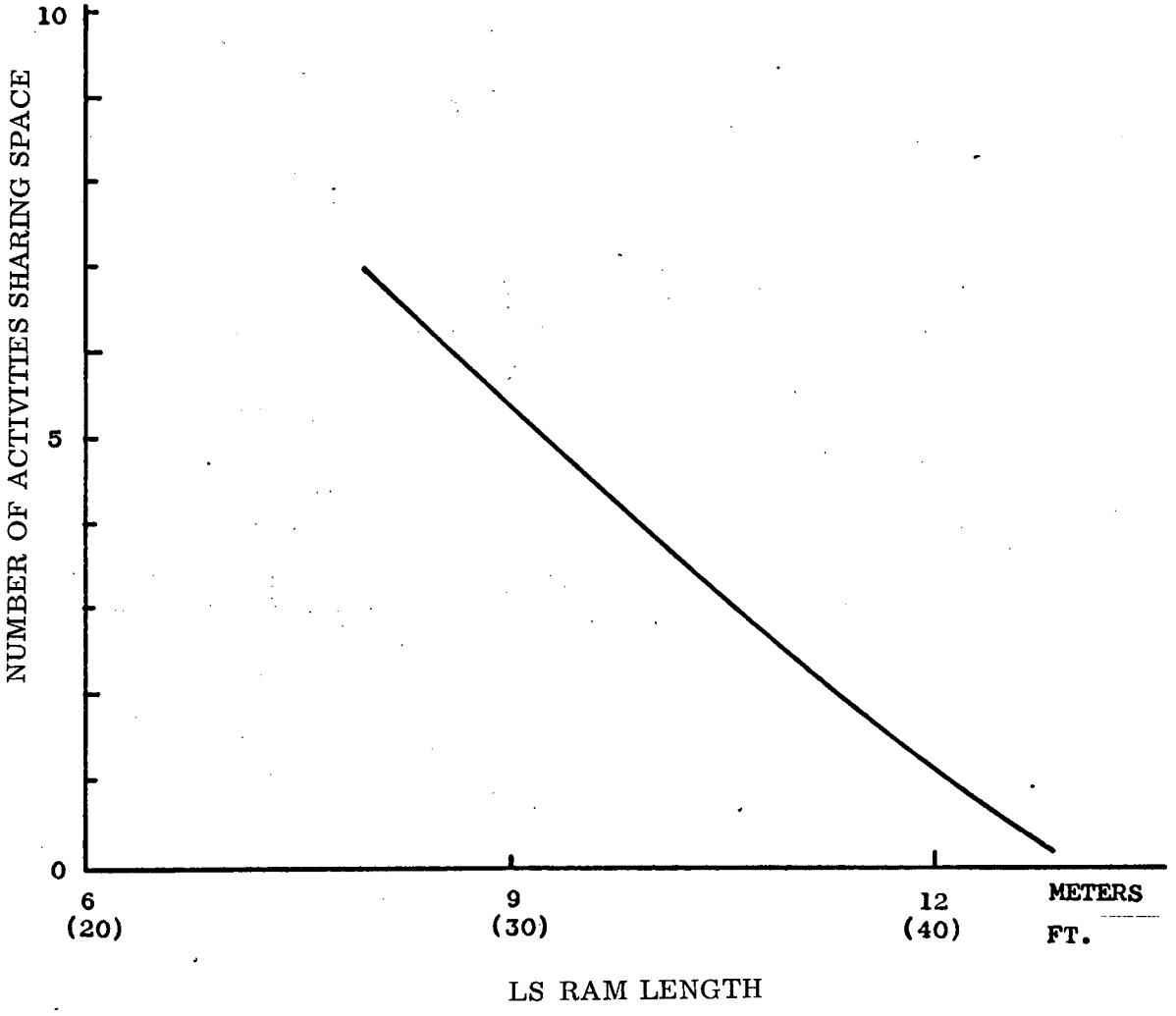



Figure 4-46. Activity Space Sharing BLH Module

very low density payload. It reaches a 17,100 lbs limit at a usable volume of 3200 $ft^3$. Neither the shuttle weight or volume limit is reached in the case of concept Number 1 for the BLH module.

If the CORE is placed in the BLH module instead of the F module, which is the case in concept Number 10, the F module reaches a maximum desired weight, in orbit, of $\approx$ 40,000 lbs at a volume of $\approx$ 3500 $ft^3$, and the BLH module reaches a weight of $\approx$ 26,000 lbs at a volume of $\approx$ 5000 $ft^3$. These weight and volume sensitivites are applicable in estimating weight and volume distributions for future Maxi Max payloads, where two or more life sciences RAMs are used.

At the conclusion of the first generation layouts, the nature of the Life Sciences research facility for Maxi Max was apparent. The facility consisted of a BLH module, an F module, and either a single RC centrifuge module or two centrifuges, an FC and an HC.

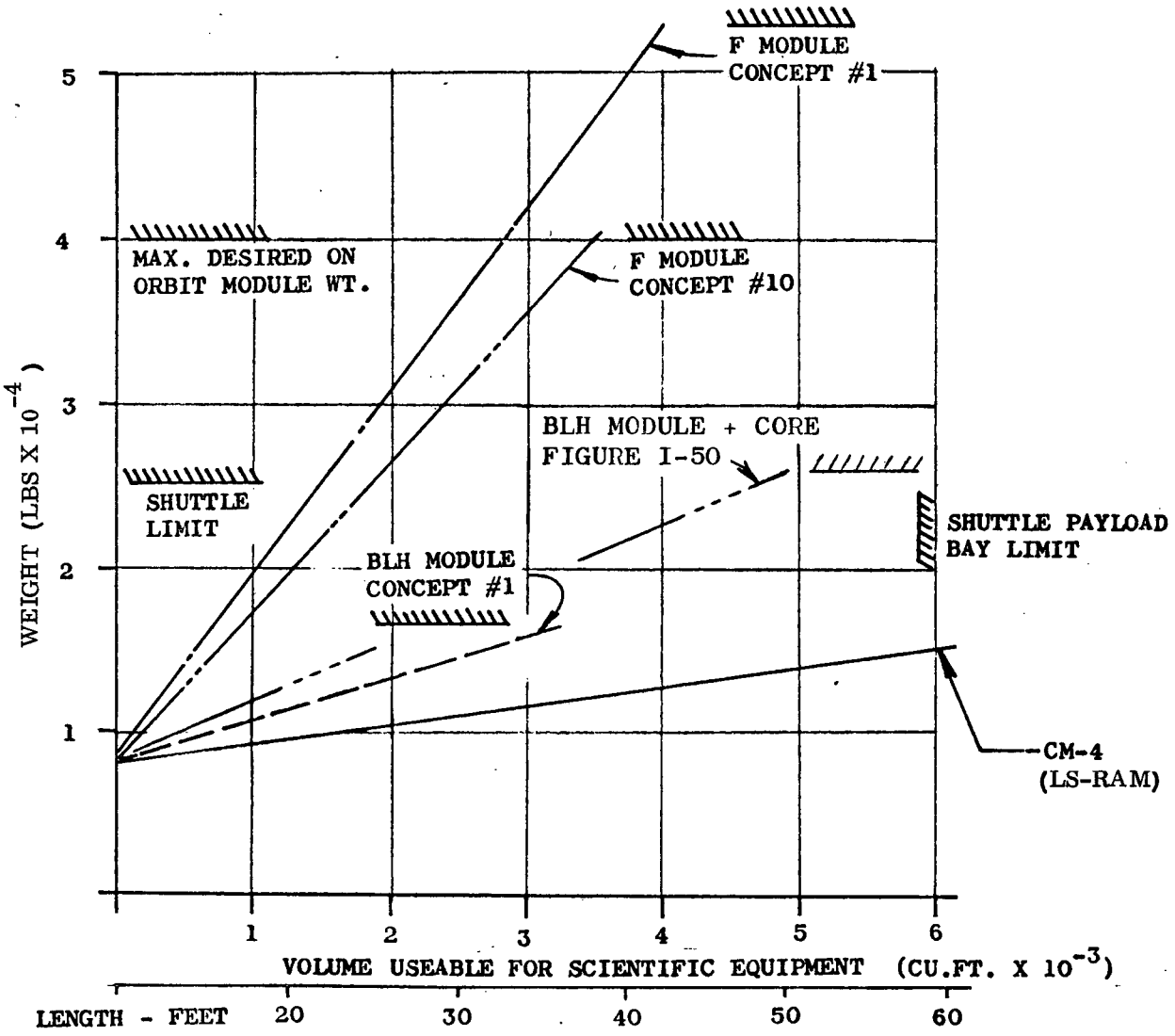



Figure 4-47. Weight and Volume Sensitivities BLH and F Modules (Maxi Max Payload)

(Drawings of the FC, HC and RC centrifuges are contained in Volume III.) There could be a separate CORE module or the CORE could be in the F module, in the centrifuge, or in the BLH module. These results aided NASA in establishing guidelines for the seoond generation layouts.

The first generation lesser payload layouts were developed based on the experience and insight gained in first generation layouts using the Maxi Max payload. These lesser payload layouts are presented in Volume III. Two examples of these layouts are shown in Figures 4-48 and 4-49 for Midi-30 and Mini-30 payloads.

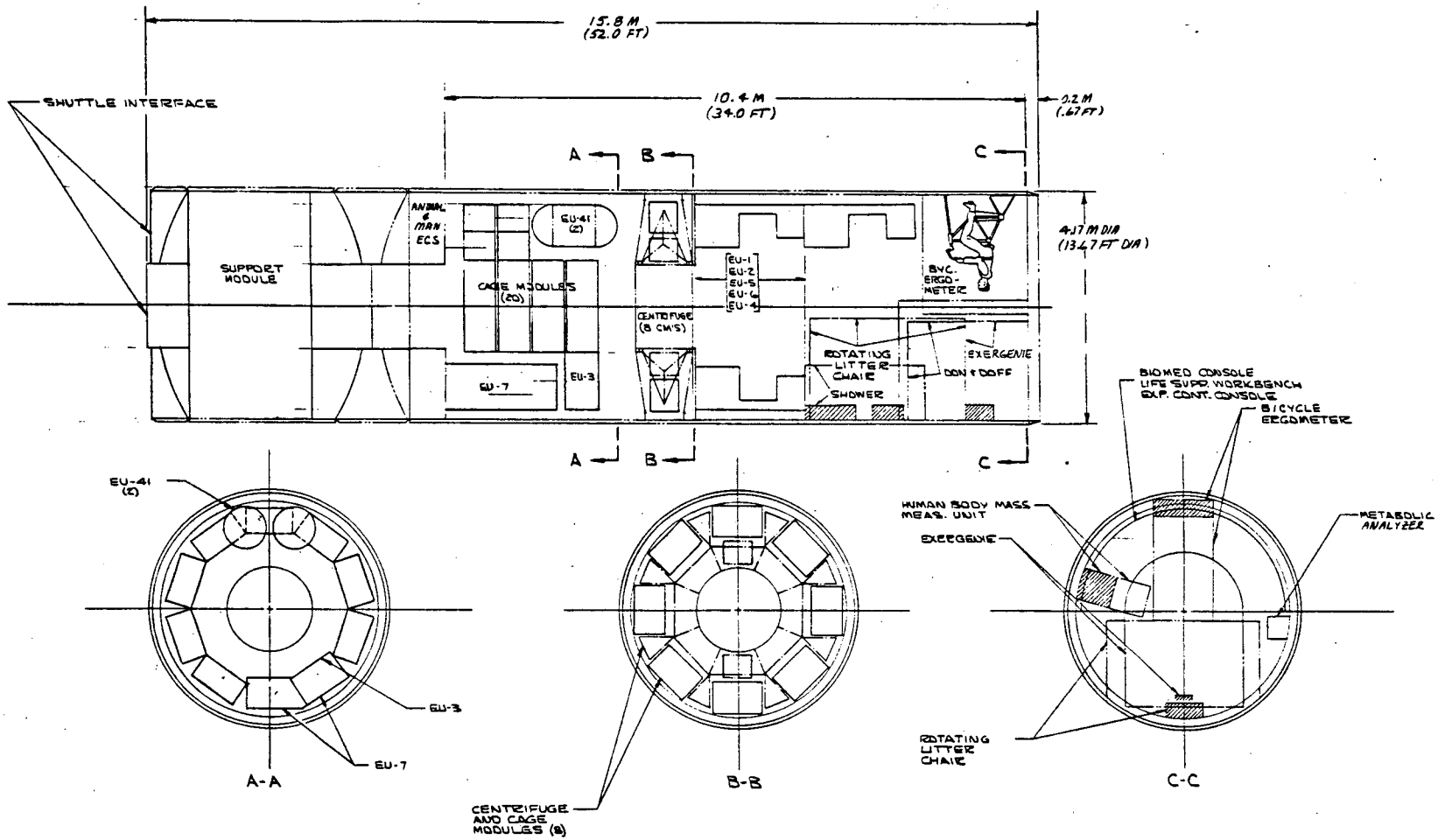



Figure 4-48. Midi-30 for Shuttle Sortie Missions

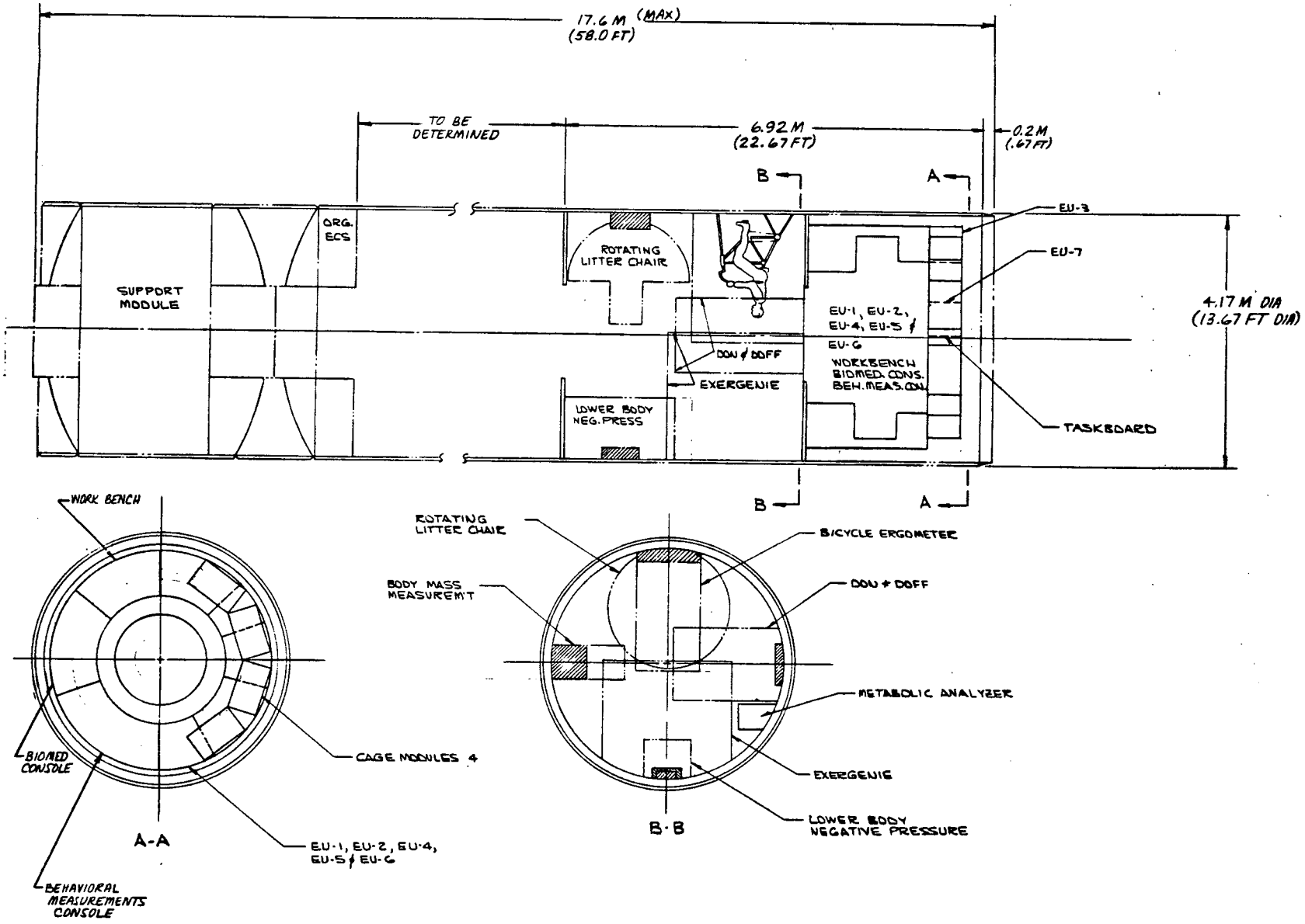



Figure 4-49. Mini-30 for Shuttle Sortie Missions

4.2.2 EQUIPMENT MODULE DESIGNS. Preliminary designs of racks, consoles, and special equipment modules were made for the second generation layouts. These addressed each equipment unit (EU) from the computer payload sorts. Predesign drawings of the equipment modules (EMs) which make up the EUs are presented in Volume III. The modules are identified by a code number consisting of the number of the EU to which it belongs, followed by a dash and the number of that particular module. For example: EU-004-9 is an equipment module required for the Preparation and Preservation Unit (EU-4); EU-004-10 is another module, or a modification of the same module for a different payload, required for the Preparation and Preservation Unit (EU 4). The drawing of the EM indicates the payload for which that particular module was designed.

Volume III also contains tables which list the equipment items (EIs) required for each EU and the number of each item required per payload. Samples of the type of drawings and lists contained in Volume III are shown in Figures 4-50 and 4-51 and Tables 4-10 and 4-11. Special emphasis was placed on the predesign of racks and consoles to achieve a high degree of modularity. The detailed weight and volume tables of EUs for each baseline payload are shown in Volume III. A summary of this data is presented in Table 4-12.

4.2.2.1 Modular Approach. After some investigation at the first generation level, it became apparent that Life Sciences research equipment lends itself well to modular rack consideration. This is due to the large number of relatively small pieces of equipment in the scientific equipment inventory. When these standard modules were arranged in the Life Science RAM, near optimal laboratory layouts were achieved quickly and easily due to the ease of layout modification possible with standard modules. For example, when the first payload layout was being critiqued, improvements appeared (ways in which the layout could be made safer, or in which crew operations could be improved). Changes in the layout and in succeeding iterations were made quickly because equipment modules being relocated automatically vacated areas which were geometrically compatible with new equipment modules being considered for the vacated area. Thus, the designer was able to make rapid design changes without disturbing the remainder of his layout. Many of the advantages of the modular concepts demonstrated in the 1/20th scale layouts will also apply to the full scale hardware in the actual Life Sciences laboratory.

The first step in the design of equipment racks (ERs) and equipment consoles (ECs) was to identify each equipment item (EI) and account for it in terms of its location in the laboratory. The grouping, distribution, and packaging was accomplished based on the functional grouping of equipment items into equipment units, and the factors listed in Table 4-13. For example, the EIs listed in Table 4-10 support the preparation and preservation functions and are grouped in EI-004, preparation and preservation unit.

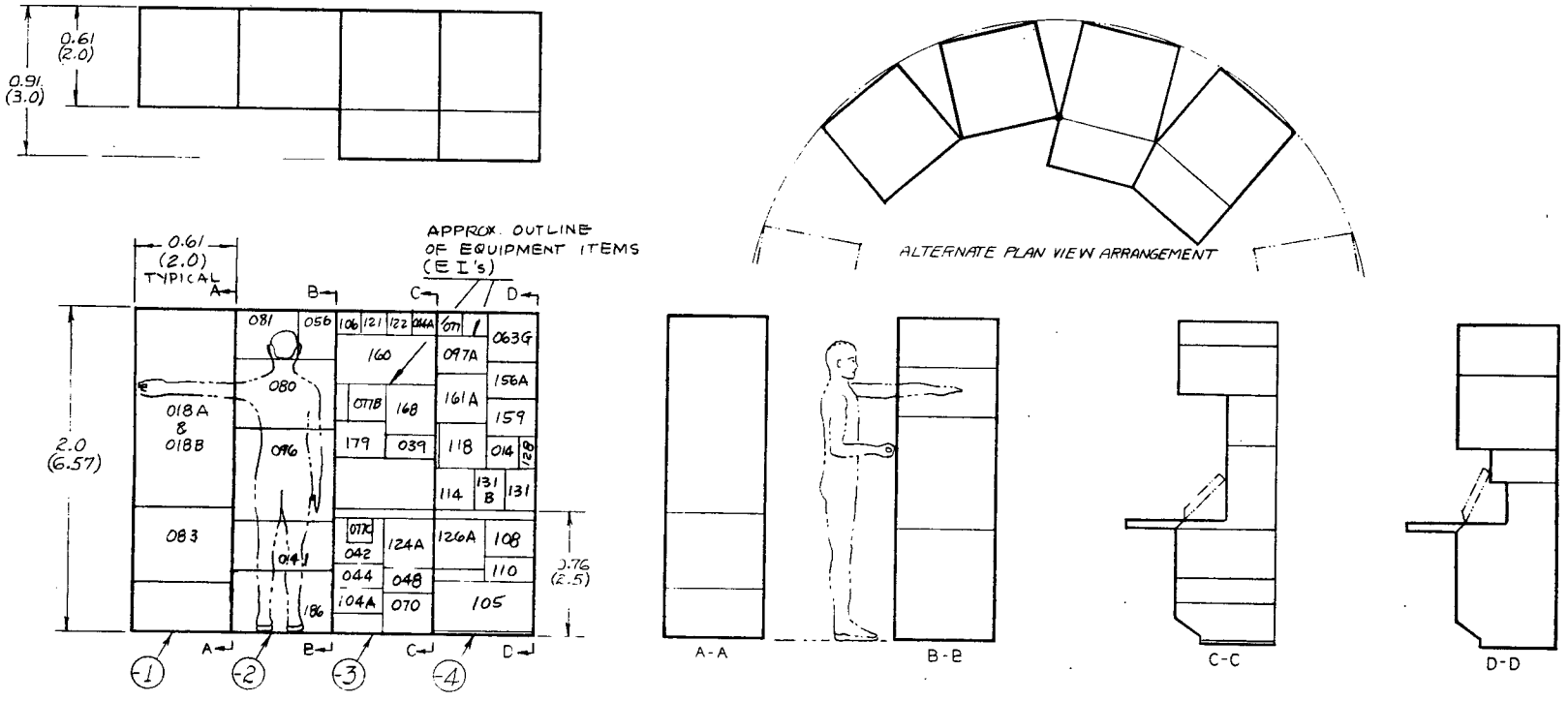



Figure 4-50. Sample EU Drawing

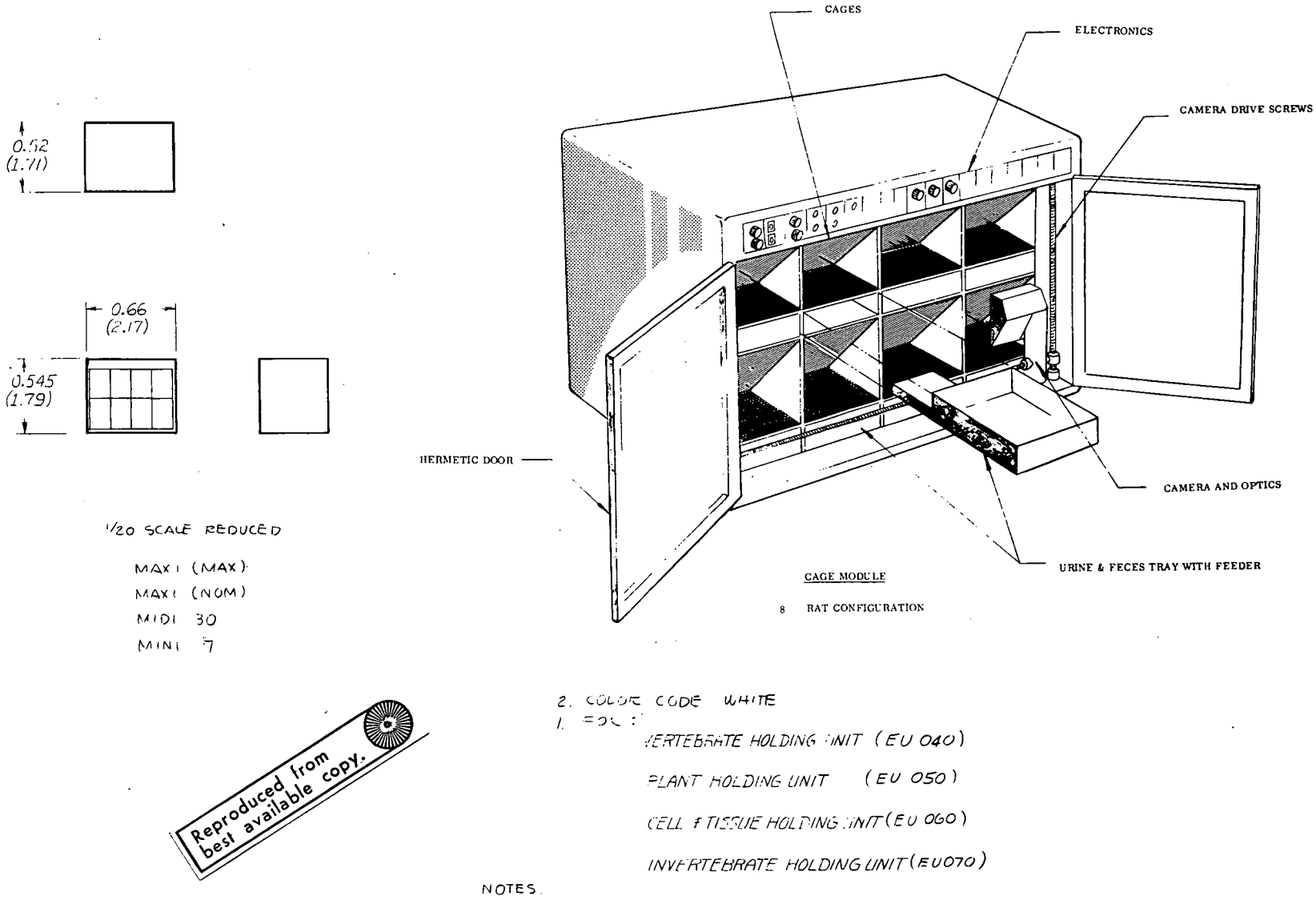





Figure 4-51. Sample of Special Equipment Module

Table 4-10. Sample EU Equipment Breakdown Table

| EI NO. | NAME | MAXI MAX | MAXI NOM | MIDI 30 | MINI 30 | MINI 7 | REMARKS |
|---|---|---|---|---|---|---|---|
| 014 | Anesthetzr (Invert | 1 | 1 | 1 | 1 | 1 | |
| 018 | Bench, Lam Flo | 2 | 2 | 1 | 1 | 1 | |
| | | (Free Body) | | | | | |
| 018A | Bench Liners, Lfb | 12 | 6 | 6 | 4 | 4 | |
| 018B | Bnch Insert Lfb, Radioc | 2 | 1 | 1 | 1 | 1 | |
| 039 | Chromatograph, Liquid Column | 1 | - | - | - | - | |
| 041 | Cntrif Frig Hi Spd | 1 | 1 | 1 | 1 | 1 | |
| 042 | Cntrif Micro | 1 | 1 | 1 | 1 | 1 | |
| 044 | Chemicals | 10 | 5 | 3 | 1 | 1 | |
| 044A | Chemicals-Radioactive | 2 | 1 | 1 | 1 | 1 | |
| 048 | Cleanr, Vacuum | 5 | 4 | 2 | 2 | 1 | |
| | | (Distributed throughout laboratory) | | | | | |
| 056 | Cryo Sys | 1 | 1 | 1 | - | - | |
| 063G | Deionizer for Pure Water | 1 | 1 | 1 | 1 | - | |
| 070 | Electrophrsis Appar | 1 | 1 | 1 | 1 | - | |
| 077 | Filtr, Chemcls | 3 | 2 | 2 | 1 | - | |
| 077B | Frezr, Cryo | 1 | 1 | 1 | 1 | 1 | |
| 077C | Fragiligraph | 1 | 1 | 1 | 1 | - | |
| 080 | Frezr, Genl | 4 | 2 | 2 | 1 | 1 | |
| 081 | Frezr, Lo Temp | 1 | 1 | 1 | 1 | 1 | |
| 083 | Frig | 1 | 1 | 1 | 1 | 1 | |
| 084 | Frig, Radio Checm Storag | 1 | 1 | 1 | 1 | 1 | |
| 096 | Glv Bx | 1 | 1 | 1 | - | - | |
| 105 | Kit, Bench Chem Anal | 1 | 1 | 1 | 1 | 1 | |
| 106 | Kit, Hematology | 1 | 1 | 1 | 1 | - | |
| 108 | Kit, Hist | 1 | 1 | 1 | 1 | 1 | |
| 110 | Kit, Microbiology | 1 | 1 | 1 | 1 | 1 | |
| 114A | Kit, Microdissection | 1 | 1 | 1 | 1 | 1 | |
| 118 | Lyphilzr (Space Vac) | 1 | 1 | 1 | 1 | 1 | |

Table 4-11. Sample Special Equipment Module Breakdown

| EI NO. | NAME | MAXI MAX | MAXI NOM | MIDI 30 | MINI 30 | MINI 7 | REMARKS |
|---|---|---|---|---|---|---|---|
| - | Cage Module | 48 | | | | | In Zero g lab |
| | | 50 | | | | | In R.C. |
| | | | 20 | | | | In Zero g lb |
| | | | 8 | | | | In Internal Cent |
| | | | | 20 | | | In Zero g lab |
| | | | | 8 | | | In Internal Cent. |
| | | | | | 6 | 4 | |
| | Note: Cages, feces management system, feeding and watering systems, and urine collector systems are provided in above cages and cage modules as required. | | | | | | |

Table 4-12. Summary - EU Weight and Volume Breakdown

| EU NO. | NAME | BASELINE PAYLOADS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | MAXI MAX | | MAXI NOM | | MINI 30 | | MINI 7 | |
| | | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] |
| 001 | Visual Records & Microscopy | 2,189 | 52 | 1,114 | 26 | 620 | 26 | 566 | 12 |
| 002 | Data Management Unit | 3,030 | 78 | 1,657 | 42 | 932 | 34 | 557 | 34 |
| 003 | Life Sciences Experiment Support Unit | 1,158 | 26 | 972 | 62 | 602 | 16 | 355 | 16 |
| 004 | Preparation & Preservation Unit | 4,389 | 142 | 3,194 | 123 | 2,228 | 71 | 1,079 | 71 |
| 005 | Biochemical & Biophysics Analysis Unit | 2,065 | 52 | 1,533 | 52 | 1,090 | 26 | 525 | 26 |
| 006 | Maintenance Repair & Fabrication Unit | 1,080 | 78 | 909 | 78 | 718 | 52 | 453 | 33 |
| 007 | Ancillary Storage | 375 | - | 260 | - | 134 | | 120 | - |
| 011 | Remote Manipulator | 1,268 | 70.4 | 638 | 70 | 606 | 70 | 618 | 70.4 |
| 012 | Body Mass Measurement & Rotating Litter Chair | 963 | 153 | 895 | 153 | 774 | 153 | | |

[1] Total Weight - Scientific Equipment Items + Rack or Console.

