NOVEMBER 1971

MDC G2595

SPACE STATION

MSFC-DPD-235/DR NO. MP-02

CREW OPERATIONS

CONTRACT NAS8-251

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MARTIN MARIETTA CORPORATION IBM International Business Machines Corporation MCDONNELL DOUGLAS CORPORATION

CAT-31

MCDONNELL DOUGLAS

CONTRACT NAS8-25140
MSFC-DPD-235/DR NO. MP-02

CREW OPERATIONS

NOVEMBER 1971

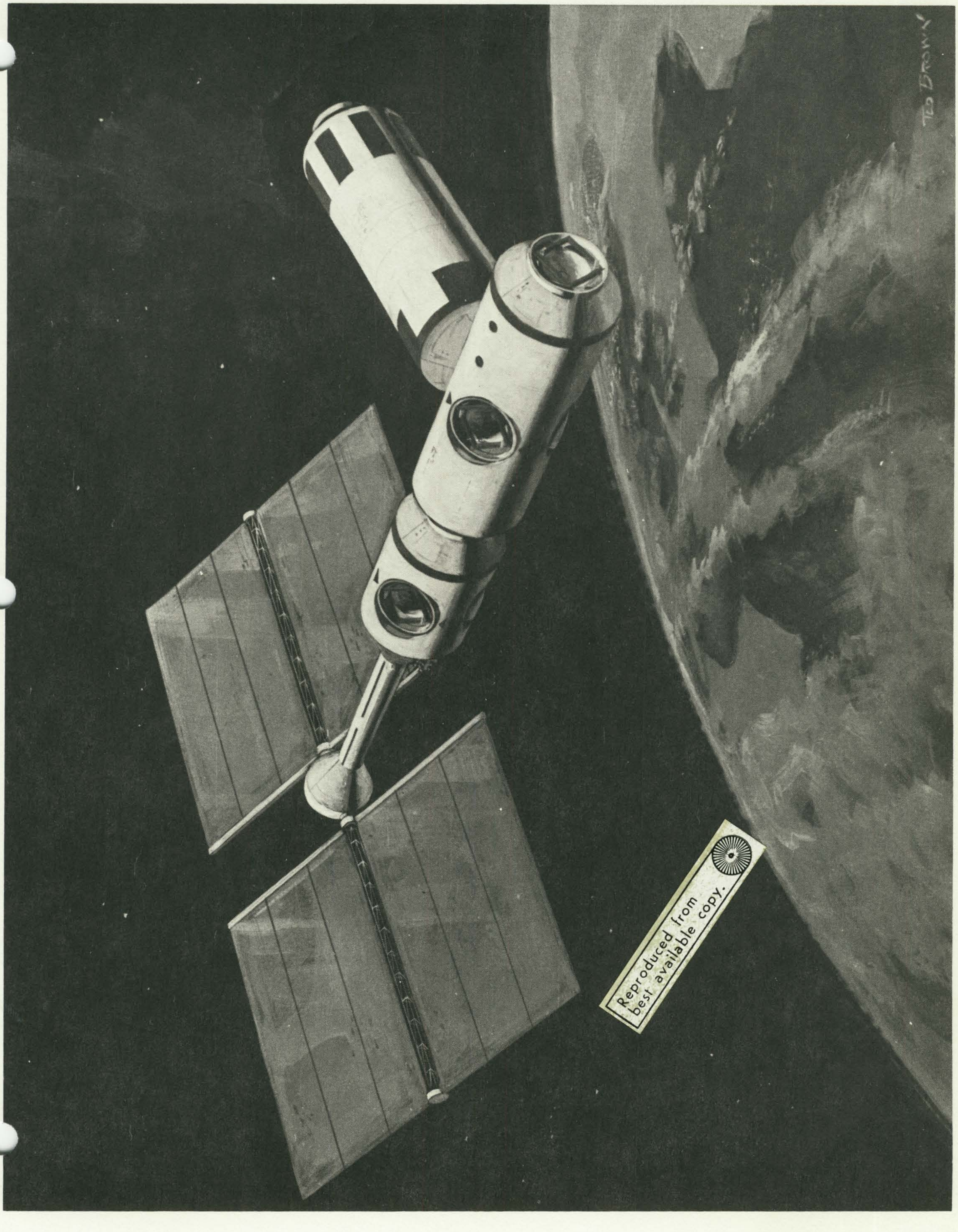
MDC G2595

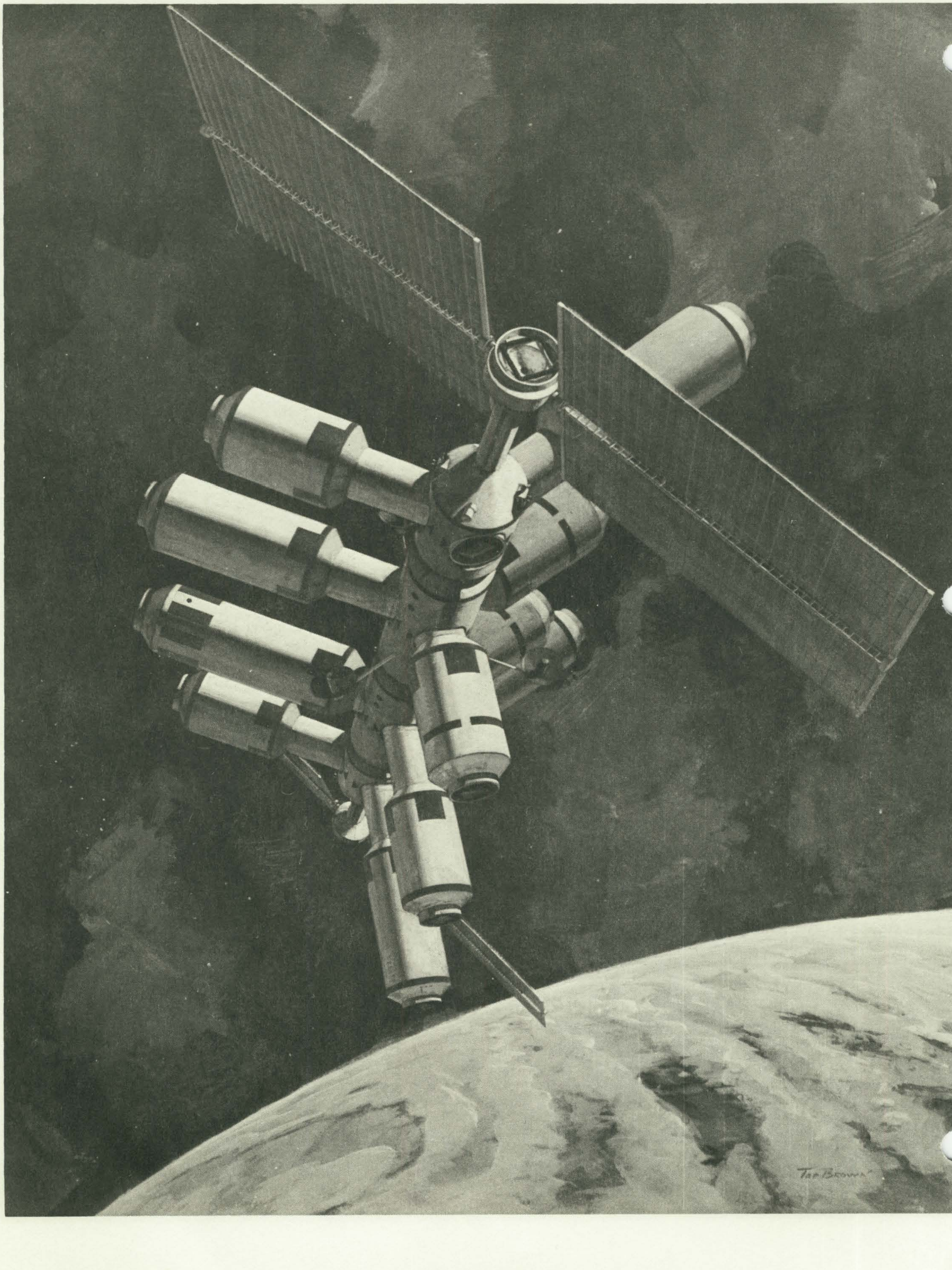
APPROVED BY:

Vern D. Kirkland

VERN D. KIRKLAND
PROGRAM INTEGRATION/OPERATIONS
DIRECTOR
SPACE STATION PROGRAM

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
5301 Bolsa Avenue, Huntington Beach, CA 92647


TED BROWN



PREFACE

The work described in this document was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the extension period has been to develop the Phase B definition of the Modular Space Station. The modular approach selected during the option period (characterized by low initial cost and incremental manning) was evaluated, requirements were defined, and program definition and design were accomplished to the depth necessary for departure from Phase B.

The initial 2-1/2-month effort of the extension period was used for analyses of the requirements associated with Modular Space Station Program options. During this time, a baseline, incrementally manned program and attendant experiment program options were derived. In addition, the features of the program that significantly affect initial development and early operating costs were identified, and their impacts on the program were assessed. This assessment, together with a recommended program, was submitted for NASA review and approval on 15 April 1971.

The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

A subject reference matrix is included on page v to indicate the relationship of the study tasks to the documentation.

This report is submitted as Data Requirement MP-02.

DATA REQUIREMENTS (DR's)
MSFC-DPD-235/DR NOs.
(contract NAS8-25140)

Category	Desig- nation	DR Number	Title
Configuration	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project Part I CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Stations Phase B Extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning Financial	MF	MF-01	Space Station Program (modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay Sizes

FOLDOUT FRAME 1

FOLDOUT FRAME

FOLDOUT FRAME 2

SUBJECT REFERENCE MATRIX

LEGEND:
- CM Configuration Management
- MA Program Management
- MF Manning and Financial
- MP Mission Operations
- SE System Engineering and Technical Description

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	**CM-02** Space Station Project (Modular) Specification	**CM-03** Modular Space Station Project Part I CEI Spec	**CM-04** Interface and Support Requirement Document	**MA-05** Phase C/D Program Development Plan	**MA-06** Program Option Summary Report	**MF-01** Space Station Program (Modular) Cost Estimates Document	**MP-01** Space Station Program (Modular) Mission Analysis Document	**MP-02** Space Station Program (Modular) Crew Operations Document	**MP-03** Integrated Mission Management Operations Document	**SE-01** Modular Space Station Concept	**SE-02** Information Management System Study Results	**SE-03** Technical Summary	**SE-04** Modular SS Detailed Preliminary Design	**SE-06** Crew/Cargo Module Definition Document	**SE-07** Modular Space Station Mass Properties Document	**SE-08** User's Handbook	**SE-10** Supporting Research and Technology	**SE-11** Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project–Part 1 CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
MOD 29																			●
MOD 40						●													

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

FIGURES

TABLES

Section 1
INTRODUCTION

1.1 BACKGROUND

With the advent of the Space Shuttle in the late 1970's, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Space Station comprised of smaller, shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as on the 33-foot-diameter Space Station—but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station Phase A-level study results are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The ISS configuration rendering is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (shown in the frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

During ISS operations, five research applications modules (RAM's) will be assembled to the Space Station. Three of these will be returned prior to completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

1.2 SCOPE OF THIS VOLUME

This volume describes the requirements for the activities involved in, and the procedures used by the crew in the operations of the Modular Space Station. For completeness and clarity, a description of all crew-related characteristics of the station and its operations are indicated.

Section 2 describes the interior configuration and arrangement of each of the Space Station modules, the facilities and equipment in the module and their operation, as related to crew habitability.

Section 3 defines the crew activities and procedures involved in the operation of the station in the accomplishment of its primary mission. It describes the operations involved in initial station buildup; and the on-orbit operation and maintenance of the station and its subsystems to support the experimental program. A general description of experiment operations is also given.

A detailed description of experiment operations at the functional program element level is presented in Appendix A, prepared by the Martin Marietta Corporation, Denver Division.

Section 2
CREW FACILITIES AND OPERATIONS

2.1 MODULAR SPACE STATION CONCEPT

The fundamental design philosophies which have shaped the Modular Space Station concept are (1) low cost through simplicity and (2) effectiveness through modern technology. The first objective is achieved by limiting the number of basic modules with multifunction elements. The second helps to reduce not only the amount of structure but also the thermal control, safety and warning, fault isolation, electrical and fluid distribution systems. Each additional module also requires another docking interface. While the Initial Space Station employs common structural and thermal control system elements, and other common elements in the individual module designs, the primary simplification and cost reduction due to commonality is in the growth from a 6-man to a 12-man station by the addition of a power subsystem module and a crew operation module, both identical to the original ISS development. A completely maintainable design was developed. Each subsystem design incorporates its own maintainability features which result in a greatly simplified total program (including development and operations).

Increased system effectiveness is achieved through the automation of station facilities to reduce nonproductive man-hours (e.g., fault isolation, failure, warning, and subsystem control). The general-purpose laboratory is designed to provide the maximum involvement of man in the research and application activities.

The ISS is capable of supporting a crew of up to six men. The basic station configuration consists of three modules: (1) a Power/Subsystem Module illustrated with deployed solar arrays and containing all power distribution equipment and other subsystems; (2) a Crew/Operations Module capable of housing up to six men and containing the station command center (attached longitudinally to the Power/Subsystems Module); and (3) a radially attached

GPL, which includes a biotechnology facility as well as laboratories for general research and applications support. Both the Power/Subsystems and the crew modules have three lateral docking ports for the accommodation of the GPL and RAM's, while the end port on the docking module is nominally used for docking the logistics module.

To achieve GSS capability, the two additional Space Station modules (Power/Subsystems and Crew/Operation) will be added to the ISS cluster. These modules are nearly identical in design with those deployed for the initial capability. These two modules double the capability of the Space Station and enable it to perform all functions required for the GSS.

GSS buildup increases the crew size from six to 12 men, and doubles the power, docking ports, etc. The initial GPL is sized for the GSS capability and off-loaded for the ISS; therefore, only one GPL is required. Special crewmen are again employed with delivery of the GSS modules to assist the ISS crew in activating the GSS. Manning to the 12-man level is accomplished by use of a second Crew Cargo Module.

2.2 MAN-SYSTEM INTEGRATION

The interior configuration of all the Space Station modules has been designed to facilitate crew operations and hence habitability. The major program requirements specified by NASA were as follows:

- No artificial g.
- Dual, independent pressure volumes.
- Provide equivalent provisions as 33-ft Station.
- Private state rooms.
- Provide for ease of accessibility for maintenance
- Provide alternate escape routes.
- 96-hr emergency capability.
- Provide emergency EVA/IVA suit station.
- Consistent with good architectural design.

To amplify and clarify the intent of these program requirements, the following general requirements or design goals were generated by McDonnell Douglas Astronautics Company (MDAC) through design analyses to guide the preliminary design effort:

A. All compartments will be designed for maximum habitability.

B. Interiors will be optimized with due consideration to ground checkout and evaluation requirements and constraints.

C. Volume allocation, equipment locations, and interior arrangement will be designed to minimize casual interference, (i.e., to avoid any interuption to crewmen while performing tasks).

D. The opportunity for freedom of choice in facility usage will be maximized.

E. The common use of free space will be applied where appropriate.

The general interior orientation and configuration selected is essentially the same for all modules, although they vary in detail according to the specific requirements of each module. The selected orientation and configuration can be described as a longitudinal orientation, using a minimum of separating walls or decks, but with arrangement of equipment and facilities for two levels of operation where possible.

Each facility work station has been sized (shape and volume) to provide sufficient free space to ensure oprimum task performance or satisfaction of needs, minimum interference from other crew members or equipment, multiple use of facilities without routine scheduling, and a maximum number of alternative areas for accomplishing specific job requirements (e.g., study or report preparation) or meeting personal needs (e.g., social activities or privacy). The location and arrangement of facilities and equipment facilitates the above capability, and minimizes the total Space Station volume requirements; while at the same time maximizing the appearance of spaciousness and the common use of free space, and facilitates the accommodation of mixed crews (male and female, scientists and astronauts) and dual-shift operations.

The concurrent development of interior configurations and crew interfaces is discussed below for each module.

2.2.1 Power/Subsystems Module

The general arrangement of the Power/Subsystems Module is shown in Figure 2-1. The placement of the various subsystem elements was determined by access requirements, module cg constraints, and related equipment proximity. Locating the docking section in the center of the module provides a clear access to install or maintain equipment located at either end.

The Power/Subsystems Module is not normally manned, but must be accessible for initial installation and checkout and for corrective maintenance for the following equipment: communications, data management, guidance and control, on board checkout system (OCS), atmospheric supply, control moment gyros (CMG's), pump-down accumulator, horizon sensor, and propellant tankage. The pressurized compartment is capable of providing a retreat from environmental hazards. Two suits for extravehicular activity (EVA) and two portable life support systems (PLSS's), three oxygen masks and a 96-hr emergency pallet are stored in the compartment.

The Power/Subsystem Module was configured to meet the following requirements:

A. Access to all equipment for installation and unscheduled maintenance.
B. Access to solar array assemblies in intravehicular activity (IVA).
C. On-orbit installation of CMG's and atmosphere storage containers:
D. Volume and space constraints:

Electronics equipment	510 cu ft
CMG's and atmosphere supply storage	210 cu ft
Docking ports	1400 cu ft
Free volume	54 cu ft
Access to CMG's and atmosphere storage area from docking ports	5 ft dia
Clearance between CMG's, atmosphere bottles	6 in.

R272

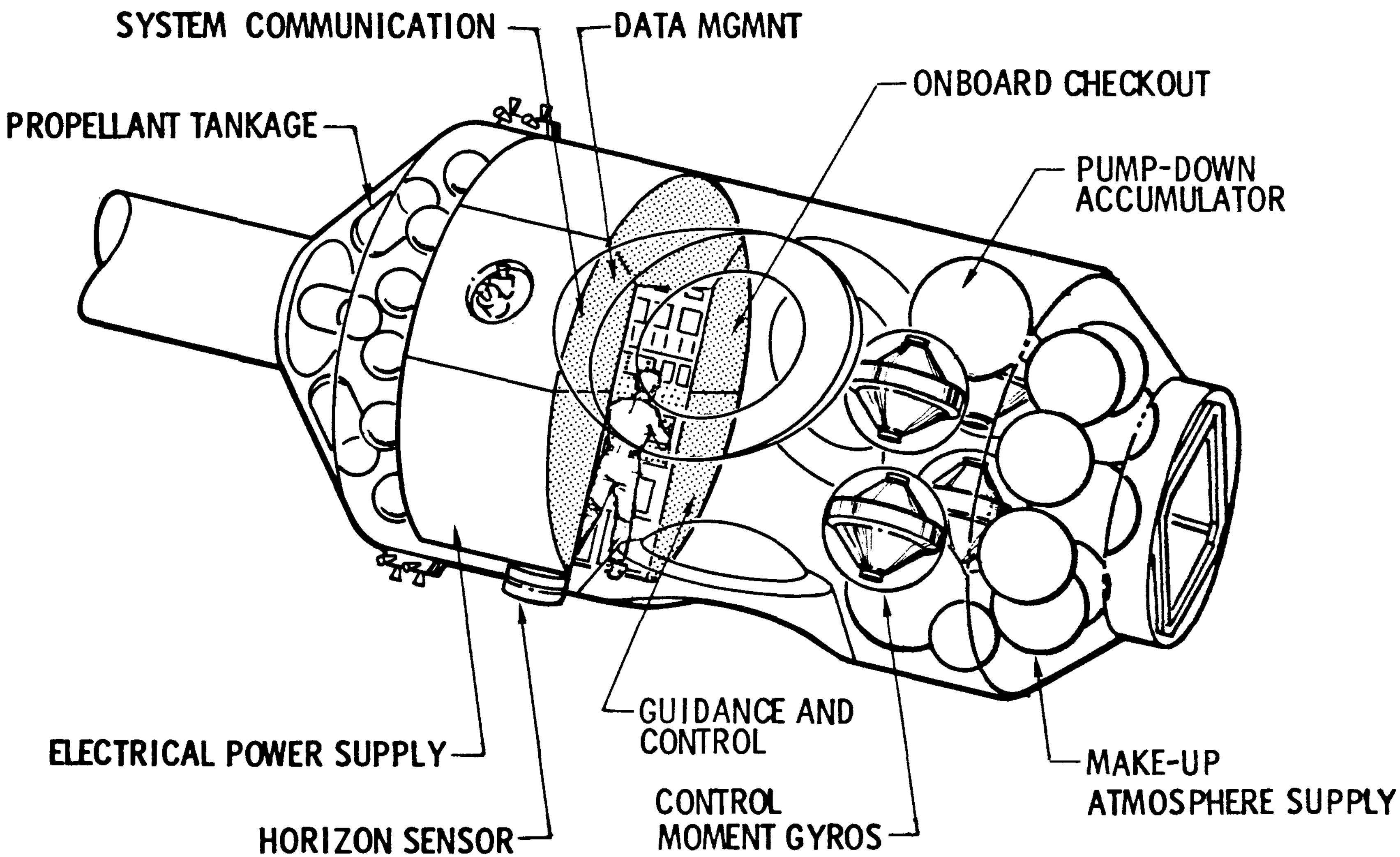


Figure 2-1. Power/Subsystems Module (1/20th Scale Model)

Figure 2-2 illustrates a 1/20th scale model of the Power/Subsystems Module in the launch configuration. It was constructed early in the study as an aid in developing crew requirements.

2.2.2 Crew/Operations Module

The Crew/Operations Module contains most of the crew accommodations. The arrangement employs a zero-g longitudinal configuration, as shown in Figure 2-3. Each of the six crew quarters contains approximately 200 cu ft of space. Two identical hygiene areas are provided, each with a shower and waste management provisions. Three crew quarters and a hygiene facility are located at each end. The galley/wardroom is adjacent to one set of quarters and the primary control center adjoins the other. A docking port area separates the galley/wardroom and the control center.

The three radial docking ports, 120° apart, are incorporated into the mid-point of the module to ensure proper clearance between modules for orbiter docking.

2.2.2.1 Private Quarters

The requirements for private quarters were aimed at providing an alternative to the wardroom for social activities, work, or study and still provide privacy when needed for sleep and other personal activities. The private quarters are approximately 7 ft by 7 ft by 4 ft (196 cu ft). Size and volume of the quarters were determined by the following: freedom for crew maneuverability in two planes requires free volume measuring approximately 6.5 ft by 6.5 ft by 3.5 ft (148 cu ft); furnishings (in place) and personal equipment occupy a volume of 33 cu ft; and the capability for dual occupancy during crew overlap. The private quarters are provided with adequate light and sound attenuation to ensure privacy and isolation. Conversely, the quarters are capable of easy conversion to two- or three-man staterooms and the design accommodates either male or female crew members, as shown in Figure 2-4. Each crew compartment contains provisions for sleeping (restraint), study, and relaxation, and a view port, as shown in Figure 2-5.

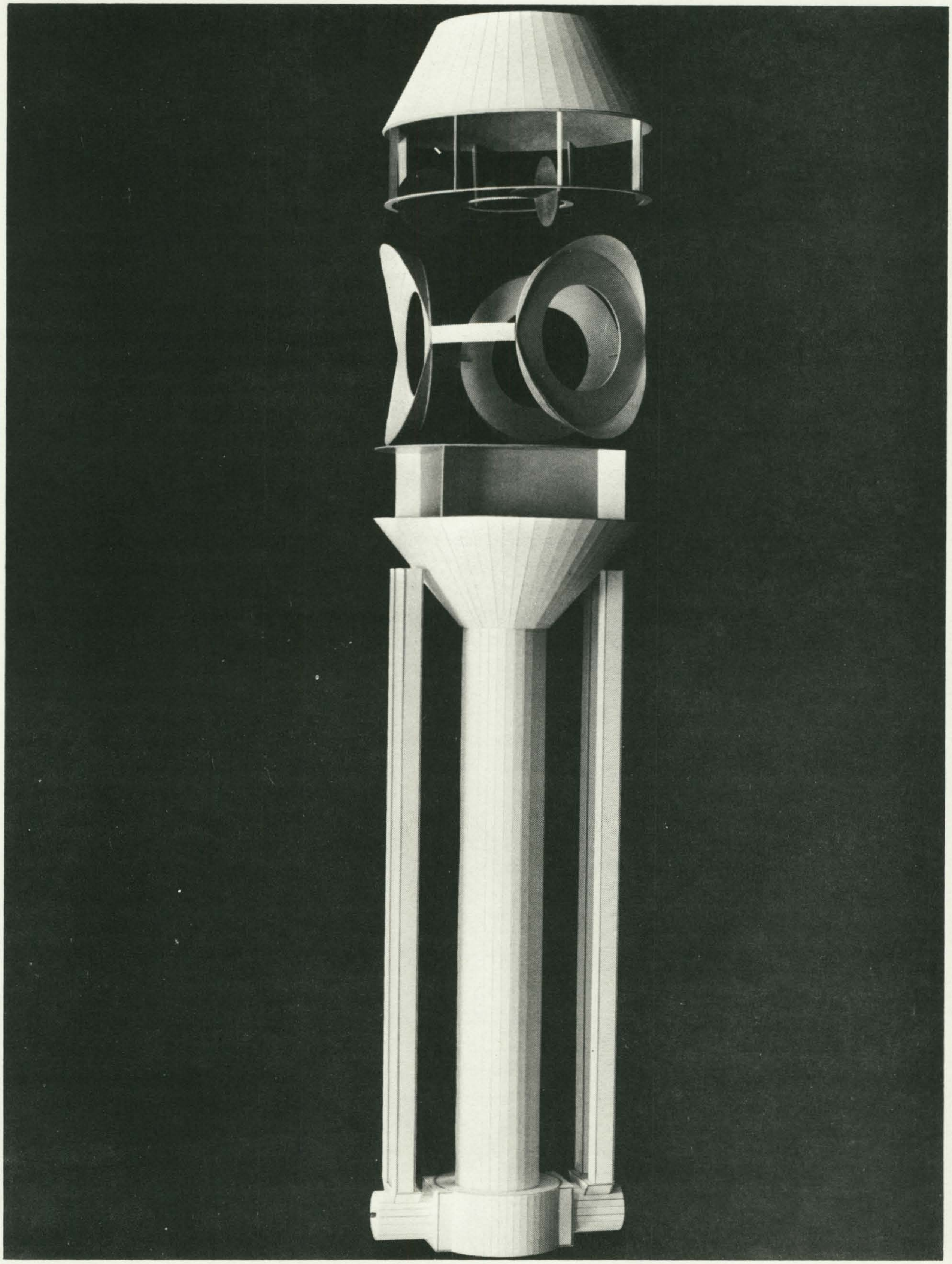


Figure 2-2. Power/Subsystems Module (1/20th Scale Model)