[2] Total Volume of Equip. Rack, Equip. Console, or Special Equipment Module-Spheres and Cylinders Taken as Parallelapipeds.

Table 4-12. Summary - EU Weight and Volume Breakdown, Contd

| EU NO. | NAME | BASELINE PAYLOADS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | MAXI MAX | | MAXI NOM | | MINI 30 | | MINI 7 | |
| | | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] |
| 012/031 | Bio Medical Man-system Integration Research Support Unit | 224 | 52 | 213 | 52 | 205 | 52 | 135 | 17 |
| 023 | Internal Centrifuge EU 021 | | | ·700 | 340 | | | | |
| 025 | Radiation Exposure Unit | 2,066 | 105 | 457 | | 426 | 105 | 111 | |
| 030 | Bicycle Ergometer & Lower Body Negative Pressure | 185 | 52.5 | 185 | 52 | 184 | 53 | | |
| 040 | Cage Module Vertebrate | 3,951 | 213 | 2,138 | 53 | 312 | 13 | | |
| 041 | Primate Cylinder & Primate Sphere | 1,350 | 187 | 1,320 | 62 | 360 | 62 | | |
| 042/071 | Holding Unit Support | 702 | 26 | 696 | 26 | 236 | 12 | 171 | 12 |
| 050 | Cage Module Plant | 1,133 | 60 | 1,056 | 53 | 197 | 7.0 | 161 | 26 |
| 060 | Cage Module Cell & Tissue | 557 | 26.6 | 584 | 13 | 175 | 13 | 141 | -0- |

[1] Total Weight - Scientific Equipment Items + Rack or Console.

[2] Total Volume of Equip. Rack, Equip. Console, or Special Equipment Module-Spheres and Cylinders Taken as Parallelapipeds.

Table 4-12. Summary - EU Weight and Volume Breakdown, Contd

| EU NO. | NAME | BASELINE PAYLOADS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | MAXI MAX | | MAXI NOM | | MINI 30 | | MINI 7 | |
| | | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] |
| 070 | Cage Module Invertebrate | 299 | 20 | 206 | 13 | 102 | 7 | 85 | -0- |
| 080 | Life Support Subsystem Test Unit, Seat and Shower | 529 | 120 | 366 | 146 | 249 | 52 | 163 | 26 |
| 091 | Behavioral Measurements Unit | 851 | 52 | 553 | 52 | 509 | 52 | 171 | 26 |
| 093 | Mobility Unit Damage Proof | 328 | 477 | 312 | 477 | 4 | Neg | | |
| Payload Sub-Totals for Zero "G" LS-RAMS | (lb) | (28,692) | 2,043 $FT^3$ | | | | | | |
| | Kg | 13,042 | 57.8 $M^3$ | | | | | | |
| RESEARCH CENTRIFUGE PORTION OF MAXI (MAX) PAYLOAD | | | | | | | | | |
| 040 | Cage Module Vertebrate | 3,951 | 213 | | | | | | |
| 041 | Primate Cylinder and Primate Sphere | 1,350 | 187 | | | | | | |
| 042/071 | Holding Unit Support | 702 | 26 | | | | | | |

[1] Total Weight - Scientific Equipment Items + Rack or Console.

[2] Total Volume of Equip. Rack, Equip. Console, or Special Equipment Module-Spheres and Cylinders Taken as Parallelapipeds.

Table 4-12. Summary - EU Weight and Volume Breakdown, Contd

| EU NO. | NAME | BASELINE PAYLOADS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | MAXI MAX | | MAXI NOM | | MINI 30 | | MINI 7 | |
| | | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] | WT[1] | VOL[2] |
| 050 | Cage Module Plant For 9 Units | 1,133 | 60 | | | | | | |
| 060 | Cage Module Cell & Tissue | 557 | 26.6 | | | | | | |
| 070 | Cage Module Invertebrate | 299 | 20 | | | | | | |
| 091 | Behavioral Measurements Unit | 851 | 52 | | | | | | |
| 120 | Habitability Equipment | 500 | 78 FT$^3$ | | | | | | |
| Research Centrifuge | | (9,343) | (863) | | | | | | |
| Payload SubTotals | | 4,240 | 24.5 | | | | | | |
| Payload | | (38,035) | 2,906 | (19,958) | (1,945) | (10,663) | (876) | (5,421) | (388) |
| Grand Totals | | 17,289 | 82.3 | 9,092 | 55.2 | 4,847 | 24.8 | 2,464 | 11.0 |

[1] Total Weight - Scientific Equipment Items + Rack or Console. kg & (lbs)

[2] Total Volume of Equip. Rack, Equip. Console, or Special Equipment Module-Spheres and Cylinders Taken as Parallelapipeds. $M^3$ & ($ft^3$)

Table 4-13. Factors Affecting Distribution of Equipment Item in Laboratory

| Degree of Clustering Required | Type of Equipment Module Required | Primary Location Required |
|---|---|---|
| Localized cluster of equipment<br>Cluster plus distributed in lab, centrifuge, space station, etc.<br>Distributed only | Console (primary function requires crew interface)<br>Equipment rack<br>Special equipment module | Zero g lab - BLH module<br>Zero g lab - F module<br>Zero g lab - BLH and F module<br>Centrifuge - H wing<br>Centrifuge - F wing<br>Centrifuge - part in H and F wing one in zero g and one in centrifuge<br>modular space station or RSM |

The next step following EI grouping was to design racks and consoles considering the man-machine interface. The factors considered are shown in Table 4-14. This resulted in the general configurations for equipment racks, equipment console, and cage modules as shown in Figures 4-52 and 4-53.

A two-meter (6.57 ft) high standard equipment module was chosen to be compatible with pressure standing and pressure walking restraint, and mobility techniques. This two-meter high equipment module is 0.61 by 0.61 meters (2 ft by 2 ft) in cross section. This selection was made based on standard electronic modules in use today, which are compatible with the planned maintainability concept. That is, equipment installed in the racks are accessible from front, side, and back; and components are within man's reach without having to first remove other components. These modules allow implementation of that concept by swinging or rolling the modules away from the wall, as shown in Figure 4-54.

Table 4-14. Man-Machine Interface Factors Considered in Equipment Module Design

| Potential Crew Working Positions at Worksite | Potential Restraint Systems at Worksite | Potential Mobility System in Use To & From Worksite | Potential Cargo Handling System in Use To & From Worksite | Potential Unique Equipment Features Required |
|---|---|---|---|---|
| standing<br>intermediate | chest, hip, thigh, foot restraints, individually and in combination | free soaring<br>controlled soaring<br>pressure walking<br>aided walking (magnetic shoes)<br>powered systems | hand held<br>body attached<br>on rails<br>powered system | knee space<br>pull out surface<br>hinged surface<br>LFB interface |

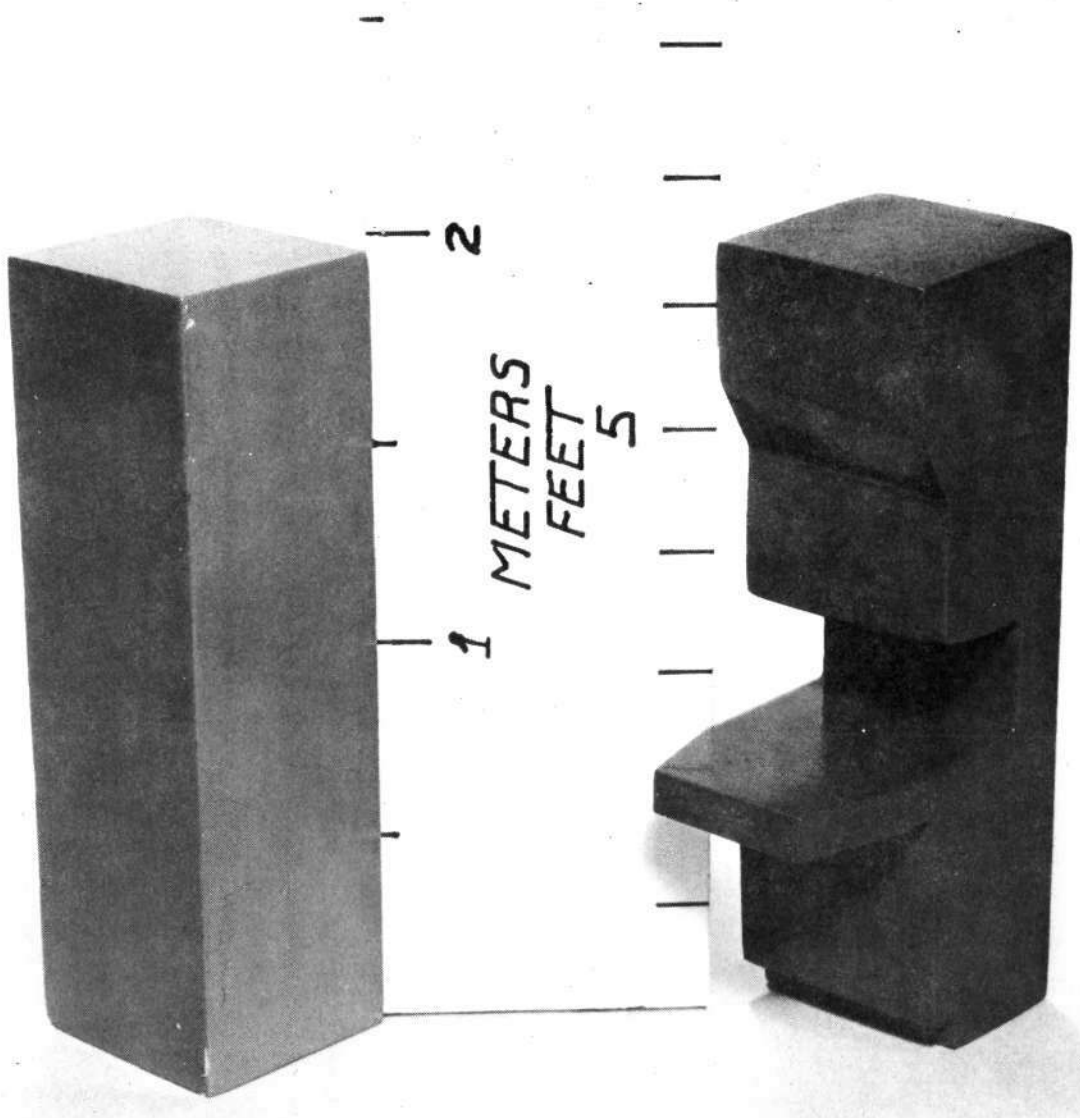



Figure 4-52. Equipment Rack and Console (Pallets)

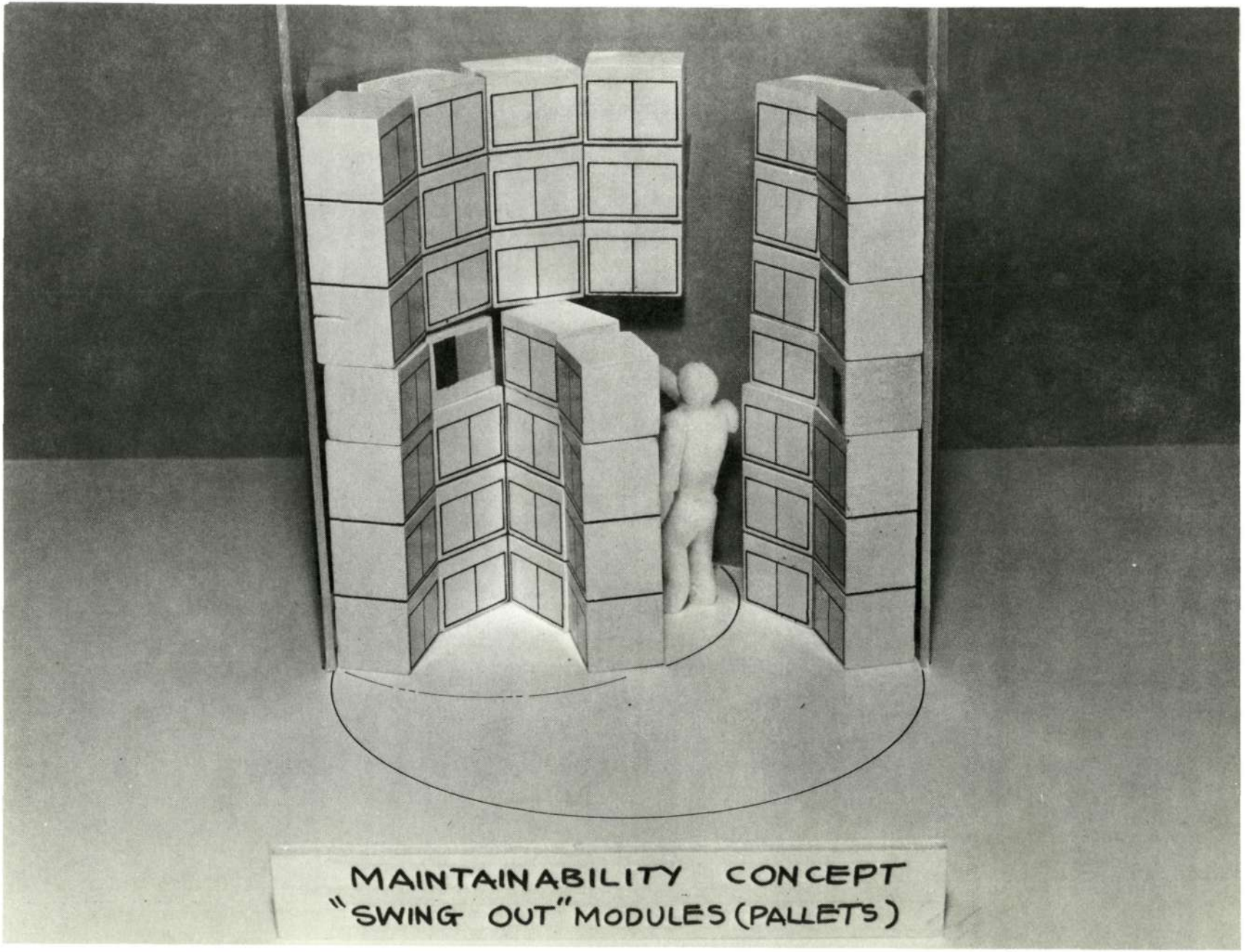



Figure 4-53. Maintainability Concept Swing Out Modules (Pallets)

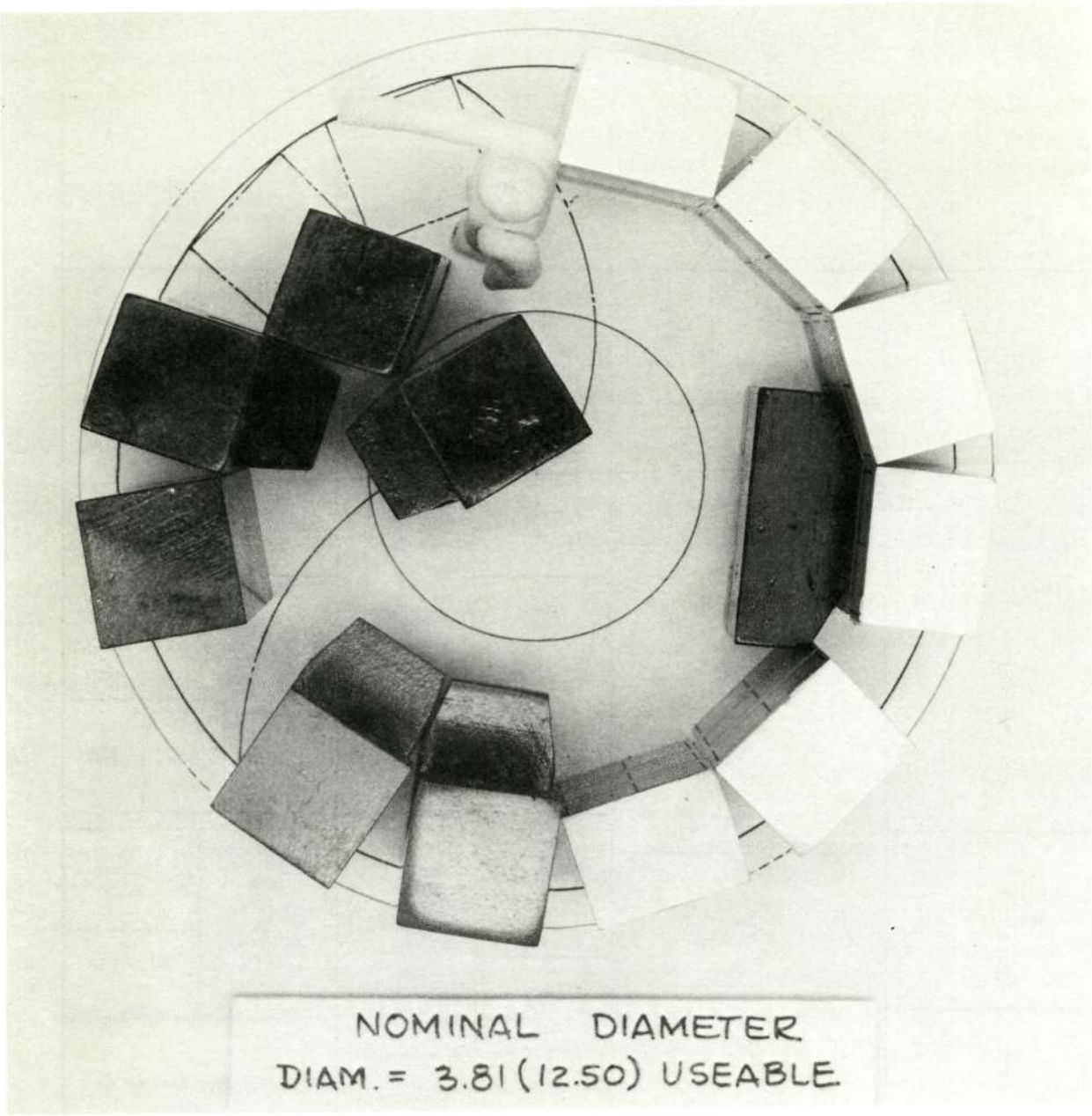



Figure 4-54. Access to Wall with Swing Out Modules

Equipment Items were laid out as illustrated in Figure 4-55 for several of the CORE equipment modules. The EIs were positioned, their arrangement evaluated, and adjustments made until a reasonable arrangement was achieved. This arrangement reflects only a preliminary review of the functional requirement for the EU rack being designed and should not be considered final.

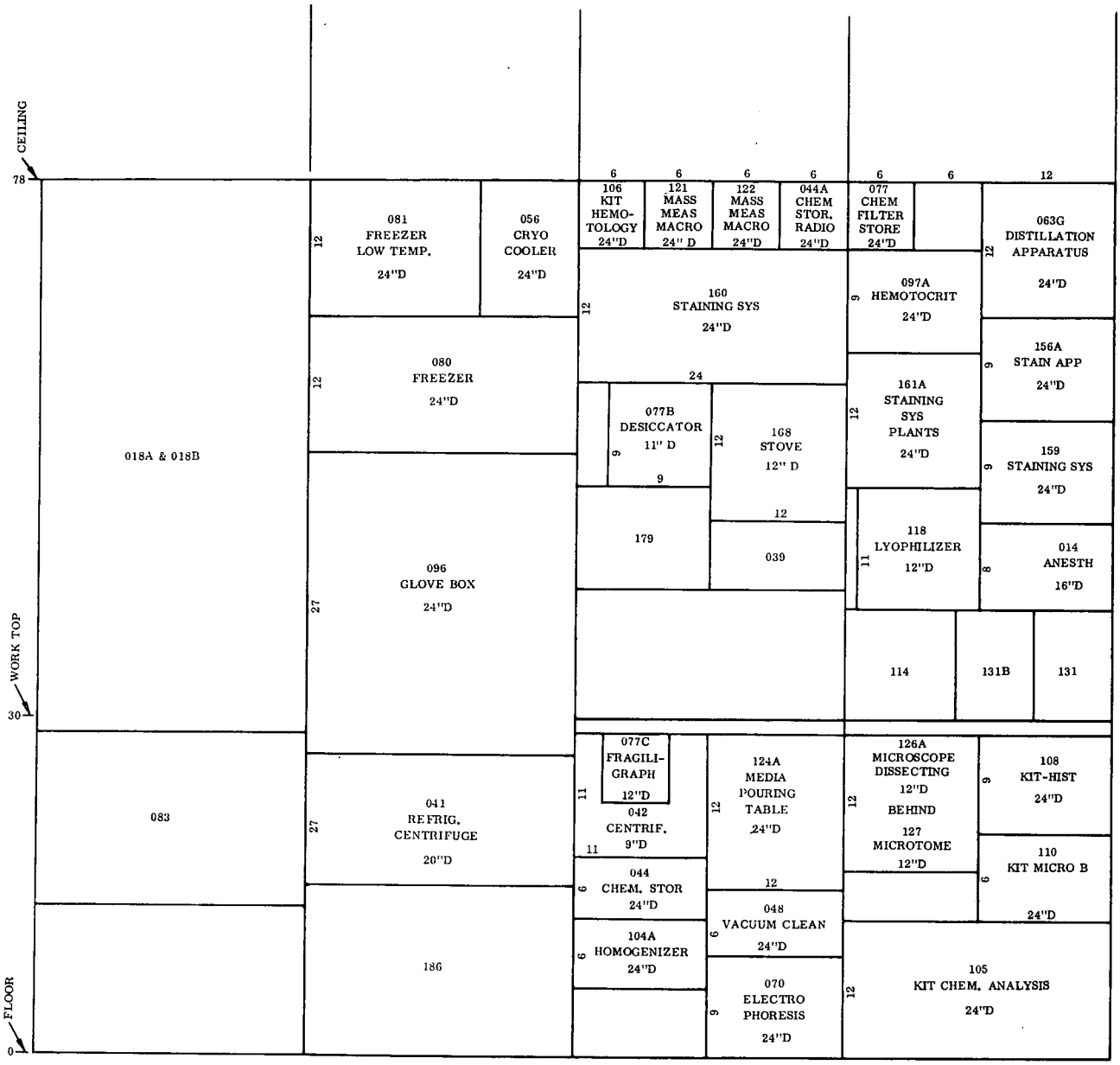



Figure 4-55. Example of an Equipment Module Layout

4.2.3 SECOND GENERATION LAYOUTS. Second generation layouts were developed using NASA guidelines for Task B. These called in part for the following payloads to be developed.

a. Maxi Max

b. Maxi Nom

c. Midi-30

d. Mini-30

e. Mini-7

The guidelines also established that the Life Sciences research facility for Maxi Max will consist of the following RAM modules: a BLH module, an F module, and an RC module. The BLH and F modules provide the zero-g laboratory and the research centrifuge module (RC) provides artificial gravity. The CORE was considered for location in either the BLH or the F module, and not in a separate CORE module or in the artificial-g created by the research centrifuge. The reason for the latter guideline was that it has been demonstrated that microbiology can be successfully achieved in a zero-g environment. These three modules are supported by a modular Space Station.

The division of the CORE between the F and BLH modules was based upon the scientific requirements. Both F and BLH research require visual records and microscopy units. Therefore, the two CORE modules were distributed equally. The basic biomedical recorder is contained in the BLH module. CRT visual displays are contained in both modules, as are the data management modules. This provides visual displays of video, as well as analog and digital data in both modules. The preservation and preparation unit is placed in the biology laboratory as the majority of the samples for analysis originate from the biological organisms. Therefore, those biological specimens of human origin must be transported from the BLH module to the biology module for analysis. The biochemical/biophysical equipment unit is also contained in the biology module for the same reasons. Maintenance, fabrication, and repair equipment unit placement is optional depending on the specific layout concept. In the baseline payload, it was placed in the biology module for optimum space utilization.

The lesser payloads (i.e., Maxi Nom, Midi, and Mini) were developed in a single module (FBLH). This module is supported by the modular Space Station for Maxi Nom and by the Shuttle Sortie missions for Midi-30, Mini-30, and Mini-7. The CM-4 type module shown in Figure 4-34 was used.

The distribution of the CORE in the Maxi Nom payload is also divided between biology and man research. The preservation and preparation is contained in the biology chamber for the same reasons given for the Maxi Max payload. The biochemistry/biophysical equipment unit is maximized. This also tends to minimize the amount of chemicals

contained in the BLH compartment. Ideally, the chemicals should be contained in a single compartment, allowing for isolation in case of spillage. The remainder of the CORE is placed in the BLH compartment. This allows the crew to observe, via the video system, all the biology organisms without entering the biology compartment.

The data developed from first generation layout work was used as a guide for second generation layout development as follows:

a. Crew safety was given first consideration in layout design.

b. Scientific responsiveness within the framework of any given payload was not compromised.

c. Flexibility in laboratory layout was emphasized (evolutionary buildup and modification capability).

d. A dual purpose research centrifuge (RC) rather than separate HC and RCs was used for the Maxi Max payload.

e. Radiology capability was reduced to accommodate one Macaque at one meter.

f. Space sharing of biomedical MS1 and LSPS functions was considered wherever possible.

g. Equipment units were made modular.

h. Commonality of function and equipment was maximized.

i. All crew mobility options were considered, such as hand walking, soaring, guided soaring, pressure walking, and powered chair.

j. Three cargo handling systems were considered: cargo on rails, man-mounted, and powered chairs.

4.2.3.1 Design Studies. The cluster configuration 1.4 in Figure 4-56, the RC on the side of the MSS was used as a guide in developing internal layouts for the Maxi Max payload. (The cluster configuration is based on the MC-DAC modular Space Station of 30 June 1971.) Different arrangements of clusters were considered, primarily cruciform (1.0) and in-line (2.0) clusters. It became apparent that the in-line configuration (2.0) is not compatible with a modular space station (MSS) concept because Life Science RAMs would have to occupy the position designated for MSS modules, or the Life Science RAMs would have to extend a second and third module out from the MSS module. Therefore, the in-line configuration was rejected for these reasons.

In the second generation layout phase of the study, the three-dimensional layout approach was used to give visibility, technical realism and credibility to the layouts. This consisted of the use of 1/20th scale models in layout development as follows: (1) fabrication of 1/20th scale models of the equipment modules; i.e., equipment racks (ERs), equipment consoles (ECs), and special equipment modules (SEMs).

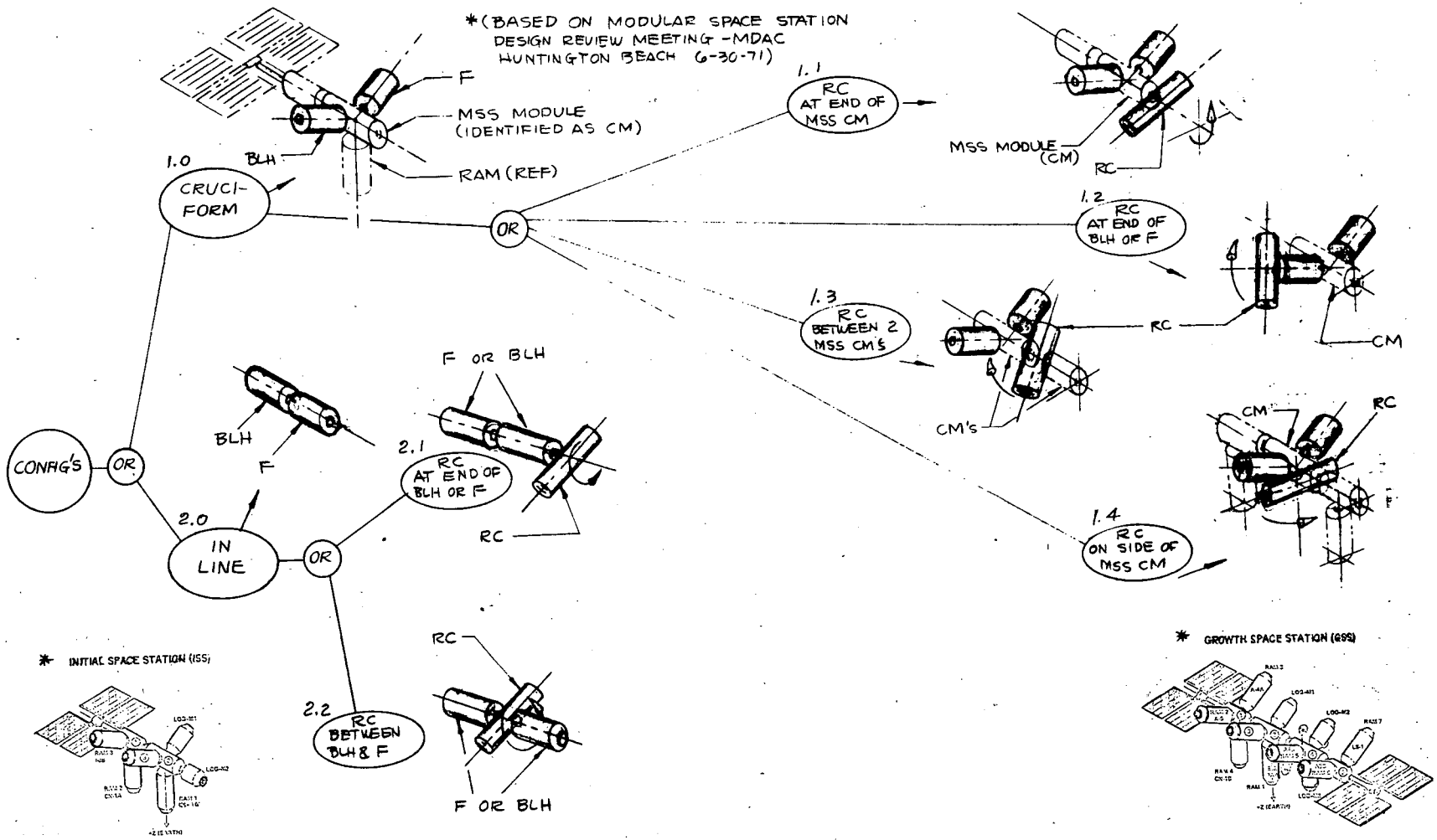



Figure 4-56. Cluster Configurations

Drawings of these equipment modules (EMs) are presented in Volume III; (2) Color coding of the EMs for rapid identification; (3) Photo documentation of the payloads in the form of EMs as shown in Volume III; (4) Fabrication of plexiglass shells representing the Life Science RAM and support modules in 1/20th scale; (5) Placement and Manipulation of the EMs within the 1/20th scale RAM for a first iteration of the initial layouts addressing; (a) a discrete payload such as Maxi Max; and (b) a discrete laboratory concept such as a longitudinal floor configuration; (6) A critique and review of each iteration to identify improvements in safety, scientific response, crew operations, restraint and mobility provisions, growth potential, increase or decrease of module length, isolation, and general arrangemement of one FPE with respect to another; and (7) Documentation by still photography of viable concepts. Figure 4-57 shows the 3D layout approach logic.

The 3D approach proved to have many advantages for life sciences payload development. Their greatest advantage was the reduced man-hours required to develop a new layout iteration. A one-hour turn-around time for each iteration was achieved. They also provided an order of magnitude improvement in visibility of layouts which cannot be obtained by two-dimensional layouts. Because of this visibility, scientist involvement in layout development was increased which enhanced the creditability of the layouts. Their involvement increased by an order of magnitude over the first generation layouts, which were developed using the conventional two-dimensional approach.

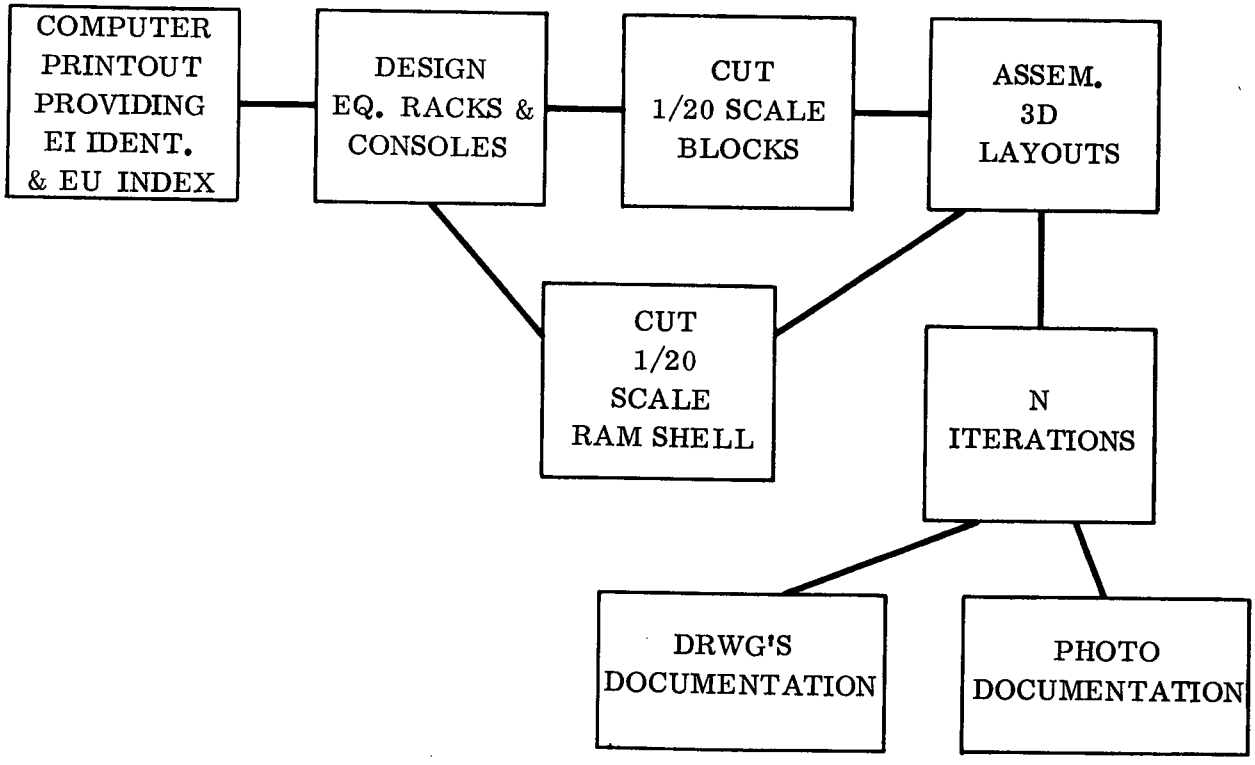



Figure 4-57. Three-Dimensional Layout Approach

A total of 18 second generation layout concepts were developed for the 5 payloads. Six were updated as baseline layouts. These are documented as drawings and photos and discussed in Section 4.1. The remaining 12 are documented as photos in Volume III.

4.2.3.2 Layout Results. The second generation layout concepts have been evaluated with respect to: (1) Crew safety; (2) Scientific response; (3) Crew operations; and (4) Design considerations. The following paragraphs summarize the layout characteristics and evaluations within these four categories.

4.2.3.2.1 Crew Safety. Crew safety considerations were given major elements in layout configuration development. All layouts are relatively safe; however, there are some differences. Table 4-15 is a summary of crew safety characteristics. Similar layout concepts are grouped under payload headings, and subheadings of LS-RAMs; such as BLH, F, and FBLH.

4.2.3.2.2 Scientific Reponse. The scientific response evaluation addresses only the variables affected by the payload layouts. The functional capability is held constant.

a. Investigator to Subject Access. The human subject relationship to the test conductor is of extreme importance for observations and measurements effectiveness. The measurement and monitoring console must be convenient to him, and the subject must be positioned for easy quick access. The affects of the equipment uitilized by human subjects must be considered. As an example, the rotative litter chair (RLC) can cause considerable disorientation and malaise while the body mass measurement device (BMMD) causes none; therefore the RLC should be close to the test conductor while the BMMD can be somewhat distant (Figure 4-16). Low use equipment items (bicycle orgometer) can be taken from storage and deployed close to the medical/behavioral console. The bicycle ergometer is normally stored under the floor prior to deployment and testing.

   The protective corridor when deployed does not permit biomedical equipment operation. In some cases the deployed corridor inhibits CORE operation, restricting biological and LSPS research operations (refer to Figure 4-26).

b. Equipment Arrangement. Equipment must be arranged to provide efficient operation. This is particularly true of the CORE where several disciplines may use the same unit.

   The characteristics of equipment arrangements for the various layouts are summarized as follows:

   1. Preservation and Preparation (EU4) and Biochemical Biophysics (EU5) should be in the biology compartment for isolation and proximity to maximum samples (refer to Figure 4-26).

Table 4-15. Crew Safety Characteristics

| Evaluation Factors | Maxi Max Payload | | | Lesser Payload | | Comments |
|---|---|---|---|---|---|---|
| | BLH | | F | FBLH | | |
| | See Figure I-47 (Vol III) | See Figure 4-16 | See Figure I-46 (Vol III) | See Figure 4-19 | See Figure 4-25 | |
| Escape Routes<br>Inter Module | Excellent, no obstructions | OK contains 2 hatches. Problems when protective corridor is deployed. (See comment.) | Excellent, no obstructions | OK must go through bio-centrifuge and bulkhead (see Figure 4-20) | OK must go through bio-centrifuge plus hatch | Crew in Biomed area has constrained escape when protective corridor is deployed. |
| Intra Module | Must be docked to main station. | Must be docked to main station. | Must be docked to main station. | N/A | N/A | See Figure 4-24 which shows the 3 LS-RAMs docked direct to the MSS CORE module. This gives minimum escape route, hence max. safety. |
| Emergency Operations<br>Equipment Access | Excellent<br>See comment | Excellent<br>See comment | Excellent | Excellent<br>See comment | Good except<br>See comment | Deployed protective corridor greatly limits equipment access |
| Hatch Operation | Clear. (Probably powered manual override.) | OK. One extra door due to dual orientations. | Clear | Clear | OK except 2 extra doors. | Figure 4-20 extra bulkhead door and must go through Biocentrifuge. |
| Pressure Wall Access | Excellent (with swing out equipment module.)<br>See comment | Excellent (with swing up equipment module.)<br>See comment | Excellent (with swing-up equipment modules.) | Excellent (with swing-up equipment modules.) | Excellent (with swing-out equipment modules.) | Constrained with protective corridor deployed |
| Protective Features<br>Isolation | None (Crew can escape to MSS) | Good 1 extra compartment | None. Can escape to MSS | Holding area isolated by bulkhead or centrifuge.<br>See comments | Holding area isolated by bulkhead or centrifuge.<br>See comments | Bulkheads are not pressurized therefore isolate spills, doors, loose organisms, etc.<br>CORE should be capable of isolation. Bulkheads possible in most cases. |
| Radiation | See comment | See comment | See comment | | | |
| Radiation | See comment | See comment | See comment | See comment | See comment | Knowledge of space radiation effects is insufficient to evaluate this parameter. Space radiation type, flux density, velocities and effect on materials and biomedicals must be determined to provide design criteria |

2. When feasible, an isolation barrier is desirable between the man research area and the biological holding area (refer to Figure 4-19). This is not feasible in the lesser payloads like Mini-7. Isolation is for control of odor, loose organisms, and chemical spills, as well as providing a noise and visual barrier to minimize disturbance of human test subject.

3. Great demands are made on the data management input keyboards and visual displays. These elements of data management should not be localized, but distributed throughout the facility at strategic points. The larger the payload, the more significant this distribution becomes (refer to Figures 4-14 and 4-16). Lesser payloads require fewer keyboards and displays.

4. The remote manipulator control console should be located as far from the docking port as possible to allow clearance for the large external manipulator arms. The requirement is for both video and direct viewing of the remote arms from the control console (refer to Figure 4-26).

5. The behavioral measurements console requires an isolation shroud for specific tests.

6. Primate cylinders were generally arranged to provide a social window between animals (refer to Figure 4-25).

7. The internal bioresearch centrifuge center hatch should be small to minimize noise and vibration and yet be large enough where crew traffic is high, to provide easy access to the various compartments. A central location provides the easy access provision (refer to Volume III, Figure I-54).

c. Organism Orientation. The organisms have a normal orientation with respect to the cage module in a ground environment. This normal orientation must be considered throughout a mission including ground buildup, launch, space flight, reentry and recovery. Figure 4-58 describes the various operational combinations that are considered in evaluating the payload layouts. When a cage module is oriented other than normal, the invertebrates and vertebrates will reorient to the gravity vector causing waste deposition on the cage wall. Substrate medium will flow when cage orientation changes for both cells and tissues, and invertebrates. Plants laying on their sides will respond geotrophically. In short, special design considerations must be given to the cage module gravity orientation.

Table 4-16 summarizes the characteristics associated with the various cage module orientations.

4.2.3.2.3 Crew Operations

Crew Anthropometry. The physical dimensions of the laboratory and its equipment should accommodate the 5th to the 95th percentile crewman. The astronaut or military aviator population is assumed to be representative of the Life Sciences crewman.

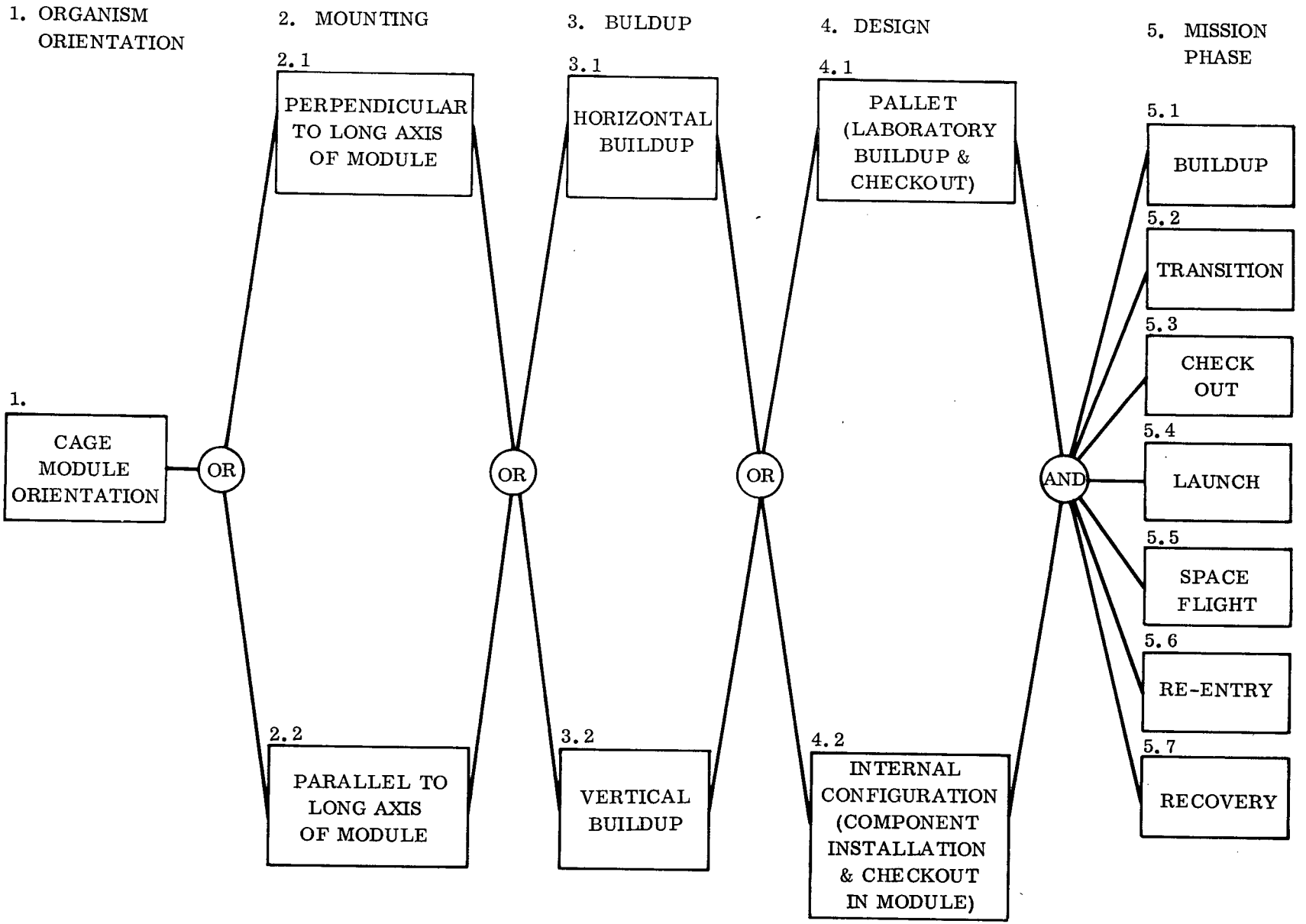



Figure 4-58. Cage Module Orientation Combinations

Table 4-16. Qualitative Cage Orientation Summary

| Operational Combination (Figure 4-58) | 5.1 Buildup | 5.2 Transition | 5.3 System Checkout | 5.4 Launch | 5.5 Space Flight | 5.6 Re-entry | 5.7 Recovery |
|---|---|---|---|---|---|---|---|
| 2.1-3.1-4.1 Figure 4-19 | OK | Problem | Problem | Problem | OK | Depends on "g" vector in shuttle | OK |
| 2.1-3.1-4.2 Figure 4-19 | OK | Problem | Problem | Problem | OK | Depends on "g" vector in shuttle | OK |
| 2.1-3.2-4.1 Figure 4-19 | Problem | Not Required | Problem | Problem | OK | Depends on "g" vector in shuttle | OK |
| 2.1-3.2-4.2 Figure 4-19 | Problem | Not Required | Problem | Problem | OK | Depends on "g" vector in shuttle | OK |
| 2.2-3.1-4.1 Figure 4-25 | OK | OK | OK | OK | OK | Depends on "g" vector in shuttle | Problem |
| 2.2-3.1-4.2 Figure 4-25 | Problem | OK | OK | OK | OK | Depends on "g" vector in shuttle | Problem |
| 2.2-3.2-4.1 Figure 4-25 | OK | Not Required | OK | OK | OK | Depends on "g" vector in shuttle | Problem |
| 2.2-3.2-4.2 Figure 4-25 | Problem | Not Required | OK | OK | OK | Depends on "g" vector in shuttle | Problem |

If civilian scientists, both male and female, U.S. and foreign, are considered potential crew members, a composite population based on the appropriate anthropometric surveys should be developed before the 5th and 95th percentile dimensions are estimated.

Crew Mobility. The choice of a mobility system has a significant impact on concept layout. Since few proposed mobility techniques are space-rated, it is prudent to base the laboratory mobility system on proven techniques (primarily handholds and handrails). But it is advantageous to design the laboratory sufficiently flexible to accommodate as many potential advanced systems as feasible. For example, long distance free-soaring is highly promising for multi-man crews but problematic due to the

potential for injury and/or equipment damage through loss of body control in flight. Figure 4-19 illustrates a laboratory layout that provides a mobility system based primarily on handhold mobility, a grid wall and/or opposing wall (or grid floor and/or ceiling). Yet this laboratory can easily accommodate long distance free-soaring, should it prove practical. It can also accommodate other mobility systems such as; guided soaring (soaring a few feet above the grid surface so that body reorientation and/or minor directional adjustments can be made by reaching out and momentarily grasping the grid); magnetic shoe mobility or shufflers (requires modification of the floor); and pressure walking between opposing floors. Other desirable features of a mobility system for the laboratory include the capability to support simultaneous multi-man mobility in all directions, to any point within the lab (e. g. , behind swing-out modules, etc. ).

Crew Restraint. An appropriate restraint device is necessary at all potential worksites. Ideally, this device should provide the capability of momentary restraint (e. g. , for rapid check reading of instruments on each cage module, etc. ) for longer duration restraint (e. g. , an analysis task at a work bench). The time required to attach and release the restraint, when going from one worksite to another, must be minimal. The grid surface discussed under crew mobility illustrates a system with these qualifications. It has the advantage of serving as a restraint and a mobility device at any point in the laboratory when each crewman is equipped with an "astro-grid" type of shoe.

Cargo Handling. The cargo handling system should allow rapid and efficient transfer of equipment and supplies to all points within the lab. Most of the masses that require movement during the operation of the Life Sciences laboratory are small, and easily handled by the crew with the single or dual-clip body-mount mode. No specific cargo handling system for these masses is anticipated. The exception may be the LFB. Current data on man's cargo handling capability in zero-g, for a mass of this size is conflicting for hand-held transfer, and lacking for the body-mount mode. Although the body-mount mode and normal mobility system is felt to be sufficient, the layouts should be designed to accommodate a cargo transfer system, such as a rail-mounted device, should it prove to be necessary. All of the layouts exhibit this potential with degraded potential for those with compartment partitioning.

Arrangement of Equipment. The equipment items and units should be grouped by functional arrangement, frequency of use, sequence of use, and importance of location principles, and optimum compromises developed when these principles conflict. In general, the equipment items in the layouts discussed herein were grouped by the functional arrangement principle. For example, the biological specimen holding units were grouped, as were the biomedical measurement devices. Modifications were made to satisfy the requirements of the other arrangements principles where necessary. For example, the same layout illustrates the placement of the CORE units between the F and BLH activities to satisfy the frequency of use requirement.

Operational Access to Equipment. All equipment items should be placed within the laboratory with adequate access for its retrieval, deployment, and/or in-place operation by the crew as illustrated in the layouts contained in this report. For example, operations can be conducted within each cage module with the aid of the LFB, including those CMs on the internal centrifuge. Figure 4-23 illustrates how the LFB can interface with each centrifuge CM through an opening in the centrifuge housing.

Maintenance Access to Equipment. Convenient access to all equipment components should be provided for servicing, repair, or replacement. Swing-out consoles were utilized and all layouts provide adequate space for console swing-out and maintenance.

Equipment Deployment. For maximum volume utilization, several of the equipment items in the BLH module should be stowed in a compact configuration and deployed when needed. Figure 4-16 illustrates the use of this technique for the MSI Protective Corridor. The volume-sharing by equipment items requires careful scheduling of the crew operations and additional task time for equipment deployment. The merits of this technique will have to be carefully evaluated during crew timeline development.

Worksite Flexibility. The layouts should allow temporary setup of equipment at a worksite for short duration tasks, or minor payload rearrangements from flight to flight. Equipment restraint at these temporary sites should require minimal crew time to attach and detach. Figure 4-20 is an example of a layout that would use a grid floor to satisfy this requirement. The necessary equipment could be quickly and effectively attached to the floor in whatever equipment grouping is most convenient to the user.

Crew Interactions and Traffic Patterns. The layouts should allow for direct multi-man crews transfer from one worksite in the laboratory to any other, with minimal interference from equipment or other crew members. Circuitous routes created by equipment arrangement, equipment operation, or other crew activity, and bottlenecks such as mid-laboratory hatches should be minimized. Figure 4-19 illustrates a layout with good traffic flow potential for the entire crew.

Visual Communications. Allowances for visual contact between elements (man-equipment or man-man) should be provided when required. For example, in Figure 4-20 the necessary visual biomedical monitoring between the test conductor and the LBNP subject is possible as the test conductor monitors his equipment in the medical monitoring module.

Multi-man Tasks. Clearances and restraint provisions should be provided so that one specialist can assist another on a task. Layouts that allow for only a one man operation at a worksite should be avoided.

Task Interference Potential. Clearances should be provided to minimize the potential for one man's task interferring with another's task. Volume-sharing is a major compromise to this requirement, and its potential for disruptive interference to laboratory operations must be controlled by effective scheduling.

4.2.3.2.4 Design Considerations

LS-RAM Geometric Characteristics. Each of the Life Sciences laboratory layouts has a different length (L)[1], weight (Wt), and volume (V). These different values were influenced by the payload size (i.e., Maxi, Midi, or Mini), and the layout design concepts. The design concepts were: (1) longitudinal (long.) floors; (2) no floors, wafer floors, or combinations of the two; and (3) combinations of concepts (1) and (2).

In concept (1), when equipment was placed outside the normal longitudinal corridor (above and below the floors), improvements in volume utilization resulted. The ability to do this, among other things, is a function of the equipment use factor. Those EM with low use factors can be placed above or below the floors. Further investigation in the form of equipment packaging, equipment module design, and crew operations analysis is required to firmly establish those EMs having a low use factor. Consideration of EM with a low use factor was not used in development of concept (2) configurations, because man has ready access to all EMs in the no floor configuration.

Values of length determined in the study are presented in Table 4-17 for fourteen groups of layouts, five groups for Maxi Max payloads and nine for lesser payloads. Differences in length appear as functions of the layout design concept used, and the payload under consideration. Figure number show groups of similar layouts for reference purposes.

For the BLH portion of the LS-RAM, higher volume utilization results if experiment space is shared among different functions, such as biomedicine and MSI. Sliding hatches applied to concept (2) given improved volume utilization by allowing EMs to be placed next to hatches that would otherwise be taken up by a swinging hatch (refer to Figure I-47 Volume III). The LS-RAM length and weight interact with the modular space station (MSS), the Shuttle as a booster, and the Shuttle used for sortie flights.

The length of all configurations studied for all payloads considered is compatible with the MSS, the Shuttle as a booster, and the Shuttle in sortie flights. Further, the Mini-30 and Mini-7 payloads applied to multipurpose laboratories leave reasonable lengths for other FPEs. Since length for all the concepts and payloads studied is compatible, then the design concepts that feature a high degree of safety, scientific response, flexibility, and crew operations provisions should be pursued.

Access for Maintenance. This design characteristic has been demonstrated in all concepts by providing swing-out, swing-up, or roll-out equipment modules as discussed in Section 4.2.2.

[1] Length of the LS-RAM is that length devoted to LS experiments only, not including the length of support modules such as the common S/S portion of the CM-4 or the RSM.

Table 4-17. Life Science RAM Lengths

| Payloads | Layout Concept | Length M (ft) | Figure References |
|---|---|---|---|
| Maxi Max | | | |
| BLH Module | 1 | 10.20 (33 1/2) | I-48 (Vol III) |
| | 2 | 7.60 (25) | I-49 (Vol III) |
| | 3 | 7.76 (25 1/2) | 4-16 |
| F Module | 1 | 11.00 (36) | I-46 (Vol III) |
| | 2 | 7.60 (25) | 4-14 |
| Maxi Nom | 1 | 13.7 (44.8) | 4-19 |
| | 2 | 10.45 (34.2) | 4-25 |
| Midi-30 | 1 | 12.95 (42.5) | I-58 (Vol III) |
| | 2 | 11.10 (36.5) | I-56 (Vol III) |
| | 3 | 11.55 (38) | I-61 (Vol III) |
| Mini-30 | 1 | 8.25 (27) | 4-29 |
| | 2 | 6.10 (20) | I-63 (Vol III) |
| Mini-7 | 1 | 4.0 (13) | 4-32 |
| | 2 | 4.26 (14) | I-64 (Vol III) |

Potential for "Standard" EMs. All concepts studied show equivalent potential for use of the 2 meter equipment modules described in Section 4.2.2.

Ground Operations. Build-up of LS-RAM on the ground. Concept (1) configuration presents a near optimum arrangement for ground build-up of the LS-RAM if it is accomplished with the LS-RAM horizontal to the ground. Concept (2) would require the use of ladders and scafolds for build-up with the axis vertical. Build-up would be difficult with the axis horizontal. One approach to be considered is the use of pallets that could be built outside, and slipped into any LS-RAM concept.

Loading into the Shuttle. For horizontal loading into the Shuttle bay, concept (1) is satisfactory; however, there is a problem when the Shuttle is erected to the vertical position. For horizontal loading of concept (2), there is a temporary problem in the cage module section, since the cage module would be 90° out of normal orientation for organisms. For vertical loading of concept (2), there is no problem.

Checkout, Launch and Re-entry in the Shuttle. With the Shuttle vertical, some provision must be made in concept (1) to reorient cage modules (CM) from a horizontal to a vertical position. This could be done by gimballing the CMs. This adds to the complexity of the design; thus, the potential for design solution is restricted.

For concept (2), the ground acceleration vector and boost vector are compatible with organism orientation. However, there is a problem if access to the inside of the LS-RAM is required for repair before launch. Possible design solutions are, use of a power pole designed for space use, or wafer floors and the use of ladders for deck to deck transport.

Concept (3) has the same orientation problems found in both concepts (1) and (2). For re-entry, all three concepts require some gimballing provision for cage modules since re-entry g is $\approx 60°$ to the axis of the LS-RAM.

a. The selected configurations will be used as starting points for the Task C integration activity.

b. The nature of the Task C work is expected to be in areas of:

   1. Power - Power required versus power available
   2. Space Station Interface - Proximity to MSS CORE modules, cluster configuration, and Shuttle vehicle docking
   3. Shuttle Vehicle Booster - Payload bay size constraints and boost capability
   4. Multi purpose Laboratory Interface - Shuttle vehicle constraints, LS-RAM portion with other FPEs, allocation of LS-RAM weight, volume and cost, portion and supporting subsystems
   5. Crew Operations Analysis - Time line analysis and traffic pattern
   6. Equipment Packaging - Modularization, installation, and arrangement
   7. Launch Considerations - Payload buildup, orientation, and acceleration vectors
   8. On-orbit Considerations - Build up and modification of payload and return of specimens
   9. Ground Operations - Ground build up of payload, checkout, loading into Shuttle, and orientations
   10. Cost-Effectiveness

c. It will be necessary during Task C to investigate the impact of the above items while:

   1. Maintaining visibility of the full range of Science capability
   2. Maintaining alternate configuration concepts
   3. Developing alternate crew operations systems
   4. Maintaining flexibility in operations analysis

d. In order to accomplish the expected Task C work baseline layouts, the following characteristics must be determined:

1. Annularity and linearity arranged equipment modules
2. Parallel and normal orientation of man to the axis of the LS-RAM
3. Types of floors, partitions, and bulkheads
4. Man mobility and cargo handling systems
5. Organism orientation, and access, and subject access
6. Ground build up launch considerations
7. Acceleration vectors, ground, launch, docking, and re-entry
8. Volumetric utilization efficiency ($\epsilon_V$)
9. Payload fraction (% P/L)
10. Weight and volume total

The baselines selected in accordance with Section 4.1, should contain at least these necessary characteristics.

# SECTION 5

# SUBSYSTEMS

RAM subsystems required to support the Life Sciences payloads include the organism environmental control and life support subsystem (EC/LSS), crew EC/LSS, data management subsystem (DMS), electrical power subsystem (EPS), and thermal control subsystem (TCS). Subsystems for reaction control, propulsion, guidance and navigation, and stability and control were assumed to be provided by the support vehicle. Inherent in this assumption is the current guideline that the Life Sciences RAM will be maneuvered into position and docked to the Space Station by the Shuttle orbiter.

A summary of the subsystem weight, volume and power is given in Table 5-1. For further details, refer to the individual sections. The table is divided into common subsystems and the organism EC/LSS. The separate listing is due to the large requirement imposed by the EC/LSS, and the fact that it is the only subsystem not common to the other FPEs.

## 5.1 ORGANISM ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

5.1.1 REQUIREMENTS AND DESIGN CRITERIA. A substantial amount of effort was devoted to defining basic metabolic requirements for the various organisms in order to study appropriate EC/LSS designs. This data is presented in Section 5.1.3. In summary, the primary EC/LSS loads result from the vertebrate organisms. A summary of vertebrate oxygen consumption and heat output is shown in Table 5-2 for a chimpanzee, monkey, and rat. These three organisms, of the body weights indicated, were used for calculating overall laboratory metabolic loads. Also given are the ratios of the animal oxygen consumption to that of man. These ratios were used to compare the size of the laboratory organism EC/LSS loads to those of man-systems. As an example, the metabolic load of 46 rats is approximately equivalent to that of one man. Hence, the environmental control system (ECS) for 46 rats may be about the size of a one-man ECS.

A summary of organism metabolic loads aboard the baseline payloads is shown in Table 5-3. Also shown are the number of cage modules required. A cage module is a basic holding unit sized for 8 rats, or about 16 dwarf marigolds, it was shown previously in Figure 4-51. As shown in Table 5-3, the Mini-7 payload contains only two cage modules for cells and tissues (C/T), and one cage module each for plants (P) and invertebrates (I). The Mini-30 payload contains 2 Macaque monkeys, 16 rats and 4 cage modules of plants (P), invertebrates (I), and cells and tissues (C/T). The total metabolic load is approximately equivalent to that of 0.84 man. The total load

## Table 5-1. Summary of Subsystem Weight, Volume and Power*

| SUBSYSTEMS | MINI-7 | | | MINI-30 | | | MAXI-NOM | | | MAXI-MAX | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WT kg (lb) | VOL $m^3$ ($ft^3$) | POWER kwatts | WT kg (lb) | VOL $m^3$ ($ft^3$) | POWER kwatts | WT kg (lb) | VOL $m^3$ ($ft^3$) | POWER kwatts | WT kg (lb) | VOL $m^3$ ($ft^3$) | POWER kwatts |
| COMMON SUBSYSTEMS: | | | | | | | | | | | | |
| CREW EC/LSS | 70 (164) | 0.41 (15) | 0.25 | 70 (164) | 0.41 (15) | 0.25 | 208 (460) | 0.65 (23) | 0.72 | 511 (1130) | 1.68 (60) | 1.72 |
| DATA MANAGEMENT | 151 (333) | 0.33 (11.7) | 1.10 | 306 (675) | 0.67 (23.7) | 2.22 | 513 (1132) | 1.08 (38.1) | 3.52 | 739 (1630) | 1.60 (56.3) | 5.01 |
| ELECTRICAL POWER | 79 (174) | 0.09 (3.3) | -- | 123 (270) | 0.14 (5.1) | -- | 277 (611) | 0.32 (11.5) | -- | 549 (1208) | 0.64 (22.6) | -- |
| THERMAL CONTROL | 274 (603) | 1.05 (37) | 0.12 | 356 (783) | 1.64 (58) | 0.16 | 926 (2037) | 3.82 (135) | 0.43 | 1897 (4173) | 9.13 (322) | 0.89 |
| SUBTOTALS | 574 (1274) | 1.88 (67) | 1.47 | 855 (1892) | 2.86 (102) | 2.63 | 1924 (4240) | 5.87 (208) | 4.67 | 3696 (8141) | 13.05 (461) | 7.62 |
| ORGANISM EC/LSS | 17 (38) | 0.03 (0.9) | 0.06 | 176 (388) | 0.25 (8.5) | 0.14 | 660 (1450) | 1.89 (66.8) | 1.83 | 1950 (4290) | 5.6 (197) | 6.34 |
| TOTALS | 591 (1312) | 1.91 (68) | 1.53 | 1031 (2280) | 3.11 (111) | 2.77 | 2584 (5690) | 7.76 (275) | 6.50 | 5646 (12431) | 18.65 (658) | 13.96 |

*Excluding consumables (see Section 4.1).