R272

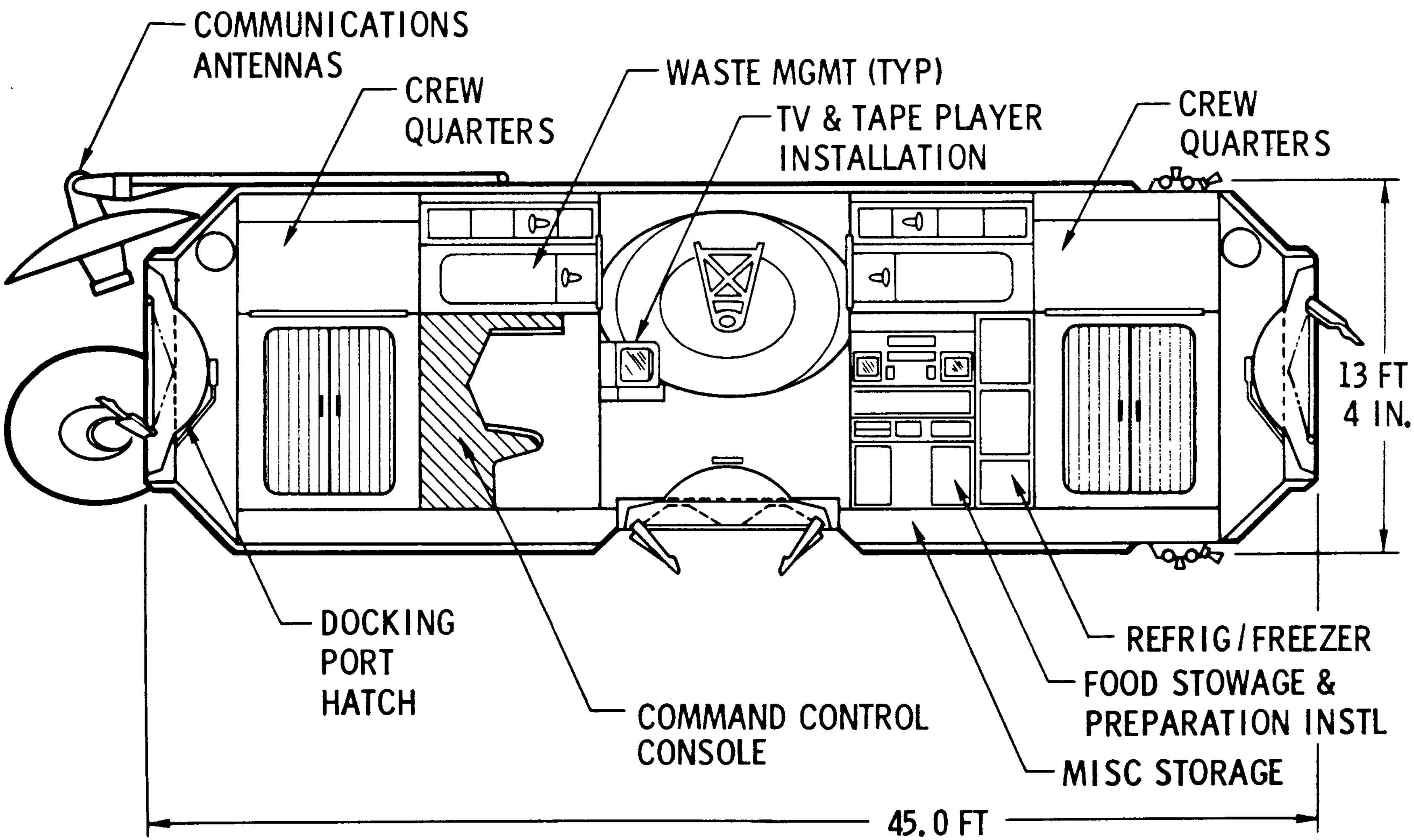


Figure 2-3. Modular Space Station Crew/Operations Module

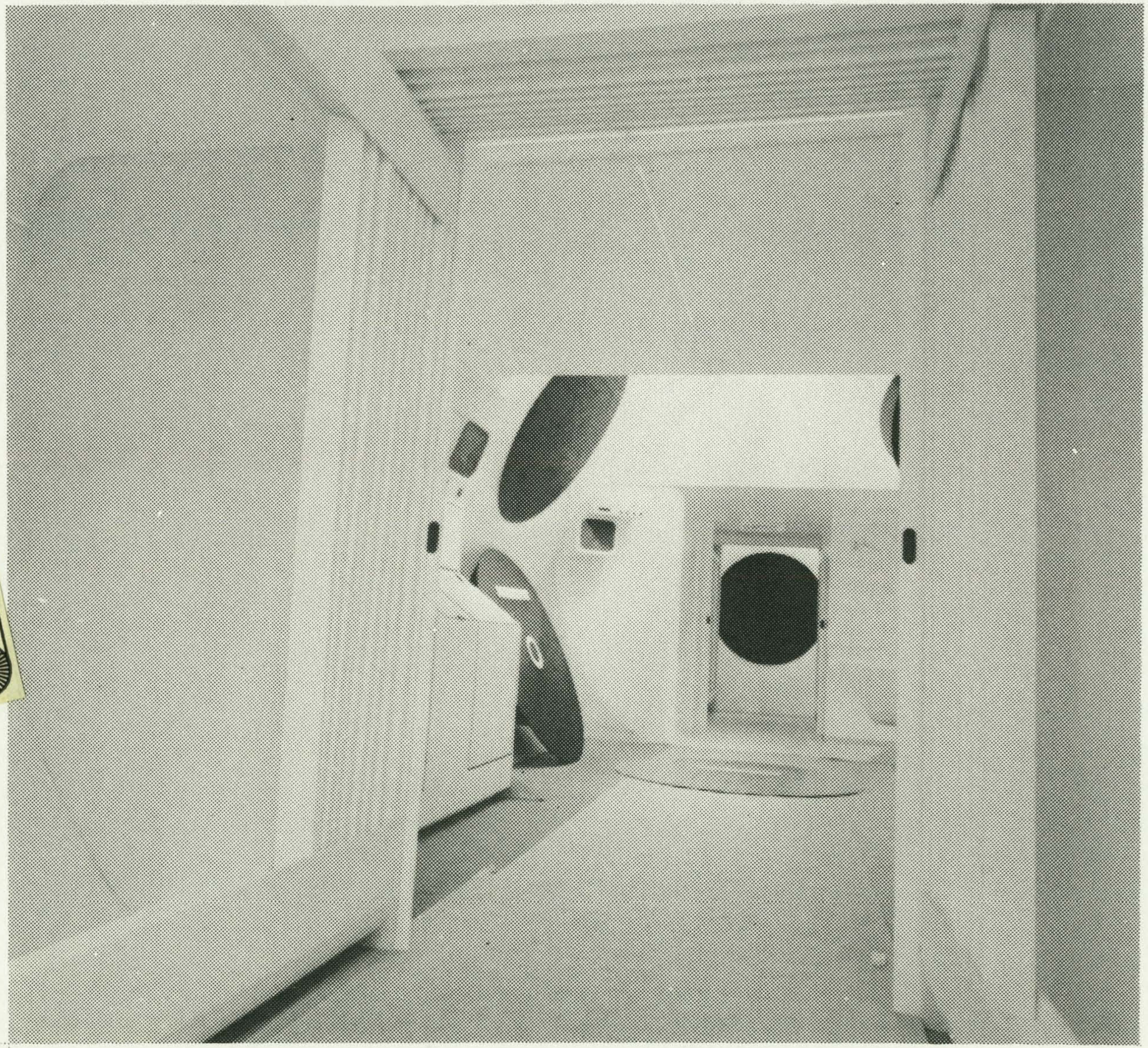


Figure 2-4. Crew Operations Module (Full Scale Mockup)

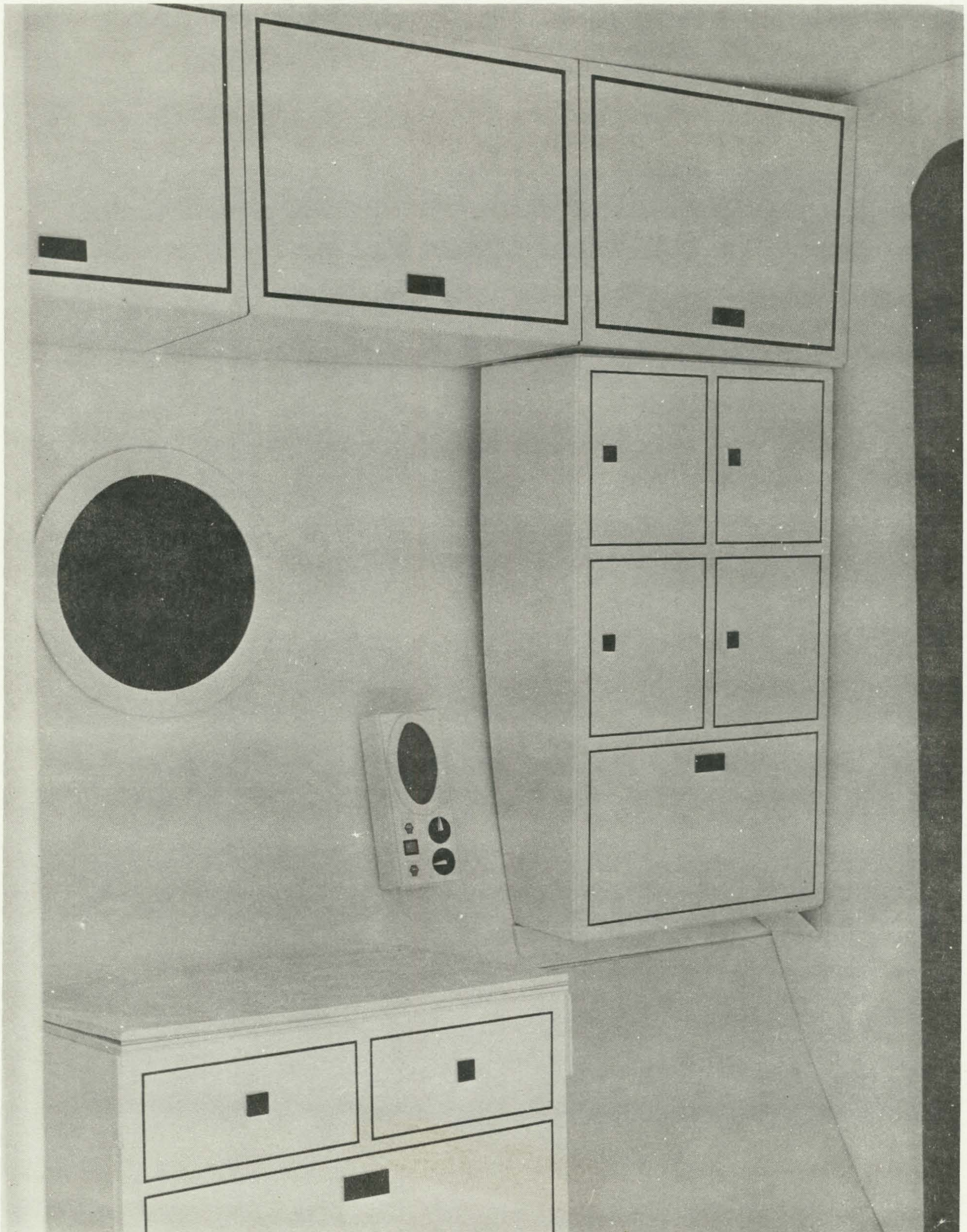


Figure 2-5. Private Quarters

2.2.2.2 Wardroom/Galley/Gymnasium

The wardroom/galley/gymnasium area is designed for multiple use for a variety of simultaneous on- and off-duty activities without interference. The wardroom/galley/gymnasium requirements are as follows:

A. Simultaneous use by six men for the same or different activities.

B. Food preparation center capable of preparing, serving, storing, and clean-up of meals for one to six men.

C. The total volume of the wardroom/galley/gymnasium will be equal to the largest single free-space requirement plus volume for additional equipment or competing activities. Hence, the gymnasium area (14 ft by 10 ft by 8 ft) of 1,120 cu ft plus 600 cu ft for all equipment yields a total volume requirement of 1,720 cu ft. A total of 1,920 cu ft is provided. The adequacy of these requirements were verified in full-scale mockups such as shown in Figure 2-6.

2.2.2.3 Galley and Eating Area

The galley provides equipment for food preparation, serving, storage, and clean-up. Food storage lockers (ambient and controlled temperature) accommodate a 15-day supply of wet and dry foods, including perishables, for a six-man crew. The layout is depicted in the full-scale mockup shown in Figure 2-7.

The eating area contains a removable table and six "seat" restraints. The eating area with the addition of the docking port area is capable of quick conversion to an exercise or recreation area. This concept is illustrated in Figure 2-8.

2.2.2.4 Hygiene and Waste Management Compartments

Duplicate hygiene facilities are provided to reduce interference during periods of high use (e.g., upon awakening) and to provide suitable accommodations for mixed crews. The location of the hygiene facilities—one above the galley and one above the control center wardroom area—are accessed from the docking port area. Hygiene facility requirements are as follows:

A. Two enclosed facilities with appropriate accommodations for male and female crew members.

Figure 2-6. Crew Habitability Docking Port Area (Ward Room Augmentation)

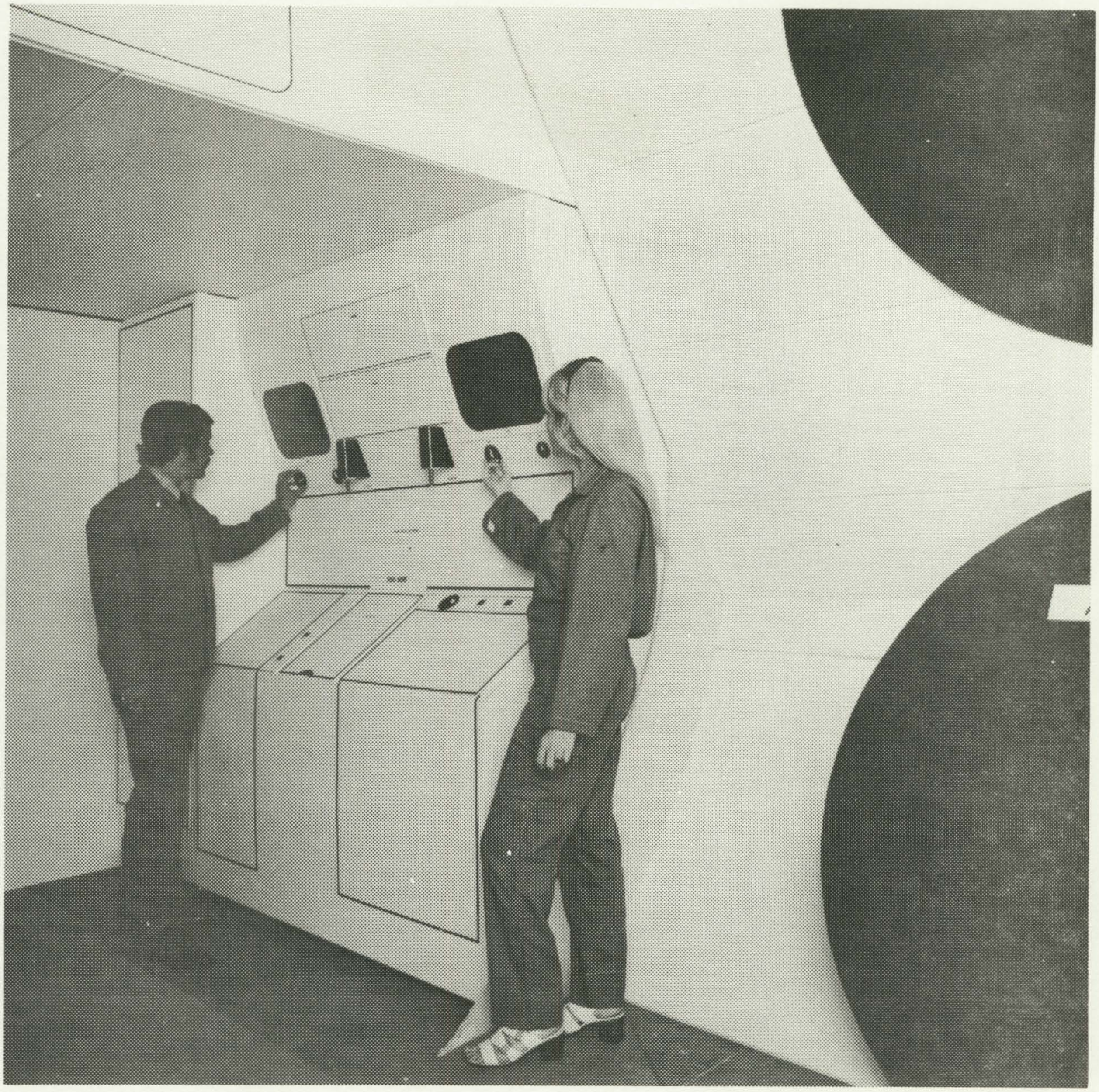


Figure 2-7. Crew Habitability – Galley

Figure 2-8. Crew Habitability - Ward Room (Eating Area)

B. Appropriate noise, odor, and contamination control in the hygiene compartments.

C. Hygiene compartments will be adjacent to the private quarters.

D. Hygiene compartments will be easily accessed from other modules, particularly the GPL.

E. The following functions and volumes have been allocated for each hygiene compartment:

Function	Volume (cu ft)
Shower	60
Waste management	65
Urinal and hand wash	30
Laundry	20
Free space	65
	240

The waste management compartment (within the hygiene compartment) contains a urine collector, fecal collector, and appropriate expendables. It is provided with appropriate controls of odor, liquid, and contamination. The design of the waste management system incorporates the prescribed urine and feces sampling capability. This compartment is shown in Figure 2-9.

A second urinal is provided outside the waste management system compartment. It shares a console space with a hand-wash (enclosed chamber sink, with hot and ambient water and metered detergent). A laundry and dryer is also provided for clothing, bedding, and other washables. A cabinet-type shower is provided with controlled water temperature and warm air flow for drying. These facilities are shown in Figure 2-10. Appropriate control of liquids is incorporated in the shower design.

Figure 2-9. Crew Habitability – Hygiene/Waste Management

Figure 2-10. Crew Habitability – Hygiene Facility

2.2.2.5 Command Control Center

The control center occupies a section similar to the galley/wardroom, but at the opposite end of the module. Its location permits observation of caution and warning indicators by off-duty crewmen in the galley/wardroom and docking port area. Its location and general layout is shown in Figure 2-11. The control console is designed to be operated normally by a single man, but permits use by a second man in certain checkout operations.

The control center has the following general characteristics. All station operations, excluding experiment operations, can be monitored and controlled from the control console. A secondary console located in the GPL provides a redundant capability. Windows are provided to allow direct viewing of docking operations and to allow for control of Space Station attitude and orientation. The control center was designed to support all known subsystems and station requirements, and to provide for growth or modification to those subsystems.

In defining the requirements for the design of the Control Center, all subsystem requirements were collected and analyzed. To these requirements were added those that might be generated by other potential candidates for inclusion in the station. These requirements were then integrated and synthesized to determine all of the potential requirements for displays and control that such a station might require in its ten-year life. General purpose, integrated display and control equipment was then defined to have the generalized capability to meet these requirements. However, a number of dedicated displays were included, where sharing of use was deemed inefficient. The control center also contains the capability for the continuous display of selected high-use information. The center also provides visual and auditory warning of emergency information.

Requirements for the control center are as follows:

A. Adjacent to but separable from wardroom.
B. Capable of temporary sight and sound isolation.
C. Front and back equipment access for maintenance.

Figure 2-11. Crew Habitability – Primary Control Center

D. One- or two-man operation.

E. Volumes (in cu ft):

Equipment	110
Operating space	105
Maintenance access	0
(Shared with other activities)	215

The resulting design concept is shown in Figure 2-12.

2.2.2.6 Subsystem and Docking Ports

Environmental control and life support (EC/LS) equipment and electrical power equipment are arranged for easy access during maintenance and servicing. Frequent replacement of batteries is anticipated for the electrical power system (EPS), for example. The volumes allocated for the EC/LS subsystem and the EPS are 200 cu ft and 25 cu ft, respectively. Additional volume requirements are 1,400 cu ft for docking ports and 400 cu ft for wiring, ducting, and nondedicated storage (see Figure 2-13).

2.2.3 General-Purpose Laboratory

As the primary work area for most of the crew and the area where crew will spend a major portion of its time, the GPL will be designed for maximum habitability and usability. The specific habitability requirements for the GPL are as follows:

A. Functional separation of different laboratory areas.

B. Study and relaxation area available to each laboratory.

C. Light isolation capability for optics laboratory and data-processing facilities.

D. Layout, arrangement, and installation which facilitates equipment removal and modification for the progressive experiment program.

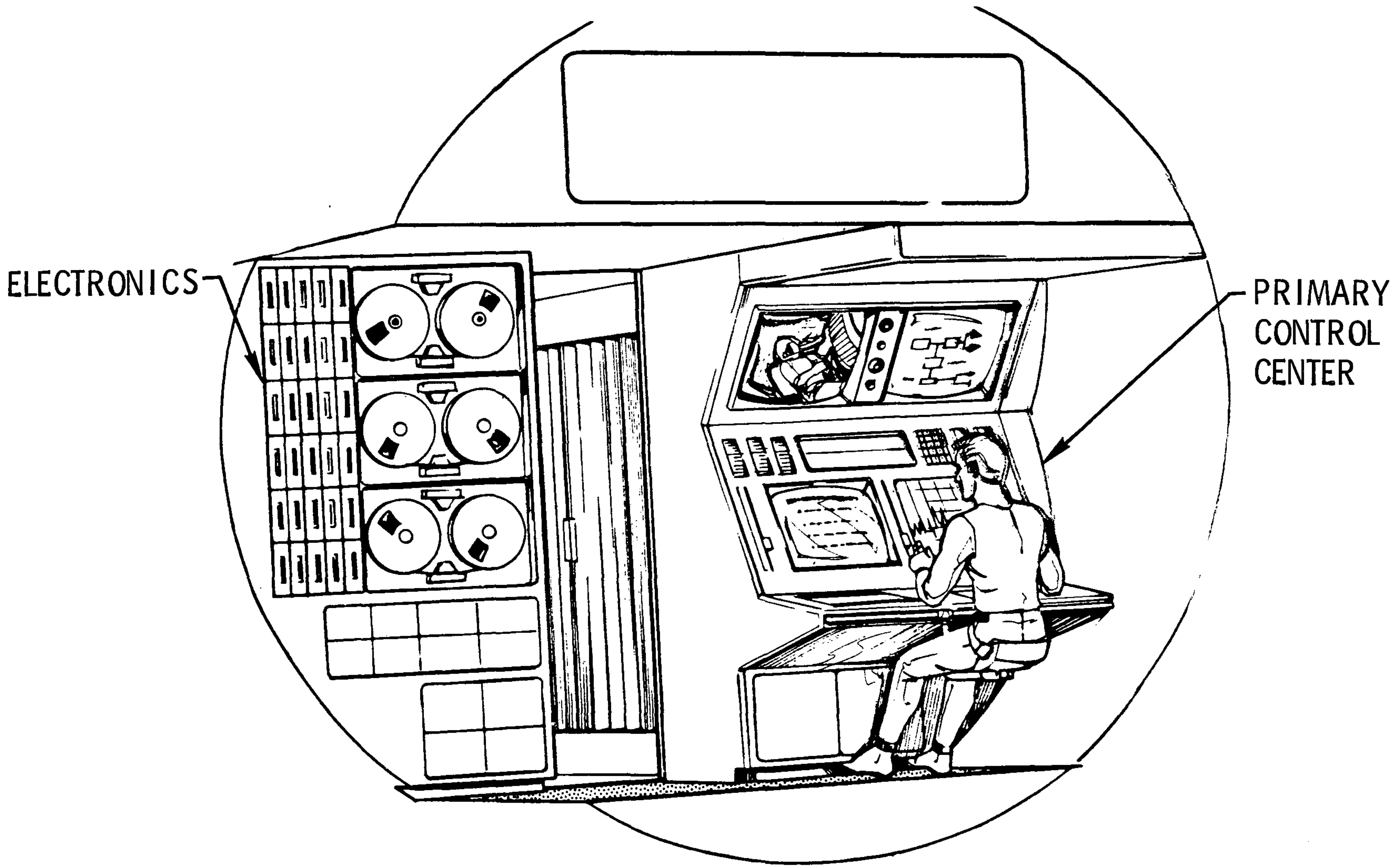


Figure 2-12. Control Center Crew/Operations Module

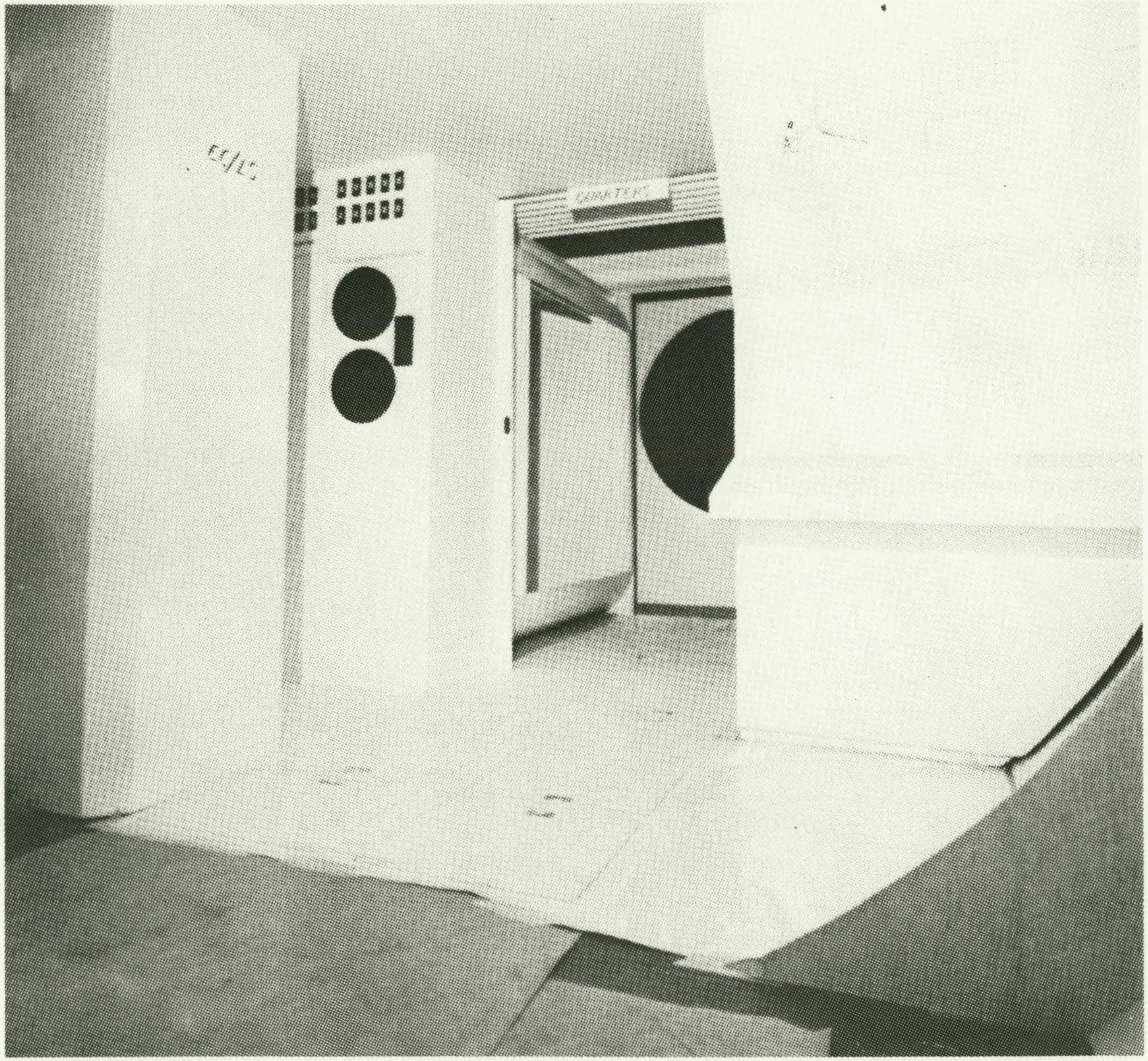


Figure 2-13. Crew Habitability EC/LS and Power

E. Prime work stations located to eliminate interference.

F. Volume and size criteria — minimums.

Aisles	24 by 78 in.
Prime work areas	33 by 78 in.
Access for maintenance	30 by 78 in.
Study and relaxation area	200 cu ft free volume

G. Accommodate size and shape of experimental equipment as dictated by changing experiment requirements.

The GPL contains the experimental equipment for the early experimental program (i. e., prior to the arrival of RAM's), much of the experimental equipment for the continuing program, all of the experiment support equipment (excluding the primary power source in the Power/Subsystem Module) and the control center from which the entire experiment program is monitored and controlled. (The control center includes the capability for control of free-flying RAM's.) Since it also contains the secondary control center for the station, the GPL has the capability for control of the total mission.

The GPL represents one of the two habitable volumes in the station with a capability for extended-duration operations. It has its own independent EC/LS system (less the oxygen supply in the power and subsystems module), houses the 30-day emergency food supply, has a water dispenser unit for reconstituting freeze-dried food, urine and fecal collection equipment and a hand wash with associated wipes, towels, etc., for total body cleansing. It was configured with sufficient free volume to accommodate six sleeping crewmen comfortably, and with its capability for "light isolation" of certain laboratory areas, and the inclusion of the isolation chamber, the GPL can even accommodate dual-shift operations on a somewhat limited basis. The isolation chamber also serves as an EVA airlock and stores two EVA pressure suits so that EVA operations can be conducted and controlled from the

GPL. A 96-hr emergency pallet (for power and atmosphere) is stored in the GPL, to provide a self-sustaining capability for that period of time in complete isolation from the rest of the station, see Figure 2-14.

The basic interior configuration and arrangement of the GPL, depicted by a 1/20th scale model is shown in Figure 2-15. The open longitudinal configuration with two operational levels enhances the appearance of spaciousness and at the same time maximizes the amount of usable free space avail- to the crew. Also, easy access to all equipment for ground checkout and evaluation is possible with a minimum of specialized ground support equipment (GSE).

Figure 2-16 shows the full-scale mockup interior configuration selected for the GPL. It utilizes two operational levels, but, except for the isolation chamber, has no permanent separating walls or floors, thereby achieving the appearance of spaciousness. Equipment is grouped functionally into laboratories or specialized facilities. Each laboratory and facility has been sized to allow up to three crewmen to work at one time. Also, there is sufficient free volume associated with each laboratory to permit up to three crewmen to confer, study, relax, or socialize, thereby eliminating the need to return to the wardroom or private quarters for such activities. Aisles and laboratories were also sized and arranged to allow crewmen to pass other crewmen at work without even casual interference. Equipment in the GPL has been located and arranged to eliminate any requirements for routine foot-to-head operations (i. e., one crewman working directly above another). The capability to easily accommodate a number of crewmen simultaneously in a variety of experiment activities is illustrated in Figure 2-17.

There are six laboratories, an isolation chamber and a secondary control center in the GPL. Photos of full-scale mockups of these facilities and drawings of the proposed equipment in them are shown in Figures 2-18 through 2-30.