Table 5-2. Summary of Preliminary Design Metabolic Data for Vertebrates

| Organism | Body Wt. KG (lbs) | $O_2$ Consumption KG/day (lb/day) | $O_2$ Consumption Animals Man | Heat Output K Joules/day Kcal/day | Heat Output Animals Man |
|---|---|---|---|---|---|
| Astronaut | 72 (158) | 0.84 (1.84) | 1.0 | 11,900 (2830) | 1.0 |
| Chimpanzee | 18.2 (40) | 0.38 (0.83) | 2.2 | 4340 (1036) | 2.7 |
| Monkey | 9.1 (20) | 0.20 (0.45) | 4.1 | 2560 (610) | 4.6 |
| Rat | 0.35 (.77) | 0.018 (0.040) | 46.3 | 230 (55) | 51.8 |

in the Maxi Nom payload is equivalent to 3.25 men and that in Maxi Max is equivalent to 12.9 men. The Maxi Nom payload and Maxi Max payload contain 28 and 96 cage modules, respectively. As indicated in Table 5-3, half of the organisms aboard the Maxi Max laboratory are in the research centrifuge module.

Table 5-4 shows a weight summary of estimated consumables aboard the various payloads. In addition to the food, water and oxygen requirements, the weight of LiOH which would be necessary to remove all the $CO_2$ generated is indicated. Consumable oxygen and LiOH requirements were large enough on the Maxi payloads to warrant the use of oxygen regeneration equipment. Water purification systems were selected for the Mini-30 as well as the Maxi payloads.

The general environmental conditions to which the ECS was designed are indicated below:

a. Cage module atmospheric pressure = 101 $kN/m^2$ (14.7 psia)

b. Temperature (vertebrates) = 297° K (75° F)

c. Temperature (cells/tissues) = 278-333° K (5-60° C)

d. Standard air $O_2/N_2$ composition

e. $CO_2$ partial pressure = 400 $N/m^2$ (3.0 mm Hg)

The EC/LSS for the organisms was designed to be consistent with the philosophy of isolation from the crew compartments of the Life Sciences laboratories. Hence, a

Table 5-3. Summary of Organism Loads Aboard The Life Sciences Laboratories

| Laboratory | Mission | Organism Load | | | | |
|---|---|---|---|---|---|---|
| | | Type | On Board | Man Equivalent | Total Man Equivalent | No. of Cage Modules |
| Mini-7 | 7-day shuttle (sortie) | Monkeys | 0 | 0 | | - |
| | | Rats | 0 | 0 | | 0 |
| | | P,I, C/T* | All*** | Negl. | Negl. | 4 |
| Mini-30 | 30-day shuttle (sortie) | Monkeys | 2 | 0.49 | | - |
| | | Rats | 16 | 0.35 | 0.84 | 2 } 6 |
| | | P,I, C/T | All | Negl. | | 4 } |
| Maxi Nom | 2 year space station, 90 day resupply | Monkeys | 2 | 0.49 | | - |
| | | Rats | 128 | 2.76 | 3.25 | 16 } 28 |
| | | P,I, C/T | All | Negl. | | 12 } |
| Maxi Max | 5 year space station, 90 day resupply | Chimps | 2** | 0.90 | | - |
| | | Monkeys | 4** | 0.98 | | - |
| | | Rats | 512** | 11.06 | 12.9 | 64 } 96** |
| | | P,I, C/T | All** | Negl. | | 32 } |

*P = Plants, I = Invertebrates, C/T = Cells and Tissues

**No. of Organisms and Cage Modules are Divided Equally Between 0-g Laboratory and Research

***All indicates that there are some P,I, and C/T on each laboratory

Table 5-4. Summary of Required Vertebrate Consumables Aboard the Life Sciences Laboratories

| Laboratory | Vertebrate Load | Mission Consumables, kg (lbs) | | | |
|---|---|---|---|---|---|
| | | Food | Drinking Water | $O_2$ | LiOH (If Used) |
| Mini-7 | 0 | 0 | 0 | 0 | 0 |
| Mini-30 | 2 Monkeys<br>16 Rats | 18 (40) | 54 (118) | 21 (46) | 33 (72) |
| Maxi-Nom (Consumables for 90 Days) | 2 Monkeys<br>128 Rats | 177 (389) | 600 (1320) | 045 (539) | 382 (840) |
| Maxi-Max (90 Days) | 2 Chimps<br>4 Monkeys<br>512 Rats | 701 (1543) | 2380 (5240) | 973 (2140) | 1520 (3340) |

separate EC/LSS for the organisms is provided and, for crew safety, it is intended to operate at a slightly negative pressure with respect to the cabin. Thus, any leakage and contamination will be from the crew compartment into the organism ECS. The crew and organism ECS each contain contaminant removal equipment for the control of any cross-contamination that does occur; however, the isolation will minimize the amount of cross flow. The isolation serves a second purpose in that the organism ECS air will not be lost in the event of an emergency or accidental cabin decompression. Thus, a laboratory wall puncture will not kill the organisms.

In addition to isolation required between the crew and the organisms, isolation between groups of organisms is required. This is done by providing local separate ECS loops for each two cage modules and for each primate cage. A small amount of air is processed centrally and therefore mixed with air from all other holding units, this air is sterilized before redistribution to the local ECS loops.

5.1.2 BASELINE ORGANISM EC/LSS DESCRIPTION. A summary of the weight, volume, and power characteristics of the Life Sciences laboratories is given in Table 5-5. The Mini-7 EC/LSS consists of a simple ventilation and dehumidification loop with LiOH for $CO_2$ removal, high pressure stored oxygen and stored water. The Mini-30 system is similar except that water is purified for re-use. For the short duration Mini flights, food supplies and wastes can be handled with the cage module, and no external transport or storage equipment is required. Both Maxi laboratories have water purification and oxygen regeneration systems. External storage is provided for food and water.

5.1.2.1 Maxi Max Laboratory Organism EC/LSS. The organism EC/LSS in this laboratory must support and equivalent load of 12.9 men divided equally between the research centrifuge and the zero g module. The 12.9 men load and resulting weight of consumables, shown in Table 5-4, justify the use of equipment for water reclamation and oxygen regeneration. In order to avoid the duplication of this complex equipment aboard the centrifuge, a single central processing system has been placed aboard the zero g laboratory. Thus, air and water from the organisms aboard the centrifuge must be transferred to the zero g laboratory for processing. Placing the central processing equipment aboard the zero g laboratory will allow for operation of this laboratory before the centrifuge becomes operational. Also, the system will not be perturbed by the stoppage of the centrifuge, or any changes in angular velocities.

A flow diagram of the Maxi Max ECS and water purification concept is shown in Figure 5-1. The ECS is divided into: (1) local loops that provide ventilating air flow, temperature, control, dehumidification and contaminant filtration; and (2) the central processing loop providing CO2 removal, oxygen replenishment, and contaminant oxidation. This system provides atmospheric contamination isolation between groups of organisms, by means of the separate local ECS loops. The use of the central processing system eliminates the duplication of the more complicated components. Air flowing to the central system is sterilized before returning to the organisms, thus preventing cross-contamination by micro-organisms.

Table 5-5. Organism EC/LSS Weight, Power, and Volume Summary

| Payload | Weight, kg (lb) | | Volume, $m^3$ ($ft^3$) | | Power (Watts) |
|---|---|---|---|---|---|
| | Fixed | Consumable Per 90 Days | Fixed | Consumable Per 90 Days | |
| 1. Mini-7 (4 Cage Modules, Stored $0_2$, LiOH) | 17 (38) | * | 0.03 (0.9) | * | 63 |
| 2. Mini-30 (6 Cage Modules, 2 Macaques, Stored $0_2$, LiOH, Water Purification) | 176 (388) | * | 0.25 (8.5) | * | 138 |
| 3. Maxi Nom (28 Cage Modules, 2 Macaques, $0_2$ and Water Reclamation) | 660 (1450) | 334 (734) | 1.89 (66.8) | 0.60 (21.3) | 1830 |
| 4. Maxi Max (96 Cage Modules, 6 Primates, $0_2$ and Water Reclamation) | 1950 (4290) | 1370 (3000) | 5.6 (197) | 2.37 (83) | 6340 |

*Contained in Fixed Values

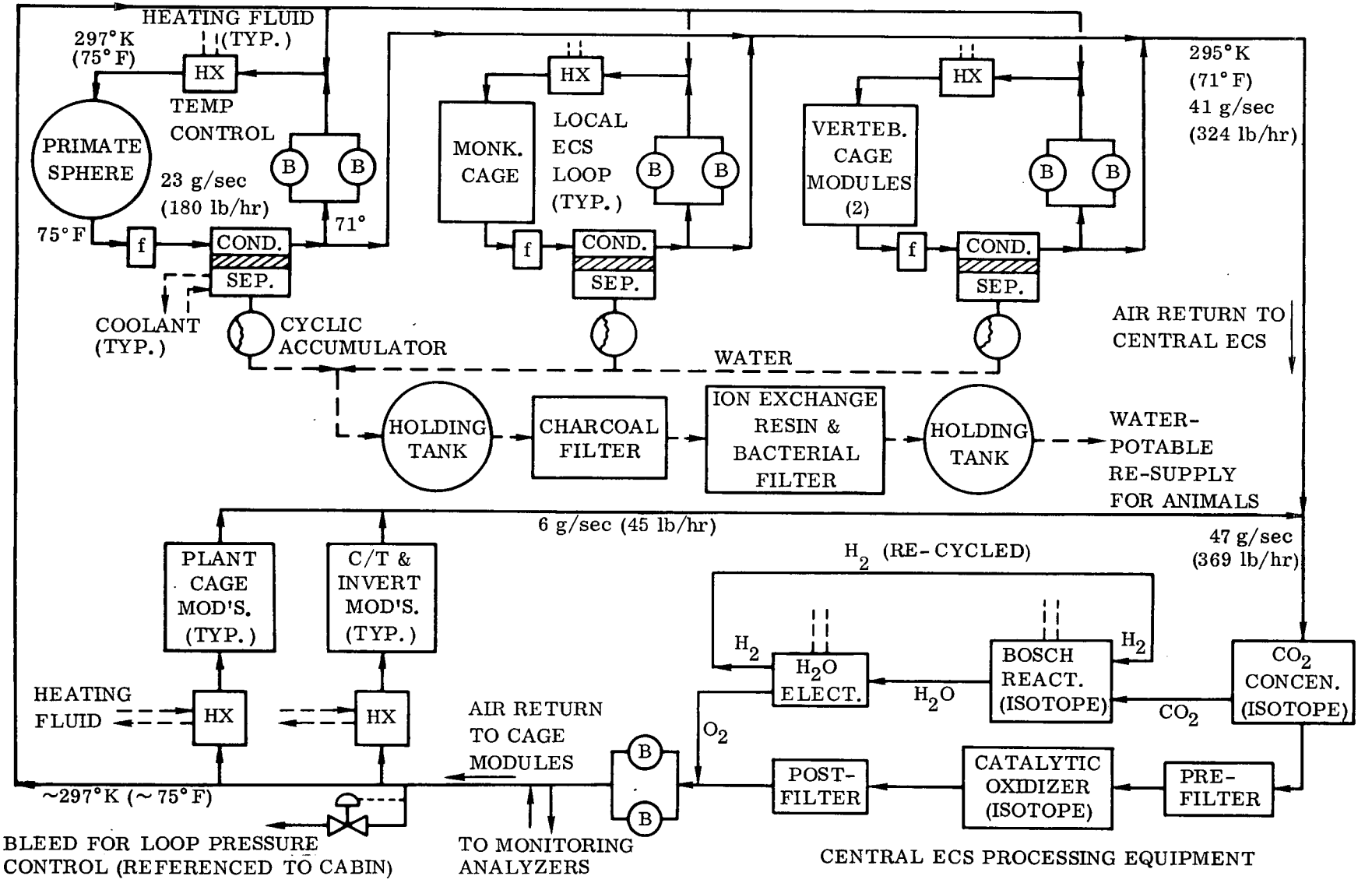



Figure 5-1. Preliminary ECS for Maxi Max Biolaboratory Organisms

The local ECS loops are designed to support 16 rats (2 cage modules), 2 Macaques, or 1 chimpanzee. These common loops may also be used for the other maxi and mini laboratories with minor modifications. The flow rate through the local loops is 23g/sec (180 lb/hr) of which approximately 1.1g/sec (9 lb/hr) is bled off to the central ECS for processing. The local loops contain activated charcoal filters for gaseous contaminant removal combined with particulate filters for debris removal. These filters are downstream of urine and fecal pad filters within each cage which also provide a degree of particulate filtration. These pads may also be treated with chemicals to provide some absorption of gaseous contaminants such as ammonia. Downstream from the charcoal filter, a condenser/separator with a by-pass control removes water vapor emanating from respiration, perspiration, urine evaporation, and fecal drying. Blowers provide recirculation of the ventilation air and are located to minimize the pressure differential between the cage modules and the cabin and yet maintain the cage module loop pressure negative with respect to the cabin. This is discussed in further detail in Section 5.1.3.3. The heat exchanger heater provides the temperature control of the cage module.

The central ECS processes approximately 41 g/sec (324 lb/hr) of air from the local loops. It contains blowers, a steam desorbed resin $CO_2$ concentrator, a Bosch reactor, a gas circulation water electrolysis unit, a catalytic oxidizer, and filters. These components represent concepts that are currently being considered for oxygen reclamation aboard advanced spacecraft. Later changes in these recommendations (such as the use of the $H_2$ depolarized cell concept for $CO_2$ concentration) are not expected to significantly alter the preliminary descriptions and parameters presented herein.

In the central ECS, air first passes through the $CO_2$ concentrator and then through the catalytic oxidizer to ensure complete sterilization of the air returning to the organisms. Both the concentrator and the oxidizer were assumed to use isotope heaters in order to conserve electrical power. The oxidizer pre-filter removes contaminants which could possibly poison the catalyst, and the post filter removes possible harmful products of the oxidation process. Both filters contain lithium carbonate. The $CO_2$ removed from the air stream in the concentrator passes to the Bosch reactor where it reacts with $H_2$ to form graphitic carbon and water. The water is electrolyzed to produce oxygen for reuse and hydrogen which is returned to the Bosch unit for reaction with more $CO_2$. The graphitic carbon formed as a by-product, is stored for later return to earth. This carbon may be usable for filtration functions aboard the spacecraft, but this capability has not yet been verified, and no weight or volume was credited to the Bosch system for this potential.

Air from the central ECS flows to the plant, invertebrate and cells/tissues modules, where it passes directly through these modules and returns to the central ECS. The flow required by these organisms and the resulting load on the central system is so low, that separate circulation loops around these cage modules are not needed. Temperature control of the inlet air to these modules is provided by the heat exchangers.

Although the inlet air could be heated to high temperatures, the low flow rate through the incubator modules will probably not be enough to make up for heat losses from the modules to the surroundings. Hence, internal heaters may be required to maintain the high operating temperatures in the incubators (see Section 5.1.2.4). These heaters were not considered to be a part of the EC/LSS. Although the air from the plant modules may be quite humid, it should not present a condensation problem. The higher air flows from the vertebrate ECS loops will be relatively dry, and will be mixed with the humid air before it enters the steam desorbed resin $CO_2$ concentrator. This unit is not adversely affected by processing humid air.

The central EC/LSS also includes a multifiltration water purification system. A filtration system is recommended because of its simplicity, and the relatively clean water to be processed. This water has essentially undergone a moderate temperature air evaporation purification process in the vertebrate cage module loops. Hence, the central filtration system functions essentially as a post treatment system, and the consumables are estimated to be quite low. The weight of the system was based on a similar system for processing humidified condensate to produce potable water. (See Section 5.2.) The system consists of pre-treatment and post-treatment holding tanks, charcoal filters, an ion exchange resin bed, and bacterial filters.

A weight, power, and volume breakdown for the Maxi Max organism EC/LSS is given in Table 5-6. In order to minimize electrical power requirements, isotope heat was assumed for the $CO_2$ concentrator, Bosch reactor, and catalytic oxidizer. The isotope power requirements are indicated in the table. Isotope heaters require special equipment such as shielding, jettisoning devices, and accidental re-entry protection. Weight and volume penalties of 55 kg/kw (120 lb/kw) and 0.03 $m^3$/kw (1.2 $ft^3$/kw) were used to cover these extra equipment requirements. They are included in the component weight and volume. The major items within the central ECS also include an estimated weight and volume provision for spares and/or redundancy to cover one year's operation.

The waste management equipment within the EC/LSS of the Maxi Max laboratory consists only of storage containers since the waste processing operations are an integral part of the experiment procedures. In order to preserve the atmospheric isolation between the cabin and the organisms, manned attendance is accomplished by means of a laminar flow bench. This device will be used to remove the metabolic wastes from the organism cages. The collected wastes will be sterilized along with the laminar flow bench liner, using the laboratory sterilizers. Following sterilization, the metabolic wastes will be compacted and stored in containers for subsequent transport to ground.

Leakage makeup gas for the organism ECS loops should not be needed because of their negative pressure with respect to the cabin. In fact, this leakage will require that some air be continually bled from the loop to the cabin to maintain the negative pressure. This can be done downstream of the catalytic oxidizer post filter to obtain

Table 5-6. Preliminary Organism EC/LSS Weight, Power, and Volume for the Maxi Max Laboratory Modules

| Item | Weight kg, (lb) | | Volume, $m^3$ ($ft^3$) | | Average Electrical Power (Watts) | Isotope Heat (Watts) |
|---|---|---|---|---|---|---|
| | Fixed | Consumable | Fixed | Consumable | | |
| I. Central ECS and $0_2$ Reclamation | | | | | | |
| Steam Desorbed Resin $CO_2$ Concentrator | 416(916) | 0 | 1.37(48.5) | 0 | 0 | 2500 |
| Bosch Reduction Unit | 160(351) | 59(130) | 0.65(23.0) | 1.29(45.4) | 550 | 150 |
| $H_2O$ Electrolysis Unit | 163(359) | 0 | 0.37(12.9) | 0 | 660 | 0 |
| Catalytic Oxidizer & Contaminant Filters | 285(627) | 85(186) | 0.54(19.2) | 0.24 (8.6) | 2910 | 3300 |
| Ducting, Structure, Blowers, Etc. | 145(318) | 0 | 0.28(10.0) | 0 | 150 | |
| Subtotals | 1169(2571) | 144(316) | 3.21(113.6) | 1.53(54.0) | 4275 | 5950 |
| II. Cage Module ECS Loops | | | | | | |
| 64 Vertebrate Cage Modules | 305(672) | 266(585) | 0.41(14.5) | 0.66(23.4) | 1280 | 0 |
| 6 Primate Cage Loops | 47(104) | 5 (12) | 0.03(1.0) | 0.01(0.1) | 200 | 0 |
| 9 Loops for P,I, C/T | 109(239) | 12(27) | 0.14(4.8) | 0.01(0.3) | 567 | 0 |
| Subtotals | 461(1015) | 283(624) | 0.58(20.3) | 0.68(23.8) | 2047 | 0 |
| III. Water Multifitration | 80(176) | 55(120) | 0.24(8.5) | 0.11(4.0) | 10 | 0 |
| IV. Waste Storage & Transfer Equipment | 127(280) | 25(55) | 0.85(30.0) | 0.05(1.6) | 10 | 0 |
| V. Food Storage & Transfer Equipment | 112(246) | 858(1888) | 0.71(25) | 0 | 0 | 0 |
| Totals | 1949(4288) | 1365(3003) | 5.59(197.4) | 2.37(83.4) | 6342 | 5950 |

sterile air. Since the organism ECS is contained within the pressurized module, the net gas leakage to space should be negligible. Any leakage that does occur will do so through the processing units such as the Bosch reactor; however, these quantities cannot be determined at this time.

5.1.2.2 Maxi Nom Laboratory Organism EC/LSS. This EC/LSS must support the equivalent of 3.25 men for 2 years with 90-day resupply. The system adopted, is basically the same as for the Maxi Max laboratory. Thus, the schematic shown in Figure 5-1 applys, except that there are fewer cage module loops, and the flow to the central ECS is lower. The components in the central ECS would therefore be smaller. Four of the vertebrate cage module loops are on the internal centrifuge and are connected to the central processing components by means of air and fluid rotation couplings. The weight, power, volume, and heat requirements of the Maxi Nom organism EC/LSS is given in Table 5-7.

5.1.2.3 Mini 30 Laboratory Organism EC/LSS. This laboratory has a vertebrate metabolic load of 16 rats and 2 macaques (equivalent to 0.84 man), and a relatively short mission duration of 30 days. Hence, a non-regenerative type ECS, with LiOH for $CO_2$ removal, and stored high pressure oxygen was used. A flow schematic of the ECS is shown in Figure 5-2, and the weight, power and volume are given in Table 5-8.

The ECS loop is very similar to the local loops used in the Maxi laboratories with the exceptions that LiOH is added, air is not bled off to a central ECS, and oxygen is added to the loop air as it is consumed. Any buildup in loop pressure due to leakage from the cabin will be bled to the supporting spacecraft (RSM) contaminant removal system. A simplified water purification system has been included because of the relatively large amount of water, 54 kg (118 lbs), required by the organisms. This system could be manually operated on a batch basis. It contains charcoal, ion exchange resin, and bacterial filters.

In addition to the vertebrate loops, an ECS loop is included to provide ventilation air to four cage modules containing plants, invertebrates, and cells/tissues. This is similar to the vertebrate ECS loops and is described in the next section.

5.1.2.4 Mini-7 Laboratory Organism EC/LSS. This payload does not contain any vertebrates. The load consists of one plant cage module, one invertebrate cage module, and two cells/tissues cage module, see Figure 5-3. The metabolic oxygen and carbon dioxide exchange rates are expected to be quite low, and thus the air circulation requirements are low. In the plant cage module, air flow is restricted to a value that will not introduce plant motion which may tend to induce acceleration forces in excess of $10^{-5}$g. A ventilation flow rate of 0.108 to 0.17 g/sec (0.2 to 0.3 cfm) was selected for each cage module. This low flow introduces a problem of heating the cells/tissues cage modules by means of the air flowing through the modules. These modules operate at temperatures above atmospheric and will dissipate more heat to the surrounding cabin than can be provided by the air at reasonable

Table 5-7. Preliminary Organism EC/LSS Weight, Power, and Volume for the Maxi Nom Laboratory Module

| Item | Weight, kg (lb) | | Volume, $m^3$ ($ft^3$) | | Average Electrical Power (Watts) | Isotope Heat (Watts) |
|---|---|---|---|---|---|---|
| | Fixed | Consumable | Fixed | Consumable | | |
| I. Control ECS and $0_2$ Reclamation | | | | | | |
| Steam Desorbed Resin $CO_2$ Concentrator | 167(367) | 0 | 0.55(19.4) | 0 | 220 | 1000 |
| Bosch Reduction Unit | 64(140) | 15(33) | 0.26(9.1) | 0.32(11.4) | 264 | 300 |
| $H_2O$ Electrolysis Unit | 65(143) | 0 | 0.14(5.1) | 0 | 730 | 0 |
| Catalytic Oxidizer & Contaminant Filters | 102(108) | 25(56) | 0.19(6.2) | 0.07(2.6) | | 1000 |
| Ducting, Structure, Blowers, Etc. | 50(110) | 0 | 0.15(5.2) | 0 | 50 | 0 |
| Subtotals | 448(985) | 40(89) | 1.29(45.6) | 0.39(14.0) | 1264 | 2300 |
| II. Cage Module ECS Loops | | | | | | |
| 16 Vertebrate Cage Modules | 76(168) | 67(147) | 0.06(2.2) | 0.17(6.0) | 320 | 0 |
| 2 Macaque Cage Modules | 12(26) | 0 | 0.01(0.3) | 0 | 50 | 0 |
| 4 Loops for P,I, C/T | 36(80) | 0 | 0.05(1.6) | 0 | 189 | 0 |
| Subtotals | 124(274) | 67(147) | 0.12(4.1) | 0.17(6.0) | 559 | 0 |
| III. Water Multifiltration Unit | 20(44) | 14(30) | 0.03(1.1) | 0.03(1.0) | 0 | 0 |
| IV. Waste Storage & Transfer Equipment | 48(105) | 7(16) | 0.25(9.0) | 0.01(0.3) | 5 | 0 |
| V. Food and Food Storage | 20(45) | 206(452) | 0.20(7.0) | 0 | 0 | 0 |
| Totals | 660(1453) | 334(734) | 1.89(66.8) | 0.60(21.3) | 1828 | 2300 |

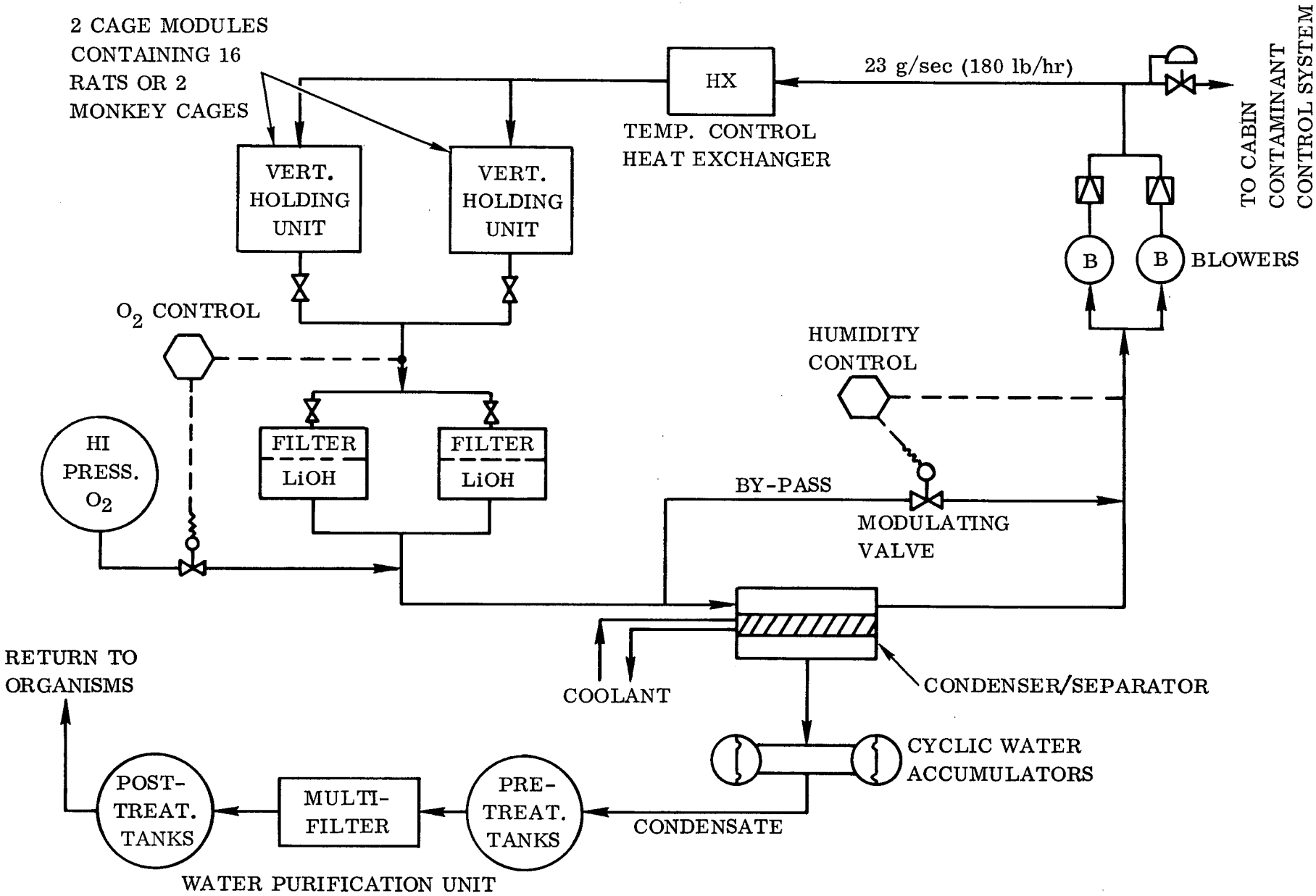



Figure 5-2. ECS Loop Concept for Vertebrate Holding Units Aboard Mini-30 (3 Loops Required)

Table 5-8. Preliminary Organism EC/LSS Weight, Power and Volume for the Mini Laboratory Modules

| MINI-LABORATORIES | WEIGHT kg (lbs) | VOLUME $m^3$ ($ft^3$) | AVERAGE ELECTRICAL POWER (WATTS) |
|---|---|---|---|
| A MINI - 7 | | | |
| ECS Loop for P, I, C/T, Water Tank, High Pressure $O_2$ Supply | 17 (38) | 0.03 (0.9) | 63 |
| B MINI - 30 | | | |
| P, I, C/T ECS Loop | 17 (38) | 0.03 (0.9) | 63 |
| Small Vertebrate ECS Loop (16 rats) | 61 (134) | 0.08 (2.9) | 25 |
| Primate ECS Loops (2 macaques) | 75 (164) | 0.11 (3.8) | 50 |
| Food | 15 (34) | 0.01 (0.4) | |
| Water Purification System | 9 (19) | 0.01 (0.5) | |
| Totals | 177 (389) | 0.24 (8.5) | 138 |

inlet temperatures. One solution would be for the modules to contain integral radiant heaters to maintain the internal temperatures and compensate for heat losses.

As indicated in Figure 5-3, oxygen is supplied from high pressure storage. Estimates of respiration rates of the organisms indicate that the plants will not produce more oxygen than the other organisms will consume. Thus, a small amount of net oxygen will be required. Carbon dioxide will be maintained at less than 400 $N/m^2$ (3 mm Hg) partial pressure by the LiOH. In addition to the LiOH for $CO_2$ removal, chemical activated charcoal, and bacterial filters will be used to remove contaminants before the mixed air is returned to the individual modules. The filters, blowers, and other pressure drop components are located so as to produce minimum pressure differentials between the cabin and the ECS loop, and yet maintain the loop negative with respect to the cabin, (see Section 5.1.3.3). Excess gas buildup will be vented to the cabin contaminant control units.