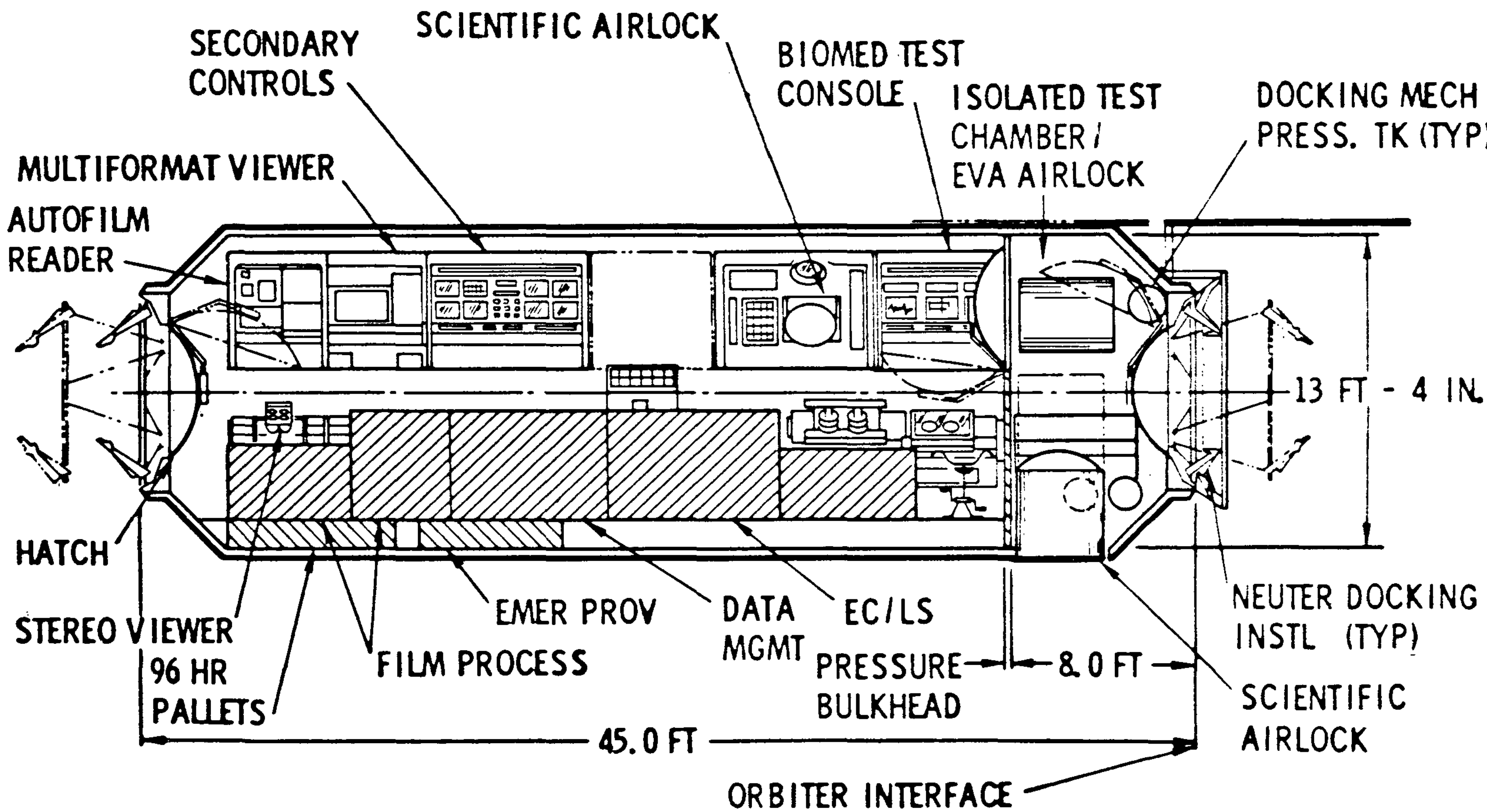


Figure 2-14. Modular SS General Purpose Lab

R272

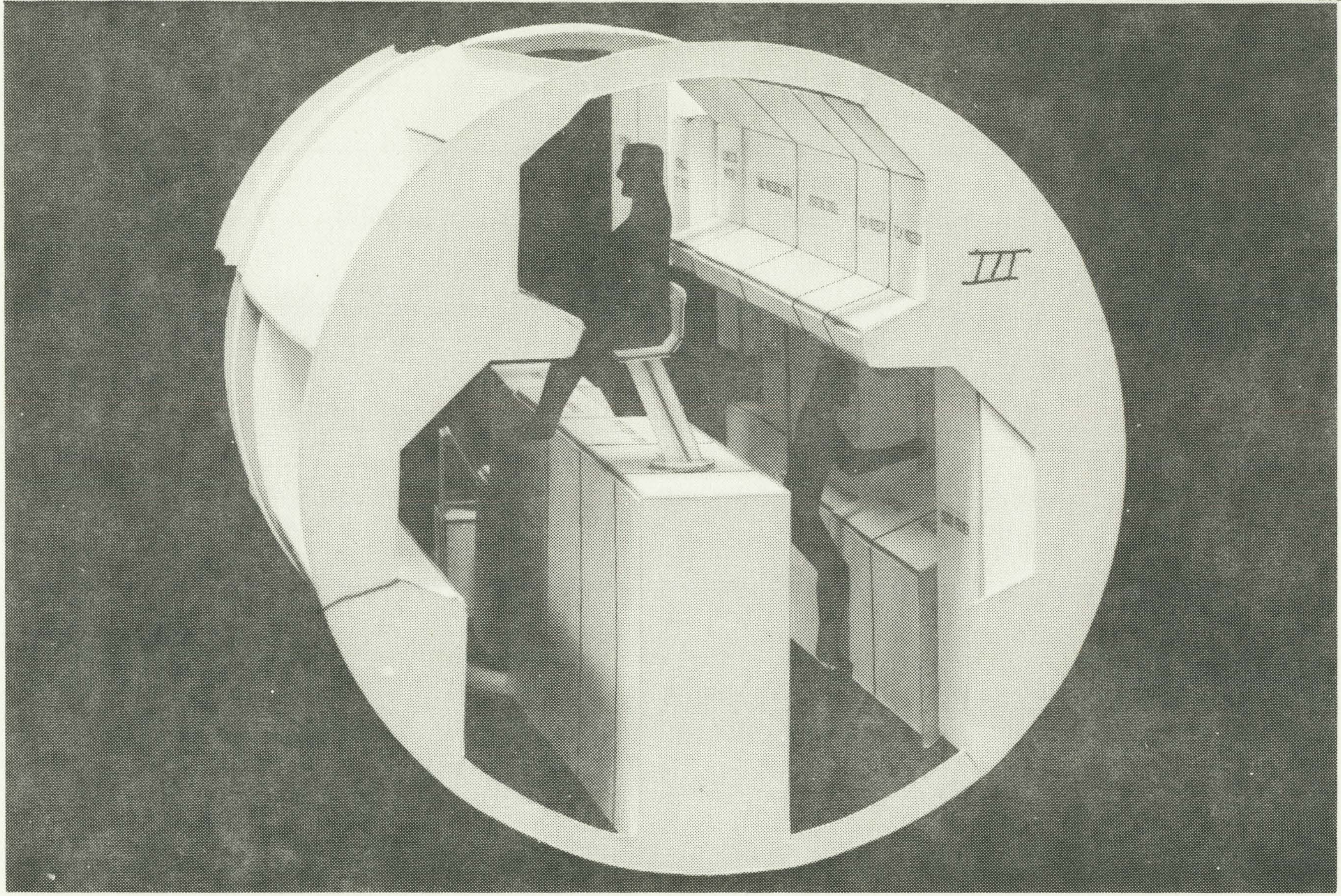


Figure 2-15. GPL Model

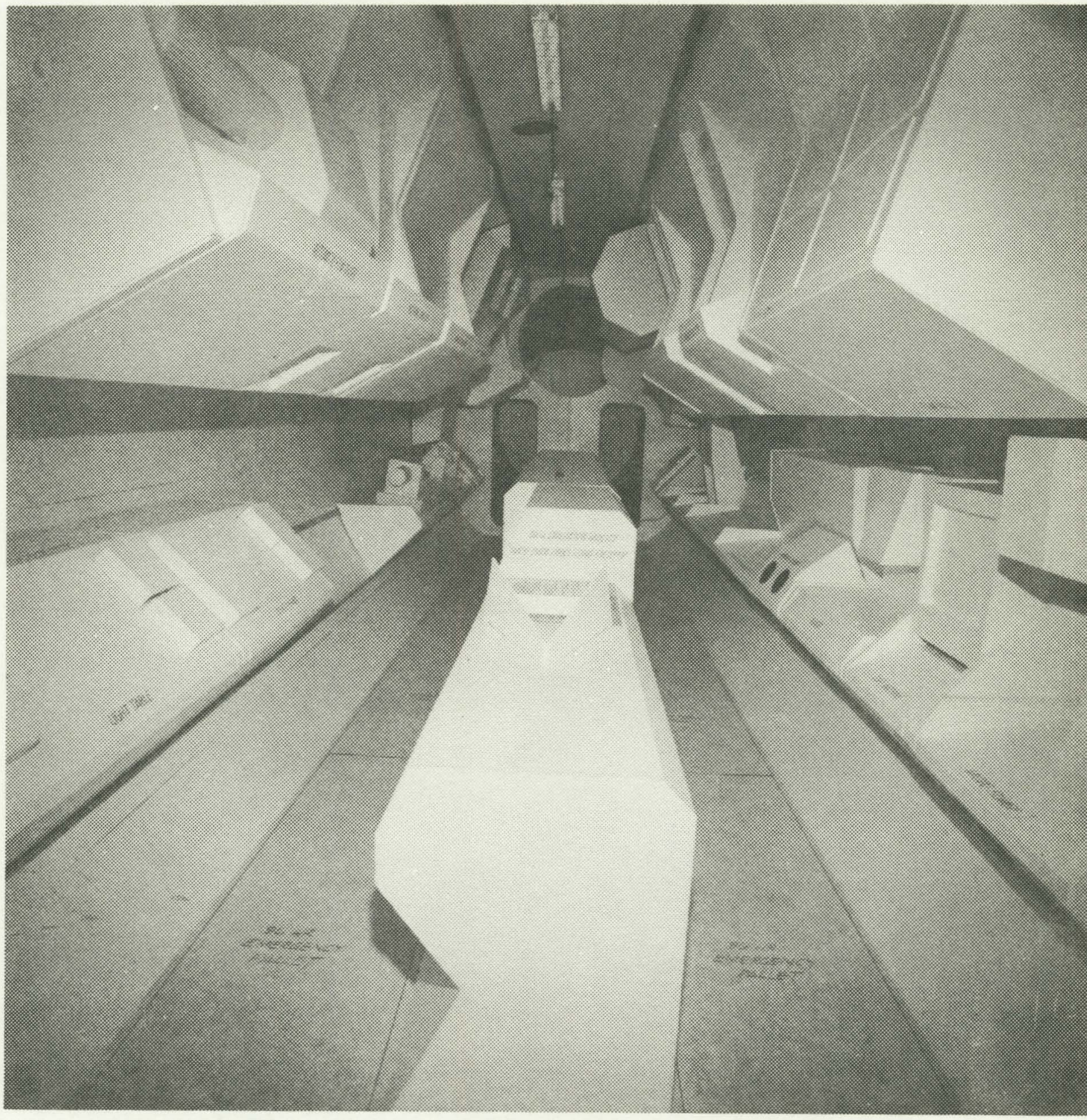


Figure 2-16. Crew Habitability – General Purpose Lab

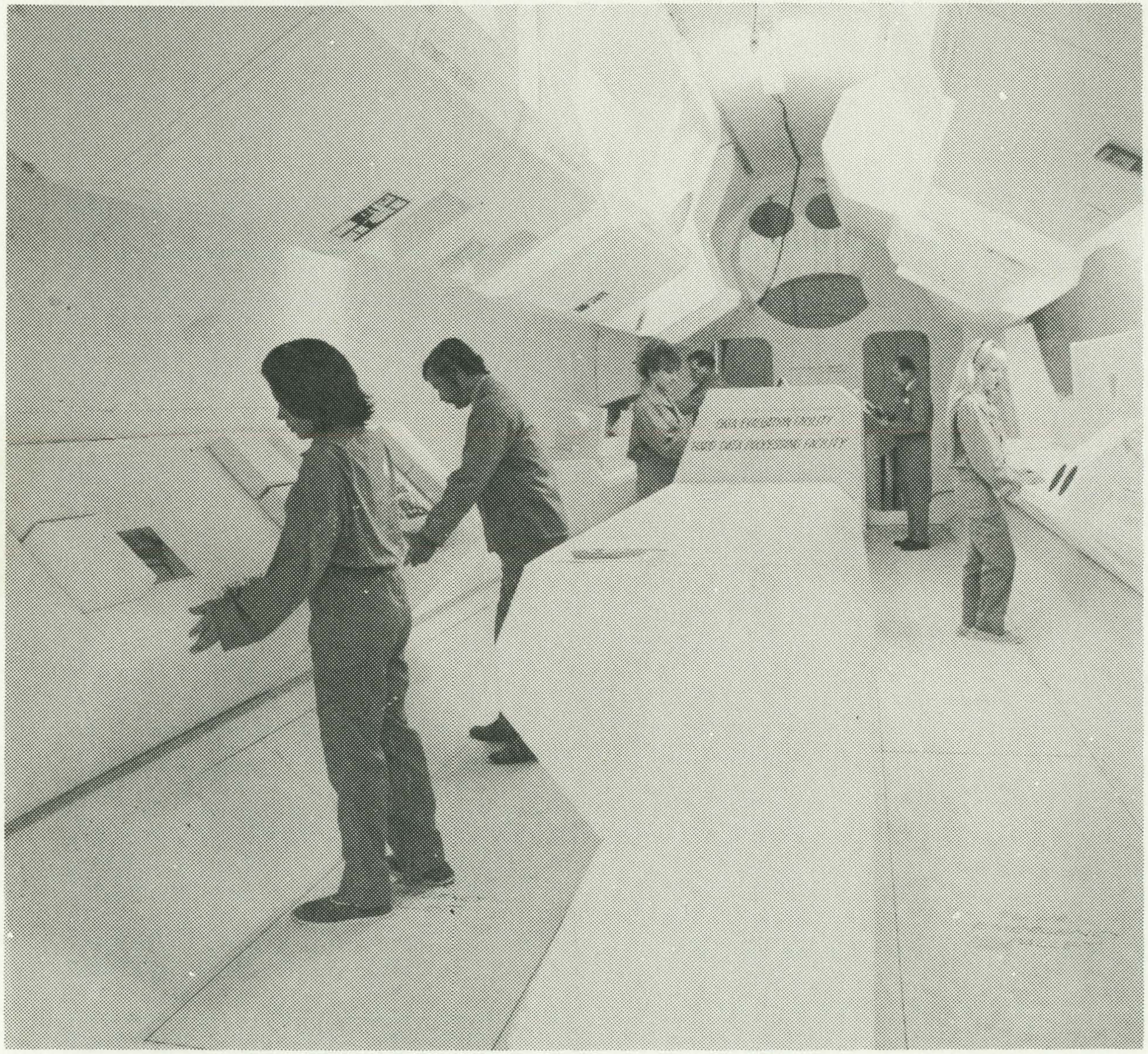


Figure 2-17. Crew Habitability – General Purpose Lab

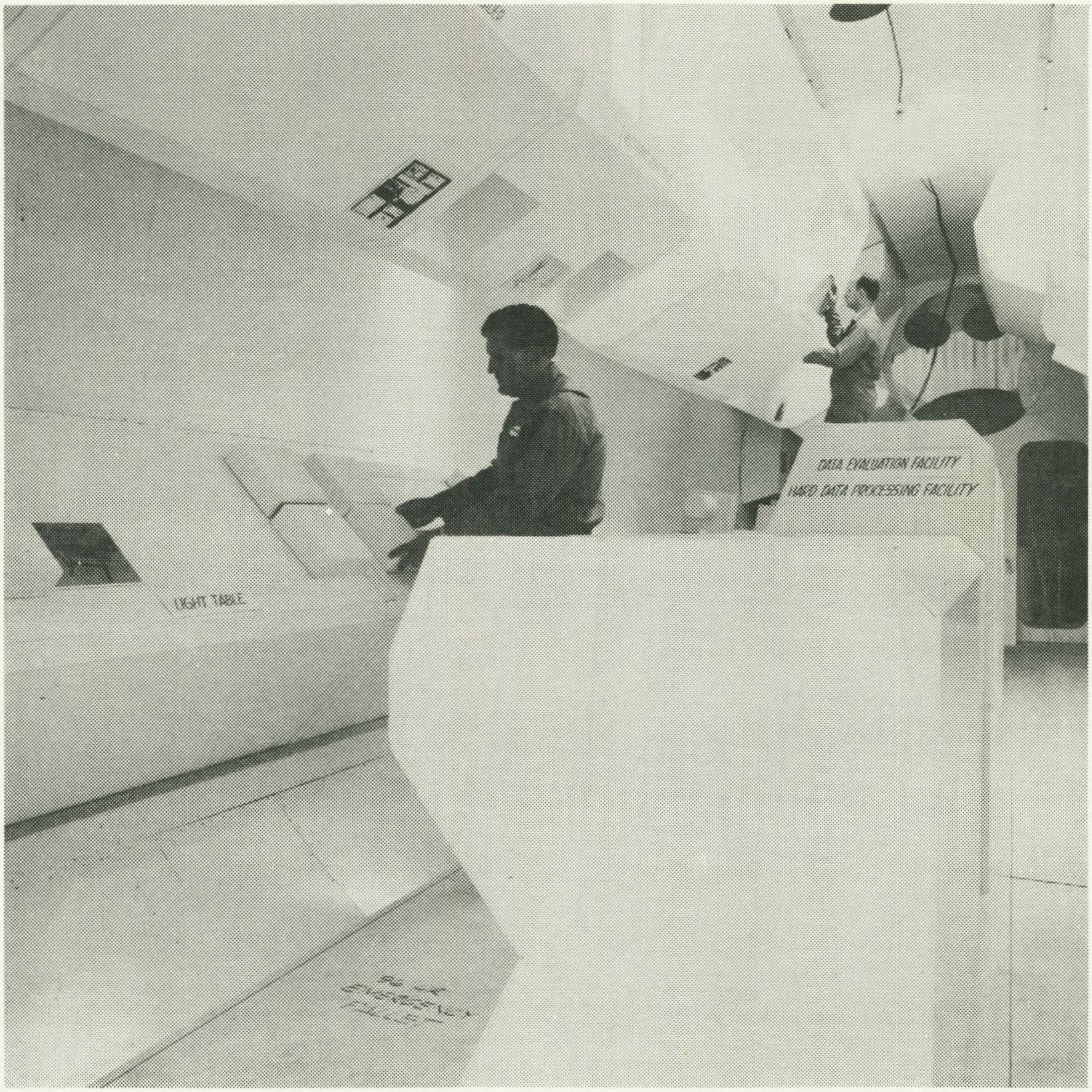


Figure 2-18. Crew Habitability – Data Evaluation Lab

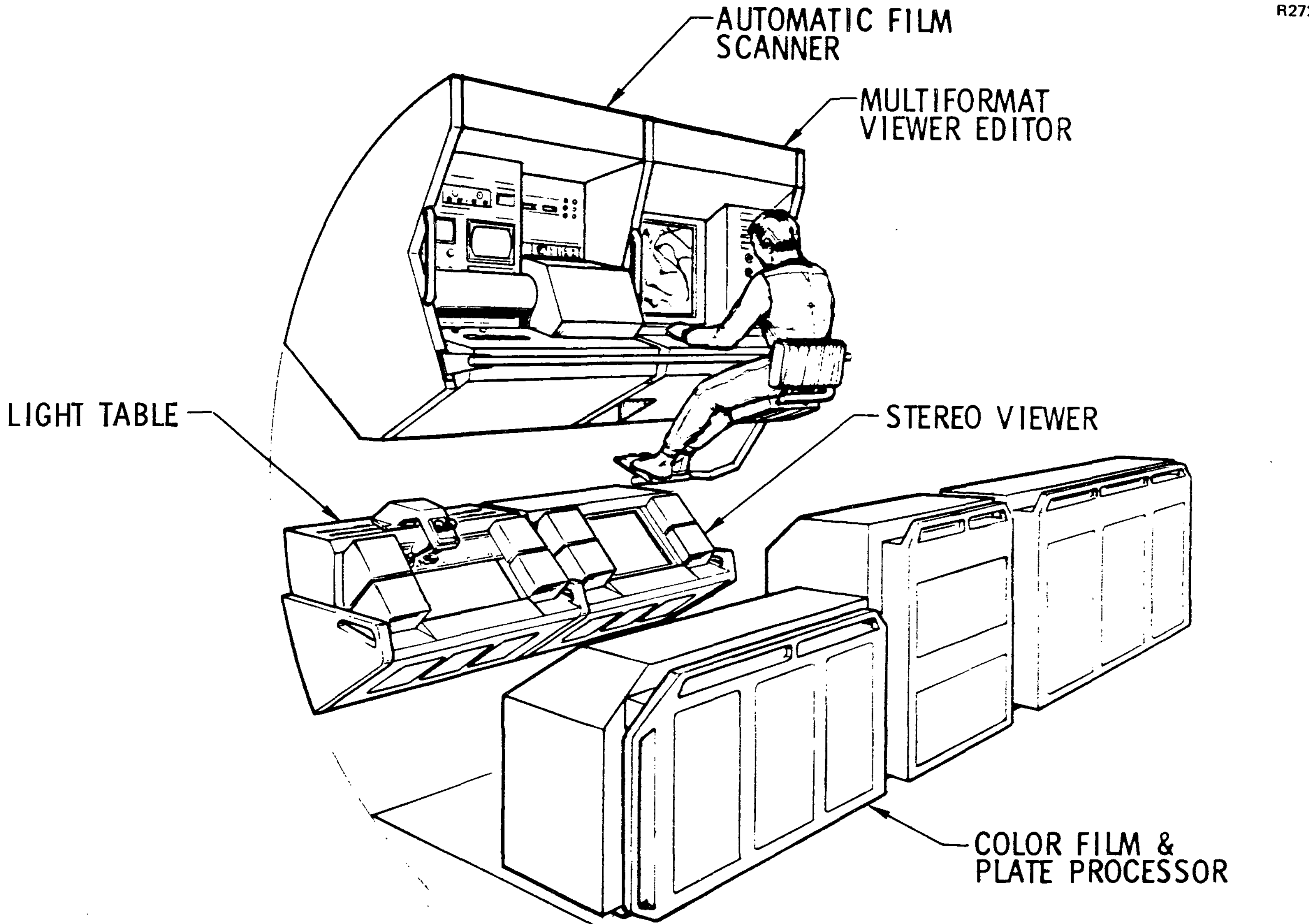


Figure 2-19. Data Evaluation Laboratory

Figure 2-20. Crew Habitability – Electrical/Elec Lab

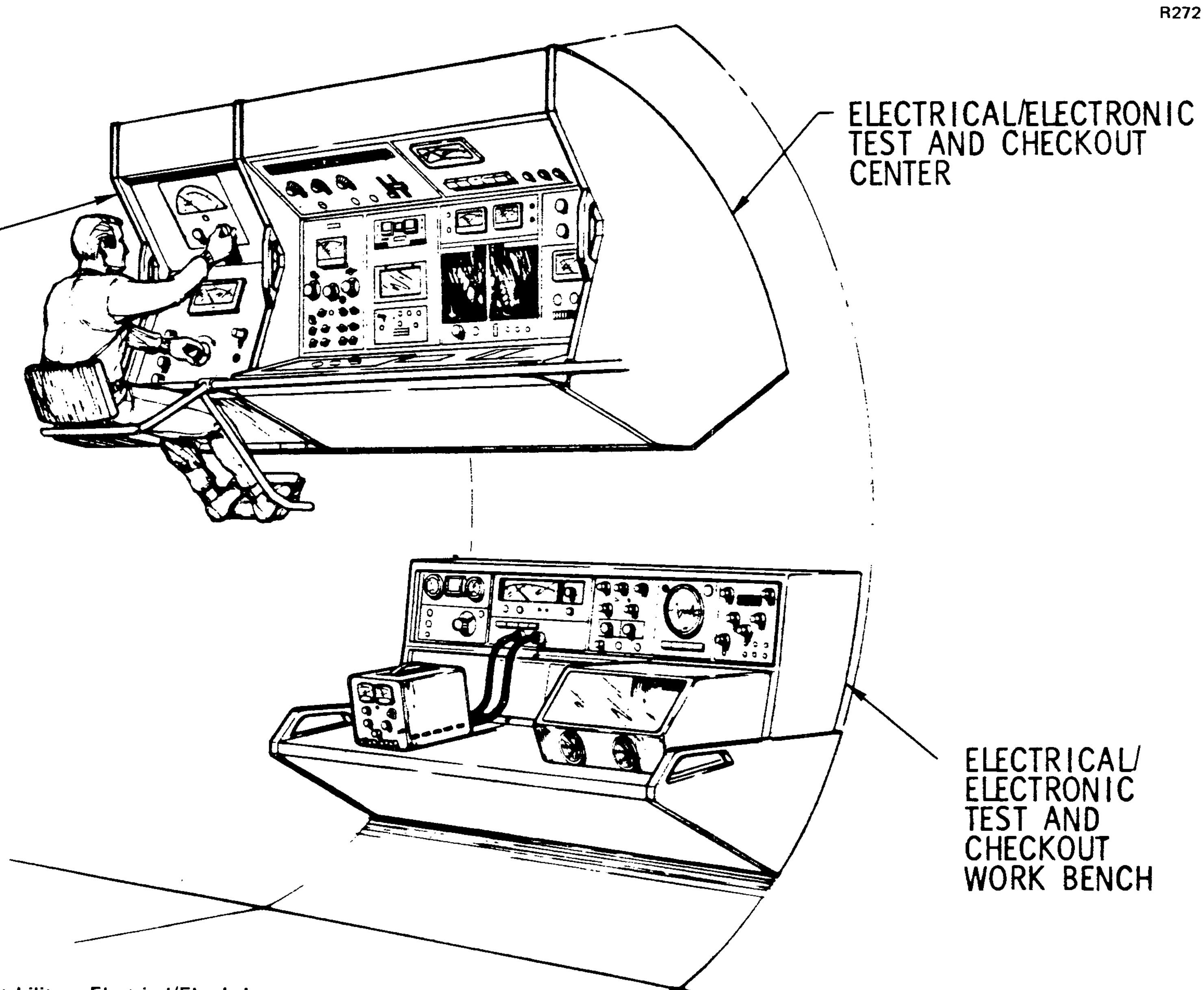


Figure 2-21. Crew Habitability – Electrical/Elec Lab

Figure 2-22. Crew Habitability – Mechanical Lab

R272

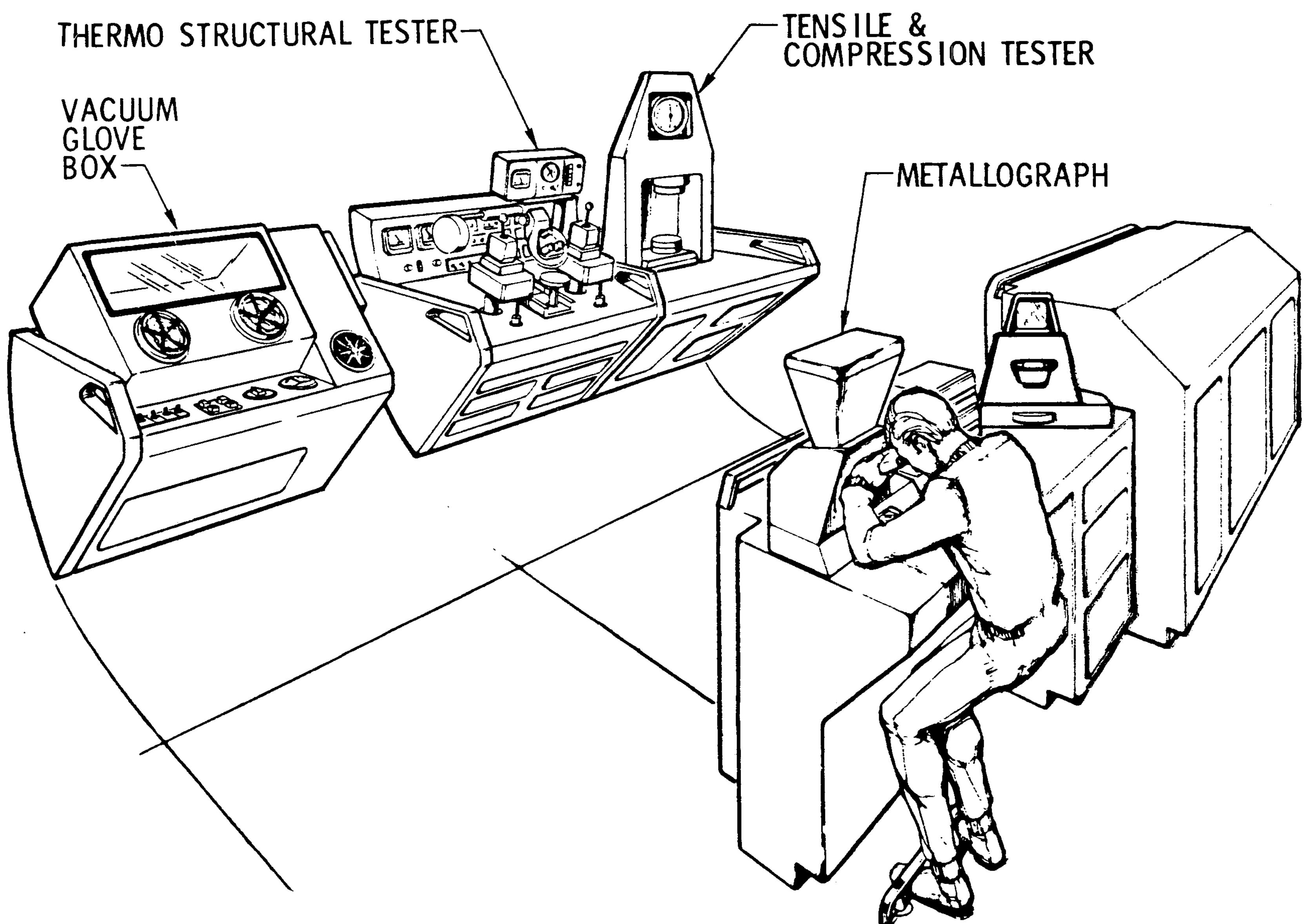


Figure 2-23. Crew Habitability – Mechanical Lab

Figure 2-24. Crew Habitability Bioscience/Biomedical Lab

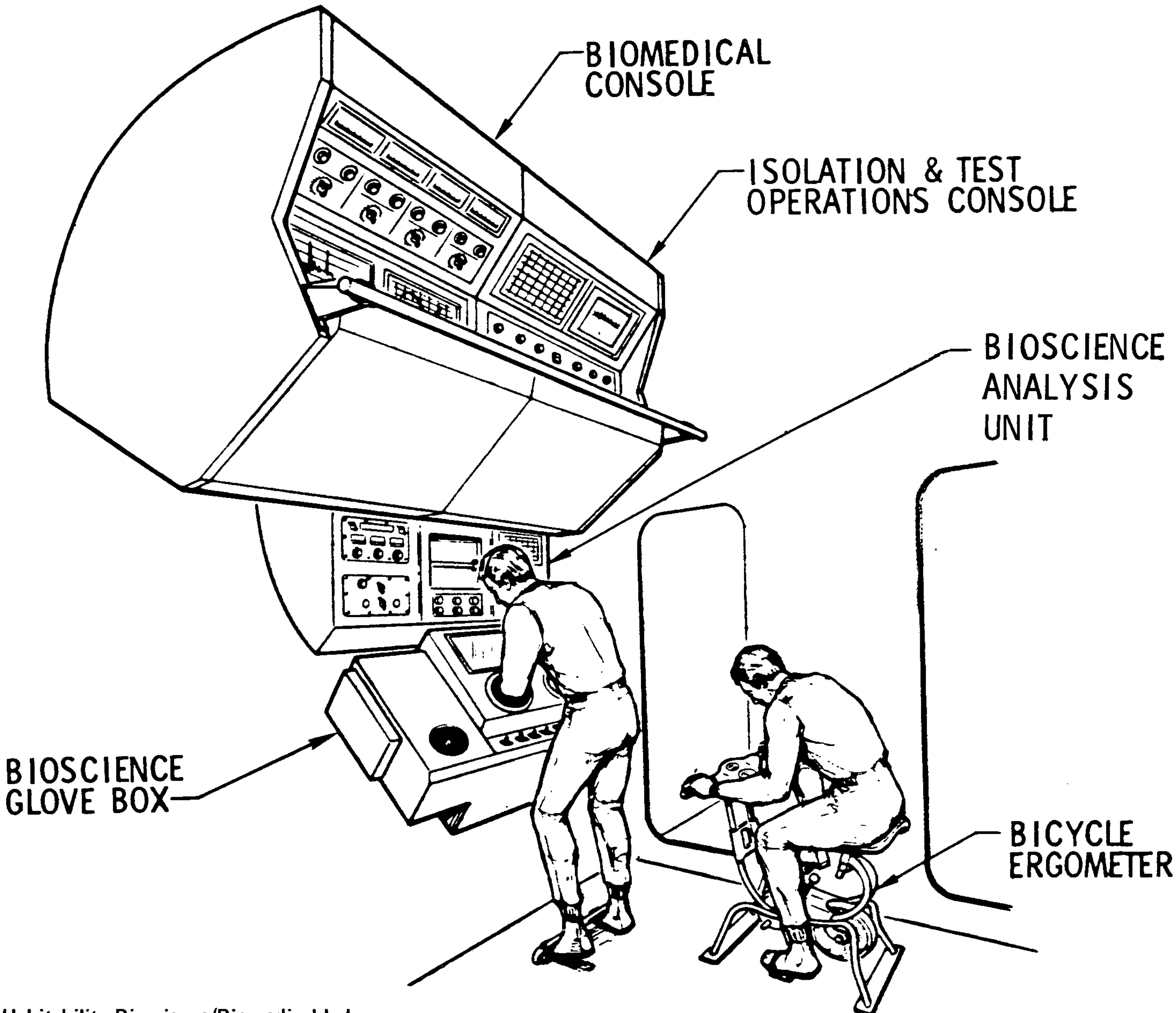


Figure 2-25. Crew Habitability Bioscience/Biomedical Lab

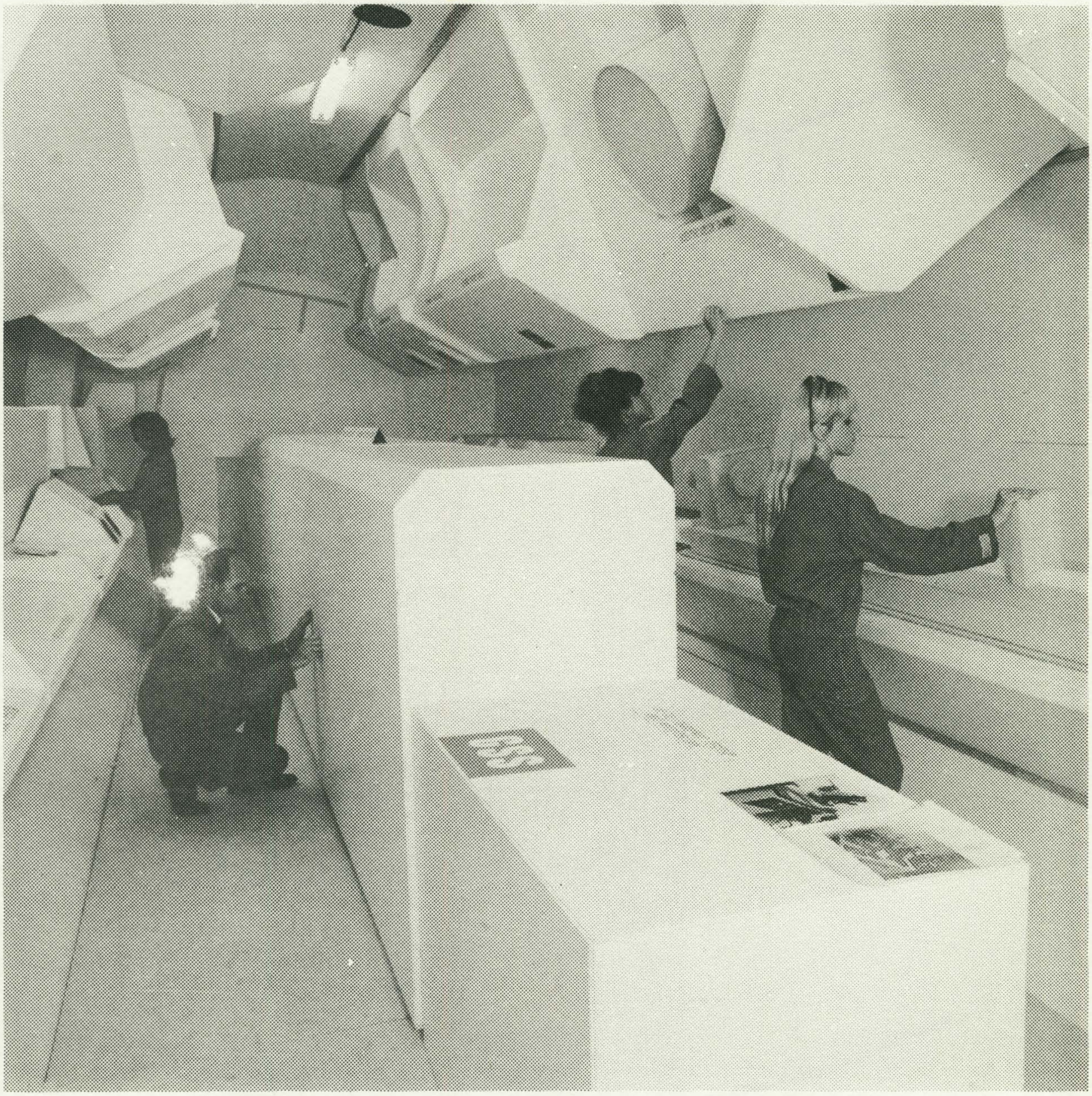


Figure 2-26. Crew Habitability Optical Laboratory

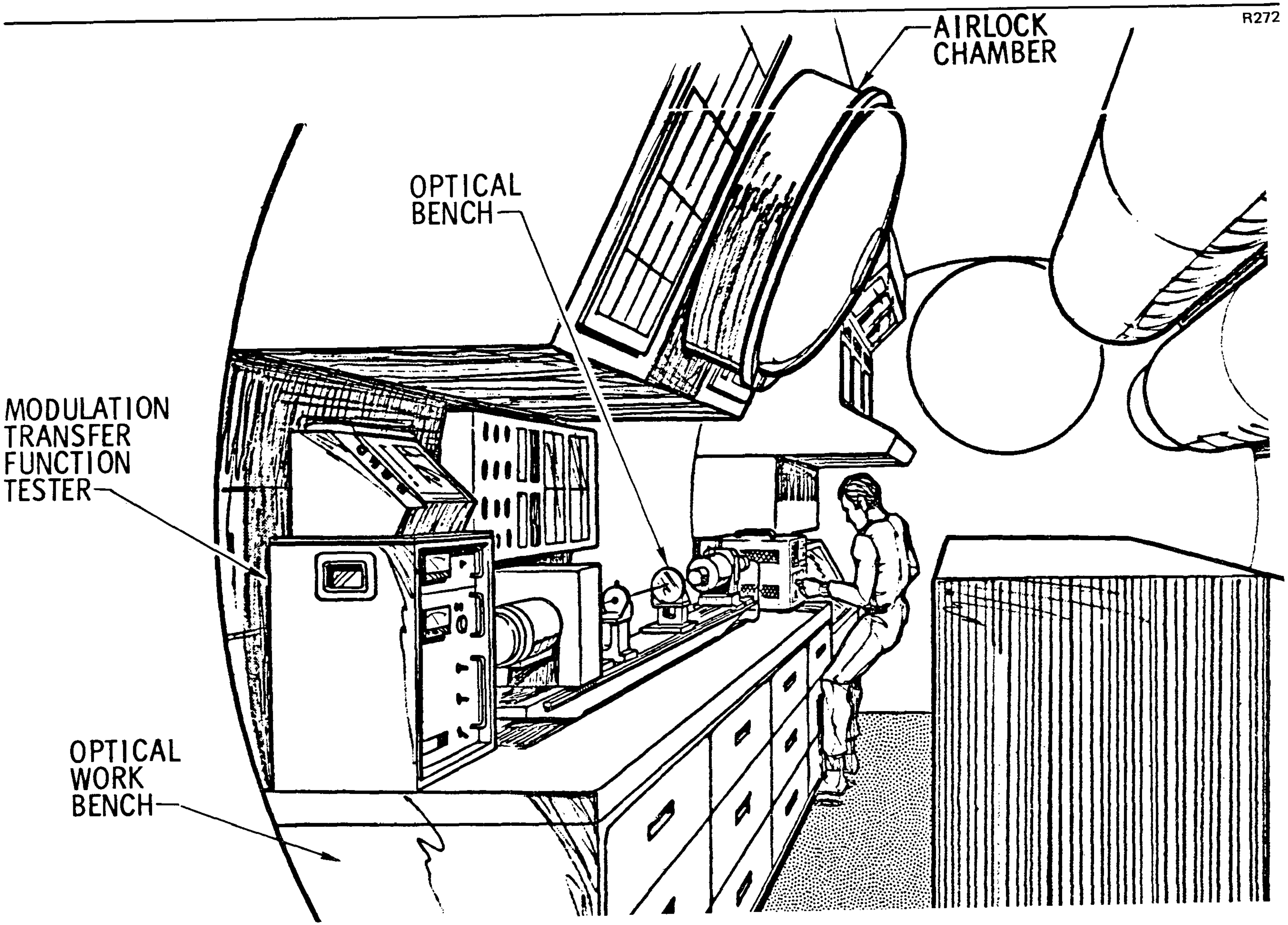


Figure 2-27. Optical Sciences Laboratory

R272

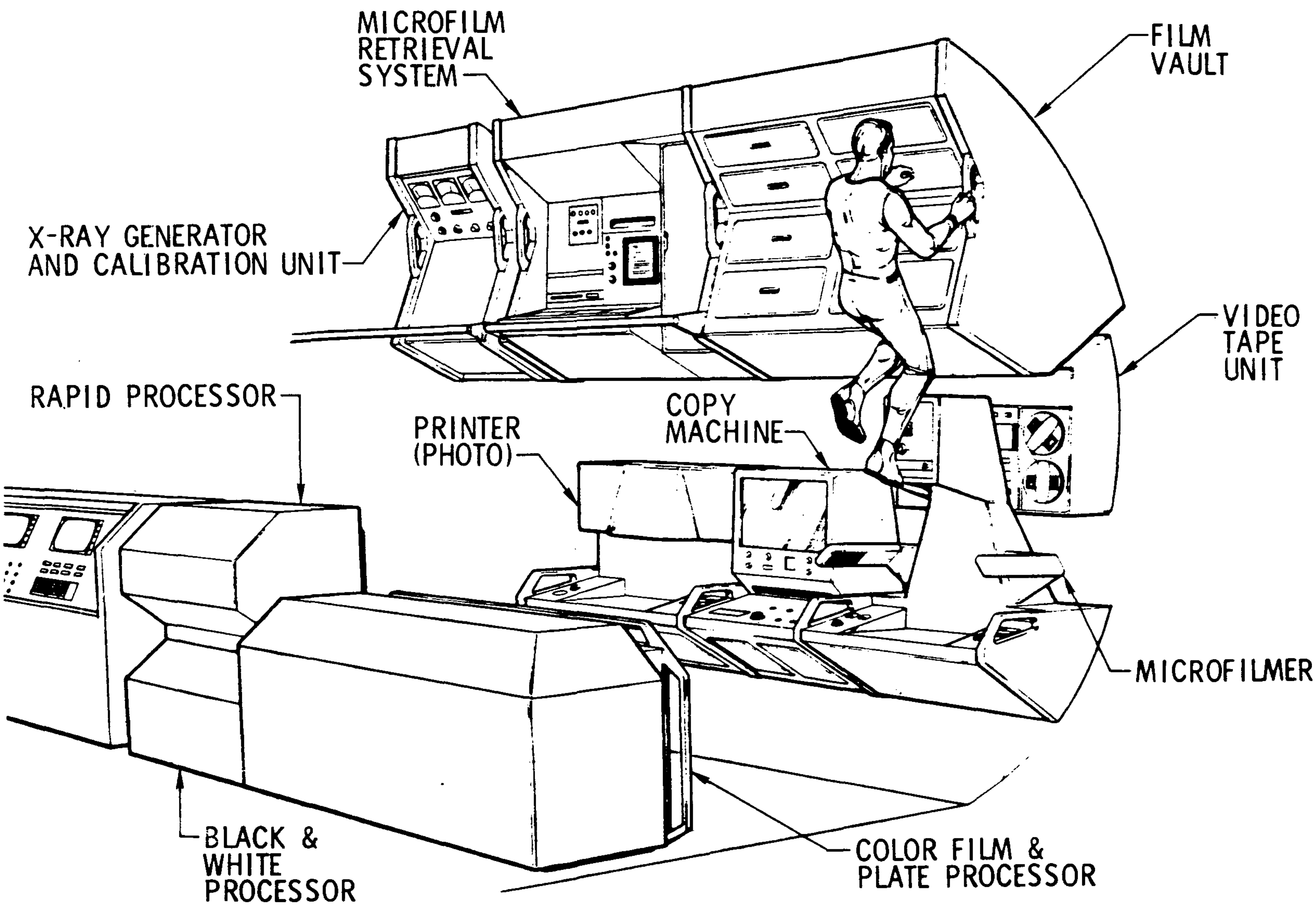


Figure 2-28. Crew Habitability—Hard Data Processing Laboratory

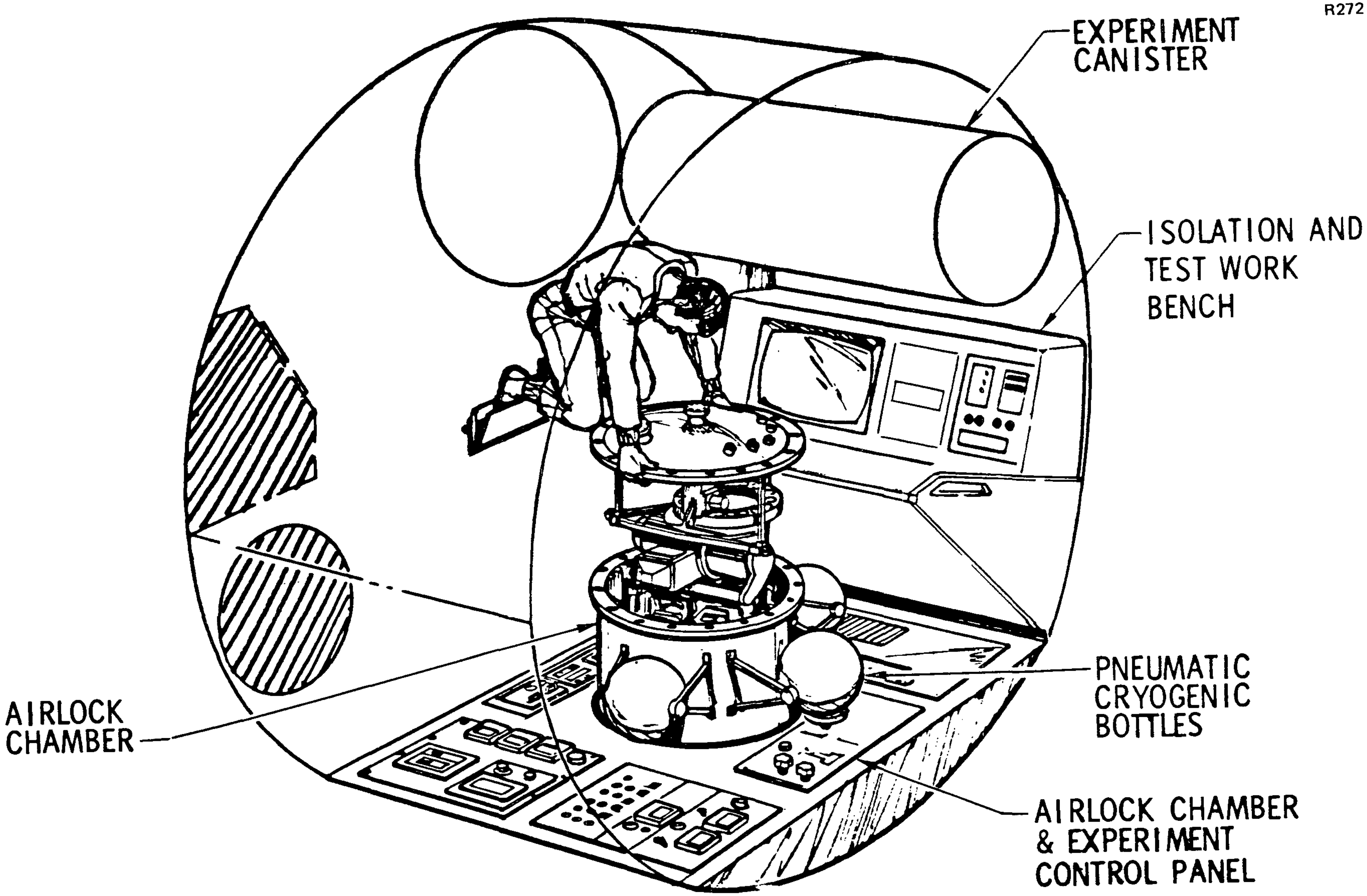


Figure 2-29. Experiment and Test Isolation Lab

R272

DISPLAYS

- MULTIFORMAT CRT
- VIDEO MONITOR
- MICROFILM VIEWER
- CAUTION-WARNING-EXPERIMENT ALERT
- CONTINUOUS-SOFTWARE CONTROL
- DEDICATED

CONTROLS

- KEYBOARDS
- MICROFILM SELECTION
- HAND CONTROLLER
- CHECKOUT UNIQUE
- SUBSYSTEM DEDICATED
- ANALOG SLEWING

AURAL CUES

- CAUTION AND WARNING
- VOICE MESSAGE GENERATOR

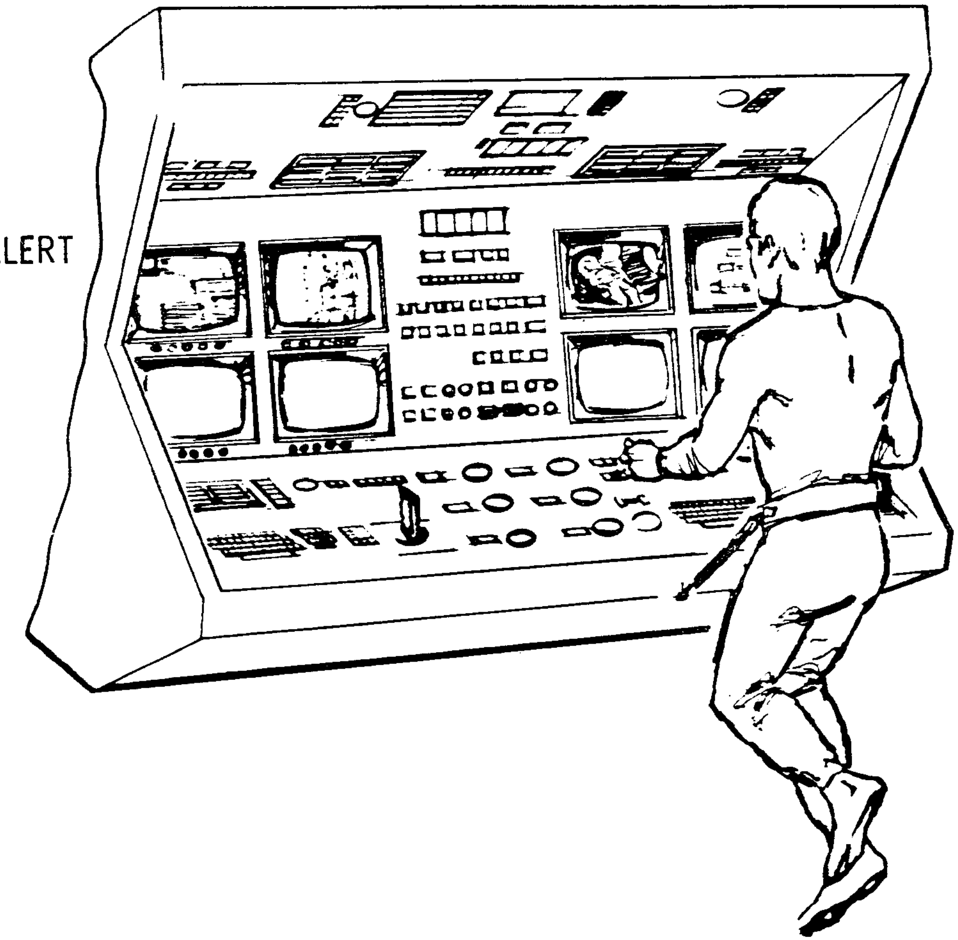


Figure 2-30. Secondary Command and Control Console

2.3 LOGISTICS MODULE

The Logistics Module is a 14-ft-dia by 28-ft-long configuration, incorporating a pressurized and an unpressurized compartment. the interior of the pressurized compartment is arranged into three basic areas: special cargo, palletized cargo, and liquid and gas cargo. The special cargo area is sized to accept off-loaded items such as the CMG's, food freezer, trash compactor, and research and applications equipment, as shown in Figure 2-31. The palletized area is configured to support 2 ft by 2 ft carry-on containers. Carry-on packages are designed to accommodate this capability insofar as possible. (The unpressurized area houses the propellant cargo tankage and high-pressure gaseous nitrogen tanks and need not be accessed by the crew.) Tankage for fluid cargo remains fixed in the module while the contents are transferred to station systems on demand.