It has been assumed that humidity will generally increase in the loop, and a condenser has been included to dehumidify the air. Individual cage module humidity levels will not be controllable, except by adjusting air flow rates. In order to minimize water losses in the plant module, the root media should probably be enclosed to prevent excessive evaporation. The condensate which does accumulate will be stored or

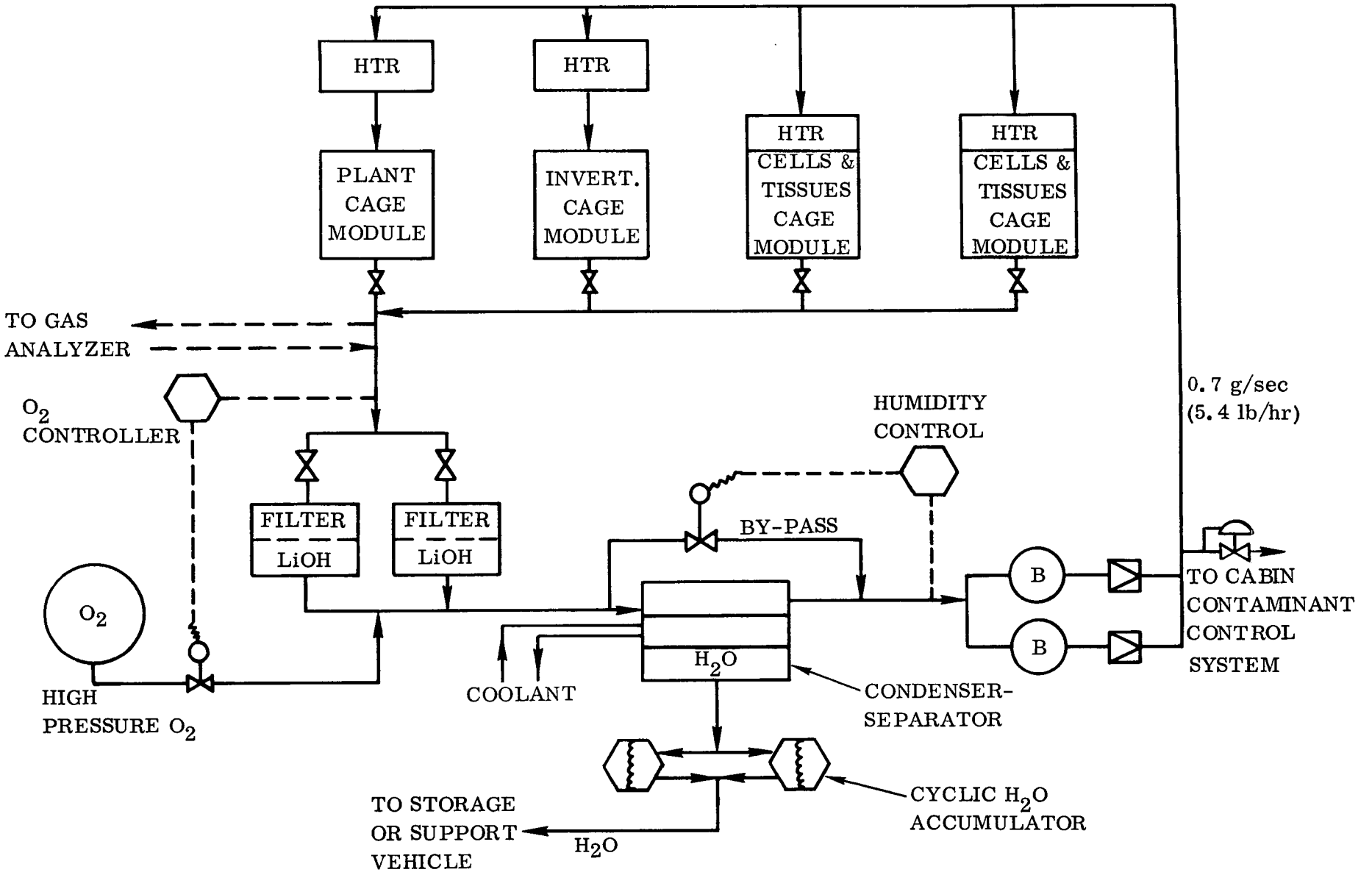



Figure 5-3. ECS Loop Concept for Mini-7 Organisms

fed to the supporting RSM for use or jettisoning. The weight, power, and volume estimates for the Mini-7 organism EC/LSS is shown in Table 5-8.

5.1.3 SUPPORTING DATA AND ANALYSIS. This section contains some of the background data and analyses that was used in the study of the organism EC/LSSs. Information which may be useful in future studies has been included.

5.1.3.1 Organism Metabolic Data. Complete metabolic data is necessary for the EC/LSS design. The data that was used is presented herein, but is not considered final. It is based on the available data from References 17, 18, and 19, and only represents approximate values. (References are listed in Section 7.)

Estimates were used where data could not be found. Verification and updating of the data presented are recommended for future studies.

Vertebrate metabolic data is presented in Tables 5-9 and 5-10. Although data for a number of organisms is included, an 18.2 kg (40 lb) chimpanzee, a 9.1 kg (20 lb) monkey, and a 0.35 kg rat were used as the basis for all EC/LSS load calculations. The 0.35 kg rat is quite large but was used to obtain conservative EC/LSS properties. Nominal design load would probably correspond to about a 0.25 kg animal. All the metabolic values in the tables are applicable only to the body weights indicated. In many cases, they were derived from data for different body weights than those shown. For such cases, the metabolic values were scaled by the ratio of body weights taken

Table 5-9. Preliminary Vertebrate Design Metabolic Data

| Organism | Body Weight | $O_2$ Consumption | | Heat Output (Nominal Design) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | | | Latent | Sensible | |
| | kg (lb.) | mg/sec. | (lb./day) | Animals per Man | joule/sec. | (Btu/hr.) | Animals per Man | joule/sec. (Btu/hr.) | joule/sec. (Btu/hr.) |
| 1. Astronaut (for reference) | 72 (158) | 9.66 | (1.84) | 1.0 | 138 | (467) | 1.0 | 38.7 (132) | 98.3 (335) |
| 2. *Chimpanzee, pantroglodytes | 18.2 (40) | 4.35 | (0.828) | 2.24 | 50.4 | (171) | 2.73 | 15.0** (51.3) | 35.1 (120) |
| 3. *Monkey, m. rhesus | 9.1 (20) | 2.38 | (0.453) | 4.1 | 29.6 | (101) | 4.62 | 5.62 (19.1) | 24.0 (82) |
| 4. Rabbit, european, oryctolagus cuniculus | 3.5 (7.7) | 0.971 | (0.185) | 9.95 | 13.0 | (44.1) | 10.6 | 5.04 (17.2) | 7.89 (26.9) |
| 5. Marmot, marmota sp. | 1.0 (2.2) | 0.318 | (0.0605) | 30.4 | -- | | -- | -- -- | -- -- |
| 6. Guinea Pig, cavea porcellus | 0.5 (1.1) | 0.163 | (0.031) | 59.4 | 3.27 | (11.1) | 42.1 | 0.97** (3.3) | 2.29 (7.8) |
| 7. *Rat, norwegian, rattus norvegicus | 0.35 (0.77) | 0.208 | (0.0397) | 46.3 | 2.66 | (9.02) | 51.8 | 0.86 (3.0) | 1.77 (6.0) |
| 8. Hampster, golden | 0.10 (0.22) | 0.115 | (0.0219) | 84.0 | -- | | -- | -- -- | -- -- |
| 9. Mouse, house, mus musculus | 0.021 (0.046) | 0.029 | (0.0056) | 329 | 0.288 | (0.98) | 477 | 0.093 (0.32) | 0.194 (0.66) |

*These organisms were used as the basis for load calculations.
**Assigned 30 percent of total heat output.

to the exponent 0.75, Reference 19. Both oxygen consumption and heat output are given in Table 5-9, and the number of animals giving an equivalent load to that of one man are included for comparison. Latent heat output was calculated in one of two ways. If the respiration and perspiration water output weight were known, the corresponding heat output was calculated by using 2.44 M joules/kg (1050 Btu/lb). If the water output data were not available, 30% of the total heat output was assumed to be latent.

Table 5-10 gives estimated food, water balance, and feces data for various organisms. The rat food consumption was obtained from Reference 17 and the monkey food consumption from Reference 20. The chimpanzee food consumption was estimated based on the values for the monkey. This particular food is in the form of a dry, dense pellet, and was chosen for its suitability for spaceflight application. The feces weights in Table 5-10 were estimated by taking 25% of the dry food consumed. Water balance data were taken from References 17 and 18. Drinking water was taken to equal total consumption, and turnover was taken to equal total output, which equals urine plus respiration plus perspiration plus fecal water. The difference between turnover and total consumption equals water of oxidation. Fecal water was estimated by assuming it amounted to 5% of total consumption.

In addition to the vertebrates, the biolaboratory contains plants, invertebrates, and cells and tissues. The oxygen consumption of these organisms was investigated to

Table 5-10. Estimated Vertebrate Food, and Water Data

| Organism | Body Weight kg (lb.) | Dry Food Consumption g/day | Dry Food Consumption cc/day | Water Balance: Drink* g/day | Water Balance: Urine g/day | Water Balance: Turnover g/day | Water Balance: Perspir. & Respir. g/day | Water Balance: Fecal Water g/day | Feces Produced ** g/day |
|---|---|---|---|---|---|---|---|---|---|
| Astronaut | 72 (158) | | | 2810 | 1580 | 2950 | 1378 | | |
| Chimpanzee | 18.2 (40) | 257 | 184 | 963 | 634 | 1070 | 390*** | 48 | 64 |
| Monkey | 9.1 (20) | 153 | 110 | 546 | 413 | 639 | 199 | 27 | 38 |
| Rabbit | 3.5 (7.7) | | | 400 | 262 | 460 | 178 | 20 | |
| Guinea Pig | 0.5 (1.1) | | | 71 | | 83 | 25*** | | |
| Rat | 0.35 (0.77) | 13 | 9.3 | 44 | 18 | 52 | 31 | 2.2 | 3.3 |
| Hampster | 0.10 (0.22) | | | 17 | | 20 | | | |
| Mouse | 0.021 (0.046) | | | 2.1 | 0.90 | 4.3 | 3.3 | 0.11 | |

* Drinking water taken to equal total water consumed
** Calculation by assuming 25% of dry food consumption
*** Based on latent heat output assumed to be 30% of total heat. (Table 5-9)

determine whether they impose a significant load on the environmental control system (ECS). In general, they do not, and the data which indicate this are shown in Table 5-11 and discussed below. All metabolic data was obtained from Reference 17. No data was found on the respiration rates of dwarf marigolds. Therefore, the respiration rate of a sunflower was used to get an order of magnitude estimate. The value for carbon dioxide consumption was given as 57 $\mu$l/100 mg dry weight per hour. Using this value and an estimated plant dry weight of 5 grams gives a $CO_2$ consumption value of 0.134 g/day. Assuming 16 plants in each cage module gives 2.14 g/day. Further, assuming a respiratory quotient of 1.0 gives a value of 1.56 g/day of $O_2$ produced. These values are included in Table 5-11. Note that the values in the table are negative which is indicative of the fact that $CO_2$ is being consumed and oxygen produced. LiOH would not be applicable for an ECS loop providing air to a plant cage module only, since $CO_2$ would have to be supplied rather than removed. However, a loop containing oxygen consuming organisms might contain LiOH for $CO_2$ removal. If the loops were combined, an LiOH weight savings would result from the $CO_2$ consumed by the plants. The negative LiOH weights shown for the plant cage module indicates the amount of weight savings which could be credited in such a case.

Invertebrate cage module respiration loads were based on pre-pupa fruit flies (Drosophila melanogaster). A 2.15 mg fly consumes approximately 3.68 $mm^3$ ($\mu$l) of $O_2$ per hour. This is equivalent to 0.126 mg/day. Assuming a maximum quantity of 10,000 flies in each cage module yields a value of 1.26 g/day. Assuming a respiratory quotient (RQ) of one, the $CO_2$ produced is 1.73 g/day, and the LiOH required (if used) is 2.3 g/day.

Table 5-11. Order-of-Magnitude Plant, Invertebrate, and Cells and Tissues - Respiration Data

| | Plant Cage Module | Invertebrate Cage Module | Cells & Tissues Cage Module | Vertebrate Cage Module for Comparison |
|---|---|---|---|---|
| Cage Module contents used as a basis for respiratory loads | 16 Sunflowers (5 g dry each, 57$\mu\ell$ $CO_2$/100 mg dry weight per hour) | 10,000 Fruit Flys (prepupa, 2.15 mg each, 3.68 $\mu\ell$ $O_2$ per hour) | Rat Tissue (5 g dry weight, 8.75 $mm^3$ $O_2$/mg dry tissue per hour) | 8 Rats (0.35 kg) |
| $O_2$ Consumption | | | | |
| g/day | -1.56 | +1.26 | +1.5 | +144 |
| g/30 days | -46.8 | +37.8 | +45 | +4320 |
| kg/yr. | -0.57 | +0.46 | +0.55 | +52.6 |
| $CO_2$ Production | | | | |
| g/day | -2.14 | +1.73 | +2.06 | +169 |
| g/30 day | -64.2 | +52.0 | +61.9 | +5070 |
| kg/yr. | -0.78 | +0.63 | +0.75 | +61.7 |
| L.OH Required | | | | |
| g/day | -2.85 | +2.3 | +2.74 | +225 |
| g/30 days | -85.39 | +69.0 | +82.2 | +6750 |
| kg/yr. | — | +0.84 | +1.0 | +32.1 |

NOTE: All $O_2$ and $CO_2$ values assume RQ = 1.

Data on rat tissue was found and was used to exemplify the cells and tissues cage module load. A number of different types of tissue were found in Reference 17. These were averaged and found to give an $O_2$ consumption of 8.75 $mm^3$ per hour per gram of tissue on a dry basis. Very small quantities of tissue are anticipated in the experiments, and 5 grams was used for the total quantity per cage module. This gives a total oxygen consumption of 1.5 g/day.

The data presented in Table 5-11 should be considered to indicate the order of magnitude only. In addition to the P, I, C/T data, typical vertebrate cage module data is included. The comparison shows that the vertebrate $O_2/CO_2$ respiration loads are the major ones to be considered in ECS design. This is not to say, however, that non-vertebrate cage module contaminant control, temperature control, and other environmental factors are to be neglected in ECS design considerations.

Although the values in the table are approximate, they were used for preliminary concept development and sizing. For example, the Mini-7 ECS loop serves 1 plant, 1 invertebrate, and 2 cells/tissues cage modules. A net $CO_2$ buildup in such a loop was assumed for the present time, and LiOH was included for $CO_2$ removal. Later changes in these types of criteria are not expected to produce major EC/LSS design problems because of the small loads involved.

5.1.3.2 Silica Gel for Dehumidification. Adsorption was investigated as a means of dehumidifying the cage module ventilation air. Silica gel is one of the highest capacity dessicants, and was therefore the sorbent considered. At 1600 $N/m^2$ (12 mm Hg) water vapor partial pressure in air, silica gel will hold about 25% of its weight in water. Thus, 4 grams of silica per grams of silica per gram of water would be required. Its volume is approximately 1.6 cc/g (.026 $ft^3$/lb), and thus 6.4 cc of silica gel are required per gram of water adsorbed.

Considering an example of 16 rats (one cage module ECS loop), the total respiration, perspiration, urine vapor, and fecal vapor humidity load is 828 g/day. Thus, the silica gel required would weigh 3.31 kg/day and occupy 5300 cc. For the 30-day Mini-30, mission, for example, this would amount to 99.3 kg (218 lb) and 0.159 $m^3$ (5.6 $ft^3$). This weight and volume was considered excessive with respect to the weight and volume requirements of a condenser separator, and was therefore selected for use. For the Mini-7 payload, that contains no vertebrates, the dehumidification load has not been determined. This load may be low enough, so that silica gel may be the simplest means of dehumidifying the air stream, and should be considered in future studies.

5.1.3.3 Blower Placement in EC/LSS Loops. Blower placement in a closed loop is dictated by a number of factors. Pressure differentials between various points in the closed loop and the surrounding environment is one, in addition to considerations involving vibration, noise, heat balances, duct configurations, and structural support. Pressure differentials appear to be an important consideration in the organism ECS

loops because of the guideline to maintain total loop pressure below that of the cabin (to prevent contamination of cabin air by the organisms). In addition, a man-interface exists in the loop at the cage module, where the laminar flow bench will be attached and the crewman will work with the organisms through glove ports, and possibly a flexible shroud. In order to minimize the pressure differential ($\Delta P$) at this interface, and yet keep the total loop negative with respect to the blower, the cage module should be placed directly downstream of the closed loop blower. This point should also be referenced to cabin pressure, in order to keep the interface pressure constant as the ECS loop component $\Delta P$s vary (e.g., as the filter loads up and the $\Delta P$ increases).

The force resulting from various pressure differentials are shown for reference purposes in following table:

| $\Delta P$ | | Force on Areas Shown N (lb) | | | |
|---|---|---|---|---|---|
| $\frac{N}{m^2}$ | (Inches of Water) | Area $0.093 m^2$ | ($1 ft^2$) | Area $0.372 m^2$ | ($4 ft^2$) |
| 248 | (1) | 23.1 | (5.2) | 92.5 | (20.8) |
| 496 | (2) | 46.3 | (10.4) | 185 | (41.6) |
| 993 | (4) | 92.5 | (20.8) | 370 | (83.2) |
| 2480 | (10) | 231 | (52.0) | 925 | (208) |

Another factor that may be more important to the maintenance of a low $\Delta P$ at the laminar flow bench interface is the laminar flow bench blower itself. Its effect on the ECS loop flow was not considered at this time, but the same general blower placement guidelines would apply. This problem is being flagged for future study during the integration phase of the program.

5.1.3.4 $CO_2$ Removal. For the various laboratory $CO_2$ removal loads, the amount of LiOH was calculated in order to indicate the desirability of using this chemical. All such calculations were based on the following:

a. $2\ LiOH + CO_2 = Li_2CO_3 + H_2O$

$48 + 44 \quad = 74 + 18$

b. Stoichiometric LiOH $= \frac{48}{44} = 1.09$ g LiOH per g of $CO_2$

c. Actual percentage of LiOH available for reaction = 90 %

d. Actual LiOH = 1.21 g LiOH/g $CO_2$

e. Weight allowance for canister and filters = 10%

f. Total LiOH weight penalty = 1.33 g LiOH/g $CO_2$

The amount of LiOH for the various payloads was presented in Table 5-4. No formal tradeoff analyses were conducted but, based on the weights shown, LiOH was selected for the Mini laboratories, and was rejected for the Maxi laboratories. This decision is considered sound with the possible exception that a regenerable $CO_2$ removal device might be further investigated for the Mini-30 laboratory. The use of such a device, however, would introduce a central processing loop. The central loop would require a sterilizer, unless cross-contamination between the 2 monkeys and the 16 rats were acceptable to the experimenter.

In the plant, invertebrate, and cells/tissues ECS loops, another technique of controlling $CO_2$ as well as $O_2$ was considered. This was to pump a small quantity of filtered air from the cabin to the loop in order to maintain $O_2$ and $CO_2$ levels within tolerance. However, for this concept, it was assumed that air returning to the cabin would have to be sterilized, using a catalytic oxidizer or similar high temperature device. For the present flow rates (0.17 g/sec (0.3 ft) per cage module), the closed system appeared to carry a lower power penalty and was therefore selected. Further evaluation of the open loop system for Mini-7 should continue as loads, flows, and cross-contamination criteria become more accurately defined.

5.1.3.5 EC/LSS Components. High pressure oxygen vessels are included in the Mini-7 and Mini-30 ECSs. High pressure storage was selected for its simplicity, and because of the relatively small amount of $O_2$ to be stored. For the Mini-7, on the order of 0.1 kg of $O_2$ is required, and for the Mini-30 about 21 kg are required. The high pressure storage penalties that were used, are representative of proven flight hardware. They are as follows:

$$\frac{\text{Total Weight of Full Vessel}}{\text{Usable } O_2 \text{ Weight}} = 3.2$$

$$\frac{\text{Total Volume of Vessel}}{\text{Usable } O_2 \text{ Weight}} \equiv 2.9 \frac{cc}{g} \qquad \left(0.047 \frac{ft^3}{lb}\right)$$

The water purification filters weight, power, and volume were based on a multifilter unit built and tested by General Dynamics, Reference 21. The filter was designed to purify cabin humidity condensate for drinking. It consisted of charcoal, ion exchange, and millipore filters, and had the following properties:

Weight = 4.2 kg (9.3 lb)

Volume = 0.011 $m^3$ (0.4 $ft^3$)

Pump Power = 5.4 watts

Total Process Flow = 227 kg (500 lb) of water

These properties were scaled to estimate the properties of the organism EC/LSS water purification filters.

The weight, power, volume, and heat of the $CO_2$ concentrator and water electrolysis unit were also scaled to the organism loads, and were based on the values presented for these units in Reference 22. Bosch $CO_2$ reduction unit values were based on current in-house work on the design and fabrication of a 6-man unit.

## 5.2 CREW ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

### 5.2.1 REQUIREMENTS.

5.2.1.1 Philosophy and General Guidelines. The general philosophy adopted as a basis for the crew EC/LSS studies assumes that the supporting vehicle will provide most of the basic EC/LSS functions. In the case of the mini laboratories (RAMs), this would be the RAM support module (RSM) and for the maxi laboratories it would be the space station (SS). This assumption appears reasonable since the supporting vehicle must provide for full crew habitability and it supports research laboratory activities not only in life sciences but many other areas. If the crew leaves the support module for work in any laboratory module, the capacity of the support module would go unused unless its capabilities were utilized through appropriate integration and interfaces with the laboratories. Otherwise, extra equipment within the laboratories would have to be provided to pick up the load. Thus, in the interest of minimizing equipment, and the restraints on crew movement, the laboratory EC/LSSs derive most of their support from the support vehicle's systems. Although the laboratories utilize this capacity, they were configured so as not to impose added requirements on the control system. In summary, the design philosophy was to utilize anticipated supporting spacecraft EC/LSS capacity, but not perturb its design or operation. Reasonable assumptions and general knowledge of the planned EC/LSSs aboard the supporting spacecraft were used wherever necessary.

Table 5-12 contains a breakdown of crew EC/LSS functions and indicates whether these functions are provided by the supporting spacecraft, or the individual Maxi and Mini laboratories. The location of environmental control system (ECS) functional support is based in part, on the ventilation mode assumed for each of the laboratories. Since the Maxi laboratories operate in conjunction with a large Space Station complex over long periods, the consequences of microbiological contamination of the crew are more serious than the shorter term Shuttle-only supported missions. For this reason, some degree of atmospheric isolation between the laboratory and the space station is desirable. This guideline was considered for the Maxi in selecting a closed hatch mode of ventilation, with minimum air interchange with the Space Station. The Mini ECS's are configured for an open hatch mode of ventilation, with free air interchange with the supporting spacecraft modules.

Table 5-12. Guidelines on the Location of Crew EC/LSS Functions

| Biolaboratories (Payloads) | Mini 7 | Mini 30 | Maxi Nom | Maxi Max |
|---|---|---|---|---|
| Ventilation Mode | Open Hatch | Open Hatch | Closed Hatch | Closed Hatch |
| Mission Duration | 7 Days | 30 Days | 2 Years | 5 Years |
| Maximum Crew Occupancy (including subjects) | 4 | 4 | 5 | 9 |
| EC/LSS Functions | | | | |
| Airflow Control | LM | LM | LM | LM |
| Air Temperature Control | LM | LM | LM | LM |
| Air Dehumidification | RSM | RSM | LM | LM |
| $CO_2$ Removal | RSM | RSM | SS | SS |
| Contaminant Removal | RSM | RSM | LM/SS | LM/SS |
| $O_2/N_2$ Supply | RSM | RSM | SS | SS |
| Pressure Suit Circuit | LM/RSM | LM/RSM | LM/SS | LM/SS |
| Water Processing/Supply | RSM | RSM | SS | SS |
| Water Storage & Dispensing | RSM | RSM | LM | LM |
| Urine Collection & Transport | RSM | RSM | LM | LM |
| Fecal Collection | RSM | RSM | SS | SS |
| Nutrition, Hygiene & Waste Management | RSM | RSM | SS | SS |

LM = Laboratory Module (Local Support)

RSM = RAM Support Module (or Shuttle Orbiter) (Central Support)

SS = Space Station (Central Support)

As indicated in Table 5-12, purified air is supplied by the supporting spacecraft environmental control system, but flow is controlled in the laboratory. Temperature is controlled locally by heat exchange coolers, and dehumidification is accomplished locally in the maxi laboratories to minimize air interchange with the Space Station ECS. In the minis, free air interchange allows the use of RSM equipment for $CO_2$ and contaminant removal. For the maxis, to avoid duplication of the complex $CO_2$ concentration and contaminant removal equipment, limited ducted air interchange with the Space Station ECS is provided. The air returning from the laboratories to the central ECS is filtered, for bacteria and odor removal, to reduce Space Station contamination.

Oxygen and nitrogen are assumed to be provided by the storage and regeneration systems on board the supporting spacecraft. Emergency pressure suit circuit air comes from a central circuit, but is distributed and controlled in the laboratories. Water processing, fecal collection, waste management, nutrition, and hygiene are all provided by the support vehicle. The Maxi laboratories have provisions for water dispensing and urination due to the long duration of crew occupancy and the closed hatch mode of operation.

5.2.1.2 Design Criteria. The following list of general design criteria were used in establishing preliminary crew EC/LS subsystem configurations:

a. Cabin pressure = 101 $kN/m^2$ (14.7 psia)

b. Nominal cabin air temperature = 297° K (75° F)

c. Standard air $O_2/N_2$ composition

d. Atmospheric $CO_2$ partial pressure = 400 $N/m^2$ (3.0 mm Hg)

e. Atmospheric $H_2O$ partial pressure = 1070 - 1730 $N/m^2$ (8-13 mm Hg)

f. Crew design $O_2$ consumption = 1.04 kg/man-day (2.3 lb/man-day), (125% of daily average)

g. Crew design $CO_2$ production = 1.21 kg/man-day (2.65 lb/man-day), (125% of daily average)

h. Maximum respiration and perspiration = 5.99 kg/man-day (0.55 lb/man-hr)

i. Potable water required = 2.73 kg/man-day (6.0 lb/man-day)

5.2.2 BASELINE CREW EC/LSS DESCRIPTION. Table 5-13 summarizes the crew EC/LS subsystems in the Maxi and Mini Life Sciences laboratories (RAMs). More detailed descriptions are contained in the following sections.

5.2.2.1 Maxi Max and Maxi Nom RAMs. The crew EC/LS subsystems aboard the Maxi Max and the Maxi Nom RAMs are quite similar, and are described together in this section. These laboratories must provide a shirtsleeve environment for a crew

Table 5-13. Summary of Crew EC/LSS Subsystem Properties

| | | MINI 7* | MINI 30* | MAXI NOM | MAXI-MAX | | |
|---|---|---|---|---|---|---|---|
| MAXIMUM CREW SIZE | | 4 | 4 | 5 | 9 | | |
| MISSION DURATION | | 7 Days | 30 Days | 2 Yrs | 5 Yrs | | |
| RESUPPLY PERIOD | | None | None | 3 Mo | 3 Mo | | |
| VENTILATION MODE | | Open Hatch | Open Hatch | Closed Hatch | Closed Hatch | | |
| | | | | | BLH Module | F Module | RC Module |
| WEIGHT | kg (lb) | 70 (164) | 70 (164) | 208 (460) | 95 (210) | 208 (460) | 208 (460) |
| POWER | watts | 250 | 250 | 720 | 280 | 720 | 720 |
| VOLUME | $m^3$ ($ft^3$) | 0.41 (15) | 0.41 (15) | 0.65 (23) | 0.38 (14) | 0.65 (23) | 0.65 (23) |

*These are general purpose laboratories (GPL) and the crew EC/LS subsystem serves other FPEs beside those of life sciences.

of five to nine working for approximately ten hours per day. Pressure suit support is also required for emergency maintenance within the modules while depressurized. The Space Station provides for these functions via ducts and lines running into the laboratories. Pressurization lines and valves are also provided to satisfy emergency repressurization requirements.

A diagram of the equipment included in the typical maxi laboratory is shown in Figure 5-4, and the estimated weights of the components are listed in Table 5-14. Air is drawn from the Space Station in sufficient quantities to control $CO_2$ in the laboratory. However, dehumidification is accomplished within the laboratory. Air flow required for dehumidification is greater than that required for $CO_2$ removal, and equipment for $CO_2$ concentration is more complex and heavier. For this reason, Space Station $CO_2$ processing is used while local dehumidification is used to reduce air interchange with the Space Station.

Air entering the module would be drawn from the Space Station ECS at a low $CO_2$ partial pressure. Assuming a value of 200 $N/m^2$ (1.5 mm Hg), the maximum air flow to the module to satisfy the $CO_2$ control requirement is 28 g/sec (221 lb/hr or 49 cfm) for Maxi Nom (see Section 5.2.3). This air is returned to the Space Station ECS through a bacterial (millipore) and activated charcoal filter. This will reduce the possibility of Space Station contamination should laboratory air becomes contaminated. Further isolation is considered unwarranted because of the unavoidable cross-contamination that will take place every time a crewman enters the Space Station from the laboratory. The filters will minimize cross-contamination in the event of a major bacterial or gaseous laboratory contamination. The organism and crew environments are isolated from one another, so gross-contamination of the laboratory atmosphere is not likely.

Thermal and humidity conditioning of laboratory air is accomplished by cooling heat exchangers, and a condensing heat exchanger within the laboratory. The fans which force air through the sensible coolers should provide enough flow for sufficient internal module air movement and crew comfort.

Monitoring of module air for contaminants and $O_2/CO_2/N_2$ levels will be accomplished by the gas analysis equipment aboard the laboratory. Oxygen and nitrogen levels will be maintained within the laboratory by the inflow of fresh air from the Space Station. Emergency decompression valves are placed in the laboratory in case such action should become necessary due to a gross atmospheric contamination. In such a case, the module can be sealed off from the Space Station by closing the duct valves.

For pressure suited operation within the module, suit circuit lines and connectors are provided. These lines are tied into the Space Station system to avoid the duplication of blowers, coolers, and other such equipment. The failure of any portion of the suit $O_2$ circuit can endanger the life of the crew and therefore should be backed up by emergency oxygen supply units. These units are assumed to be part of the Space

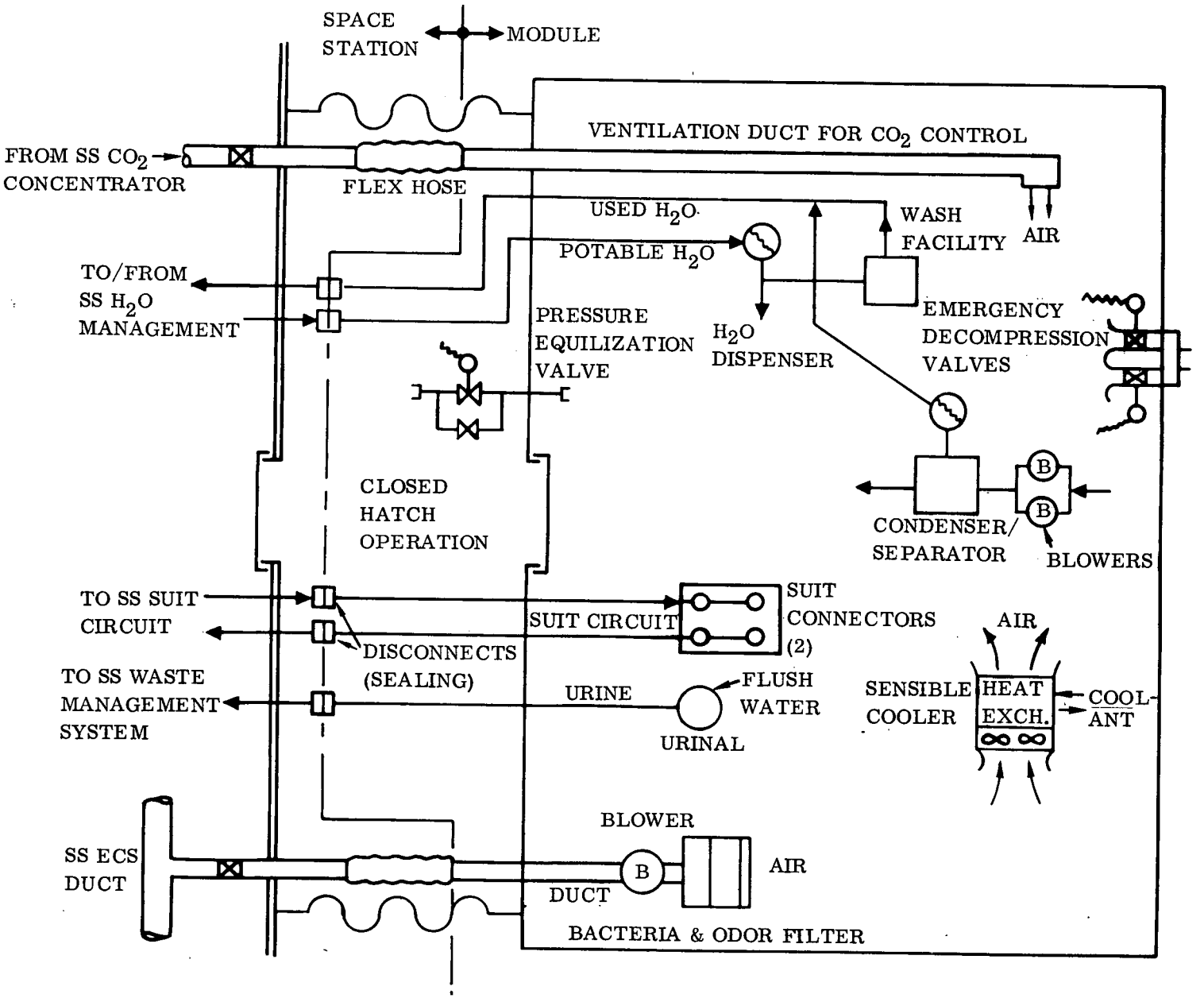



Figure 5-4. Crew ECS for Typical Maxi Laboratory

## Table 5-14. Maxi Laboratory Crew ECS Weight, Power, and Volume Estimates

| COMPONENT | MAXI NOM, NAXI MAX F, & RC MODULES | | | | | MAXI MAX BLH MODULE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Weight | | Power | Volume | | Weight | | Power | Volume | |
| | kg | (lb) | watts | $m^3$ | ($ft^3$) | kg | (lbs) | watts | $m^3$ | ($ft^3$) |
| VENTILATION DUCTING SYSTEM | 11.4 | (25) | 0 | 0.065 | (2.3) | 11.4 | (25) | 0 | 0.065 | (2.3) |
| BACTERIA & ODOR FILTER (3 mo.) | 42.7 | (94) | 0 | 0.125 | (4.4) | 0 | | 0 | 0 | |
| FILTER BLOWER | 22.7 | (50) | 250 | 0.023 | (0.8) | 0 | | 0 | 0 | |
| SUIT CIRCUIT LINES & CONNECTIONS | 10.9 | (24) | 0 | 0.006 | (0.2) | 10.9 | (24) | 0 | 0.006 | (0.2) |
| LIGHT FIXTURES | 9.1 | (20) | 200 | 0.142 | (5.0) | 9.1 | (20) | 200 | 0.142 | (5.0) |
| PRESSURIZATION/DECOMPRESSION LINES & VALVES | 13.6 | (30) | 0 | 0.028 | (1.0) | 13.6 | (30) | 0 | 0.028 | (1.0) |
| FIRE EXTINGUISHERS | 7.3 | (16) | 0 | 0.017 | (0.6) | 7.3 | (16) | 0 | 0.017 | (0.6) |
| CABIN COOLERS & FANS | 22.7 | (50) | 80 | 0.085 | (3.0) | 22.7 | (50) | 80 | 0.085 | (3.0) |
| CONDENSER/SEPARATOR | 23.6 | (52) | 0 | 0.037 | (1.3) | 0 | 0 | | 0 | |
| DEHUMIDIFICATION BLOWERS | 5.9 | (13) | 190 | 0.020 | (0.7) | 0 | | 0 | 0 | |
| WATER LINES, TANK, & DISPENSER | 12.7 | (28) | 0 | 0.020 | (0.7) | 12.7 | (28) | 0 | 0.020 | (0.7) |
| WASH FACILITY | 18.2 | (40) | (300) | 0.057 | (2.0) | 0 | | 0 | 0 | |
| URINAL & HOLDING TANK | 6.8 | (15) | (75) | 0.020 | (0.7) | 6.8 | (15) | (75) | 0.020 | (0.7) |
| TOTALS | 207.6 | (457) | 720 (375) | 0.645 | (22.7) | 94.5 | (208) | 280 (75) | 0.383 | (13.5) |

Station crew equipment inventory, and would be taken into the research modules when required.

Other equipment within the maxi laboratory includes a water supply and dispensing system, hand washing facility, and urinal. Cold potable water is stored for drinking, experiment use, hand washing, and urinal flushing. Both the wash facility and urinal must incorporate 0-g gas/liquid design concepts. Estimates of their weight, power, and volume are contained in Table 5-14.

As indicated in Table 5-14, the BLH module differs enough to include a separate column indicating the reduction in equipment. Because of the reduced potential for gaseous and microbiological contamination, greater air interchange with the Space Station is utilized. The greater air flow rate provides adequate dehumidification thus eliminating the need for a local condenser/separator. The bacterial and gaseous air filtration function has been eliminated as well as the wash facility. The greater utilization of Space Station equipment results in weight, power, and volume savings as indicated in Table 5-14.

5.2.2.2 Mini Laboratories. The Mini laboratory modules operate, attached to the Shuttle orbiter, for periods of 7 and 30 days, and also are supported by the RSM. The crew size is currently anticipated to be four men. The crew and the RAM support capacity is shared between the Life Sciences payload and those of other FPEs. Thus, the crew EC/LSS should not be entirely attributed to the requirement to support the Life Sciences payload.

The Mini research modules are expected to operate with free air interchange between them, and the supporting spacecraft (RSM) which will contain a complete EC/LSS. Thus, the requirement for EC/LSS components within the research module is reduced to those needed for ventilation, temperature control, and pressure suit support. A diagram of the mini laboratory modules would be similar to that shown in Figure 5-4 for Maxi Nom, with only these units included. The EC/LSS components for the support of four men are listed in Table 5-15 along with their estimated weight, power, and volume.

5.2.3 SUPPORTING ANALYSIS. As mentioned in the preceding section, air flow from the supporting spacecraft must be sufficient to provide atmospheric $CO_2$ control in the laboratories. It also must provide for dehumidification in the mini laboratories. The parametric curves in Figures 5-5 and 5-6 show the required air flow rates for $CO_2$ and $H_2O$ removal as a function of the rate of introduction of these gases, and the increase in partial pressure in the laboratories. For the Maxi laboratories, the ventilation is set by the requirement for $CO_2$ removal. It was assumed that any one maxi laboratory module would be occupied by five men at most, and that air from the Space Station would be available with a $CO_2$ partial pressure of 200 $N/m^2$ (1.5 mm Hg). This results in an air flow of 28 g/sec (221 lb/hr). For the mini laboratories, the air flow is established by the requirement to remove water vapor. For four men and

Table 5-15. Mini Laboratory Crew ECS Weight, Power and Volume Estimates

| Component | Dry Weight | | Average Power | Volume | |
|---|---|---|---|---|---|
| | kg | (lbs) | watts | $m^3$ | ($ft^3$) |
| 1. Ducting & Supports | 14.5 | (32) | | 0.142 | (5.0) |
| 2. Duct Fittings, Transitions, etc. | 5.5 | (12) | | 0.028 | (1.0) |
| 3. Air Heat Exchanger & Fan | 11.4 | (25) | 50 | 0.057 | (2.0) |
| 4. Pressurization/Decompression Lines & Valves | 13.6 | (30) | | 0.028 | (1.0) |
| 5. Gas Sample Lines | 1.4 | (3) | | -- | -- |
| 6. Suit Circuit Lines and Connections | 10.9 | (24) | | 0.006 | (0.2) |
| 7. Light Fixtures | 9.1 | (20) | 200 | 0.142 | (5.0) |
| 8. Fire Extinguisher | 3.6 | (8) | | 0.008 | (0.3) |
| TOTALS | 70.0 | (164) | 250 | 0.411 | (14.5) |

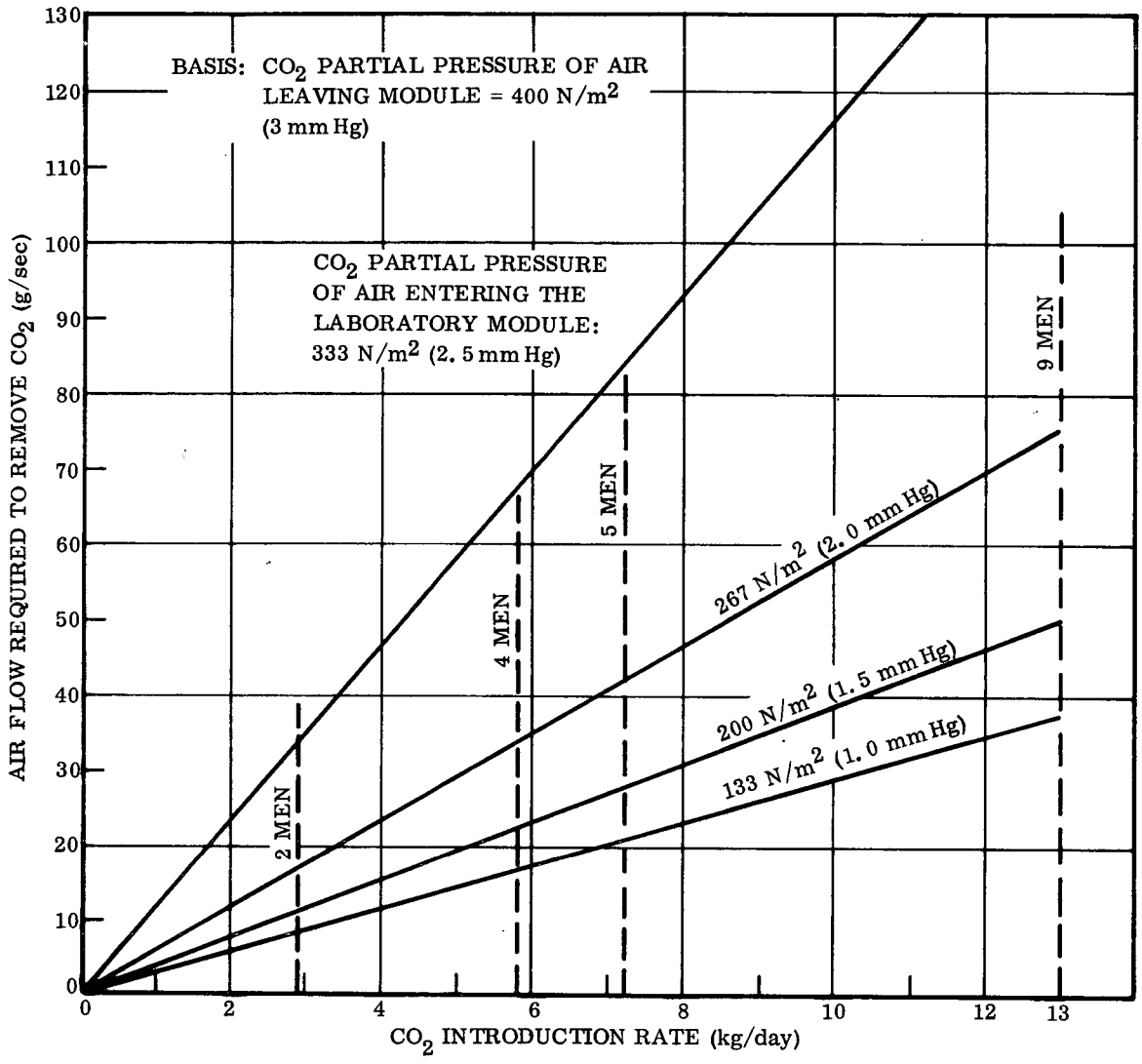



Figure 5-5. Ventilation Air Required to Remove $CO_2$ From Laboratory Modules

a partial pressure rise of 267 N/m$^2$ (2 mm Hg), a flow of 170 g/sec (1350 lb/hr) was used as a guideline.

## 5.3 DATA MANAGEMENT SUBSYSTEM

This section summarizes the conceptual design for a Data Management System (DMS). Detail discussions of the DMS are presented in Section 2.0 of Volume III. The requirement of the DMS is to aid experimenters with experiment management through control of equipment and data acquisition, processing, and disposition. The ground rules used are as follows:

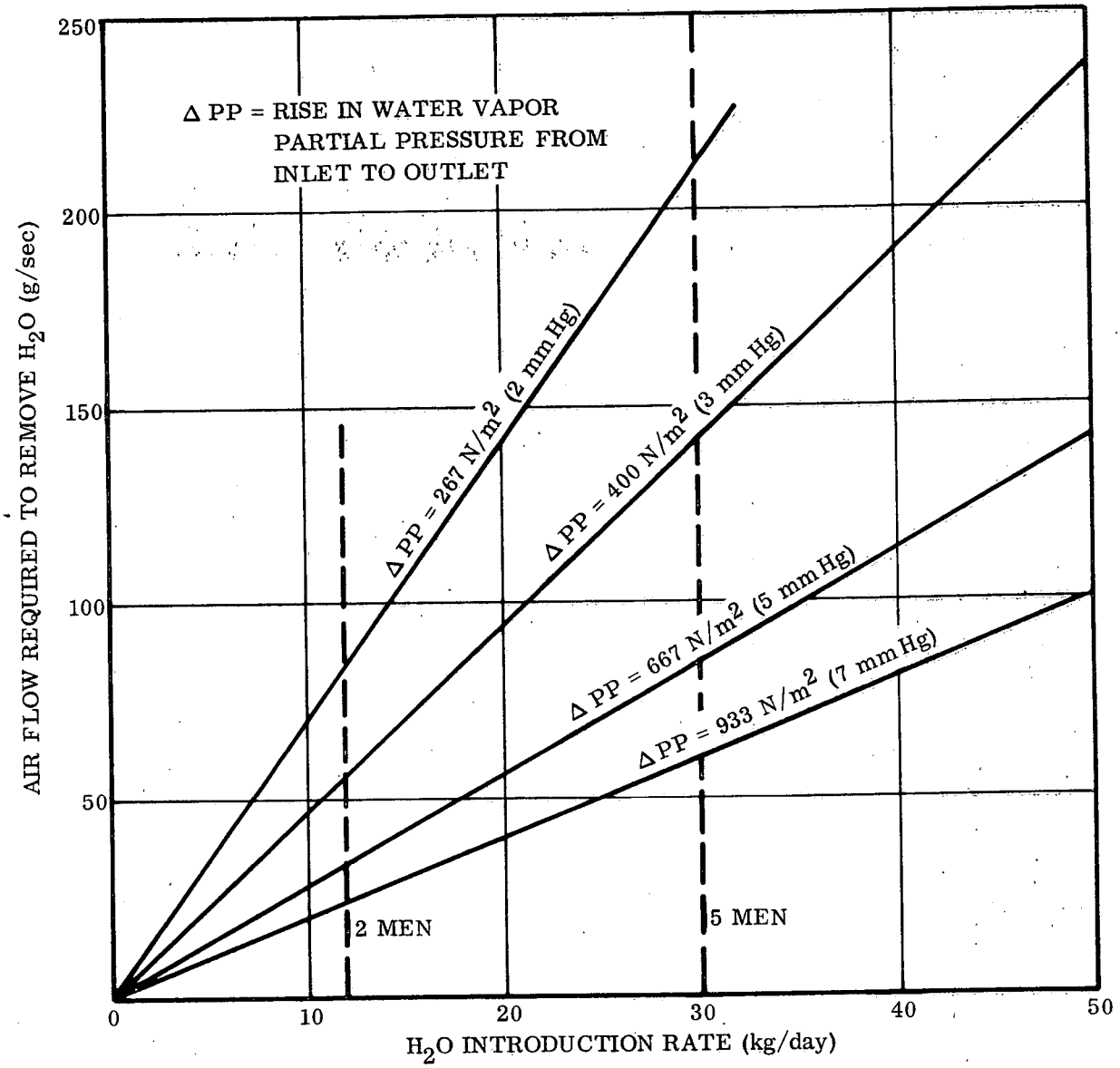



Figure 5-6. Air Flow Required to Remove Water Vapor from Laboratory Modules

a. The design will build upon the concept of the Data Management Unit of the Life Sciences Common Operations Research Equipment (CORE) as presented in the Blue Book Reference 1.

b. The concept design will be based upon data requirements presented in the above reference, but modified as determined necessary by the results of this current study.

c. The concept design will be limited to the basic, general-purpose framework of the DMS. Experiment instrumentation and associated special data processing devices are not considered herein. However, the DMS will be designed to readily interface with all instrumentation and such devices.

d. All external communications will be conducted via the support modules for the Sortie and Space Station missions.

e. There will be no capability for independent, detached laboratory module operations. However, there will be a capability for automatic operations during short, unattended periods such as launch.

The general approach used to design the DMS was to classify the data handling requirements, and select the concepts to be used for each requirement. Next, the hardware needed to implement each technique was determined and assembled to form an integrated Data Management System.

5.3.1 REQUIREMENTS AND SELECTION OF TECHNIQUE. Data handling requirements, presented in the Blue Book, were reviewed and the kinds of data to be handled were broadly classified as: (1) sampled; (2) continuous; (3) video, (4) audio, (5) computer, (6) control; (7) miscellaneous. In the discussion that follows, the above classifications, and basic handling techniques are described.

5.3.1.1 Sampled Data Requirements. Measurements in this classification are typically amperage, displacement, power, force, position, pressure, strain, temperature, and voltage. This classification of data is ideally suited for handling in a pulse code modulated (PCM) form. PCM data can be readily introduced into a computer for processing, and the total PCM data stream is in an organized format that can be efficiently stored on instrumentation tape and transmitted to ground.

5.3.1.2 Continuous Data Requirements. Measurements in this classification are typically physiological signals such as ECG, EEG, and EMG. Most experiments require some measurements in this classification. These signals originate in analog form from numerous sources and a variety of special equipment is required for processing and display. Usually, only a few signals are processed at any one time. Typically, the experimenter must make some special setup of equipment to select, process, display or store the signals desired for an experiment. For these reasons, a flexible analog data handling system is required. Basically, this system should be a network of analog data signal trunk lines interconnecting equipment work areas and appropriate switching and signal conditioning. An RF link is required to extend trunk lines into the centrifuge. Selected analog signals must, also, be temporarily incorporated into the PCM format. This could be done by using a PCM data cycle format with unused time slots dedicated to this purpose. The sources of data using these time slots may often change, however, the basic PCM format will not.

5.3.1.3 Video Data Requirements. Television capability will be required at all principal activity areas, such as the Visual Records and Microscopy Unit, Plant Research Support Unit and the Research Centrifuge. Some areas such as the Plant Research Support Unit, or Holding Units may require coverage of many image sources during a single experiment. These areas could be instrumented with several

cameras that time share a single video channel, or, with a single camera that will periodically scan the many sources.

Television data handling requirements can be met with a switchable network of video signal trunk lines that interconnect cameras, monitors and video tape machines as required. While there are several possible sources and users for video signals, it is estimated that not more than three channels will be active at one time. Two video data trunk lines will require extension by RF link into Centrifuge. Television data will be stored on video tape for later review onboard or transfer to ground via a support module. Storage and transfer requirements are not defined at this time; however, it appears that the system should provide the capability to record and/or transfer at least one channel continuously.

5.3.1.4 Audio Data Requirements. There are no unusual audio data requirements, and a handling system using conventional techniques will be suitable. The proposed handling system is basically a switchable network of audio signal trunk lines that interconnect microphones, speakers, audio tape recorders, and signal conditioners. An audio signal could be switched to an analog signal trunk and treated as an analog signal to record on tape. It is estimated that not more than three audio channels will be required to be active at one time.

5.3.1.5 Computer Data Requirements. The data management computer will be required to handle many kinds of data from several sources, and perform a variety of computer operations. In-coming computer data includes: (1) PCM data, (2) digitized analog data, (3) time from time code generator, (4) quick access computer storage data, (5) computer tape storage data, (6) data from the support module, and (7) interactive graphics data. Outgoing data includes: (1) control data to external devices, (2) storage data to quick access computer storage and computer tape machines, (3) data to the support module, (4) digital-to-analog converted data, and (5) interactive graphics data. Each of these data links with the computer will require a hardware interface to condition the data and manage the transfer from one medium to another. An important consideration is to relieve the computer of high-rate repetitive functions that are most efficiently accomplished externally.

5.3.1.6 Device Control Data Requirements. Equipment operations in the laboratory must be automated by computer control, where practical, in order to minimize experimenter attention and to insure reliable operation. Most of these operations are simple, low rate, and long term. Typically, a sensor is sampled by the PCM system and a status display is updated, and if the condition is out of some predetermined tolerance, an equipment operation is automatically initiated by the computer which restores the sensed condition to an acceptable state. An example of this kind of operation is the monitoring and control of an environmental control parameter.

5.3.1.7 Miscellaneous Data Requirements. This classification includes general purpose film using equipment and signal conditioners which are not included elsewhere.

5.3.2 DATA MANAGEMENT SYSTEM FUNCTIONAL DESCRIPTION. The Data Management System functional capabilities are illustrated in Figure 5-7. Its functional capabilities are most conveniently described by considering each of its major functions separately. These are summarized in the following sections and discussed in detail in Volume III, Section 2.

The quantity of equipment units required will vary according to overall data management requirements. However, the functional design of the system is intended to be independent of load, within anticipated bounds.

A summary of data management equipment is shown in Table 5-16. The weight, power, and volume requirements for the smaller payloads shown in the table appear unreasonably high. This is due to the assumption that all basic DMS capabilities would be included for the smaller Life Sciences payloads, and the DMS would be shared by other FPE payloads. The sharing concept is discussed in Section 5.3.4.

The major functional capabilities of the Data Management System include: (1) PCM Data Handling; (2) Analog Data Handling; (3) Video Data Handling; (4) Audio Data Handling; (5) Computer Data Handling; (6) Computer Control of Devices; and (7) Miscellaneous Data Handling.

5.3.2.1 PCM Data Handling. PCM data is handled by the PCM Data Control Unit, and the PCM Data Acquisition Unit shown in Figure 5-7. PCM data acquisition is controlled by the data management computer, by execution of the data acquisition program. Modification and initial execution of this program is by operator control. During initial execution, direct-memory-access (DMA) channels of the computer, and a peripheral PCM data formater are "setup". Thereafter all PCM data acquisition operations proceed automatically under control of the DMA channels and PCM data formater.

5.3.2.2 Analog Data Handling. The analog data handling system is a group of analog data acquisition, processing, signal conditioning, switching, and storage equipment interconnected by a network of wide-band data trunk lines.

Wide-band data acquisition units are used at remote locations where analog data sources and users are concentrated. A selector unit at each acquisition unit is used by the experimenters to connect selected signal sources and users, in the vicinity, to the trunk lines. The trunk lines terminate at a switching matrix in an analog data handling unit. This analog data switching matrix is used by the experimenters to route signals between acquisition units, or between trunk lines and nearby, commonly used analog data handling equipment.

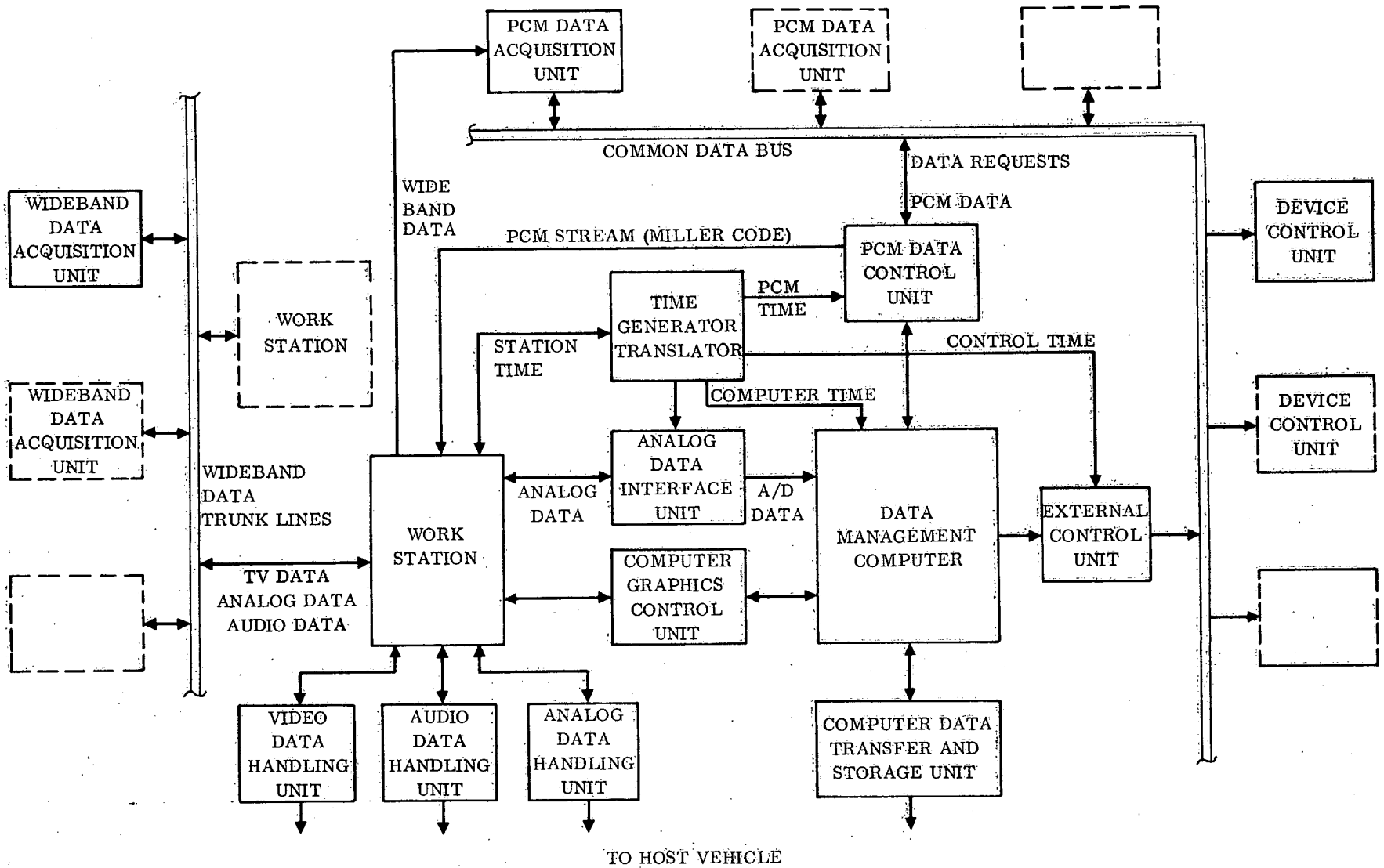



Figure 5-7. Data Management System

Table 5-16. Data Management System Equipment Summary

| Equipment Group | PAYLOADS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MINI-7 | | | MINI-30 | | | MAXI-NOM | | | MAXI-MAX | | |
| | Weight kg (lbs) | Vol. $m^3$ ($ft^3$) | Power w | Weight kg (lbs) | Vol. $m^3$ ($ft^3$) | Power w | Weight kg (lbs) | Vol. $m^3$ ($ft^3$) | Power w | Weight kg (lbs) | Vol. $m^3$ ($ft^3$) | Power w |
| PCM Data | 16 | .023 | 55 | 20 | .029 | 75 | 24 | .035 | 95 | 46 | .065 | 195 |
| Analog Data | 132 | .273 | 1020 | 132 | .273 | 1020 | 144 | .282 | 1040 | 198 | .345 | 1290 |
| Video Data | 81 | .179 | 605 | 81 | .179 | 605 | 98 | .210 | 665 | 122 | .257 | 780 |
| Audio Data | 12 | .018 | 180 | 12 | .018 | 180 | 13 | .020 | 200 | 26 | .039 | 390 |
| Computer Data | 195 | .476 | 1385 | 195 | .476 | 1385 | 211 | .494 | 1435 | 307 | .829 | 2201 |
| Computer Device Control | 10 | .014 | 50 | 12 | .017 | 60 | 16 | .023 | 80 | 28 | .041 | 140 |
| Misc. Data | 7 | .015 | 5 | 7 | .015 | 5 | 7 | .015 | 5 | 12 | .020 | 10 |
| TOTAL | 453 (998) | .998 (35.2) | 3300 | 459 (1012) | 1.007 (35.6) | 3330 | 513 (1132) | 1.079 (38.1) | 3520 | 739 (1630) | 1.596 (56.3) | 5006 |
| Power Duty Cycle Reduction | | | 1500 | | | 1500 | | | 1530 | | | 1813 |
| Average Daily Power (24 hour basis) | | | 1800 | | | 1830 | | | 1990 | | | 3193 |
| MINI-7 1/3 Share | 150.9 (333) | .333 (11.7) | 600 | | | | | | | | | |
| MINI-30 2/3 Share | | | | 306.0 (674) | .672 (23.7) | 1220 | | | | | | |

Analog data may be handled independently of the data management computer and the other data handling systems (PCM, video, audio, computer, and device control). However, three analog data links to the computer are provided for those operations that require computer support. One link is provided by signal lines from the analog data switching matrix to multiplexer channels of a PCM data acquisition unit. The PCM acquisition unit used would be one located near the switching matrix, and some of its multiplexer channels would be reserved for this purpose. The resultant acquired data would be incorporated into the PCM data stream. Another link is provided by signal lines from the switching matrix to an analog-to-digital (A/D) converter that inputs data into the computer. The third link is provided by digital-to-analog converters for data from the computer to the analog data switching matrix.

5.3.2.3 Video Data Handling. The video data handling system is a group of video equipment; such as cameras, camera commutators, monitors, switching, and tape machines inter-connected by a network of wide-band data trunk lines. The equipment and functions for the analog, video, and audio data handling systems are similar, and should be packaged together to save weight and space wherever possible.

5.3.2.4 Audio Data Handling. The audio data handling system is a group of audio equipment; such as communication sets, switching, and tape machines interconnected by a network of wide-band data trunk lines.