A two-man EVA airlock is located at the interface of the pressurized compartment and orbiter. The airlock also serves as a means of egress and ingress between the orbiter and the Logistics Module. Cargo handling aids are provided to mechanically assist crewmen in off-loading large-mass items (more than 200 lb) which are easy to move but difficult to control. Generally, cargo remains stowed in the Logistics Module until needed, or until the Logistics Module is replaced.

2.4 BASELINE SUBSYSTEMS

Baseline subsystems characteristics are summarized in Table 2-1. The operation and maintenance of these subsystems is a crucial responsibility of the operations crew. The crew time allocations for subsystems were reevaluated during this study. The objectives were to ensure that all tasks have been identified and further that the most up-to-date data are made available. A brief summary of each subsystem follows.

Electrical power for the Initial Space Station at 115 vdc is provided by a gimbaled foldout solar array. A solar heat collector, which provides heat for EC/LS processes, is located on the array to take advantage of the sun orientation. Thermal control is provided by active, redundant radiator loops on each module. The external fluid is Freon-21 and the internal heat conduction fluid is water.

R272

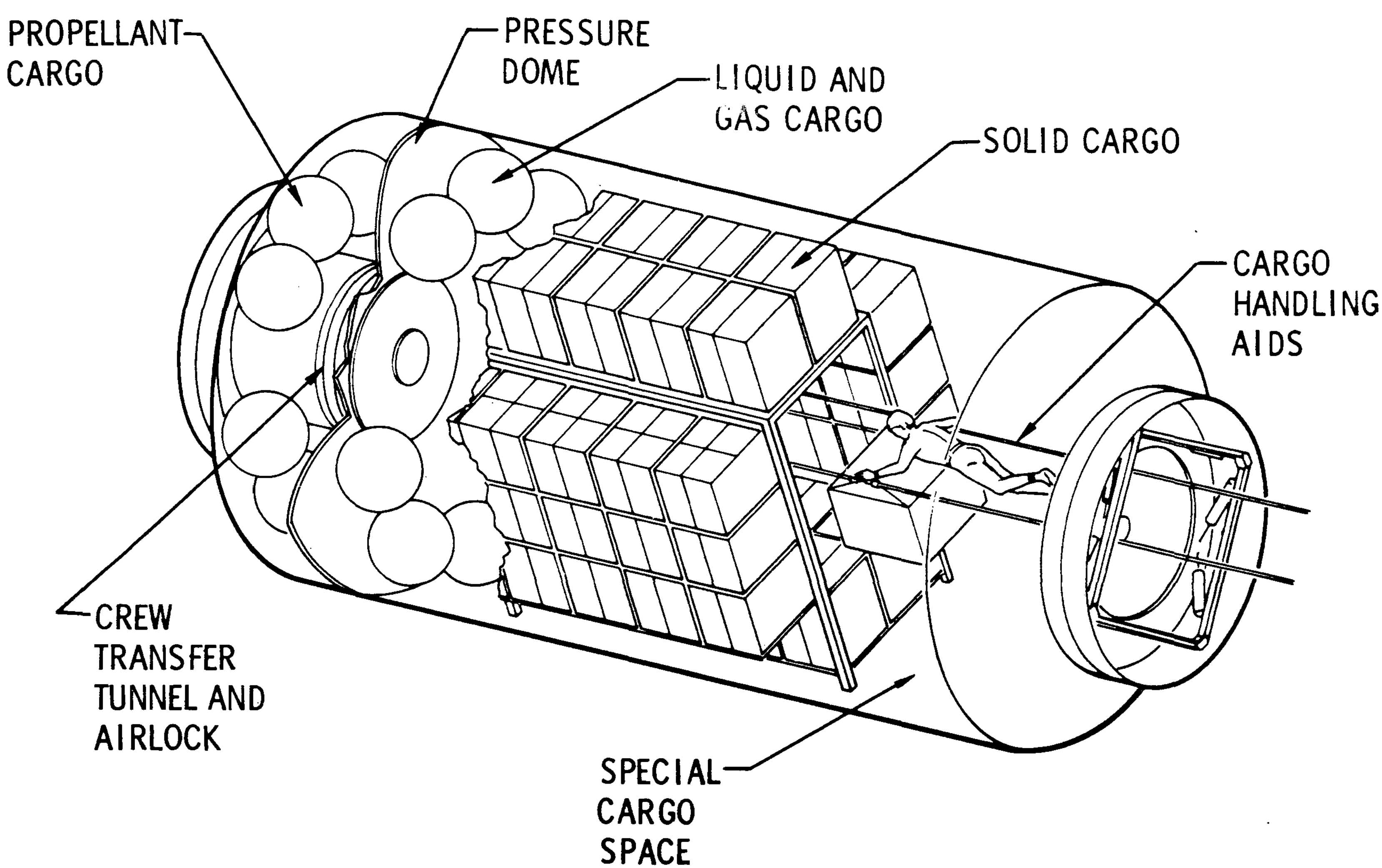


Figure 2-31. Logistics Module

Table 2-1

ISS BASELINE SUBSYSTEMS

EC/LS	Communications
Two 6-man systems Closed water (reverse osmosis) Open oxygen (mole sieve) Solar heat collection	ISS — S-band to modified manned space flight network VHE and K_u-band to relay satellite GSS — K_u-band to free flyers
Electrical Power	**Data Management**
Gimballed foldout arrays Two-step buildup 17 kwe; 32 kwe	Centralized multi-processors and distributed computers Data bus Multipurpose displays
Propulsion	
N_2H_4 high-thrust CO_2 resistojets	
Guidance, Navigation, and Control	**Onboard Checkout**
CMG's Stellar/inertial reference Trimmed horizontal orientation All attitude capability Manual docking Ground navigation	Integrated with data management subsystem Automated operation Fault isolation to lowest replaceable unit

The power module contains storage tanks and vacuum pumps for evacuating airlocks within the station and attached RAM's. Module repressurization gases are also stored in the power module. The crew and GPL modules each contain six-man EC/LS subsystems. These provide CO_2 and humidity control, atmosphere purification, and water recovery and purification. Waste CO_2 is collected in short-term storage tanks and used as a propellant for the resistojet orbit-keeping propulsion system.