5.3.3 COMPUTER DATA HANDLING. A hypothetical application for the Computer Data Graphics Control Unit is discussed below to describe this systems' capabilities. Assume an experimenter wants to:

a. Monitor incoming ECG data during an experiment

b. Extract only the data during a representative interval

c. Perform a computer programmed waveform analysis on the extracted ECG data

d. Display results of the analysis in graphic form on a CRT

e. Add annotation to the CRT display

f. Store the CRT display on film

g. Store the raw data interval on tape as a computer data file

h. Store the ECG analysis results in the quick-access storage as a computer data file

The incoming data could enter the computer as part of the PCM data stream, or enter through the A/D converter if acquired by the analog data handling system. The data could enter by both. Since ECG data are typically handled by the analog data handling system, it would be available at the analog data switching matrix. It is directed into the computer by using the Graphics Control Unit to setup the A/D multiplexer programmer and its associated DMA channel to the computer.

A graphics executive program is always resident in the computer to service the graphics control unit. To setup the analog data link to the computer, the experimeter gains the attention of this program by depressing a function key on the function keyboard. The executive program responds by displaying a menu of available programs on the alphanumeric CRT. The experimenter points to the analog data acquisition program (included in the menu) with the light pen and presses its associated switch. The executive program then transfers the analog data acquisition program from the quick-access storage and executes it. The acquisition program displays a menu of setup alternatives on the CRT. These include multiplexer channels to digitize, rate to digitize, and size of the analog data input buffer. The experimenter indicates his choice for these parameters using the light pen and switch. He then depresses a function key to start the operation. Thereafter the incoming digitized data stream repeatedly fills the analog data input buffer from top to bottom, automatically, under control of the A/D programmer and DMA channel.

The next step is transfer, into the computer, the special process program to be used to process the data. This is done in the same manner as was used for the analog data acquisition program. The special process program will display a menu of setup alternatives on the CRT. Generally the setup specifies the software linkages between the analog data input buffer, the special process program, and the graphics display program. Some setup parameters cannot be specified by selection from a predetermined menu. In this case the alphanumeric keyboard is enabled when the light pen indicates what parameter is to be setup. The information is entered from the keyboard and displayed on the CRT. All selections made with the light pen are also displayed. The experimenter depresses a function key to start the operation after he is satisfied that the setup is correct.

The next step is to call the graphics display program and specify its setup. This is done in the same manner as above. Many setup specifications are required. A basic graphic display format is chosen from a file of standard formats, and the keyboard is used to add annotation to the format. The format chosen is probably one to display a graphical time history. The time length of the displayed interval, the display scales, and the method used for "paging" the display frame are chosen. The experimenter depresses a function key to start the operation after he is satisfied that the setup is correct. The incoming data are displayed on the CRT in real-time. Time is always available to the computer, and the time scale is updated for each new page.

The graphic display program enables, and is able to service, most of the control equipment of the computer graphics control unit. The experimenter is able to apply human judgments to the process by using the control equipment, primarily the function keys. In this example he monitors the incoming data being displayed on the CRT until he is ready to select a representative interval. Several methods are available to do this. One way is to depress a function key at the beginning and end of the interval. Another way is to enter the start and stop time through the keyboard and the graphic display program automatically extracts this interval if a function key has "armed"

this function of the program. Another way is to enter the interval length and arm a function key that is depressed by the experimenter whenever he chooses to designate the start of an interval. A waveform analysis is performed on the extracted data by the special process program, the results of the analysis are displayed on the CRT and both the raw data and results are temporarily stored until disposition is made by function key action. The experimenter probably would choose a display mode that would hold the extracted interval of raw data on the CRT and the results would be added to that display.

A function key is used to couple a slave CRT to the graphic CRT. The copied image on the slave CRT is recorded on film by a camera fixed to the slave CRT for this purpose. Other function keys direct the data intervals to be stored in the medium specified.

5.3.3.1 Computer Control of Devices. Computer control of equipment is provided by a device control program executed in the computer and an associated external control unit peripheral to the computer. Modification and initial execution of this program is by operator control. During initial execution, a DMA channel of the computer, and the external control unit are "setup". Thereafter all device control operations proceed automatically under control of the DMA channels and external control unit.

5.3.4 ALTERNATE APPROACHES. Many trade-offs must be considered and resolved before a firm configuration can be selected for the data management system. During this contract, the approach used was to define the independent equipment necessary to satisfy the Life Sciences payload with minimum constraints imposed by the supporting vehicle and mission. The follow-on phase to this study would investigate the interface, and integration aspects of the preliminary designs presented herein. It is anticipated that the data management subsystem penalties could be substantially reduced as a result of such studies. Several aspects of such integration are:

a. Share a data management system with other payloads. The DMS sized for the MAXI NOM payload could provide data management services to other FPE payloads similar to the Life Sciences MINI-7. Figure 5-8 shows curves (solid lines) for weight, volume, and power required for data management equipment listed for each of the four payloads as a function of the length of the module required. The lists were compiled under the assumption that all basic DMS capabilities would be included for small payloads. The solid curves indicate unrealistically high DMS loads for the small payloads. The dotted curves have the shape one would expect, and are probably reasonable estimates to use for DMS properties, assuming a DMS shared by other than Life Science payloads.

b. Use some data management functions available aboard the support modules. The weight, volume and power requirements of the DMS presented herein could be considerably reduced if some of its functions are provided by the support module.

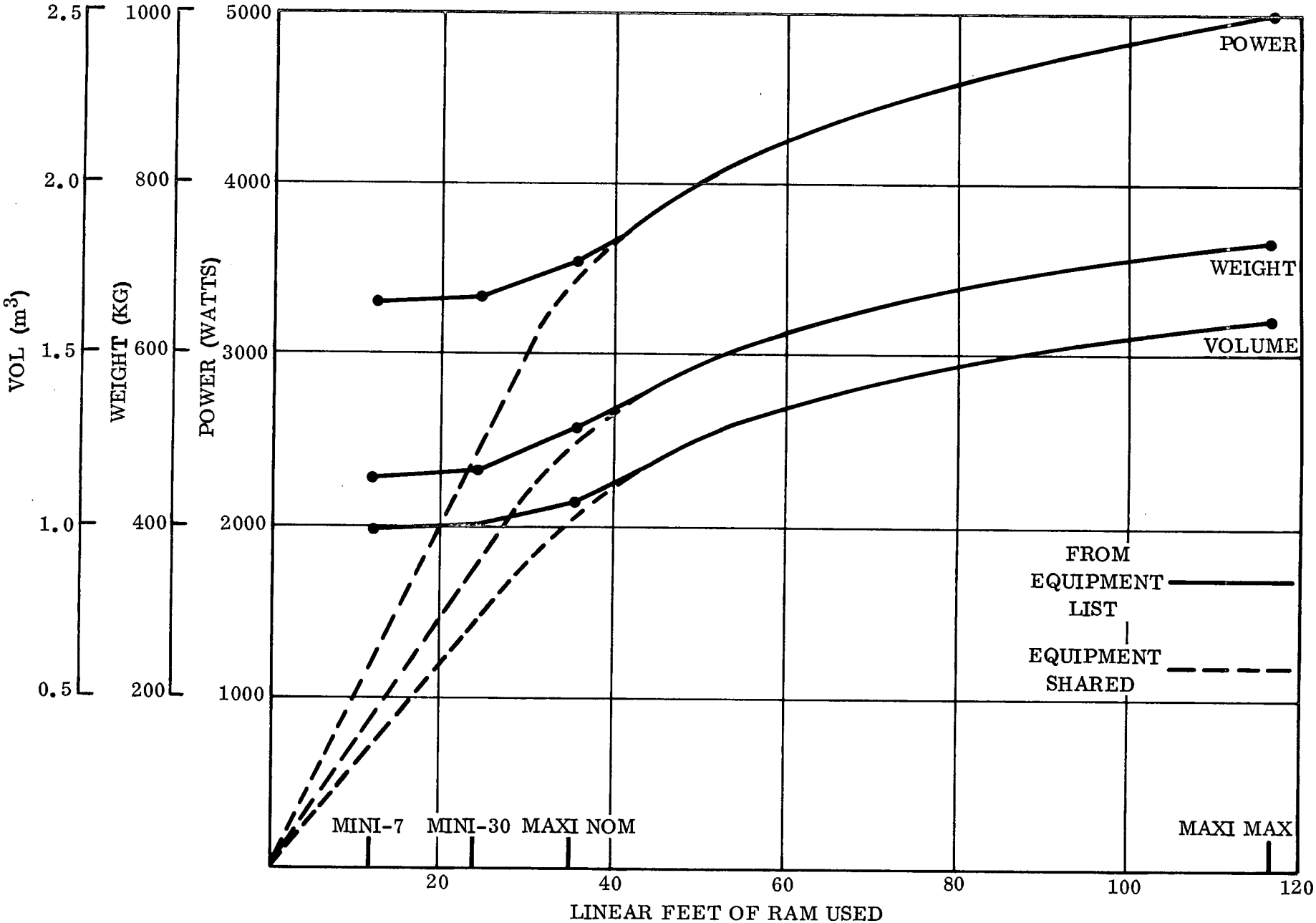



Figure 5-8. Data Management System Requirements (Weight, Volume, and Power)

The data storage function (for data never, or seldom, retrieved for on-board use) could be moved to the support module. This would move two instrumentation tape machines, two video tape machines, two computer tape machines and one audio tape machine to the support module. The portable audio tape machine and the loop analog tape machine would not be moved. The DMS weight would be reduced by 129 Kg, volume by 0.346 $m^3$ and power by 1250 watts. This represents a more than one-third reduction in case of the MINI-7 payload, and almost one-fourth for Maxi-Max.

It appears unlikely that the data management computer could be moved to the support module and still retain the flexibility that a dedicated computer provides. Most of the equipment having complex interfaces with the computer would also have to be moved, or their interfaces designed to operate through a common data bus. Some equipment, such as the computer graphics control unit, must be located in the experimenter work area.

c. Provide experiment setup, monitoring, control, data processing, and analysis using ground facilities. The DMS presented herein provides audio, analog, video and computer data links to the support module that can be used for real-time data or command transmission. Command and control data are transferred from the support module as computer data files. However, if the function of experiment setup, monitoring, control, data processing, and data analysis are to be handled primarily by ground facilities continuously in real-time (or nearly so), then; the DMS should be tailored for this mode of operation. This mode would require more automation of such functions as signal switching. A communication system might have to be added. Data storage requirements would probably be reduced. However, an automatic, short-term, continuous "fill and dump" capability might be required. Much of the signal monitoring and computer graphics capability would not be required. Communication satellites would probably have to be used.

d. Use the same common data bus system for the Life Science DMS, RAM, SS, and Shuttle. The common data bus system was not discussed in detail in the functional description of the DMS. Candidate common data bus systems are being studied under other current contracts for RAM and Shuttle. For the sake of commonality, the system chosen for these vehicles should be used. The DMS organization presented herein is intended to be independent of the bus system used.

## 5.4 ELECTRICAL POWER AND THERMAL CONTROL SUBSYSTEMS

5.4.1 ELECTRICAL POWER SUBSYSTEM. The Life Sciences laboratory modules always operate attached to a supporting spacecraft, even during rendezvous and docking to the Space Station by means of the Space Shuttle orbiter. Therefore, no operational power sources and their associated storage equipment are required aboard the laboratories. The main requirements is for power distribution equipment and some power conditioning equipment.

The loads for each of the baseline laboratories were estimated and are shown in Table 5-17. As a preliminary estimate conditioning equipment and distribution equipment were assumed to be required, and to carry weight and volume penalties as follows (Reference 9):

| | |
|---|---|
| Conditioning Equipment | 13.6 kg/kw (30 lb/kw) |
| | 0.015 $m^3$/kw (53 $ft^3$/kw) |
| Distribution Equipment | 11.4 kg/kw (25 lb/kw) |
| | 0.014 $m^3$/kw (.5 $ft^3$/kw) |

using the above values, the weight and volume estimates of electrical power subsystem components are shown in Table 5-17.

5.4.2 THERMAL CONTROL SUBSYSTEM. Preliminary thermal control subsystem (TCS) properties were estimated by using the current concepts being developed at GD/Convair on the RAM study. These concepts, in conjunction with estimated Life Sciences laboratory heat loads were used to obtain preliminary weight, power, and volume of this TCS (see Table 5-18).

Table 5-18 summarizes the estimated heat load requirements. The electrical heat dissipated by the Life Sciences payload equipment was taken equal to the electrical power requirements presented in Table 5-17. For the mini payloads that share the laboratory with other FPEs, the heat dissipation by the other FPE equipment was not known and therefore not included. Thus, the TCS sizes developed herein for the mini laboratories are for the Life Sciences payload heat dissipation only. The total crew metabolic load was based on the worst case when the full crew complement would be working in the Life Sciences laboratories. For the maxi laboratories, isotope heaters are used for some of the central organism EC/LSS processing units, such as the catalytic oxidizers. These loads (see Section 5.1) were added to the loads to be dissipated by the TCS.

The TCS major equipment shown in Table 5-18 includes liquid loop components, cold plates, the heat rejection radiator, and the module wall insulation. The liquid loop components include pumps, accumulators, heat exchangers, filters, lines, and valves. A dual loop system is used with water inside and Freon 21 outside (see Figure 5-9). The cold plate weight and volume were based on 80% of the heat load being cold plated. Penalties of 7.9 kg/kw (17.3 lb/kw) and 0.0041 $m^3$/kw (0.145 $ft^3$/kw) were used. Radiator weight and volume were based on radiator area, and penalties of 3.43 kg/$m^2$ (0.7 lb/$ft^2$) and 0.015 $m^3/m^2$ (0.02 $ft^3/ft^2$), where the area refers to wall areas requiring insulation. In general, this was taken to equal the area of the whole module circumference plus the area of one end. For the Mini-7 and Mini-30, 1/3 and 2/3, respectively, of this area was used as that proportion of the RAM used to support the Life Sciences payload.

Table 5-17. Estimated Electrical Power Subsystem Requirements for the Life Sciences Laboratories

| | MINI-7 kw | MINI-30 kw | MAXI-NOM kw | MAXI-MAX kw |
|---|---|---|---|---|
| LOADS: | | | | |
| Experiment Equipment | 1.17 | 1.23 | 2.38 | 4.60 |
| Organism EC/LSS | 0.06 | 0.14 | 1.83 | 6.34 |
| Data Management Subsystem | 1.10 | 2.22 | 3.52 | 5.01 |
| Crew EC/LSS | 0.08 | 0.17 | 0.72 | 0.72 |
| Thermal Control Subsystem | 0.12 | 0.16 | 0.43 | 0.89 |
| Total Average Power | 2.53 | 3.92 | 8.88 | 17.56 |
| Total Peak Power (125 percent of Average) | 3.17 | 4.90 | 11.10 | 21.95 |
| EPS EQUIPMENT: | | | | |
| Conditioning Equipment | | | | |
| Weight kg | 43 | 67 | 151 | 299 |
| Volume $m^3$ | 0.047 | 0.074 | 0.167 | 0.329 |
| Distribution Equipment | | | | |
| Weight kg | 36 | 56 | 126 | 249 |
| Volume $m^3$ | 0.045 | 0.069 | 0.157 | 0.311 |
| Total EPS Weight kg (lb) | 79 (174) | 123 (270) | 277 (611) | 549 (1208) |
| Total EPS Volume $m^3$ ($ft^3$) | 0.092 (3.3) | 0.143 ( (5.1) | 0.324 (11.5) | 0.640 (22.6) |

Table 5-18. Estimated TCS Requirements of the Life Sciences Laboratory Modules

| | TOTAL HEAT LOAD (kwatts) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | MINI-7 | | MINI-30 | | MAXI-NOM | | MAXI-MAX | |
| LOADS: | | | | | | | | |
| 1. Life Sciences Payload Electrical Power | 2.53 | | 3.92 | | 8.88 | | 17.56 | |
| 2. Isotope Heat Dissipation | 0 | | 0 | | 2.30 | | 5.95 | |
| 3. Total Crew Metabolic Load, 171 watts/man (583 Btu/man-hr) | 0.68 (4 men) | | 0.68 (4 men) | | 0.86 (5 men) | | 1.54 (9 men) | |
| **Total Heat Load** | 3.21* | | 4.60* | | 12.04 | | 25.05 | |
| EQUIPMENT: | kg | $m^3$ | kg | $m^3$ | kg | $m^3$ | kg | $m^3$ |
| 1. Liquid Loop Components & Structure (including liquid) | 146 | 0.34 | 156 | 0.42 | 340 | 0.91 | 5.75 | 1.80 |
| 2. Cold Plates | 20 | 0.01 | 29 | 0.02 | 76 | 0.04 | 158 | 0.08 |
| Total Non-Integral Equipment | 166 | 0.35 | 185 | 0.44 | 416 | 0.95 | 733 | 1.88 |
| 3. Integral Radiator | 81 | 0.36 | 116 | 0.52 | 435 | 1.94 | 906 | 4.03 |
| 4. Module Wall Insulation (integral)** | 27 | 0.34 | 55 | 0.68 | 75 | 0.93 | 258 | 3.22 |
| Totals of All Equipment for Life Sciences Payload Heat Rejection (lbs and $ft^3$ in parentheses) | 274* (603) | 1.05* (37) | 356* (783) | 1.64* (58) | 926 (2037) | 3.82 (135) | 1897 (4173) | 9.13 (322) |

*These values are for rejection of heat from the life sciences payload equipment only.

**1/3 of the module wall insulation weight and volume were used for Mini-7.

2/3 of the module wall insulation weight and volume were used for Mini-30.

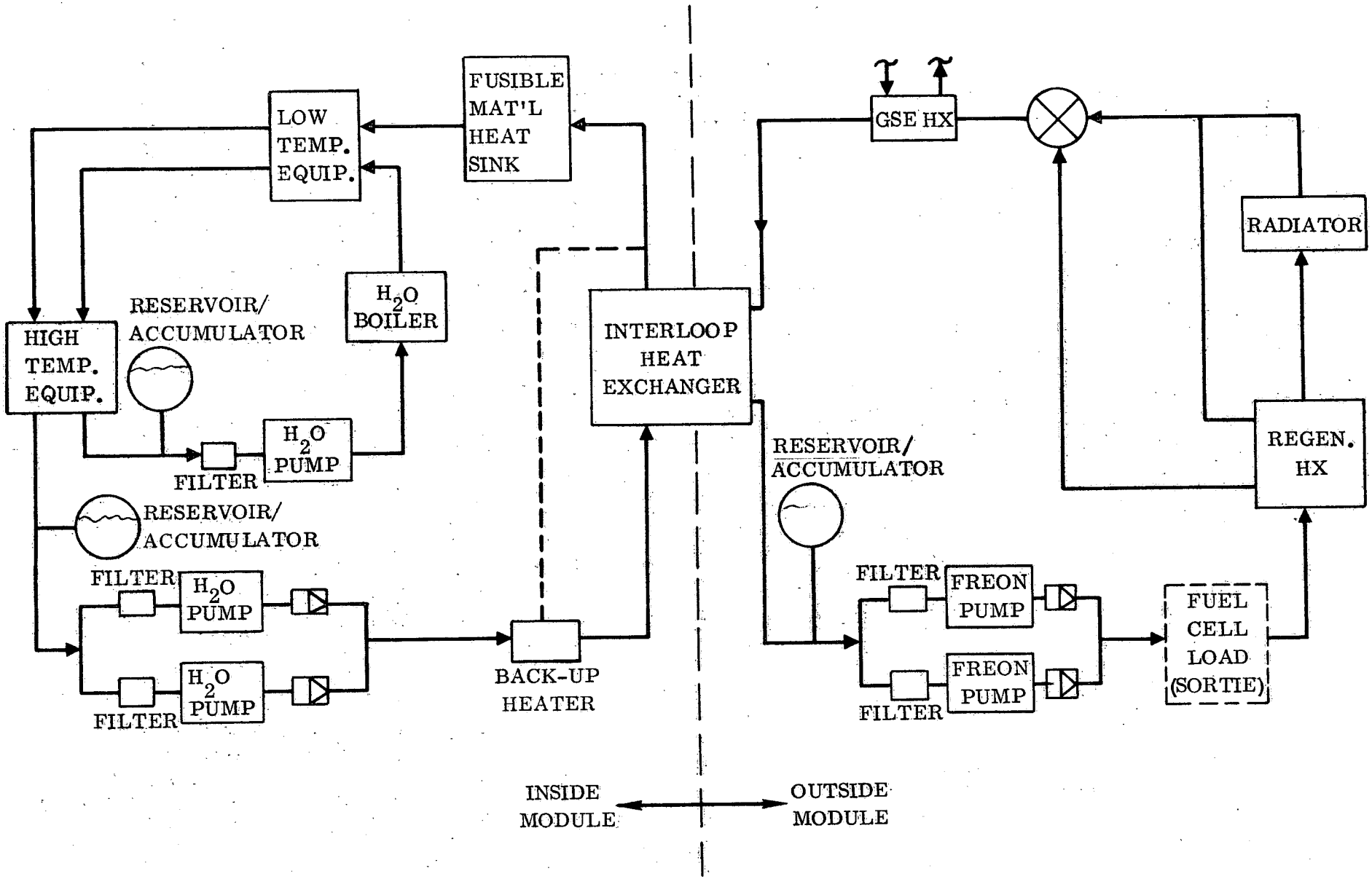



Figure 5-9. Thermal Control Subsystem Concept

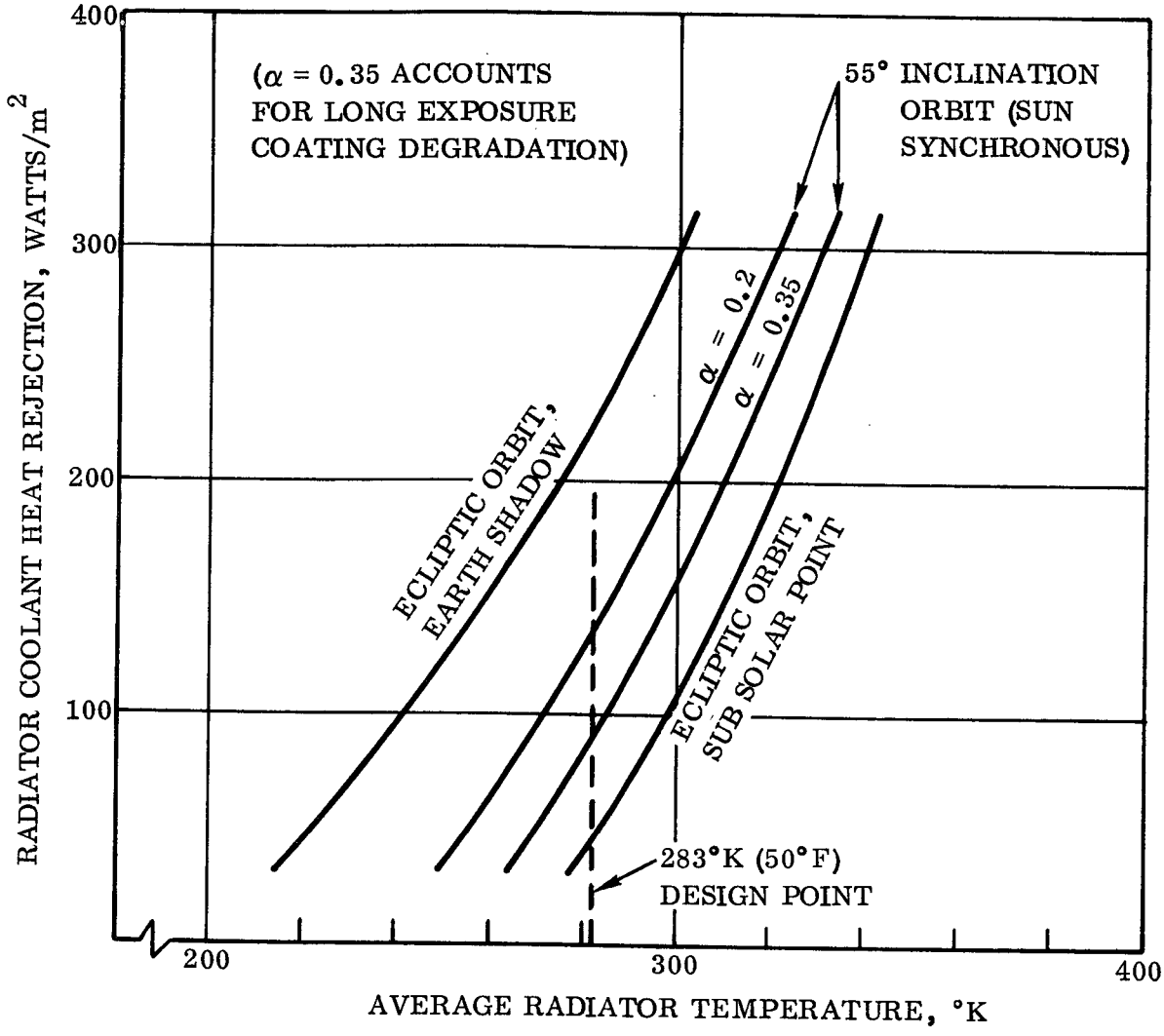



Figure 5-10. Average RAM Radiator Performance During Ecliptic and 55° Equitorial Inclination Orbits

The heat rejection radiator area depends upon such factors as the average sink temperature which is a function of panel orientation and orbital parameters, radiator surface temperature, radiator solar absortivity, and thermal emissivity. The radiator sizing was based on the performance shown in Figure 5-10,which is currently being used as a guideline on the GD/Convair RAM study. For an assumed average radiator temperature of 283° K (50° F), and the normal 55° inclination orbit, the design heat rejection is 135.6 watts/$m^2$ (43 BTU/hr-$ft^2$) for the Sortie missions, and 94.6 watts/$m^2$ (30 BTU/hr-$ft^2$ for the Space Station. The lower value for the space station case results from the greater degradation which has to be taken into account over the longer duration missions. This results in a degraded (higher) solar absortivity ($\alpha$) as indicated.

# SECTION 6

# RESOURCE REQUIREMENTS

This section summarizes the resource requirements portion of the Life Sciences Payload Definition Study. It includes discussions of the cost analysis approach and resulting cost estimates associated with the baseline payloads. It should be noted that the reported cost estimates are preliminary for the Life Sciences payloads, and do not include costs for other necessary elements of the total Manned Space Station Program, such as the Space Station, the development and investment costs for the Space Shuttle vehicle, or the Research Applications Module (RAM).

Candidate supporting Research and Technology (SRT) tasks developing out of the Life Sciences Payload Definition Study are discussed in Section 6.2. These tasks represent equipment items requiring varying degrees of state-of-the-art advancement necessary to provide a high degree of confidence in their development. The problem areas, technology, and development requirements for each of these items are discussed.

## 6.1 COST ANALYSIS

6.1.1 APPROACH. The approach used to estimate the cost of experiment equipment and supporting hardware, and subsystems for the baseline payload concepts is shown in Figure 6-1. It indicates the basis used to estimate the cost of space-rated equipment from commercial or earth based equipment. Historical cost data points for space-rated equipment, space modified ground commercial equipment, aircraft equipment, and ground commercial equipment were accumulated from in-house data sources. These data sources included information on equipment and subsystems similar to those items expected to be used in the Life Sciences laboratories. To aid in the use of these data, the experiment equipment was categorized into a number of groups containing similar types of equipment. The objective was to seek analog historical data points which would increase confidence in resulting cost estimates. These groups are listed below:

a. Electrochemical
b. Electromechanical
c. Electronic
d. Optical
e. Structural
f. Data Processing
g. Tools and Kits
h. Cameras
i. Pneumatic or Hydraulic
j. Miscellaneous Equipment

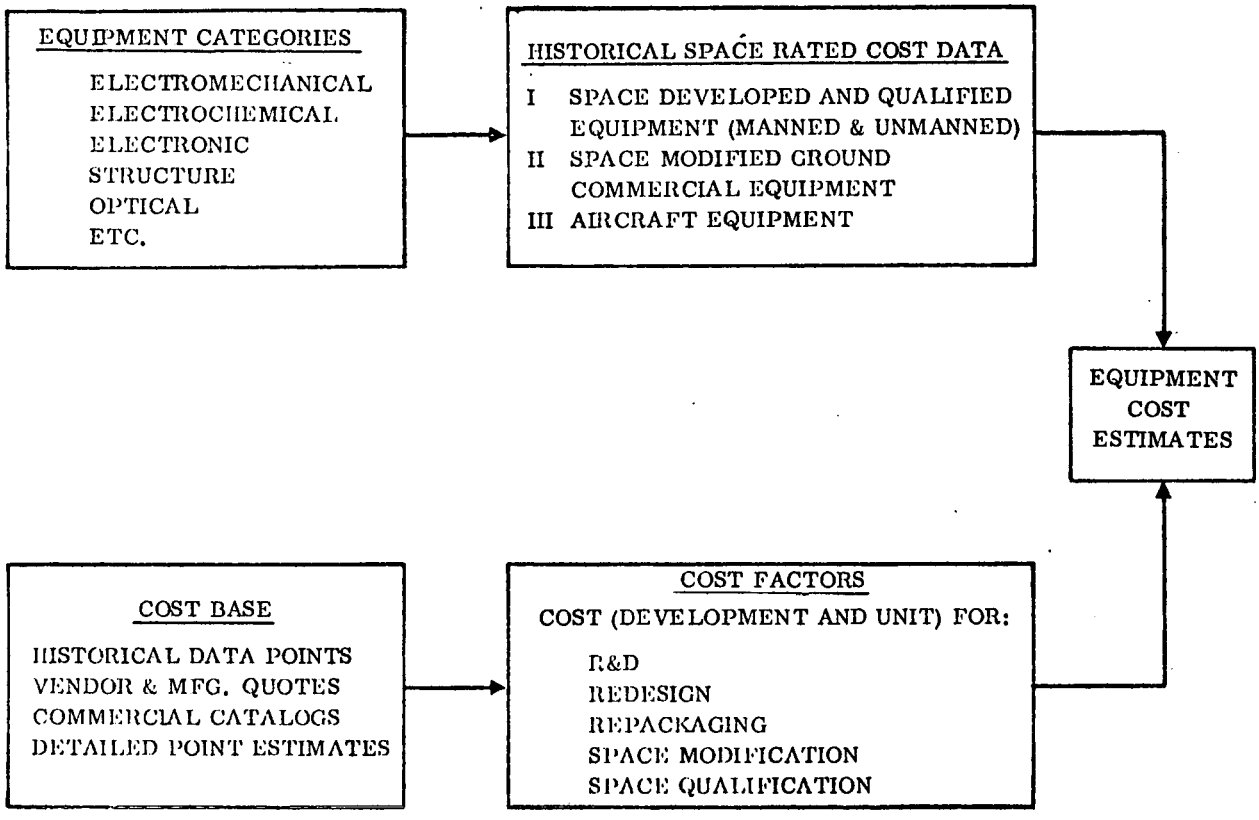



Figure 6-1. Experiment Equipment Cost Estimating Approach

In addition to historical data points on space type hardware, the cost base was augmented by data obtained from manufacturers, vendors, commercial catalogs, and detailed point estimates. Cost data received from manufacturers were associated with procuring off-the-shelf equipment items. Some estimates were obtained relative to the additional costs required to modify, or otherwise develop items for space operation. However, these estimates varied widely for similar equipment items manufactured by different companies, and were not generally used. Instead, cost factors were estimated which could be applied to the off-the-shelf costs to give estimates for space rated hardware. These factors were derived for each of the equipment items listed in the computer inventory. These were established for each equipment item depending on the development required to render it usable for a space laboratory. The development required was rated into five categories, and factors for both development (non-recurring) and unit (recurring) costs were defined for each category as determined from an analysis of the historical and manufacturer data. The categories used were:

a. R&D - SRT - item for which no definable ground hardware exists that requires new development programs.

b. Redesign - existing equipment item requiring major modification for space use.

c. Remanufacture - existing item having acceptable configuration but requires remanufacture with space rated components.

d. Repackage - item that is basically space rated but requires reconfiguration to fit laboratory modularization concept.

e. Minimal Effort - item that is basically space rated and off the shelf but may require minor modification.