Guidance, navigation, and control (GNC) equipment is located primarily in the power module. Instruments include gyros, horizon sensors, star sensors, and star trackers. CMG's and monopropellant (N_2H_4) thrusters provide attitude control. GNC computations are performed in the central data management subsystem (DMS) computer. The data bus interconnects the computer and other DMS components, as well as the other subsystems. Voice communications are provided to the Shuttle via VHF and to the ground via S-band using the data relay satellite system (DRSS) and the manned space flight network (MSFN). Wide-band digital and video data are transferred to the ground via K_u-band DRSS.

Additional details regarding the design analyses and trade studies performed to optimize crew operations and interior configurations are given in SE-01, Detail Preliminary Design of Subsystems.

PRECEDING PAGE BLANK NOT FILMED

Section 3
CREW OPERATIONS ANALYSIS

The analysis of crew operations encompasses three major areas of the Modular Space Station program: (1) buildup and initiation, (2) sustained operations, and (3) logistics support. (Space Shuttle flight support required for the preflight delivery and postflight support of the Modular Space Station are discussed in MP-01, Mission Analysis.)

3.1 MODULAR SPACE STATION BUILDUP

Space Station buildup operational events are summarized in Figure 3-1. This phase of the mission covers the first 60 days (three launches) of the Space Station program. During this phase of the mission, two assembly crewmen will accompany each of the Space Station modules to orbit as passengers in the Space Shuttle. These assembly crewmen will perform the interface mating, checkout, and operation functions on the Space Station while the Space Shuttle remains attached to the configuration. During their orbital stay, these crewmen will depend upon the Shuttle for life support while working in the Space Station module(s).

3.1.1 Power/Subsystems Module

The Power/Subsystems module will be launched first. It will be equipped with an EC/LS system and with one set of batteries which provides the electrical power until solar array deployment and checkout. Although this power and atmosphere capability provides the crew with a shirtsleeve environment, the men will enter this module (and the other two modules during buildup) in pressurized suits and remain in them until all systems have been checked out.

The Power/Subsystems Module buildup timeline is presented in Figure 3-2. As shown in this figure, at approximately four hours ground-elapsed time (GET) the Space Shuttle bay door will be opened and the module deployed on

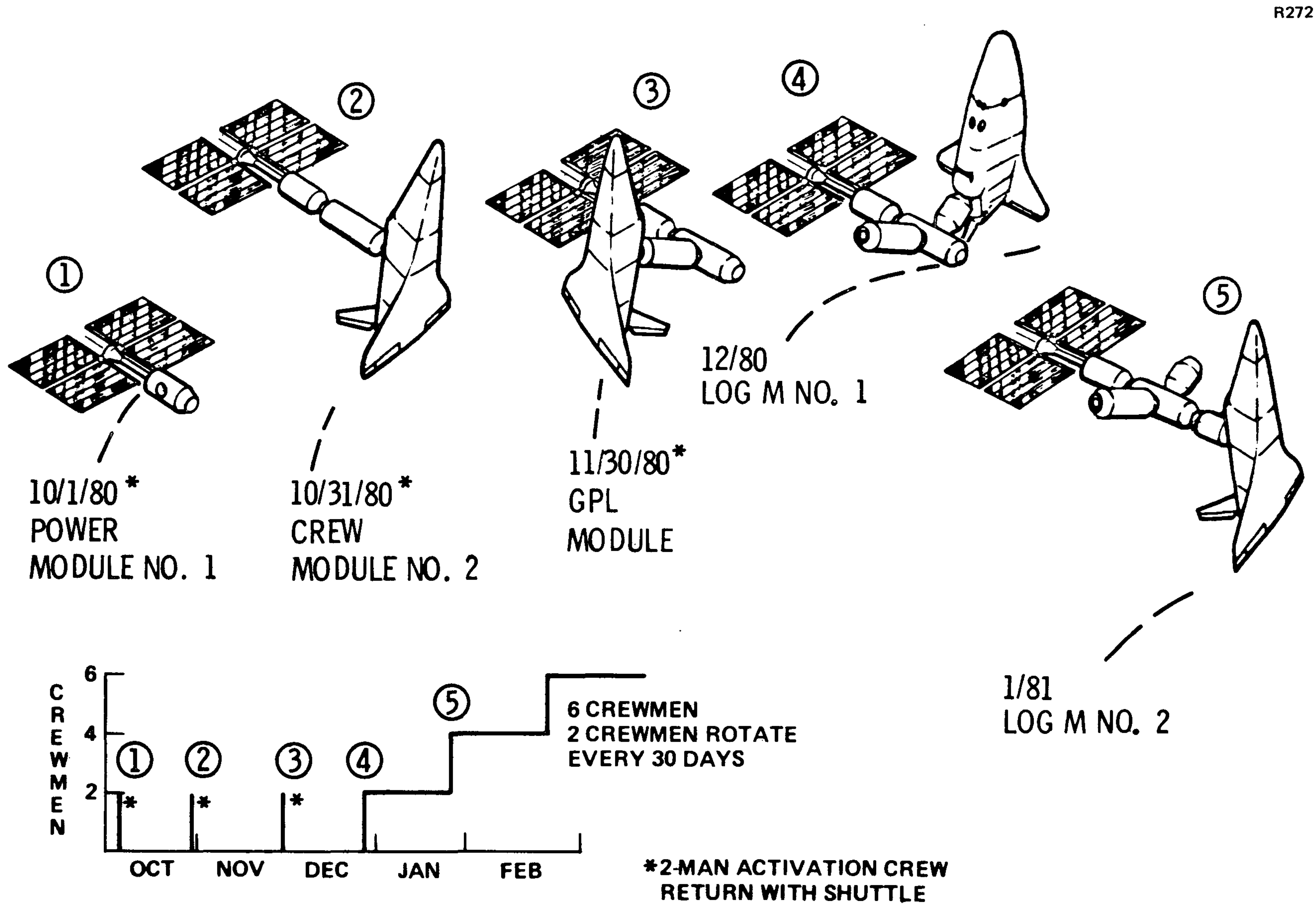


Figure 3-1. Space Station Buildup Operations

R272

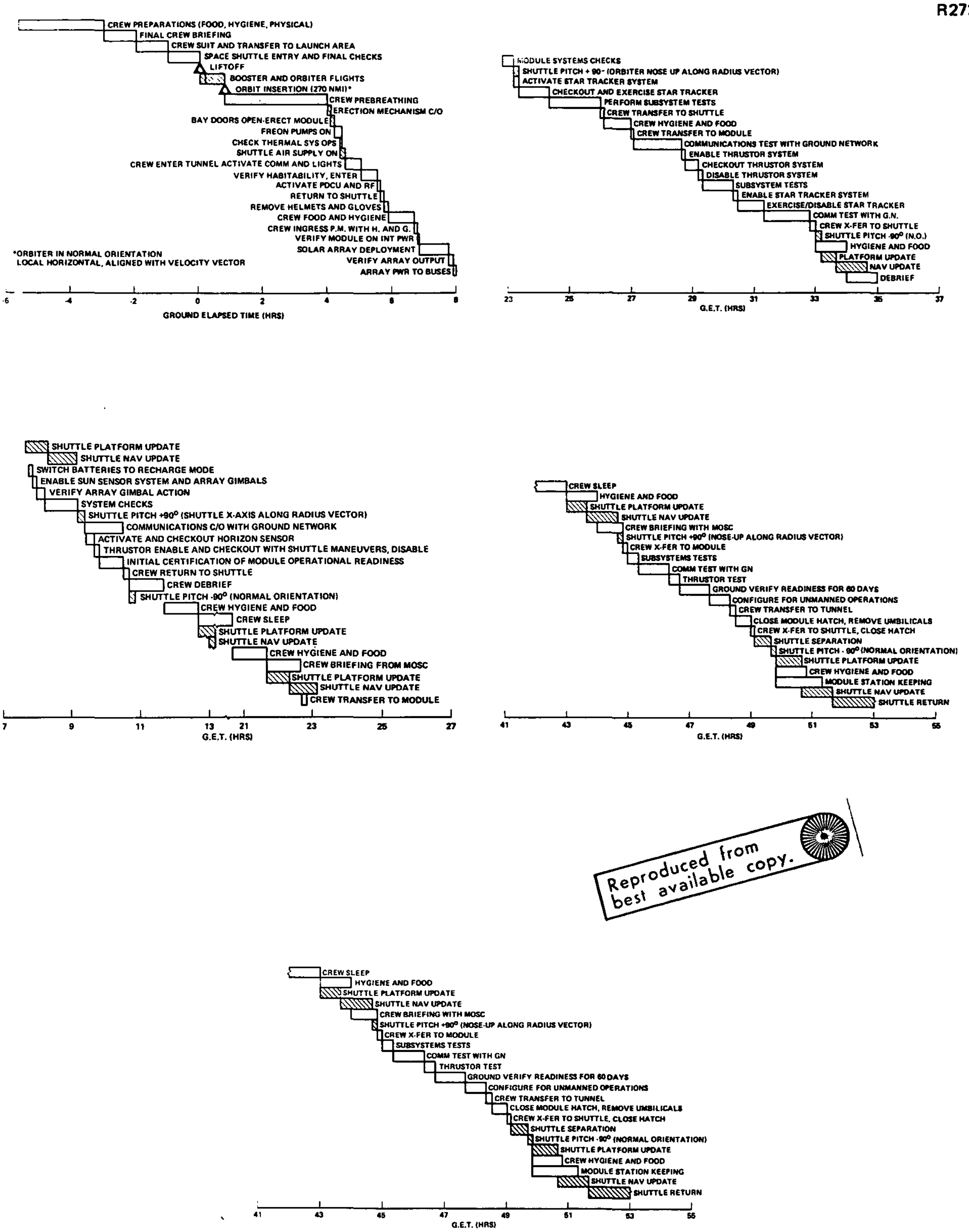


Figure 3-2. B/U Timeline – Power Module

the payload interface pallet. Once the operation of the thermal system has been verified, the crew will prepare the module subsystems and the Space Shuttle airlock for entry to the payload module. The Space Shuttle crew will then activate the atmosphere supply flow into the module. The air supply will utilize the nominal atmosphere distribution system in the module, holding the onboard atmospheric supply for backup.

The two assembly crewmen, in their IVA suits, will then enter the Space Shuttle airlock. An expandable tunnel will be used for crew transfer from the Space Shuttle to the Power/Subsystems Module hatch. At the module hatch, there will be a viewing window and a habitability verification readout station. The crew can equalize pressure across the entry hatch at this location, and can activate the internal communication systems and lighting systems of the module.

Once the habitability of the module has been verified, the crew will open the hatch and enter the module. Following entry, the crew will use the portable display and control unit (PDCU). This unit is shown in Figure 3-3. It operates with the data management system computer and has the functional capabilities of the control and display console scheduled for delivery in the Crew/Operations Module, but it operates in a manual, one-command-at-a-time, mode. The PDCU can thus be used for command activities and for diagnostic routines for fault detection and isolation. Following these activities, the crew will return to the Shuttle, doff suits, and complete food and waste management.

The crew will then reenter the Power/Subsystems Module in shirtsleeves and complete the checkout operations. The first activity is the deployment of the solar array system (see Figure 3-4). Once the array support beams are in place and held by removable over-center locks, the twelve array panels will be deployed by means of the Astromast assembly. This assembly consists of a collapsed truss beam which snaps into place one section at a time, thereby extending the sections ahead of it.

Once the arrays are deployed, the crew will check the power generation capability of the system and then switch the power source to the arrays. The

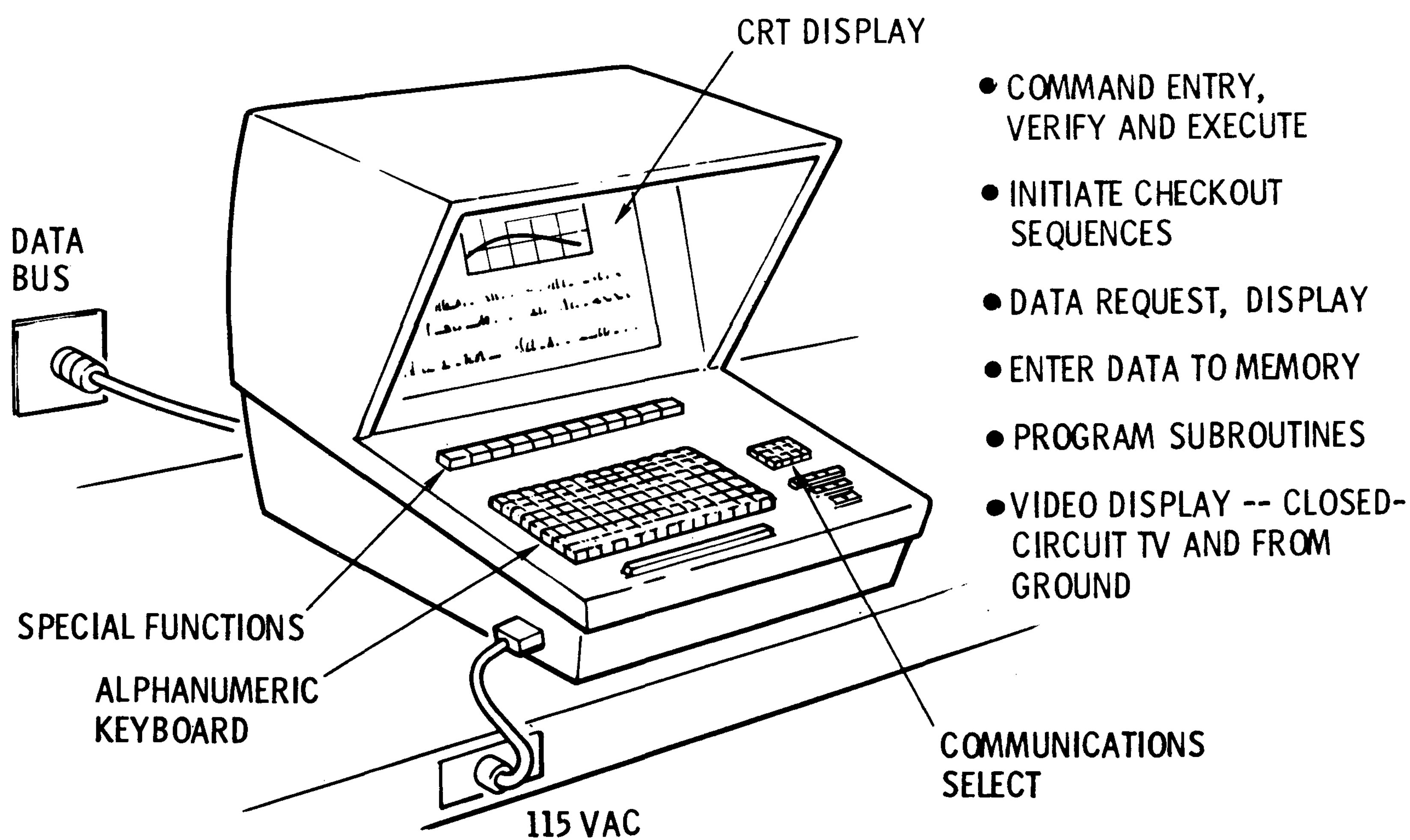


Figure 3-3. Portable Display and Control Unit

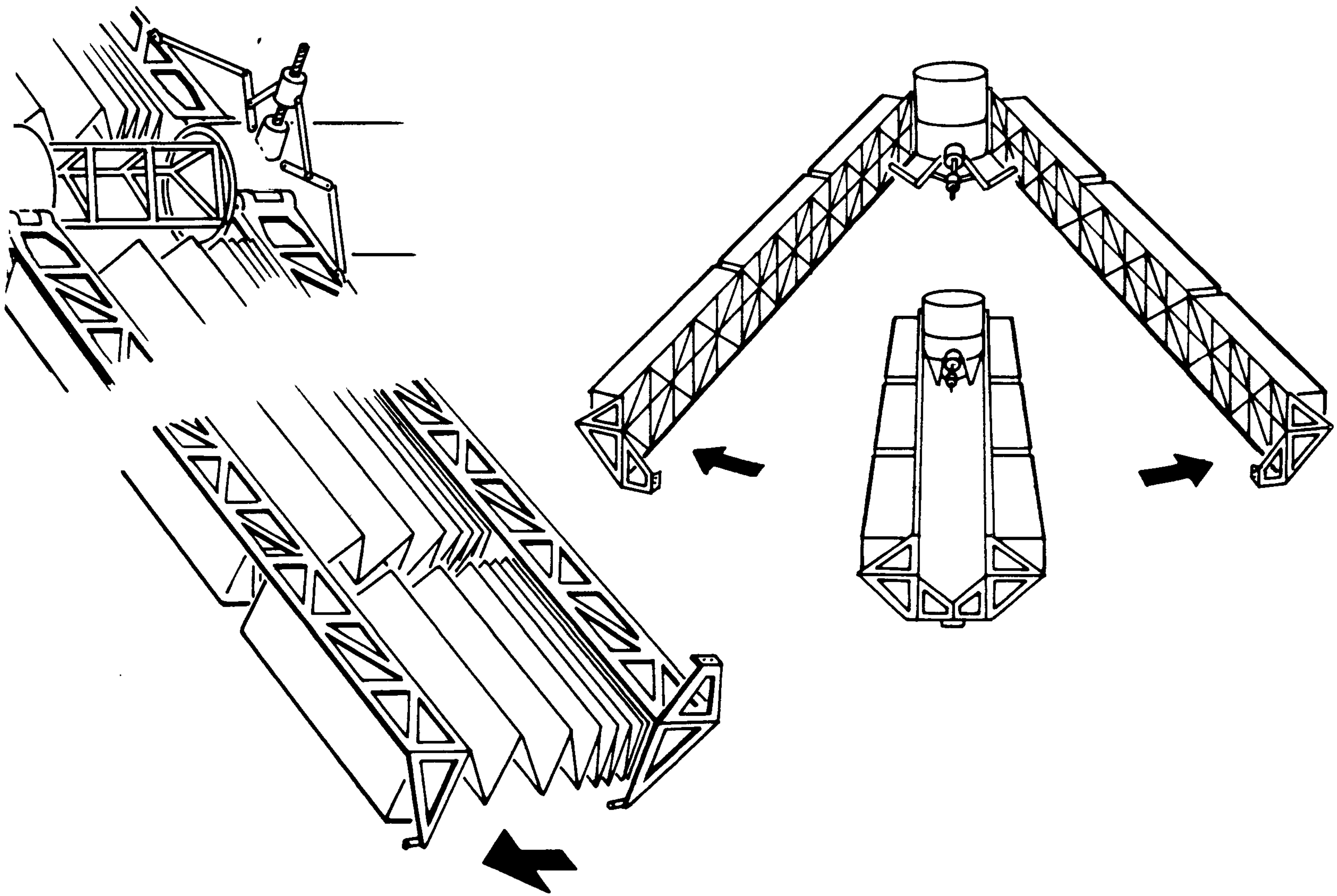


Figure 3-4. Solar Array Support Struct Deploy

batteries onboard the module will then be switched to the recharge mode, initiating normal power system operation. At this time, the solar array orientation control system will be activated and checked out. Proper system response and panel operation can be evaluated by the crew while the Space Shuttle maintains orbital rate of the total configuration.

With the module on solar array power, the assembly crew will begin a communication test on the VHF and S-Band systems with the ground network. While one crewman is performing these tests, the second crewman begins the next activation sequence for the high-thrust, N_2H_4 propulsion system. The propulsion system will be checked by the crewman by means of a series of controlled tests that are repeated several times to accumulate a reasonable amount of operating time in the space environment. With verification of this system operation, the system is deactivated and the initial certification of the module operational readiness is attained. The crew will return to the Shuttle, debrief with mission operations support on the ground, and prepare for a sleep cycle onboard the Shuttle.

On the second day, the crew will reenter the Power/Subsystem Module to check the horizon sensor and star tracker systems. Once this check is completed, the Space Shuttle will return to its normal orientation. The crew will then perform periodic tests on the module's subsystems, similar to a "shakedown cruise."

Following 24 hours of shakedown cruise, the crew will prepare for release of the module and return of the Space Shuttle. This operation will begin once the on-orbit crew and the ground support personnel have established the module's readiness for 60 days of unmanned operations. The Power/Subsystems module will be configured for unmanned operations by activation of the atmosphere supply onboard the module. The crew will then transfer to the payload tunnel area and secure the module hatch. Following this, the crew will disconnect the umbilicals across the interface and then enter the Space Shuttle airlock, securing the tunnel hatch. The tunnel will then be depressurized and the Shuttle will orient the module to its separation attitude. Once the desired attitude has been attained, the Space Shuttle will separate from the

Power/Subsystems module. Following separation, the module propulsion system will be activated and the hatch cover closed over the exposed docking port by RF command from the Space Shuttle. For one orbit or more, the Shuttle will station-keep, with the module monitoring proper subsystem operation. At the proper time, the Space Shuttle, with the assembly crewmen onboard, will initiate the retrofiring for return to Earth and completion of the first phase of the buildup operations.

3.1.2 Crew/Operations Module

The second module launched will be the Crew/Operations Module. Once the Crew/Operations Module is delivered to orbit and docked to the longitudinal docking port of the Power/Subsystems Module, 36 interfaces will be mated between the two modules. To perform the operations of mating these module-to-module interfaces, two assembly crewmen will accompany the Crew/Operations Module to orbit as Space Shuttle passengers.

This second flight of the buildup operations also includes the first direct docking operations of one module to another, utilizing the Space Shuttle systems. The technique for direct docking utilizes manual control by a Space Shuttle crewman located at the docking station in the Space Shuttle airlock.

The docking aid is a T-bar device located above the target docking hatch and, when viewed through the Space Shuttle docking telescope, its image yields information relative to lateral and vertical displacement of the Space Shuttle. The docking mechanism consists of a docking collar with two protruding guide arms on one module, and an identical collar on the other module with two guide arms in opposite corners to provide a neuter type of arrangement. The guide arms force alignment in the lateral, vertical, and roll positions during final closure. At closure, capture links located on the guide arms hold the collars together while the collars are retracted by collapsing their hydraulic energy-absorbing members. When the two mating surfaces are in contact, 24 interdigitated hooks (12 on each module) are engaged, and redundant seals are pressurized to seal the docking interface.

Figure 3-5 presents the buildup timelines for the crew and operations module delivery mission. As shown in the figure, at a ground elapsed time of approximately five hours, the Space Shuttle will have completed rendezvous with the Power/Subsystems Module and the Shuttle bay door will be opened and the module deployed for docking. As during the Power/Subsystems Module deliver mission, the freon loop of the Crew/Operations Module will be activated following module deployment from the Shuttle payload bay. During the ascent of the Space Shuttle, the mission operations support personnel have completed their operational commands to the target module, activating the rendezvous and docking aids and deploying the hatch cover over the target docking port.

Before initiating the terminal docking maneuver, the high-gain antenna located on the Crew/Operations Module must be rotated to the docking orientation. This orientation eliminates any interference with the docking operation, including the docking pilot's view. Also, the RF link between the Space Shuttle and the Power/Subsystems Module will be verified, as it is required for the nominal docking operation.

At a ground elapsed time of approximately six hours, the docking operation will be completed. Immediately following docking completion, the Space Station attitude control system will be deactivated and the orbiting configuration attitude orientation will be controlled by the Space Shuttle until completion of the on-orbit activities. Once this system has been deactivated, the crew will transfer to the Shuttle airlock and enter the crew transfer tunnel. Once the two assembly crewmen arrive at the entry hatch into the Crew/Operations Module, they will activate the module lighting and intercom systems and perform visual checks to establish the habitability of the module.

The Crew/Operations module contains the atmosphere control system and sufficient oxygen and nitrogen for 12-man days of habitation; however, this will be kept in reserve and the module(s) will be supported by the Space Shuttle environmental control system.

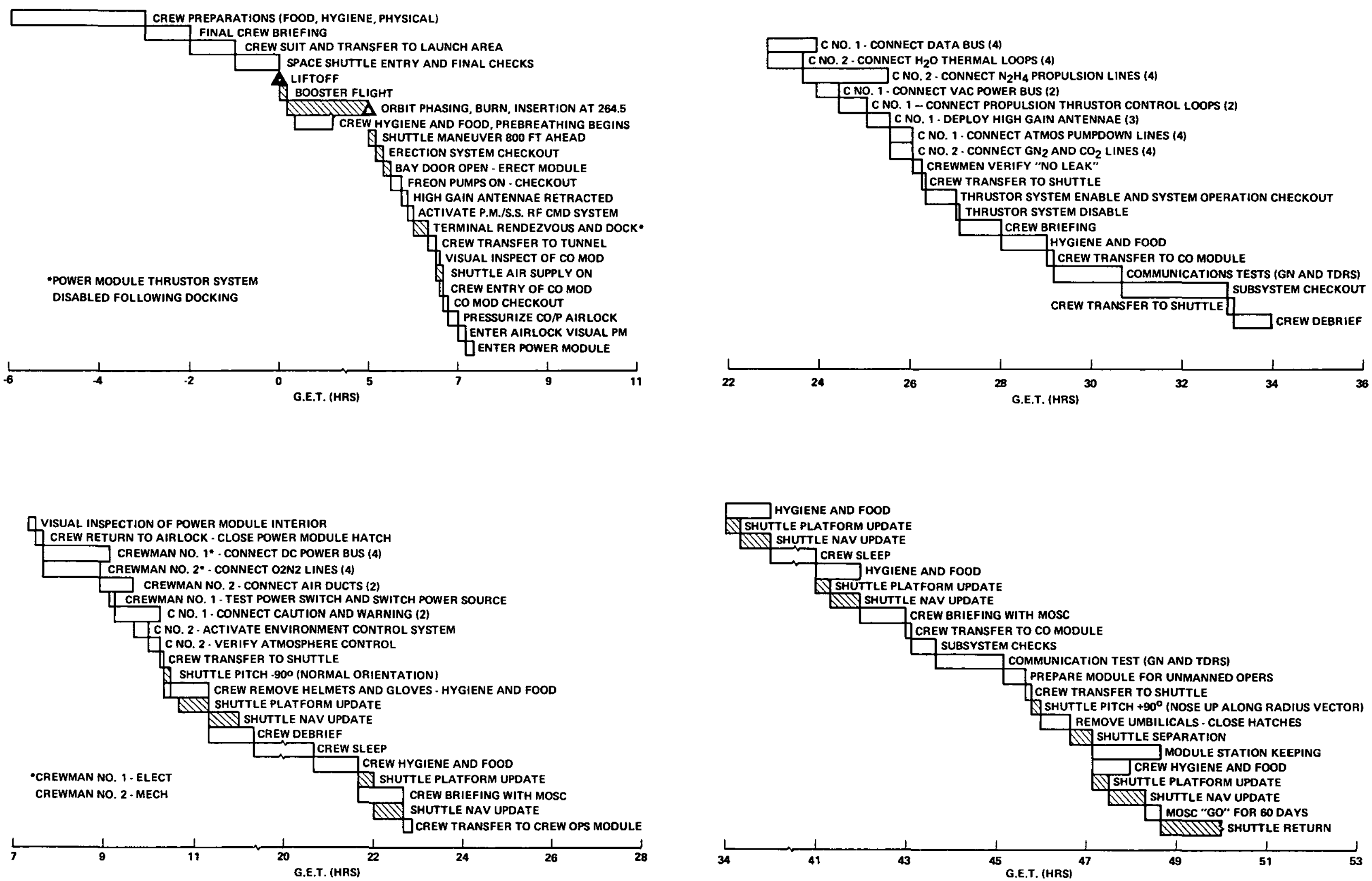


Figure 3-5. B/U Timeline – Crew/OPS Module

The crewmen will equalize pressure across the hatch, enter the module in pressurized suits, and perform a visual check at the interface of the Crew/Ooperations Module and the Power/Subsystems Module. They will equalize pressure in this natural airlock between the modules, and then enter this airlock. In this position, the crew will perform visual checks of the Power/Subsystems Module through the view port in the hatch. The crew will then enter the Power/Subsystems Module and visually inspect the module.