The resulting development, and unit cost estimates are included in the equipment inventory listing. Cost estimates for design or payload sensitive items are based on their definition, when available, for each payload.

Development cost estimates include the costs of functional and environmental tests associated with equipment development. Depending on the item's complexity, these tests may account for up to 50% of the development cost. This cost will vary with the development required to space rate a piece of equipment. Unit cost estimates represent the procurement cost for each unit of a space rated item needed in each payload.

Experiment equipment integration costs, that include interface hardware, integrated software, and integrated testing, are additional to the basic equipment development cost. This cost varies with equipment complexity and the particular payload design concept used. Based on prior Convair experience, the experiment equipment integration cost is estimated at 50% of the total experiment equipment cost.

6.1.2 COST CATEGORIES AND ASSUMPTIONS. The baseline payload cost summary data shown in Section 6.1.3 involves ten cost elements. They are:

a. RAMs (Research Applications Modules)

b. Common subsystems

c. Organism environmental control system

d. Experiment equipment

e. Research centrifuge

f. Experiment equipment integration

g. Laboratory maintenance and refurbishment

h. Equipment spares

i. Dedicated module launches

j. Cargo launches

Assumptions made about these elements are as follows:

a. RAM and common subsystem cost estimates do not include development costs.

b. The organism environmental control system cost estimate includes development and unit costs.

c. The data management subsystem cost estimate is included in the experiment equipment estimate, and includes development and unit costs.

d. Experiment equipment integration is estimated at 50% of the total equipment cost.

e. Laboratory maintenance and refurbishment costs are estimated at 50% of the total equipment cost over a nominal 10 year program.

f. Equipment spares costs are estimated at 200% of the equipment unit costs for a nominal 10 year program. This is derived from 50% of unit cost for initial spares, and 15% of unit cost per year thereafter.

g. Dedicated Shuttle launch operations costs are estimated at $4.5 million per launch, based on data provided by NASA during the RAM studies. Shuttle payload capability is assumed to be 11,360 kg (25,000 lb).

h. Cargo launch costs are calculated on the basis of a 7100 kg (15,625 lb) payload capability per Shuttle launch, and are pro-rated accordingly.

i. Launch costs, dedicated and cargo, are those required for initial placement of the payload in orbit.

j. Cost estimates associated with flight operations, ground support equipment, ground mission support facilities are not included in the baseline payload costs.

k. Cost estimates do not include those for earth based control facilities required to parallel the experimentation of the space laboratory.

l. Cost estimates are in 1971 dollars and no inflation, discounting, or growth costs are considered.

These assumptions are consistent with Convair's experience on similar types of space program studies.

6.1.3 BASELINE PAYLOADS COST SUMMARY. The preliminary baseline payload cost estimates are summarized in Table 6-1, and consist of entries for various cost categories.

Module costs are for procurement of two RAMs for the Maxi Max payload, and one RAM for the Maxi Nom payload. Both the Mini-30 and Mini-7 payloads module costs are pro-rated, since the RAM is shared with experiments from other scientific disciplines. The common subsystems include the crew environmental control, thermal control, and electrical power subsystems. Their cost estimates are for procurement only. The research centrifuge cost estimate includes both development and unit costs, and is based on Convair entrifuge studies performed for NASA under Contract NAS-1-9904.

Table 6-1. Baseline Payload Cost Summary

| Cost Element | Costs in $ Millions | | | |
|---|---|---|---|---|
| | Maxi Max | Maxi Nom | Mini-30 | Mini-7 |
| Modules and Common Subsystems(1) | 24.86 | 14.78 | 8.29(2) | 3.81(2) |
| Research Centrifuge | 155.36 | - | - | - |
| Organism ECS | 42.50 | 28.10 | 12.90 | 4.28 |
| Experiment Equipment R&D Cost | 120.53 | 92.92 | 84.85 | 60.49 |
| Experiment Equipment Unit Cost | 43.23 | 20.38 | 13.16 | 11.12 |
| Dedicated Launches | 13.50 | 4.50 | 3.40(2) | 1.40(2) |
| Cargo Launches | 4.18 | 4.09 | - | - |
| Subtotal | 404.16 | 164.77 | 122.60 | 81.10 |
| Equipment Integration | 81.88 | 56.65 | 49.00 | 35.80 |
| Lab Maintenance and Refurbishment | 81.88 | 56.65 | 49.00 | 35.80 |
| Equipment Spares | 89.60 | 40.77 | 27.11 | 22.25 |
| Total | 657.52 | 318.84 | 247.71 | 174.95 |

(1) Data management subsystem cost is included in experiment equipment costs.
(2) Pro-rated cost.

Dedicated launches are those requiring the total Shuttle payload capability. When combined module and scientific payload weight exceeds 11,360 kg (25,000 lb), the excess is presumed to be delivered to orbit as cargo. Cargo launch costs are pro-rated at $635/kg ($288/lb) for a Shuttle cargo payload capability of 7100 kg (15,625 lb).

Preliminary cost estimates for each experiment equipment item are shown in the equipment inventory printout. Some of the items in the inventory are payload or design sensitive, and their cost estimates are determined separately. All estimates are for space rated items. Other data include on card 4 are estimates of the degree of development required to space rate each item, the development time required to space rate each item after research and development go-ahead, and the development risk or degree of uncertainty associated with the development of each item.

Total experiment equipment costs are listed for each baseline payload in the computer sorts printout. The cost for each equipment item that is design or layout sensitive is added to the computer generated costs to come up with a total cost estimate.

The payload cost summary gives cost estimates for the independent development of each payload. For a payload evolution say from Mini-7 to Mini-30 the additional development and unit costs of experiment equipment would approximate the difference of these costs between the payloads. This cost difference is due to the additional items required by the higher capability payload concept.

Table 6-2 itemizes the Life Sciences CORE cost estimates for each of the baseline payloads by equipment unit. These estimates account for multiple units of equipment items required in each payload sort.

Table 6-2. Life Sciences CORE Cost Summary

| Equipment Unit | Costs in $ Millions | | | |
|---|---|---|---|---|
| | Maxi Max | Maxi Nom | Mini-30 | Mini-7 |
| 1. Visual records and microscopy unit | 9.39 | 6.93 | 6.61 | 6.16 |
| 2. Data management unit | 41.81 | 27.74 | 25.38 | 24.68 |
| 3. Life Sciences experiment support unit (1) | 1.14 | 0.95 | 0.83 | 0.27 |
| 4. Preparation, preservation and retrieval unit | 15.81 | 15.05 | 13.26 | 9.19 |
| 5. Biochemistry and biophysics analysis unit | 16.49 | 12.23 | 10.30 | 6.66 |
| 6. Maintenance, repair, and fabrication unit | 14.21 | 14.14 | 14.01 | 11.49 |
| 7. Ancillary storage unit | 0.11 | 0.08 | 0.04 | 0.04 |
| Total | 98.96 | 77.12 | 70.43 | 58.49 |

(1) Waste Management System costs are included in Organism EC/LS costs.

## 6.2 PRELIMINARY SUPPORTING RESEARCH AND TECHNOLOGY (SRT)

Twelve major SRT items were identified during the preliminary concept phase of the LSPD study. The SRT needs have been identified in terms of the research required to make the items applicable for the space laboratory. The finalized versions of the required SRT activities will be developed during the integrated program plan phase of the study (Task D). The SRT items identified here, plus those identified during Tasks C and D, will be a part of that study activity. Preliminary cost data is included in the present equipment inventory; however, these costs are considered only first-cut and have not had the benefit of an in-depth costing analysis, as would be performed in Task D.

6.2.1 HOLDING UNITS FOR ORGANISMS. A common organism holding system is required for at least each FPE. The ideal system would be one that could be used as an incubator for the cells and tissues, and for invertebrates, an artificial green house for plants, and a cage support system for vertebrates from mice to small primates.

The holding system must supply environmental control, support observations and measurements, and allow for isolated human operations. The system must work in ground laboratories and simulators, and through the launch and re-entry profiles, as well as in space.

The holding units should be modular with separate components, easily maintained and lightweight. A modular approach aids in low cost. The holding units should be adaptable to any FPE and easy to reconfigure. A conceptual design of a holding unit is shown in Figure 6-2.

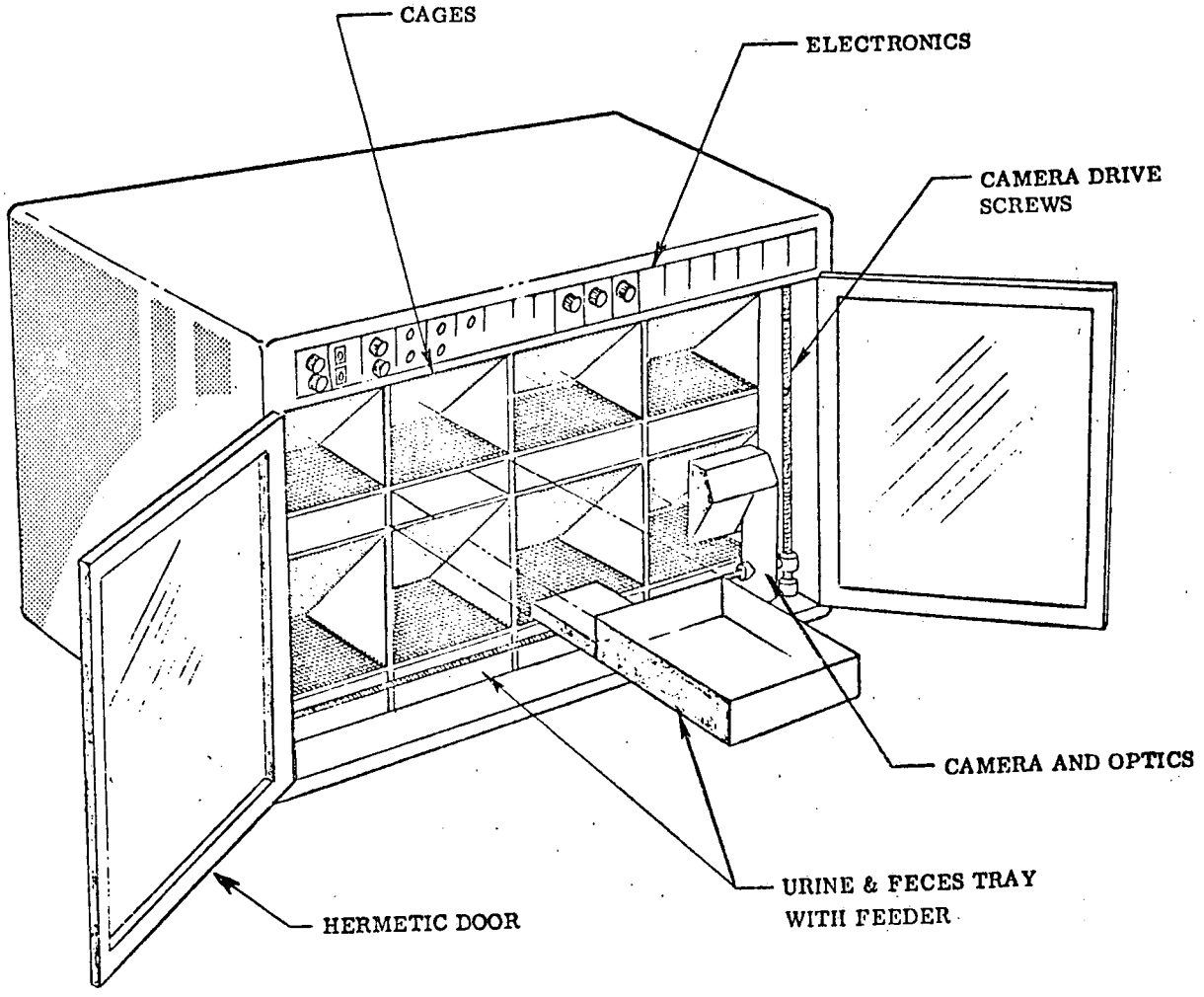



Figure 6-2. Organism Holding Unit

6.2.2 VERTEBRATE CAGING. A caging system is required to contain organisms in the holding units. These systems must provide organism restraint, support observations and measurements, and provide solid, paste and liquid food, and waste management. Food and waste management for vertebrates presents areas for precise development. Urine, feces, hair and other particulates present a hazard to the health and well-being of vertebrates. The proposed air flow and mechanical devices all perturbate the gravity

requirement established for the organism. A system is required that will remove the particulates, but will not disturb the gravity requirement for the organism.

The second caging system design is required for the metabolic analysis of organisms. The metabolic mass balance (MMB) cage must provide the same conditions as the general holding cage, plus be capable of: (1) collecting, separately, the feces, urine, hair and particulate debris; (2) measure food and water consumption; (3) measure oxygen consumed and carbon dioxide produced; (4) measure heat output; and (5) measure respiratory water loss.

The two types of cages are required for a range of vertebrate organism sizes. Candidate organisms may be mice, rats, marmots, rabbits, and small primates. The cages should be of a geometric configuration to be compatible with the holding unit system; (i.e., one rat cage can be replaced by four mouse cages, or one mouse colony cage or eight rat cages can be substituted for one primate cage).

6.2.3 LAMINAR FLOW BENCH (LFB). A modified portable glove box with a built-in laminar flow system is needed to provide an isolated operational interface between the experimenter and the biological organisms. Figure 6-3 shows one approach to an LFB for space application.

A related requirement for isolation exists between experimental groups of organisms. Without isolation, any disease affecting an experimental group would most likely spread throughout the lab colony destroying the experiments. The LFB provides this isolation.

The LFB also performs the following functions:

a. The laminar flow system maintains clear vision to the subject while keeping debris; such as urine, feces, water, and hair away from the subject.

b. Provides a portable workbench that can be appropriately outfitted for the desired task, and taken to the organism. Moving a biological organism to the work area might exceed the allowable gravity levels established for the organism.

c. Provides an instrumentation complex (video display, CRT display) at the holding unit, allowing setup and checkout of the experiment instrumentation (camera adjustments, bioelectronic calibration and adjustment, feed and water dispenser checkout, etc).

d. Provides a means of transporting samples from the holding units to the preservation and preparation unit while maintaining isolation.

Glove box operations are also required for other biological functions; such as toxic chemical management, and radiobiological research. Toxic chemical management can be accomplished in the LFB by interfacing with a cage module type equipment rack containing the chemicals.

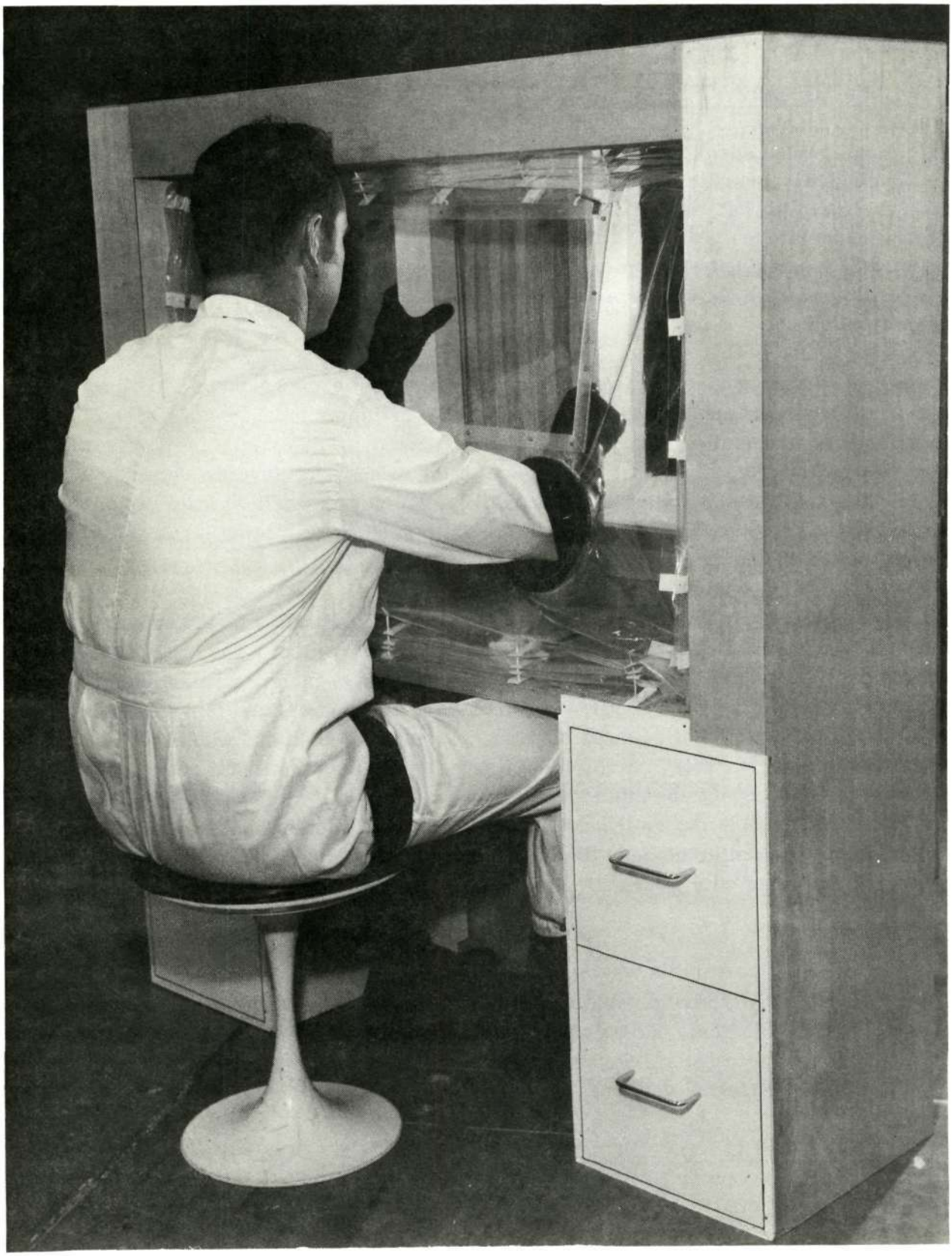


Figure 6-3. LFB For Space Application

Radiochemistries can be performed in the LFB by using a liner fabricated from shielding fabric and a shielding glass. In this case, the radiochemicals are contained in a portable device which can be moved throughout the laboratory as needed.

6.2.4 WASTE MANAGEMENT SYSTEM. Life Sciences research produces significant quantities of metabolic and experimental wastes. The waste material includes plant and animal parts, spent cells and tissue cultures, invertebrate culture substrates, radiobiologicals, chemicals, feces, disposable tools, and wipes. A study is required to determine: (1) what must be done to the material in preparation for safe storage; (2) how much of each type will be produced; (3) what wastes can be safely mixed; (4) can water be extracted economically prior to storage; (5) is compaction or incineration feasible; and (6) how can waste be transported throughout the lab without causing contamination.

Much of the waste production data required for study must be based on a defined payload laboratory concept and layout approach. Experiments must be considered for the worst pathogen, chemical and radiochemical expected, to determine the waste management design criteria. The final disposition of the waste must be considered. Is it to be left in space, does it return with the facility, or must a waste storage container be exchanged between the laboratory and the logistic vehicle, imposing mass and volume constraints on the containers?

6.2.5 ORGANISM ENVIRONMENTAL CONTROL SYSTEMS (ECS). A separate ECS is required to support organisms contained in the holding units. The basis for the organism ECS is isolation of man from organisms, and organism groups from other organism groups. Isolation is required to avoid both chemical and biological cross-contamination. Additionally, most laboratory organism colonies, whether they are vertebrates, invertebrates, or cells and tissues, produce significant odors. Terrestrial laboratories utilize the exterior atmosphere for some odor control, and laboratory personnel work a few hours and go home allowing decontamination. The space investigator could not go home if the entire facility was common with the organism holding. Significant odor could affect human performance and sense of well being in all areas.

The primary ECS question is whether the organism ECS must contain a separate air supply, or can facility air be used if properly conditioned. Specifications are required for the level of biological, chemical contaminants, and odor allowed in the man compartment, from the organism compartment, and vice versa. Absolute isolation imposes extremely stringent demands on a man operated laboratory.

6.2.6 SAMPLE FIXATION AND STAINING APPARATUS. Detailed analysis of tissue will most likely be done on the ground. Some of the tissue specimens can be preserved

as tissue blocks, while others need to be fixed on a glass slide and stained for ground analysis. A staining device to perform the Wright's stain for blood smears has been developed by NASA. This concept should be advanced to accommodate fixing, and staining processes for other plant and animal tissue and microbiological staining, especially the Gram's stain process.

6.2.7 AUTOMATIC CLINICAL ANALYSES. A number of automatic clinical analyzers are available today as off-the-shelf items. Two automatic clinical analyzers and an automatic urine analyzer have been developed for NASA biomedical measurements. The number of measurements that these machines can accomplish is small compared to the total biochemical measurements required. Caution must be taken in selecting the parameters to be measured in space, in contrast to preservation for ground analysis. Measurements in space should be done only if: (1) the information is required for the control or completion of the present experiment; (2) the sample cannot be preserved and stored for the time it takes to get to the ground lab; (3) identical space and ground analyses are required to prove the absence of sample modification by preservation, the space environment or the re-entry profile; and (4) analytical results are required to input ground controls.

A study is required to determine what biochemical measurement capabilities are required in space for all Life Sciences research. The present blood analyzers should be evaluated for adaptability to the new required measurements. The accepted analyzer should then become a target for research to include additional space analysis. The present urine analyzer, developed for primate research, should be considered for up-rating to accommodate all required space urine analyses.

6.2.8 ORGANISM VIDEO AND FILM RECORDS. A video/cinemagraphic system is required to monitor large numbers of organisms supported in cage modules. The system must be capable of a variety of visual records, including video, still photos, time lapse photography, and standard cinematography. It should be computer controlled. It must be flexible, allowing for routine coverage as well as by computer and manual control of "ad hoc" observations. The visual records should be taken with minimal or no organism perturbation.

A time, date, organism identification system is required imprinted on all visual records. The video records must be compatible with TV downlink support vehicle systems.

6.2.9 DATA MANAGEMENT. Physiological measurements from man and organisms are expected to be voluminous. However, greater than 90% of this data is normal, and the least informative beyond that point. Reliable software programs should be developed to process, record selected portions, update existing programs to the new parameters, and continue monitoring. Additionally, the programs should be capable of recording data leading into an out of tolerance condition. As an example, if 10 minutes of data

is required leading to the out of tolerance, then the system should record 11 minutes. If the data is normal, discard the oldest minute of data and if it is out of limits, maintain the past data plus all future data until the condition is corrected.

Discrete measurements from environmental parameters, maintenance tasks, and equipment outputs should be processed and/or compacted to minimize the volume of data to be dumped.

Analytical instrument output should be evaluated to determine what is required for experiment analysis, and how the resulting data might be processed.

6.2.10 INTERNAL BIORESEARCH CENTRIFUGE. A bioresearch centrifuge is required to provide a gravitational field to control organism in the space environment. A conceptual design of the bioresearch centrifuge used for the Maxi Nom laboratory is shown in Figure 6-4. The centrifuge should have the greatest radius feasible. It should support organisms in cages and cage modules identical to those in the lab environment. This includes all data management, environmental control, and experimenter access. Acceptability of stopping the centrifuge during experimentation must be determined.

Control organisms in a rotogravity field are subject to gravity plus additional conditions such as coriolis, high gravity gradient, and vibration. Biologists must have a data base on the effect of these conditions on candidate organisms. Therefore, a prototype centrifuge should be developed, with the operating parameters of the space centrifuge to begin the baseline data, and to aid in the development of the space system.

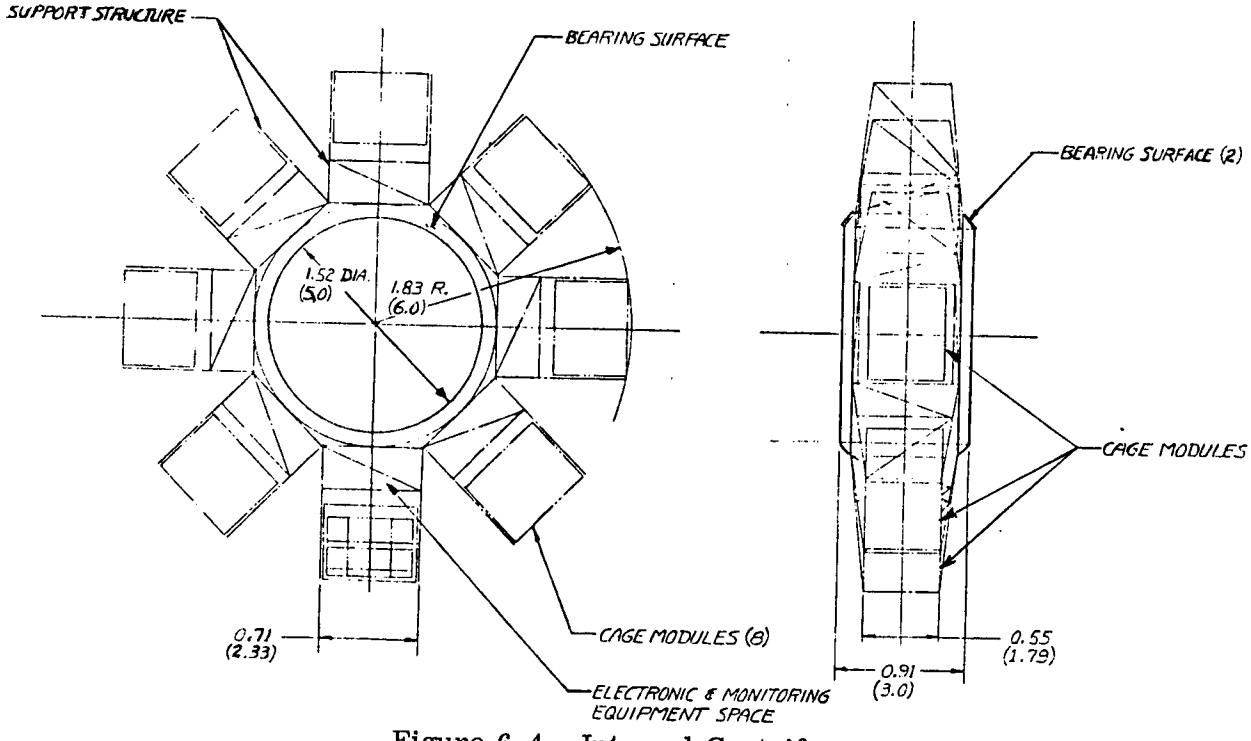



Figure 6-4. Internal Centrifuge

6.2.11 GROUND ORGANISM SIMULATOR. Control organisms are required to support most biological experiments. A study is required to determine the requirements of a ground control simulator. It could be a rather simple device in the Principal Investigator laboratories or a single, broad capability simulator at a NASA center where Principal Investigators take their control organisms. A common comprehensive simulator complex would bring together various scientific teams who have experiments in space, and will also provide collaboration on resulting data, a common data dump point, and a permanent facility. In addition to the scientific requirements, cost effectiveness of such a facility must be studied.

6.2.12 GROUND SUPPORT OF COMMON CAGE MODULES. The modular approach to equipment for organism holding and management implies a system where Principal Investigators would check out from NASA, the necessary common modular equipment months or even years prior to flight, to allow time to implement experiment specific hardware, setup and develop experiments, and develop the required data base. In order to accomplish this, a ground support system is required for the cage modules that will provide environmental control, data management, visual records, and organism access in a manner as identical to the flight phase of the experiment as possible. Figure 6-5 shows an engineering breadboard of a ground support concept.

The study should include a determination of whether the ground support system should also support organisms in cage modules during logistics missions.

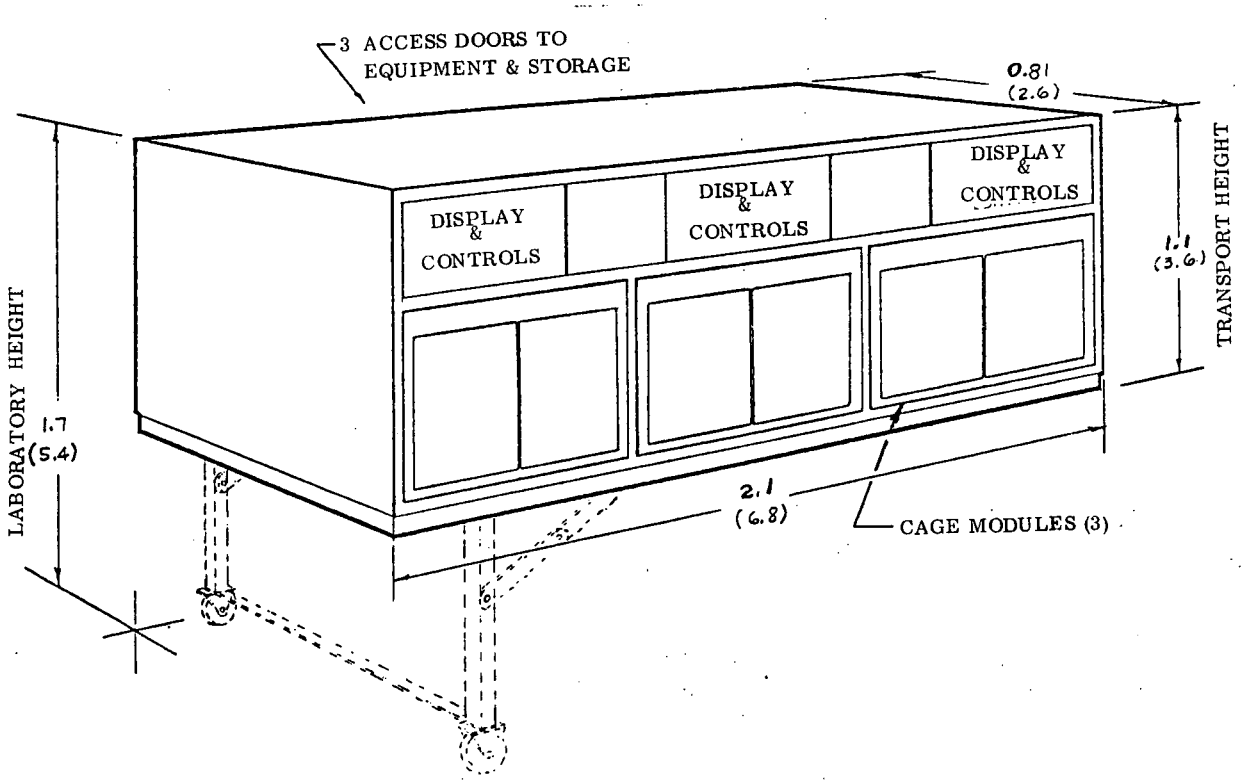



Figure 6-5. Ground Support and Transfer Module



C.S.

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