Following visual inspection, the two assembly crewmen will return to the Crew/Operations Module to begin mating the interface, securing the hatch into the Power/Subsystems Module. Until the electrical power interfaces (see Figure 3-6) are mated and checked out, the Crew/Operations Module is dependent on the Space Shuttle for its electrical supply. While the first assembly crewman (an electrical technician) is completing the power interface, the second assembly crewman (an electromechanical technician) will mate the oxygen, nitrogen, and air ducting interfaces. Approximately two hours after the initiation of the interface mating, the Crew/Operations Module will be on the Space Station power source.

The times required for the interface matings are presented in Table 3-1. The values shown in the first column represent estimates of the time required to complete the mating of the connection type of interface listed in the left-hand margin. These times were then corrected for the space environment, depending upon whether they could be done in IVA suits or were more likely to be accomplished in shirtsleeves. The third data column presents the corrected time for the interface mating and the final column presents the total connection time, including the test and checkout requirements.

Table 3-2 presents the detailed requirements for interface connections between the Power/Subsystems Module and the Crew/Operations Module, in terms of time required for total subsystems completion. The interfaces connected by the second crewman employ quick disconnects with interlocks to the shutoff valves for emergencies. The connections are encased in transparent bags, which indicate leakage through condensation or swelling.

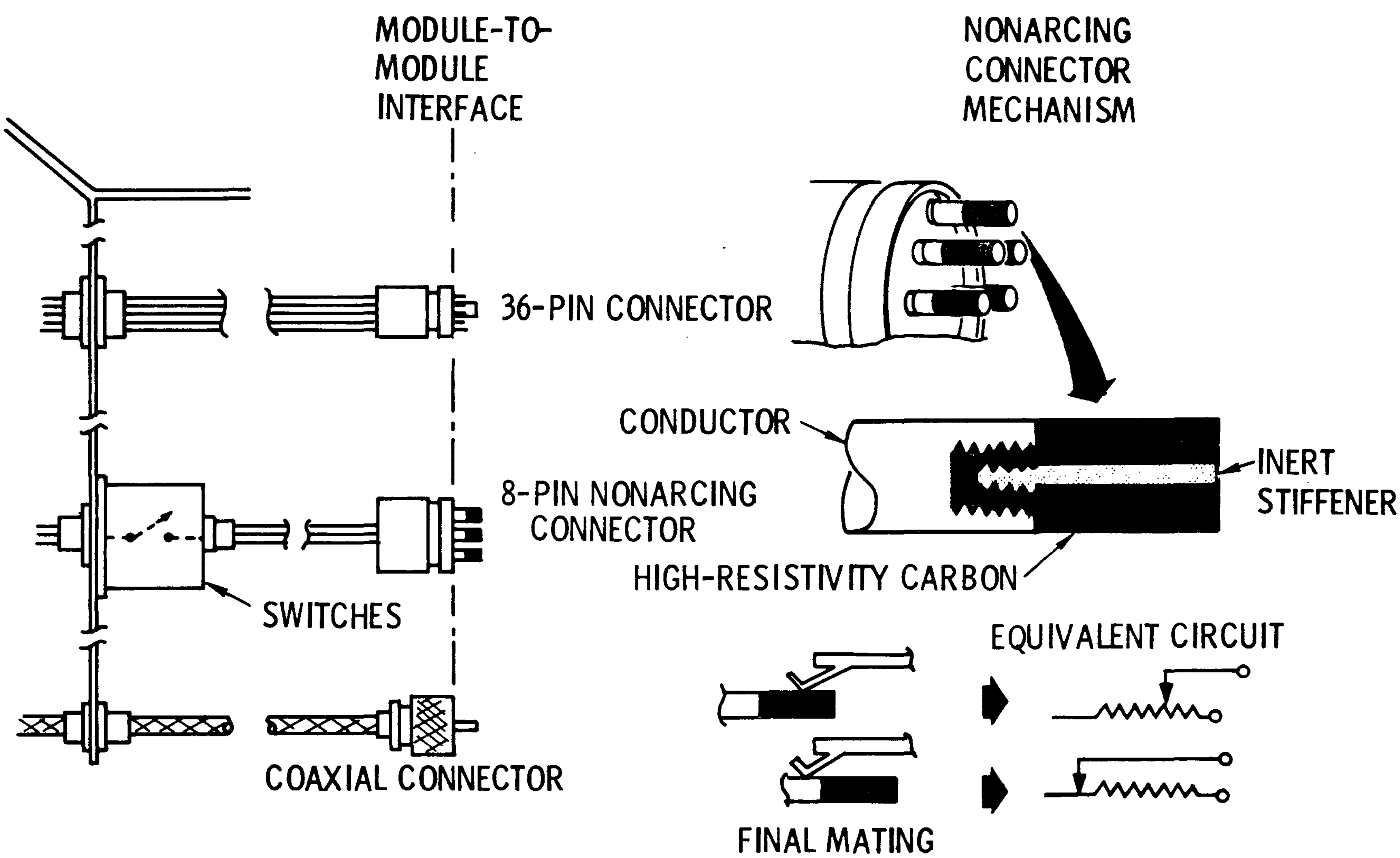


Figure 3-6. Electrical Interface Connection Concepts

Table 3-1

DETAIL ESTIMATES - INTERFACE CONNECTIONS

Connection	Unstow, Mate Torque, Secure Time (min)	Correction for Space Environment*	Hookup Time (min)	Test and Checkout Time (min)	Total Connect Time (min)
Air Ducts	6	3.5	21	3	24.0
Gas Lines (O_2, N_2)	4	3.5	14	3**	17.0
Fluid Lines (H_2O)	4	1.5	6	5**	11.0
Fluid Lines (N_2H_4)	18	1.5	27	10**	37.0
Power Bus (VDC)	5	3.5	17.5	5	22.5
Power Bus (VAC)	5	1.5	7.5	5	12.5
Data Bus	6	1.5	9	10	19.0
Caution and Warning	6	3.5	21	10	31.0
Gas Lines (Pumpdown)	4	1.5	6	3	9.0

*Correction factors: 3.5 (avg) for space suit; 1.5 (avg) for zero G

**120-min leak test adequate for all fluid systems

Table 3-2

POWER/CREW - DETAIL INTERFACE ESTIMATES

Connection	Number	Hookup Time (min)	Checkout Time (min)	Total Time (min)
Air Ducts	2	42	6	48
Atmosphere Supply	4	64	12	76
Power (VDC)	4	70	20	90
Caution and Warning	2	42	20	62
H_2O Thermal	4	24	20	44
Atmosphere Pumpdown	4	24	12	36
Propulsion (N_2H_4)	4	72	40	112
Propulsion (GN_2, CO_2)	4	24	12	36
Data Bus	4	24	40	64
Power (VAC)	2	10	20	30
Thruster Control	2	18	20	38

Total time = 636 man-min

Once the atmosphere interfaces are mated and the module is on Space Station power, the crew will activate the environmental control system and verify proper atmospheric control. Following these operations, the crew will return to the Space Shuttle, remove the IVA suits, debrief, and perform a food and sleep cycle.

The second day, the crew will be briefed by the support personnel on the ground to identify any anomalies which occurred during their sleep cycle, and then reenter the Crew/Operations Module to continue the buildup operations. One of the first activities to be completed on the second day is the mating of the hydrazine propulsion lines. Since N_2H_4 is considered a hazardous fluid, it is transferred inside an evacuated sleeve. The interface surfaces of both the fluid line and the outer sleeve are joined by appropriate means (bolts, V-band clamps, etc.). The outer sleeve can be retracted for ease of connection of the inner line. On completion of the interface mating, the crew will return to the Crew/Operations Module and secure the hatch, isolating the interface volume from both modules. By proper valve manipulation, these lines will then be evacuated, and the propellant lines filled from the source tanks in the Power/Subsystems Module.

The high-gain antennas will then be deployed to their normal position, from the stowed position utilized during docking. Following this operation, the crewmen will verify no leaks in the N_2H_4 feed lines and then transfer to the Space Shuttle. Once in the Space Shuttle, the thruster system will be enabled and the propulsion system on the Crew/Operations Module operated to verify system integrity. On completion of the test, the crew will deactivate the system and perform a food and hygiene cycle on the Space Shuttle.

The crew will then transfer into the Crew/Operations Module, verify the habitability of the crew tower interface airlock, and begin the communications tests with the high-gain antennas. Because the Space Shuttle structure tends to obscure the antennas, orientation of the cluster must permit continuous viewing for checking acquisition and handover operations. The orientation will depend on the position of the orbit relative to the satellites.

Following the initial communications tests, the assembly crew will perform a total of 10 hours of subsystem tests on primary, redundant, and backup systems to establish the operational readiness of the two modules. Typical of the subsystem activation and checkout operations is the one associated with the urine recovery system presented in Figure 3-7. The first step in activating the urine recovery system is to verify that all manual isolation valves are in the correct position and that the thermal fluid from the solar collector is present at the heat exchanger. One of the chemical treatment tanks is then activated. During normal operation, when one storage tank is filled, the second starts to accumulate urine while the first is automatically switched to the wick system. The circulating air system drives air through the heat exchanger and across the wicks, evaporating the water which is subsequently condensed in the two-stage condenser. The water is then filtered through charcoal and bacterial filters and transferred to the water management storage units. During the checkout operations, purified water will be used to simulate urine, to provide the operational test. Principal monitor parameters are heat-exchanger outlet, fluid level in the storage tanks, and quantity of remaining treatment chemicals and system balance.

Once the operational readiness of the modules has been established, the crew will prepare the module systems for operations and then transfer to the payload tunnel area and secure the Crew/Operations Module hatch. After this, the crew will disconnect the umbilicals to the Shuttle and then enter the Space Shuttle airlock. The tunnel will then be depressurized and the Shuttle will orient the modules to their separation attitude. Once the attitude is attained, the Shuttle will separate from the modules, activate the configuration propulsion system, and close the hatch cover over the exposed hatch. For one orbit or more, the Shuttle will station-keep with the modules and return to the Earth at the proper time, completing the second phase of the buildup operations.

3.1.3 General-Purpose Laboratory

The third and final flight of the buildup operations is the delivery and mating of the GPL to the Crew/Operations Module. Table 3-3 presents a detail

R272

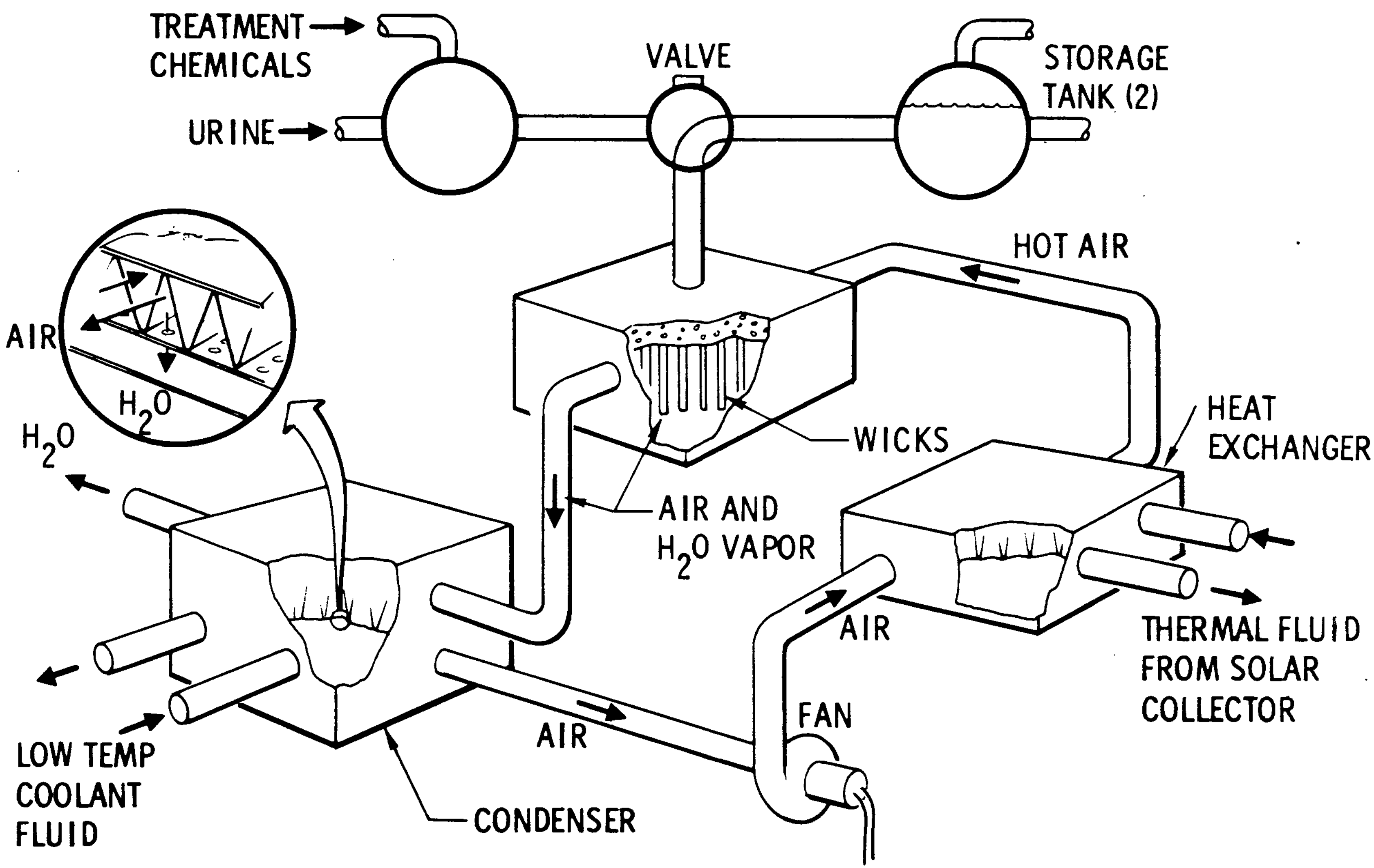


Figure 3-7. Urine Recovery System

Table 3-3

CREW/GPL - DETAIL INTERFACE ESTIMATES

Connection	Number	Hookup Time (min)	Checkout Time (min)	Total Time (min)
Air Ducts	2	42	6	48
Atmosphere Supply	4	64	12	76
Power (VDC)	4	70	20	90
Caution and Warning	2	42	20	62
H_2O Thermal	4	24	20	44
H_2O Life Support	6	36	30	66
Atmosphere Pumpdown	4	24	12	36
Data Bus	4	24	40	64
Power (VAC)	2	10	20	30

Total time - 516 man-min

summary of the interfaces between the GPL and the Crew/Operations Module. As shown, once docking has been completed, 32 interface connectors will be mated between the two modules.

The buildup operations timeline for this mission is presented in Figure 3-8. As shown in the figure, the Space Shuttle terminal rendezvous is completed at a GET of approximately 10 hours. The GPL is deployed for docking at a GET of 14 hours. Once deployed, the module's freon pump is turned on, and docking is completed 15 hours after liftoff. Due to the extensive phasing requirement during the ascent portion of the mission, the crew will perform an 8-hour sleep cycle during ascent.

Following docking, the two assembly crewmen will transfer to the Space Shuttle airlock and tunnel and to the GPL test and isolation chamber hatch. At this position, the crewmen will verify the habitability of the chamber, activate the lighting system and the intercom system, and enter the chamber (assumed to be in IVA suits with helmets and gloves on). The crew will perform a visual inspection of the chamber and then transfer to the GPL hatch. The crew will establish the habitability of the GPL and then enter the laboratory portion of the module for visual isnpection. Following inspection, the crew will move to the GPL hatch located at the interface of the GPL and Crew/Operations modules. The two assembly crewmen will then pressurize the natural airlock at the interface, equalizing pressure across the hatch, and they will enter the airlock. After a visual check of the crew operations module through the viewing window in the hatch, the crew will equalize the pressure across the Crew/Operations Module hatch and enter the Crew/ Operations Module. After a visual inspection of that module, the crew will return to the GPL, securing the crew module hatch.

The two crewmen will then begin the required interface mating operations, which require a total of six hours and thirty minutes. Once the interface mating has been completed, the crewmen will transfer to the Space Shuttle for normal operations of food, hygiene, and sleep. Following these activities, the crew will transfer to the GPL and perform ten hours of subsystem

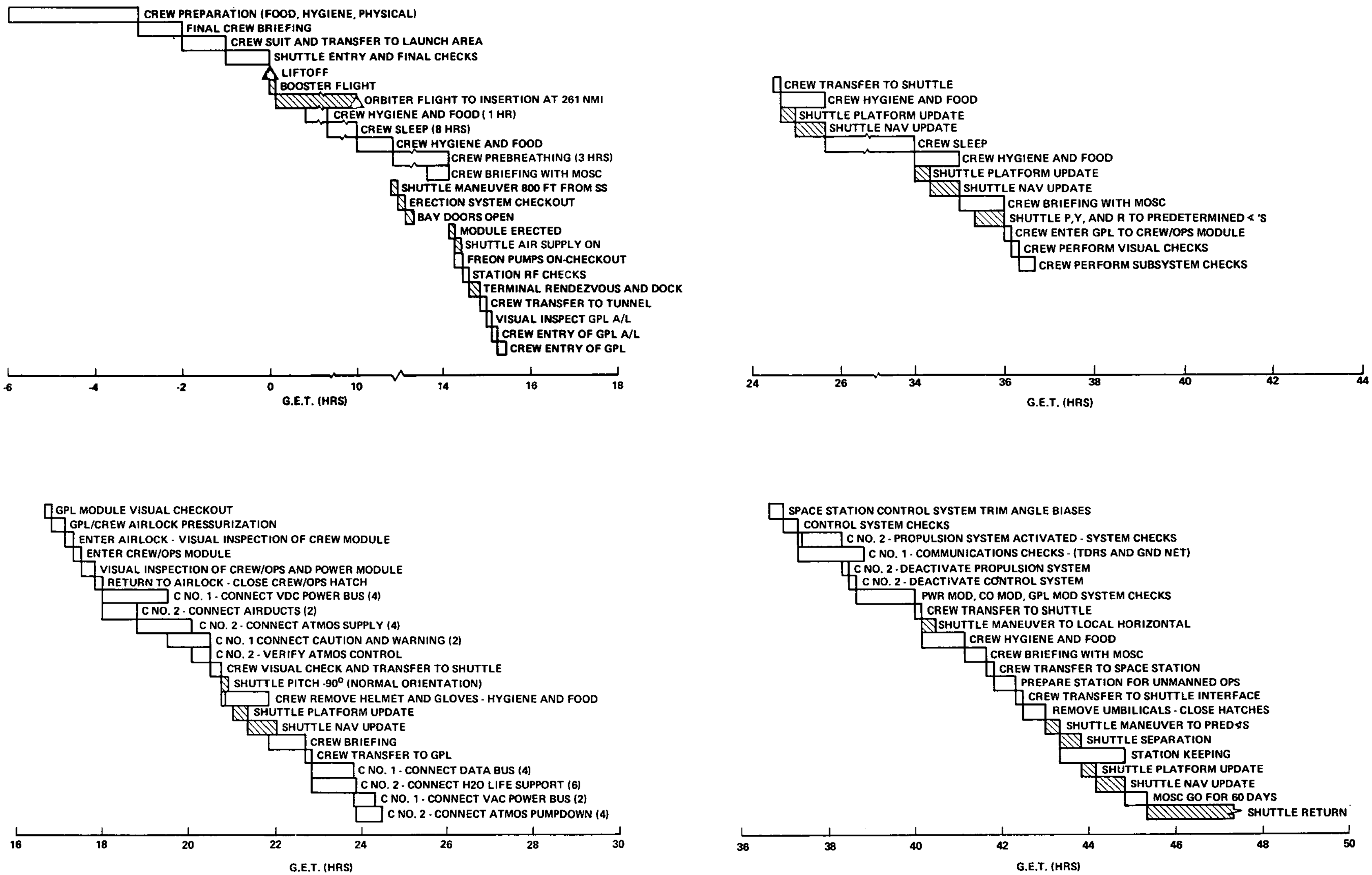


Figure 3-8. B/U Timeline – GPL Module

operations and checkout to verify the operational readiness of the configuration. Following these activities, preseparation operations will begin. The remaining activities parallel those described previously for separation, station-keeping, and return.

3.1.4 Logistics Module

The fourth launch will be the first Log Module plus two sustained operations crewmen carried as passengers in the Space Shuttle. Following docking to the Crew/Operations Module, the interfaces presented in Table 3-4 will be mated, the systems checkout, and then the off-loaded equipment, such as those candidates presented in Table 3-5, will be carried onto the Space Station and installed at the proper location.

As shown in Figure 3-9, rendezvous with the orbiting Space Station occurs approximately seven hours after liftoff. Following deployment of the logistics module from the Shuttle payload bay to the docking position, the Log Module will be docked to the Crew/Operations Module. The Space Station crewmen will transfer from the Shuttle, through the tunnel, to the Log M hatch. Following the establishment of habitability of the module and activation of the lighting and communications system, the two crewmen will enter the Log Module. After completing a visual check of the Log Module interior, the crewmen will transfer to the interface hatch at the interface of the Log Module and Crew/Operations Module and equalize pressure across the hatch into the natural airlock.

The crewmen will enter this airlock and equalize pressure into the Crew/ Operations Module. Once this operation has been completed, the crewmen will enter the crew operations module and perform a visual check of the Space Station interior. They will then return to the Log M and begin the interface mating between the Log and the crew operations module. Once the power and atmosphere control interfaces have been mated, the Log M is switched from Shuttle support to Space Station subsystem support. The crew will then return to the Space Shuttle and, with habitability verified, they will remove their helmets and gloves and perform a hygiene, food, waste management, and sleep period.

Table 3-4

LOG M/CREW - DETAIL INTERFACE ESTIMATES

Connection	Number	Hookup Time (min)	Checkout Time (min)	Total Time (min)
Air Ducts	2	42	6	48
Atmosphere Supply	4	64	12	76
Power (VDC)	4	70	20	90
Caution and Warning	2	42	20	62
Data Bus	4	24	40	64
Propellant N_2H_4 Supply	2	36	20	56
Propellant GN_2 Supply	2	12	6	18
Gas Lines (Pumpdown)	4	24	12	36

Total time = 450 man-min

Table 3-5

EQUIPMENT TRANSFER/INSTALLATION

Item	Quantity	Module	Transfer Distance (ft)	Time per Unit Transfer (min)	Unit Install Time (min)	Total Time (min)	Unit Weight (lb)
CMG	5	Power	38	20	30	250	400
Battery	4	Power	50	18	60	312	389
O_2 (repressurization)	1	Power	33	15	15	30	289
GN_2 (repressurization)	4	Power	33	15	15	120	277
O_2 Tank (metabolic)	3	Power	33	15	15	90	289
Battery	8	Crew	18	15	60	600	389
Water Tank	3	Crew	22	12	15	81	386
Trash Compactor	1	Crew	26	15	25	40	110
Food (freezer refrigerator)	4	Crew	15	10	10	80	228
IVA/EVA Units	6	Crew	28	10	5	90	74
Battery	8	GPL	34	18	60	624	389

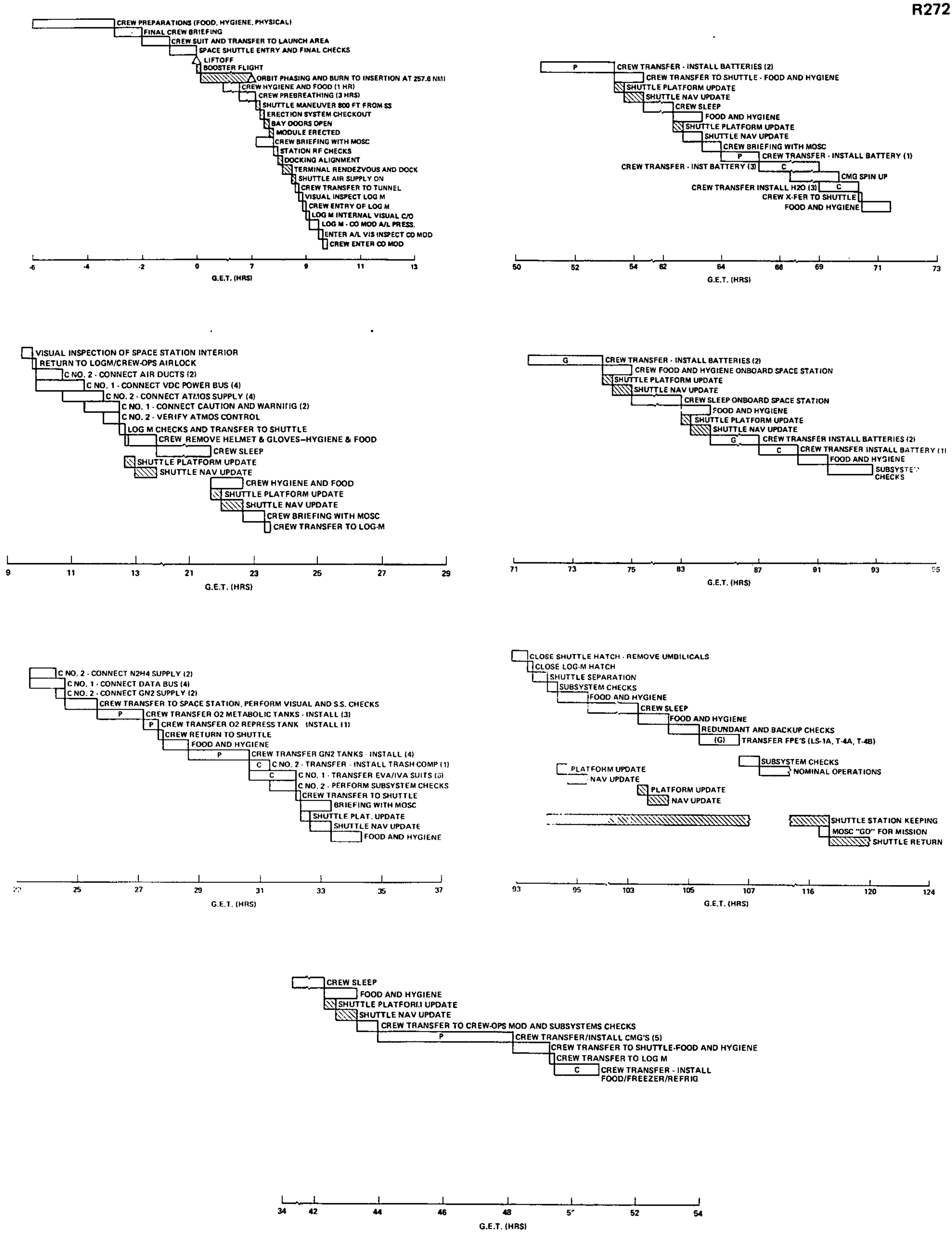


Figure 3-9. Buildup Timeline—Logistics Module

After a briefing with the ground support personnel, the crew will transfer to the Log M to complete the interface mating required between the logistics vehicle and the Space Station. Once the interface operations have been completed, the crew will begin transfer of equipment which has been off-loaded from the Space Station modules for launch.

Following the transfer and installation of the off-loaded items, the newly installed equipment will be checked out and its operability verified. At approximately 75 hours GET the crew will utilize the Space Station for their food, hygiene, and sleep cycles. Approximately 93 hours following liftoff, the Space Shuttle will separate from the Space Station, leaving the two crewmen onboard the Space Station to begin nominal operations. After station-keeping for approximately one day on-orbit, the Space Shuttle will return to earth.

A total of three logistics missions is required to complete the activation operations and build the on-orbit crew to a six-man level. These flights will be 30 days apart, resulting in completion of buildup and activation five months after the first Space Station launch. During the buildup and activation operations, a crew duty-cycle day of 20 hours was utilized. The short duration of the missions indicated that the crew did not require the nominal four-hour recreation period each day, therefore, none were scheduled. This approach enables greater utilization of the crew time on-orbit; however, during sustained operations, with the crew on-orbit for extended periods, the recreation and relaxation periods should be and have been included in the daily schedules.

3.2 ORBITAL OPERATIONS

The sustained operations of the Space Station for crew operations analysis were divided into four areas; experiment operations, station operations, logistics support, and safety. In general, the experiments and their operations represent the Space Station mission, while the station operations represent the support activities on-orbit which are required for mission accomplishment.

3.2.1 Experiment Operations

Detailed descriptions of experiment operations with associated timelines at the FPE level are given in Appendix A prepared by the Martin Marietta Corporation Denver Division. Only the more general features of the crew's involvement in these operations is discussed in this section.

The GPL is the center of operations for the primary Space Station mission. The general arrangement of equipment was described in Section 2. The experiment operations center was shown in Figure 2-25 with individual work stations of each Laboratory/Facility shown in Figures 2-18 through 2-24. These figures represent the functional grouping of equipment into laboratories or specialized facilities. Each has been sized to allow up to three crewmen to work at one time. Also, there is sufficient free volume associated with each area to permit up to three crewmen to confer, study, relax, or socialize, thereby eliminating the need to return to the crew module for such activities.

Equipment requiring frequent access for servicing or maintenance was located in the center consoles. Equipment located around the periphery of the module is hinged so it can be swung out for maintenance or access to the module walls. Handholds and foot restraints are located throughout the module for safety and efficient operations.

In addition, a movable, adjustable pelvic/foot restraint is provided at the upper-level equipment for operation and maintenance. Two handrails, one on either side of the module, extend the length of the GPL in front of the consoles. Several pelvic/foot restraints are attached to these handrails. They can be moved along the rail and locked in place at any angle, including the relative angle between the foot and pelvic restraint.

The support required by the experiment program from each of the subsystems is summarized in Table 3-6. This table shows the crew operations involved as well as the facilities, tools, and equipment.

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS

Subsystem	Operations	Facility	Equipment	Tools
Data Management	Cable/plug repair	Storage in test facility		Wire strippers Flat cable strippers Wire Printer Diagonals Longnose pliers Portabin volt-ohmeters Solder gun Connector/pin tools Terminal crimper Screw drivers Allen wrenches
	Equipment analysis and repair	Test facility	Power supplies Oscilloscope Digital multimeter Digital counter Function generator	

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Subsystem	Operations	Facility	Equipment	Tools
Data Management (Continued)			Vacuum/ nitrogen source Fluke/null meter Ultrasonic cleaner Micro search terminal Signal sources	
Onboard Checkout	Component removal and replacement	Storage		Circuit card puller Screw driver Standard removal tools (depends on package concepts)
	Cable/plug repair	Storage	Volt-ohmeter	Wire strippers Flat cable strippers Wire printer Wire cutters Needle-nose pliers Connector/pin tools

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Subsystem	Operations	Facility	Equipment	Tools
Onboard Checkout (Continued)				Crimping tools Screwdriver Allen wrenches
	In-place equipment analysis and fault isolation	Electrical/ electronics laboratory	Same as below	Circuit card extender/puller Test leads Breakout box
	Bench-level equipment analysis	(Multiinstrument test bench)	Multichannel oscilloscope Volt-ohmeter Multifunction signal generator Power supplies Electronic counter Oscilloscope camera	Circuit tap plug Screwdriver Test leads Alligator clips Pliers Holding device Mallet Magnifier

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Subsystem	Operations	Facility	Equipment	Tools
Stabilization and Attitude Control	Sensor replacement[1]	Deploy/retract pressurizable compartment	Volt-ohmeter Oscillo-scopes Power supplies	Standard
Stabilization and Attitude Control	Electronics module replacement[2]	Electronics test laboratory	Oscillo-scope, signal generator, etc	Standard
Stabilization and Attitude Control	CMG replacement	NA	Mechanics tools	Standard
Stabilization and Attitude Control	CMG repair	NA	Mechanics tools, bear-ing puller	Standard
Guidance and Navigation	Sensor replacement[3]	Deploy/retract pressurizable compartment	Volt-ohmeter Oscillo-scopes Power supplies	Standard

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Subsystem	Operations	Facility	Equipment	Tools
Guidance and Navigation	Electronics module replacement[4]	Electronics test laboratory	Oscilloscope, signal generator, etc	Standard

1. Includes the following sensors: Horizon sensor, gyros.
2. Includes the following electronic assemblies: sensor interface electronics, CMG electronics, control electronics and jet drivers, power conditioners.
3. Includes the following sensors: star trackers, star sensors, rendezvous radars.
4. Includes the following electronic assemblies: sensor interface electronics.

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - ELECTRICAL POWER (Continued)

Assemblies	Operation	Facility	Equipment	Tools
Solar Array and Orientation	Replacement of solar panels (feasibility TBD - required EVA)	Storage	Special handling tools to transport panels	Wrenches Torque wrench
	Replacement of motors, bearings and dynamic seals, pumps	Storage	Special puller for exposing bearings and seals	Wrenches Torque wrench
Energy Storage	Replacement of battery modules	Storage		
Transmission Control and Distribution	Connect/disconnect electrical umbilicals	None		Special electrical disconnect tool
	Replacement of black boxes, inverters, battery chargers, battery load regulators, and shunt regulators	Storage		Screwdrivers Torque wrench Electrical disconnect tool Plug pin tools

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - ELECTRICAL POWER (Continued)

Assemblies	Operation	Facility	Equipment	Tools
Subassemblies - Components	Switches	Magnifier	Oscilloscope	Allen wrenches
	Circuit breakers	Circuit card vise	VTVM	Screwdrivers
	Limiters	Clean box	Load box	Inspect mirror
	Relays	Storage	Tachometer meters	Nylon gloves
	Motors	Test facility	Circuit card tester	Torque wrench
	Instruments			Side cutters
	Sensors			Solder gun
	Lights			Continuity test light
	Circuit cards			Circuit card puller
	Brushes			Plug pin tools
	Cable			
	Battery modules			

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - EQUIPMENT AND FACILITIES FOR MAINTENANCE (Continued)

Subsystem	Operation	Facility	Equipment	Tools
Communications	Normal maintenance and replacement			Connector pliers Mounting rack tool Other small hand tools*
	Replacement of coaxial cables, connectors	Communications equipment test facility	Signal generators, Oscilloscope, spectrum analyzer, multimeter, power meter	

*Tools chosen for data management may also be used for emergency repairs at lower levels.

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - PROPULSION (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
Checkout Leak Check Valves/Bellows Connections		Gas supply	Bas bottle Hand valves Pressure gages Bubble soap solution	Misc hand tools
Subsystem	Visual display (P;T)			
Functional Valve Control Sequence Checks	Propellant control panel Visual display (P_1 events)			
Instrumentation Calibration		Instrument calibration and functional check	Gas supply Pressure gage Temperature sensors Voltameter/current tester Ohmeter	Misc electrical and mechanical hand tools

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - PROPULSION (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
Checkout (Continued)				
Electrical Continuity Function Resistance Check		Component test areas	Gas supply Pressure gages Hand valves Voltameter/ current traces Ohmeter	Misc electrical and mechanical hand tools
Regulator	Strip charts (P)			
Response Thruster Valves	Strip charts (volts) Strip chart (events)	Contigent test area	Gas supply Pressure gages Hand valves Voltameter/ current traces Event recorder	Misc electrical and mechanical hand tools

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - PROPULSION (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
Checkout (Continued)				
Heaters Resistance Functions	Strip chart (temperature)	Component test area	Temperature control box	Misc electrical hand tools
			Temperature sensors	
			Ohmeter	
			Voltameter/current traces	
Replacement Components/inst Tankage (load or Unload) Thruster modules Umbilicals Instrumentation		Spare storage		Misc hand tools
		Cleaning (liquid)		Eva tethers
		Hazard storage	Handling dolly/fixture	Hand tools
		Cleaning (liquid)	Handling fixture	Hand tools
		Cleaning (liquid) as noted above		PLSS
				Pressure unit assembly
Cleaning/ Decontamination		Purge gas	Built-in capability	Hand tools

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - PROPULSION (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
Checkout (Continued)				
Line Repair		Argon purge gas Cooling water Cleaning (liquid)	Brazing Equipment Tube benders	Braze heads Tube cutters/ deburrers
Propellant Check No. FE N_2O Particle Content		Propellant laboratory	Propellant sampler (bottle and valves) Filters Laboratory equipment	Hand tools

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Subsystem	Operation	Facility	Equipment	Tools
EC/LS	Component Replacement of Valves Fans Pumps Compressor Connectors Sensors Heaters Filters Canister Electronic control Separator Motor Hoses	Storage bin	Conventional portable checkout equipment, such as volt-ohmeter, oscilloscope, electronic counter Special portable plug-in equipment, such as flow meter, temperature meter, or pressure sensor Portable leak detector Plumbing repair equipment (contingency tube cutters tube flare,	Conventional hand tools modified for zero-gravity use such as tubing wrenches, screw drivers, pliers, or allen wrenches

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Subsystem	Operation	Facility	Equipment	Tools
EC/LS (Continued)			etc (same as propulsion)	
	Module replacement of Heat exchanger subassembly Tank subassembly Membrane module			
	Radiator repair		Brazing (contingency)	Wrenches

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - HABITABILITY (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
Housekeeping Equipment	Replace Repair Adjust	GPL	Pneumatic system leak detector	Continuity test light Phillips screw-drivers (3- and 6-in.)
Recreation Equipment	Repair Adjust	GPL	None	Allen wrench, size to be determined
Radiation and Meteoroid Detection Equipment	Repair Adjust	None	Calibration instrument	Circuit card tester Circuit card puller Continuity test light
Maintenance Equipment	None	None	None	None
Food and Food Management Equipment	Repair Replace Adjust Sensors, electrical unit	None		Repair kit contents
Religious Worship Provisions	Repair	None	None	
Emergency Equipment	None	None	None	Special emergency equipment repair kit

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS - HABITABILITY (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
EVA Support Equipment		None	None	Special EVA repair kit
Pressure Suit Assembly (PSA) Support Equipment	PSA monitor panel	None	None	Special PSA repair kit
Damage Control and Safety	None	None	None	Hole plug kit
Medical Equipment	None	None	None	Special medical equipment repair kit
Mechanical	Maintenance of mechanical system; i.e., gimbal rollers, hydraulic systems, elevators, and cargo-handling devices	Tool-storage areas, mechanical assembly/ disassembly areas	Holding fixtures	Wrenches
	Docking shock struts; door mechanisms, door seals, window seals			Torque wrenches, allen wrenches glove box

Table 3-6

GPL SUPPORT REQUIRED BY SPACE STATION SUBSYSTEMS (Continued)

Functions or Operations	Operational Monitors and Controls	Facilities	Equipment	Tools
Personal Equipment	Repair	GPL	None	Circuit card tester Soldering gun Soldering needle Continuity test light
Restraint Equipment	Replace/repair restraint locking clamping device and fabrics	GPL	None	Allen wrench (size to be determined) Fabric mending kit (contents to be determined)
Exercise Equipment	Repair of mechanical linkage-cables, electrical alternator load control	None	Volt-ohmeter	Socket set with 3/8 drive, and 3/8, 7/16, 1/2, 9/16 in. sockets Same as personal equipment
Hygiene Equipment	Adjust Repair	GPL		Same as personal equipment Allen wrench, 5/32 Phillips screw-drivers, (3- and 6- in.) B-nut wrench, to be determined

3.2.2 Station Operations

Sustained operations will be initiated with the third Log M flight five months after the first launch, when the ISS crew is increased to six men. ISS operations will continue until four years and seven months later when the Space Station crew is increased to 12 men. Over the entire Space Station program, a total of approximately 275,000 man-hours of productive operations will be provided on-orbit. Of these, 88,000 will be provided during ISS operations.

The crew will be delivered to orbit as passengers onboard the Space Shuttle. Once docking has been completed, the two crewmen will enter the Shuttle airlock, transferring through the expandable tunnel to the payload pallel interface. The crewmen then will equalize the pressure across the Log Module hatch, open the hatch, and transfer through the Log Module airlock and the Log Module to the Space Station. The exit of crewmen returning to earth is the reverse operation along the same path.

The Space Station design approach has paid careful attention to minimizing crew tasks and complexity associated with routine operations and maintenance activities to provide the maximum possible number of man hours on-orbit for experiment operations. The general crew functions for the on-orbit crew include the following station operations:

a. Subsystem operations.
b. Inventory control.
c. Logistics vehicle checkout and operations.
d. Resource planning.
e. Station maintenance.
f. Safety and medical care.
g. Experiment interfaces.
h. Onboard checkout.
i. Contingency modification.

All of the daily routine operations for station operations will be automated to the maximum extent practical. A typical example is the monitoring of critical parameters and activation of appropriate warning devices for out-of-tolerance conditions. The actuation of appropriate response to warnings will be a crew responsibility; however, system switching to redundant or backup systems will also be automated as much as possible. During each shift, one crewman will be assigned the responsibility of the control console located in the Crew Operations Module. When operations are minimal at this position, the operator will perform other duties, but he is available if malfunction or emergency conditions arise requiring his attention.

Additionally, the crew will perform the following activities: food preparation and cleanup, hygiene and waste management, rest and relaxation, physical fitness and exercise, housekeeping (cleanup), and routine medical and dental care.

Since some of the subsystem requirements were changed for the Modular Space Station, it was deemed necessary to reexamine crew requirements for station operations to ensure adequate crewtime to support experiment operations. Personal activities were not reexamined in detail since they remained the same as for the 33-ft station, and equipment, procedures, and general philosophy regarding crew-equipment interfaces are unchanged for the Modular Space Station.

The major effort for the Modular Space Station crew operations analysis was to determine the time required for routine operations. The time for personal activities was defined as 90 min a man per day for eating, hygiene, and waste and 8 hr a man per day for sleeping. Thus, the essential objective of the analysis was to determine how the crew spends its 10 hr a day of duty time.

To facilitate the generation and compilation of these data, the form shown in Figure 3-10 was devised. The form is based on the premise that all subsystem tasks can be categorized under four major headings. An increase in crew involvement is inherent in the second tier categories, as shown in Table 3-7. Each subsystem designer completed the forms for the equipment for which he is responsible. An assembly-level breakdown was used to identify tasks. The frequency and duration (F&D) were then entered on the form. With these raw data, it was possible to compile crew time requirements in various formats in order to better understand what crew responsibilities are and how much time should be devoted to them.

CONFIGURATION: IC		ISS X GSS				RESPONSIBLE ENGINEER		PARKER			DATE 6/18/71		R272

f (DAYS) d (MIN) CODE NUMBER		CREW TASKS 1.0 VERIFY STATUS 1.1 OBSERVE OPERATING COND	1.2 CONFIRM/DETERMINE QUANTITATIVE MEAS	1.3 ADJUST TO EFFECT PROPER OPERATION	2.0 ACTIVATE/DEACTIVATE 2.1 FLIP SWITCH	2.2 WARMUP/SHUT DOWN	2.3 MANUALLY CLOSE VALVE/ SHUT DOWN	3.0 SERVICE 3.1 FLIP SWITCH	3.2 REMOVE COVER	3.3 MANUALLY CLEAN/ LUBRICATE	4.0 MONITOR/CONTROL 4.1 MONITOR AUTOMATIC OPS	4.2 MONITOR SEMIAUTO-MATIC OPERATIONS	4.3 MANUALLY CONTROL OPERATIONS	ADDITIONAL DETAILS
HI THRUST ADB0100	f	60				30								
	d	5				1								
ADB0200	f	60		90										
	d	10		15										
ADB0300	f	60												
	d	5												
ADC0100	f	60				30								
	d	10				2								
ADC0200	f	60												
	d	5												
ADD0100	f	60			30									
	d	10			1									
ADE0100	f	60												
	d	5												
LO THRUST AEB0100	f	30								30				
	d	10								10				
AEC0100	f	30		90										
	d	10		10										
AEC0200	f	30												
	d	5												

Figure 3-10. Crew Operations Analysis

Table 3-7

CREW/OPERATIONS ANALYSIS SUBSYSTEM REQUIREMENTS

1.	Verify Status	3.	Service
1.1	Observe on-off condition	3.1	Flip switch
1.2	Confirm or determine quantitative measurement	3.2	Remove cover
1.3	Adjust to effect proper operating condition	3.3	Manually clean or lubricate
2.	Activate/Deactive	4.	Monitor and Control
2.1	Flip switch	4.1	Monitor automatic operation
2.2	Warm-up or shut down	4.2	Monitor semiautomatic operation
2.3	Manually close valve or replace unit	4.3	Manual control

Table 3-8 shows the periodic time requirements for each of five subsystems. The interval (daily, every seven days, every 10 days, etc) is indicated in the left-hand column. The number of events for each interval is in the next column. The minutes required to accomplish the task are entered under each subsystem designation. Totals are provided by subsystem and by interval. (Communications, data management and onboard checkout are not included in the table.)

As shown in Table 3-8, much of subsystem operations is performed in daily or weekly tasks. These tasks involve routine inspection of equipment or displays to ensure that equipment is functioning normally or that consumables are actually used as planned. The less frequently performed tasks involve periodic replacement or scheduled servicing (i.e., preventive maintenance).

Corrective maintenance tasks are excluded from this analysis. They are reported in MP-01, Mission Analysis. The time allocated for corrective maintenance is 130 min a day and that time requirement is included in this analysis.

A significant effort for the Space Station crew is mission planning and control. These activities are summarized in Table 3-9. They are computed on a daily basis (i.e., an average for each day). Actually, a given crewman might confer with ground personnel once or twice a week, but his average expenditure is estimated as 10 min per day.

Mission planning and control reflects primarily the crew interface with the data management system as well as communications with the ground. The crew must enter data on a daily basis and call up any information it requires. A total daily average of 345 min for mission planning and control resulted from this analysis.

Another step in the analysis was to reevaluate the time allocated for housekeeping and logistics to reflect the onboard processor and compactor to handle trash and the pantry concept for cargo. A total of 145 min was computed for food preparation and issue (one man preparing and issuing food to three or more crewmen), galley and station cleaning and cargo handling.

Table 3-8

SUBSYSTEMS OPERATIONS SCHEDULE
(Duration in Min)

Interval (days)	No. of Events	Structure	GNC	Environment Control	Propulsion	Electrical Power	Subtotals
1	15	30	14	46		10	100
7	15	100	14	30		20	194
10	4			324			324
30	12				49	49	98
60	7				50		50
90	9				25	45	70
180	9			210		95	305
Daily Avg		44	16	88	3	16	167

Table 3-9

CREW OPERATIONS TIME REQUIREMENTS

Functions	Time (Daily Averages in Min)
Mission Planning and Control	
Activity scheduling	20
Status reporting (10 min/crewman)	60
Ground status report	30
Communications (10 min/crewman)	60
Review data transmittion	15
Recording	15
Inventory control	15
Configuration control	10
Staff conference (20 min/crewman)	120 (345)
Housekeeping Logistics	
Food preparation and issue	55
Galley cleaning	45
Station cleaning	15
Logistics removal/storage	30 (145)
Subsystems operations	167
Subsystems maintenance	130
Subtotal	787 (1.3) Man-equivalents
Available for Experiments	2,813 (4.7)
Total	3,600 min
Duty Time Available (6 x 10 hr)	

The subtotal of 167 min for subsystem operation was entered and the updated maintenance estimate of 130 min yielding a grand total of 787 min or the equivalent of about 1. 3 man days. One man day equals 10 hr. The remainder of 3, 600 total duty hours is available for experiments. (i. e., The equivalent of 4. 7 men/day.)

The major result of these analyses was to verify earlier estimate that station operation and housekeeping function would require less than 2 men/ day, on the average, for their accomplishment. The general crew complement is required to accommodate a changing experiment program. Such flexibility will require a broad range of scientific background in order to minimize detailed instructions for the overall training program. As shown in Figure 3-11, one crewman is assigned the responsibility for station operations and maintenance, the Space Station commander. A second crewman, the experiment officer, is primarily responsible for all experiment operations, but is also responsible for experiment interface operations. The four remaining crewmen are assigned to the experiment operations. Principal investigators may be included in the group of four experiment operations personnel. The scientific crew will require a minimum of astronaut training; primarily, Space Shuttle passenger responsibilities, Space Station safety, emergency, and personal duties training (waste management, hygiene, etc.).

The crewman's duty cycle on-orbit will nominally be 90 days. Crew overlap during crew rotation is nominally planned for 12 hours, though this period could probably be reduced if required. The crew will be recruited for continuous support of the program with one on-orbit duty cycle every year. The balance of the year will be spent in mission preparation, proficiency training, debriefings, and as mission operations support personnel on the ground. As mentioned previously, each crewman will be trained in more than one skill to provide backup operational capabilities on-orbit. Table 3-10 presents a crew requirements summary for comparison between the three types of crewmen.

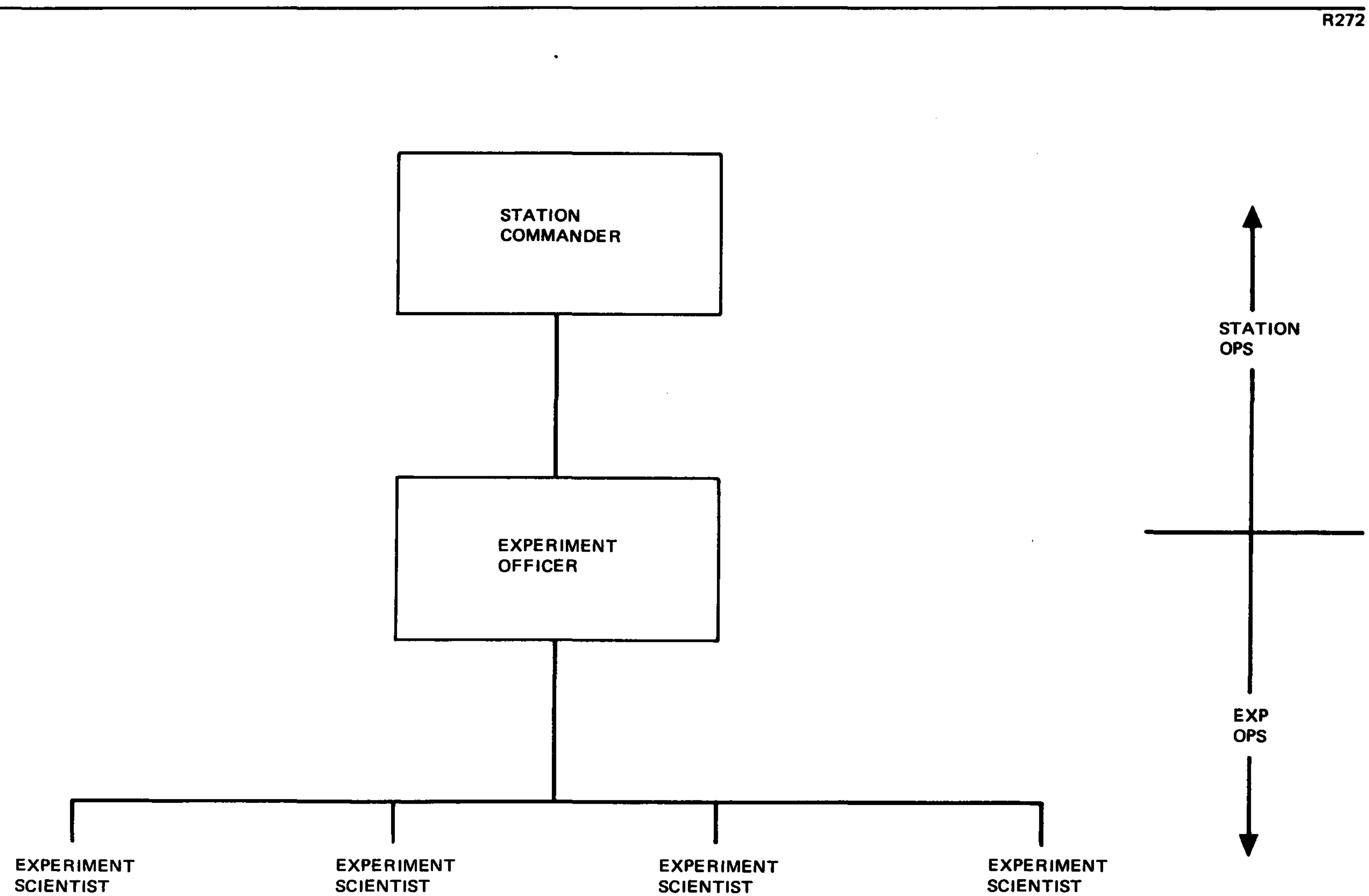


Figure 3-11. ISS Space Station Organization

Table 3-10

CREW OPERATIONS SUMMARY

Astronaut	Experiment/Scientist	Principal Investigator
Continual flights	Several flights	One or two flights
Operation of subsystems	Operations of scientific equipment	Operation of one type of equipment
General training	General training and proficiency training in selected areas	Limited training on Space Station required activities
Duty scheduled on 90-day centers 270 days apart	Duty scheduled on FPE groupings	Duty scheduled with special equipment

3.2.3 Logistics Support

The Shuttle provides the transportation system to deliver and return the crew, RAM's, experiment equipment, and supplies to the Modular Space Station. An analysis of crew rotation requirements, Space Station subsystem resupply cargo, and experiment (RAM's, equipment, samples, data, and resupply) cargo was accomplished to identify the flight requirements for the ISS and GSS operations. The other key factors that were integrated with the cargo requirements to establish the flight schedule were:

A. The shuttle delivery and return payload capability is 20, 000 lb.

B. The maximum shuttle launch frequency is every 30 days.

C. The shuttle can accommodate a maximum of two passengers.

D. Crew rotation cycles are based on a nominal frequency of every 90 days.

E. The maximum cargo payload accommodation of a Logistics Module is 14, 000 lb.

F. The maximum cargo payload capability of a Crew Cargo Module is 11, 000 lb.

G. The Modular Station initial buildup and on-orbit assembly logistics support will include the delivery of off-loaded subsystem equipment and a large inventory of spares over and above the nominal resupply requirements.

H. Resupply cycles are scheduled on nominal 90-day centers.

I. Experiment Case 534 will be used to establish a flight schedule. The results of the analysis impacting the ISS flight schedule include a total cargo weight of 254, 000 lb delivered to the ISS during five years of operation.

A detailed description of station subsystem and experiment cargo requirements including cargo mix of gases, liquids, and solids by weight and volume is presented in SE-06.

Cargo Handling

The on-orbit "pantry concept" developed during the 33-ft station study was reevaluated for the modular station design and operation. The reevaluation concluded that the pantry concept was the best concept and operational mode for on-orbit storage, inventory control, cargo transfer (loading and unloading), and daily utilization by the crew. Tradeoffs emphasized crew time, storage requirements aboard the station, and scheduling of cargo tasks. The pantry concept continues to provide the minimum onboard storage requirements for other station modules, represents the minimum crew time required for cargo transfer, and allows the transfer of cargo on an as-needed basis or noninterference scheduling with experiment operations.

The requirement for 120 days of supplies on orbit after each resupply cycle is satisfied by having 30 days of operating spares, consumables, and expendables onboard the station and 90 days of supplies in the logistics module. With the arrival of the next logistics flight, the returning Logistics Module also returns the supplies not utilized plus cargo from the station. The new Logistics Module delivers 90 days of supplies and the cycle continues with each Logistics Module rotation. Another approach is to off-load the remaining supplies not utilized onto the station rather than return all unused cargo to ground inventory. An analysis of the cargo manifest concludes that almost all of the nonutilized items would be spares for the first 11 quarters of ISS operations. The spares would be added to the inventory and controlled by the combined on-orbit/ground inventory control system. Future flights would then be void of these items. The additional onboard storage for these items would be minimal.

The remaining quarters (11 to 20) of ISS operations require two Logistics Module deliveries for each 90-day phase to satisfy resupply requirements.

Cargo transfer operations will be similar to those developed for the 33-ft station. Selected liquids and gases will be transferred by a transfer system controlled from the Space Station command control console (Figure 3-12) to the subsystem using points (RCS, RAM, GPL, etc) throughout the station. The fluid or gas will be pumped or gas pressure-fed to effect transfer. Each neuter docking port on the Modular Space Station will have the interface connectors and capability to mate to the Logistic Modules for these transfer operations. All cryogenics will be transferred by the crew from the Logistics Module to the GPL or RAM. The study emphasis on low initial cost eliminates all large quantities of cryogenics for controlled transfer by pumping. Current technology has not developed an operational system or technique for cryogenic transfer in zero g. DDT&E costs to develop a system for cryogenic transfer would exceed the study guidelines for low initial cost. The 33-ft station study considered developing a system to pump or transfer cryogenic by a controlled transfer system. Small quantities of special fluids or gases required for experiment operations will be transferred the same as solid cargo.

Solid cargo transfer will primarily be accomplished by the crew, which will hand-control and translate each item on an as-needed basis or periodically according to schedule. The majority of solid cargo items can be safely handled and transferred by the crew from the Logistics Module or Crew Cargo Module to the power, crew, or GPL modules without the aid of a cargo-handling system. However, the characteristics of a few items exceed the

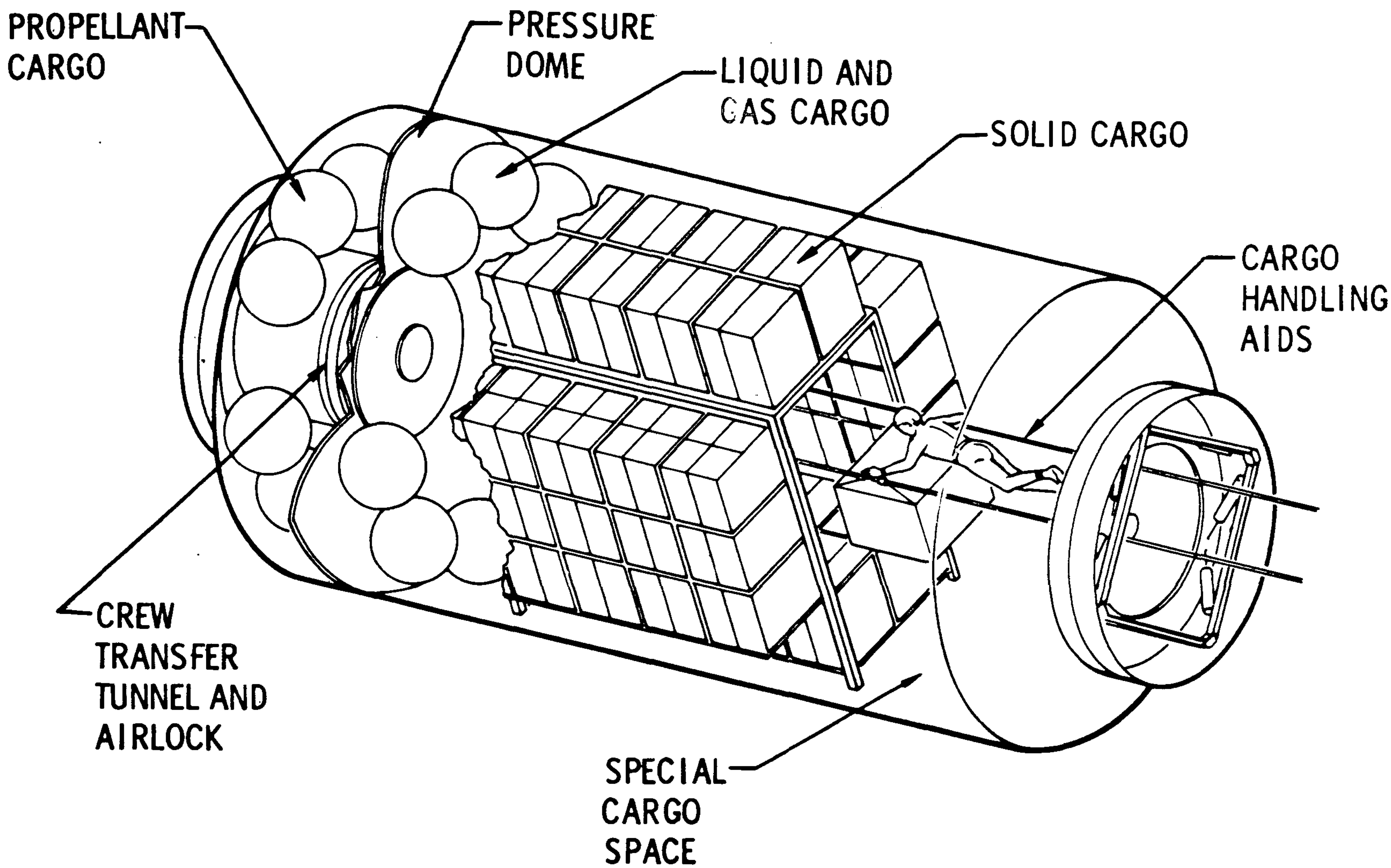


Figure 3-12. Logistics Module

capability of a crewman to safely control and constrain the movement of the item without the assistance of a mechanical aid or cargo handling device. These characteristics include size or shape, moment of inertia, and safety precaution (e.g., transfer of high-pressure gas tanks at 3,000 psig).

Some of the items will be resupplied periodically throughout the ISS operations and will require a transfer from the Logistics Module to a station module. The experiments will also require the periodic delivery and transfer of equipment or resupply of cargo having the characteristics requiring a transfer system to assist the crew. Since the usage rate of the transfer system is periodic rather than routine with each resupply flight, a simple system that can be easily installed and removed for onboard storage is desired rather than a more sophisticated and permanent system throughout the station. A proposed concept for a minimum system is presented in the following paragraphs and would be delivered to the station on the first Logistics Module.

A dual-cable cargo moving system is depicted in Figures 3-13 and 3-14. The system features include the following:

A. Two cables are attached to fixtures located in the aisleways of each station module and Logistics Module. Separate cables are attached on each side of the aisle to provide directional control of the cargo transfer.
B. The cables are anchored at convenient intervals.
C. No fittings are required on the cables.
D. Removable cable trackers are easily and quickly installed by a crew member.
E. A dead-man brake is provided on the tracks.
F. Anchor pins seize continuous cable run.
G. Corners can be conveniently traversed.
H. The system is easily adaptable to cargo container design.
I. No maintenance is required.
J. Minimum storage is required on the station.
K. Minimum crew time for installation or removal.

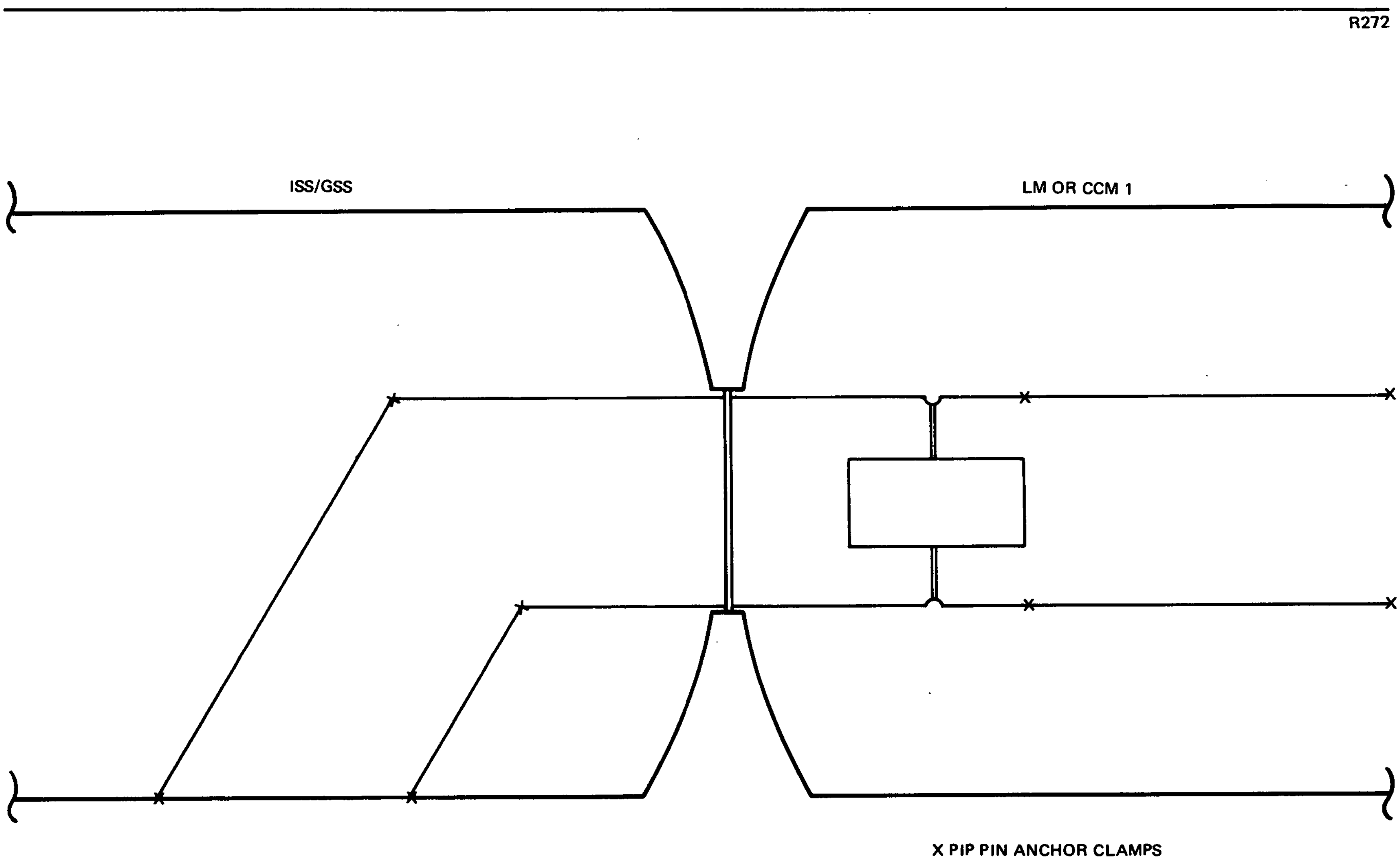


Figure 3-13. Transfer Cable System

R272

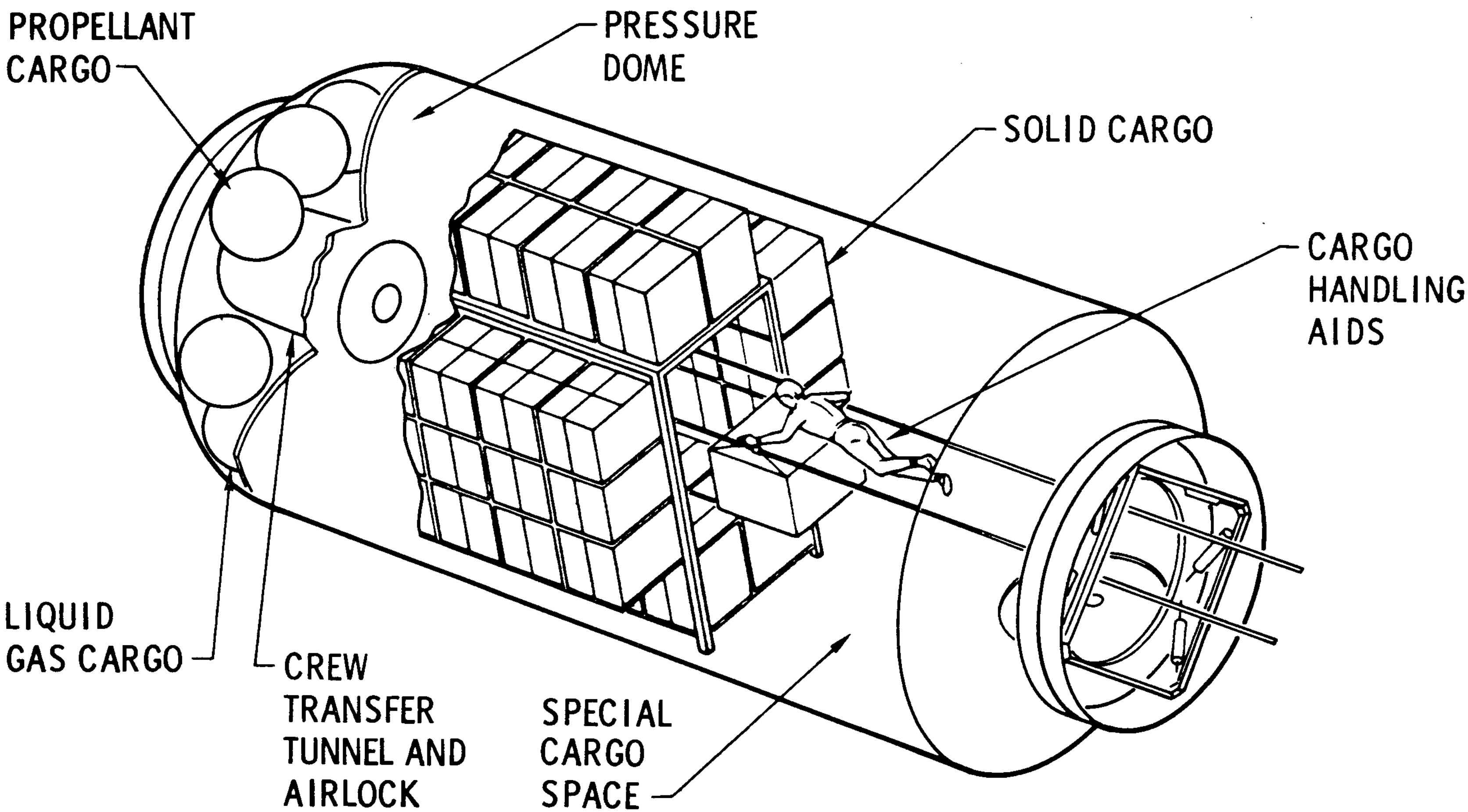


Figure 3-14. Cargo Handling System

Equipment requiring use of the system during ISS activation would include that described in Table 3-11.

Table 3-11
CANDIDATE EQUIPMENT REQUIRING TRANSFER SYSTEM

Item		Quantity	Transfer From Log Module To
CMG's		4	Power/Subsystems Module
Repressurization Gas	O_2	1	Power/Subsystems Module
	GN_2	4	Power/Subsystems Module
Megabolic Gas	O_2	2	Power/Subsystems Module
	O_2	2	Crew/Operations Module
Pumpdown Accumulators		2	Power/Subsystems Module
Water Tanks		2	Crew/Operations Module
Batteries		1 set	Power/Subsystems Module
		2 sets	Crew/Operations Module
		2 sets	GPL
Food (Refrigerators)		2	Crew/Operations Module
(Freezers)		2	
Trash Compactor		1	Crew/Operations Module

To operate the system, the crew would attach the cable runs from the LM to the equipment location aisle zone in the station module where the equipment or item is to be transferred. The crew would then proceed to the storage rack of the LM and attach one cable tracker to the cable. The tracker is clamped and locked on the cable and is normally spring-loaded to the brake position. The crew depresses the trigger mechanism releasing the brake and the tracker is free to slide along the cable. Releasing the trigger automatically engages the tracker brake.

With one tracker installed, the crew would then attach an adjustable cargo constraint cable. One end anchors to the tracker and the other end attaches to the cargo-packaging fitting. The tracker and anchor remove the cargo-holding constraints (bolts, straps, etc), releasing the cargo from its storage rack. The cargo item is pulled into the aisleway to allow installation of the second tracker, and guide cables are then adjusted to the proper tension to constrain the cargo. The crew is now ready to translate the cargo along the cable run.

The crewmen release the tracker brake and the crewmen provide the force to translate the item. The crew performs the reverse procedure to remove and install the item at its destination point. Figure 3-15 further demonstrates the use of the proposed system. The system provides a very simple, easy-to-operate and store, minimum-maintenance system and cost compared to other systems evaluated.

3.3 DUTY CYCLES

The mission ground rules which affect the duty schedules are summarized as follows:

A. The ISS will be operational when fully manned (at least two crewmen), and fully configured, including the GPL and at least two RAM's.

B. The baseline workday is 10 hours, with one day off. The work period will be scheduled within a 12-hour tour of duty for seven days a week.

R272

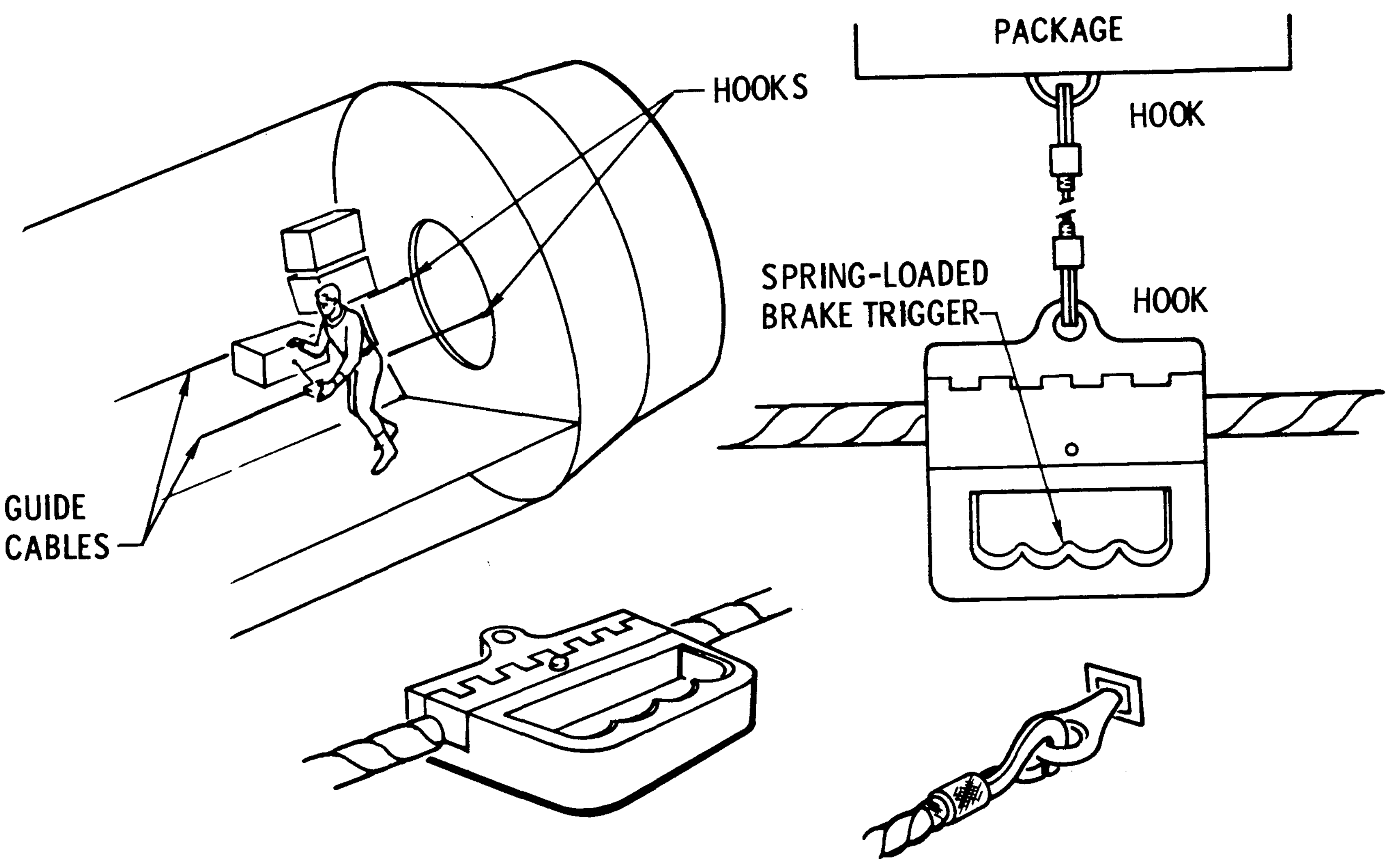


Figure 3-15. Cargo Handling System Components

C. For on-orbit operations, no system or subsystem design will prohibit single or dual-shift operations, even though a dual shift is currently recommended.

D. An on-orbit scheduling technique is used to integrate scheduled subsystem maintenance with experiment operation and maintenance to minimize operational interferences among these activities.

The duty cycle recommended for the ISS is two 12-hour tours or responsibility to provide 24-hour coverage of all operations and still permit considerable choice in the scheduling of activities. Scheduled duty time will actually consist of no more than 10 hours within the 12-hour tour of responsibility. During the remaining two hours, the crewmen is available if required; that is, he is not asleep or otherwise not readily available. With this arrangement, only four meal periods are actually required, two of which could be scheduled to bring both shifts together.

Figure 3-16 depicts a generalized duty cycle for three crewmen who share a 12-hour tour of duty. It illustrates how three crewmen can be available concurrently for those tasks requiring three men and retain the appropriate breaks for hygiene, waste, eating, and off-duty time. Actually, the total shift is extended to 15.5 hours, which would provide a desirable overlap of shift operations. It also indicates how individual variation in duty cycling is attained without comprising any constraints.

Tables 3-12 through 3-15 shows the time requirements and scheduling of activities for the four crewmen whose primary responsibility is station operation and maintenance. Crewmen No. 1 and 2 are responsible for first shift operation and crewmen No. 3 and 4 for second shift operations.

The crewmen can schedule the order of performing tasks to suit the needs of the day or their own personal needs without jeopardizing the operation and maintenance of the station.

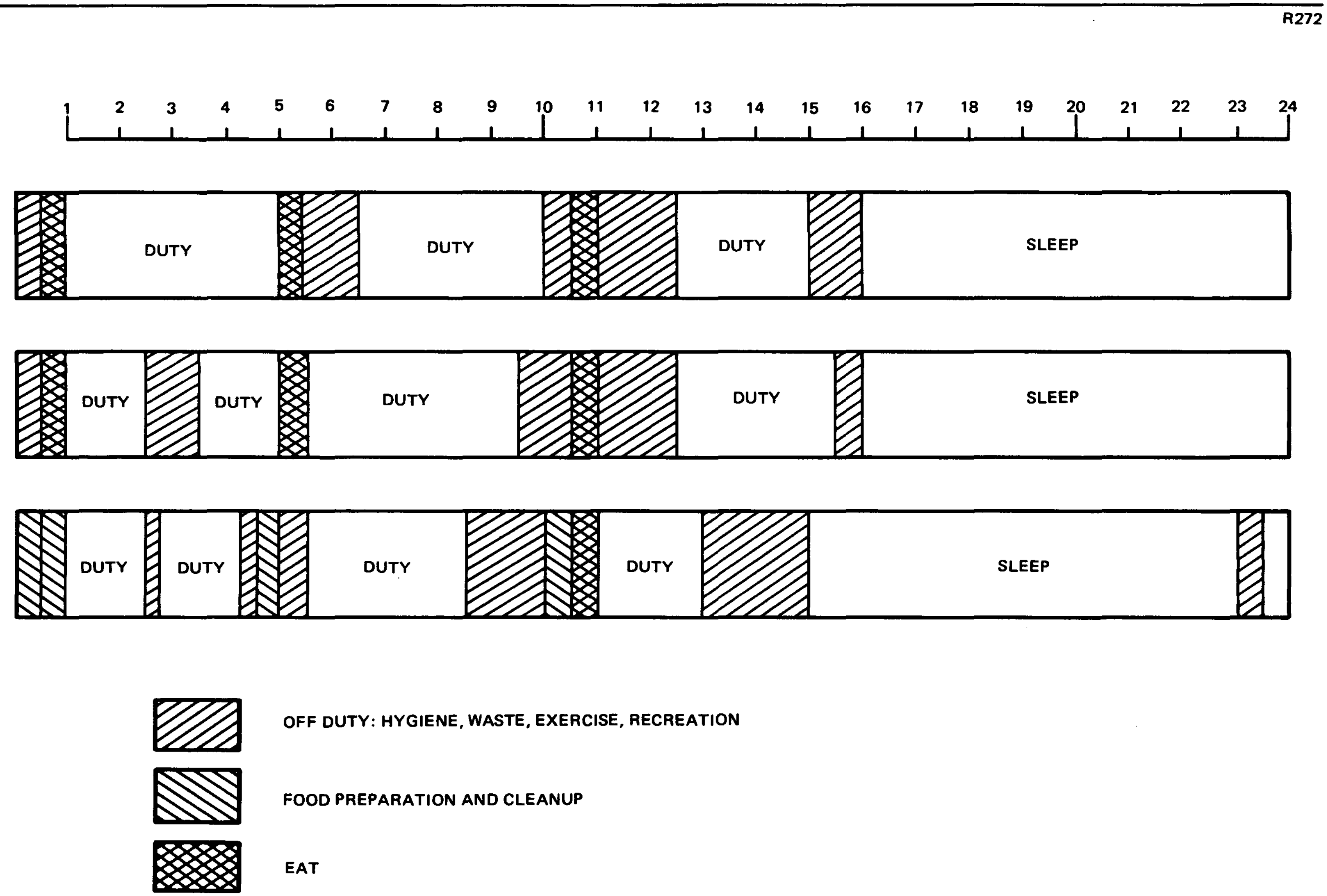


Figure 3-16. Generalized Duty Cycle for 3 Crewmen

Table 3-12

ACTIVITY TIME REQUIREMENTS AND SCHEDULING - CREWMAN NO. 1

Activity	Hygiene and Waste (min)	Eat (min)	Off Duty (min)	Duty (min)	Food Preparation (min)	Sleep (min)	Total (min)	Daily Schedule (hr)
Food Preparation					30		30	0730
Eat		30					30	0800
Duty				195			195	1115
Hygiene and Waste	15						15	1130
Food Preparation					30		30	1200
Eat		30					30	1230
Duty				165			165	1435
Off Duty			90				90	1605
Hygiene and Waste	15						15	1620
Food Preparation					30		30	1650
Eat		30					30	1720
Duty				120			120	1840
Off Duty			90				90	2010
Hygiene and Waste	30						30	2040
Sleep						480	480	0600
Hygiene and Waste	30						30	0630
Duty				30			30	0700
Totals	90	90	180	510+	90	480	1440	

Table 3-13

ACTIVITY TIME REQUIREMENTS AND SCHEDULING - CREWMAN NO. 2

Activity	Hygiene and Waste (min)	Eat (min)	Off Duty (min)	Duty (min)	Sleep (min)	Totals (min)	Daily Schedule (hr)
Hygiene and Waste	30					30	0730
Eat		30				30	0800
Duty				90		90	0930
Off Duty			45			45	1015
Duty				90		90	1145
Hygiene and Waste	15					15	1200
Eat		30				30	1230
Duty				240		240	1630
Off Duty			45			45	1715
Hygiene and Waste	15					15	1730
Eat		30				30	1800
Off Duty			90			90	1930
Hygiene and Waste	30					30	2300
Sleep					480	480	0700
Totals	90	90	180	600	480	1400	

Table 3-14

ACTIVITY TIME REQUIREMENTS AND SCHEDULING - CREWMAN NO. 3

Activity	Hygiene and Waste (min)	Eat (min)	Off Duty (min)	Duty (min)	Food Preparation (min)	Sleep (min)	Total (min)	Daily Schedule (hr)
Duty				90			90	0830
Hygiene and Waste	30						30	0900
Sleep						480	480	1700
Hygiene and Waste	30						30	1730
Eat		30					30	1800
Duty				90			90	1930
Off Duty			45				45	2015
Duty				60			60	2115
Hygiene and Waste	15						15	2130
Food Preparation					30		30	2200
Eat		30					30	2230
Duty				210			210	0200
Off Duty			45				45	0245
Hygiene	15						15	0300
Food Preparation					30		30	0330
Eat		30					30	0400
Off Duty			90				90	0530
Duty				90			90	0700
Totals	90	90	180	540	60	480	1440	

Table 3-15

ACTIVITY TIME REQUIREMENTS AND SCHEDULING - CREWMAN NO. 4

Activity	Hygiene and Waste (min)	Eat (min)	Off Duty (min)	Duty (min)	Sleep (min)	Total (min)	Daily Schedule (hr)
Duty				90		90	0830
Hygiene and Waste	30					30	0900
Sleep					480	480	1700
Hygiene and Waste	30					30	1730
Eat		30				30	1800
Duty				90		90	1930
Off Duty			45			45	2015
Duty				90		90	2145
Hygiene and Waste	15					15	2200
Eat		30				30	2230
Duty				240		240	0230
Off Duty			45			45	0315
Hygiene and Waste	15					15	0330
Eat		30				30	0400
Off Duty			90			90	0530
Duty				90		90	0700
Totals	90	90	180	600	480	1440	

3.4 SAFETY

Two general requirements in the Program Specification Document (CM-01) guided the safety design effort. They are:

3.1.3.4 The Space Station will rely on the Shuttle for emergency removal of the crew with 48 hours of alert notification.

3.2.6.1.2 Safety is a mandatory consideration through the total program. As a goal, no single malfunction or credible combination of malfunctions and/or accidents shall result in serious injury to personnel or to crew abandonment of the Space Station.

As the study progresses, more detailed specifications were developed. Many of these significantly affect crew operations; therefore, they are outlined below with a summary of the design (procedural or equipment) implementation.

3.2.1.1.2.2 Meteoroid protection shall be provided by the MSS design when exposed to the meteoroid flux given in TMX-53865, Second Edition, August 1970.

3.2.3.5 The probability of no loss of pressure in a habitable module shall be 0.9 or greater during the initial 10 years of Space Station operation.

3.7.1.3.5.2 Provisions shall be made for detecting, locating, and repairing meteoroid damage.

The following meteoroid protection features are provided: meteoroid bumper, total pressure monitor, leak sensors, caution and warning, repair kit, and compartment evacuation precedence (as discussed earlier). These features are discussed in detail in SE-03, Detailed Preliminary Design.

3.2.1.1.1.4 Onboard systems shall be provided for checkout, monitoring, warning, and fault isolation to a level consistent with safety and with the in-orbit maintenance and repair of failures or damage shall also be provided. As a goal, the overall station operations shall not be substantially degraded by selected repair modes.

3.2.1.1.23 Space Station systems which incorporate failure-related automatic switch-over controls shall be designed to provide crew notification of the switch-over and conform proper operation of the system on-line. For critical failures the crew shall be automatically notified of conditions requiring crew attention.

Onboard systems are provided with automatic checkout and warning for critical parameters. This capability includes automatic visual and oral notification, automatic initiation of fault isolation, independent redundant sensors, dedicated display, separate power, full backup capability from alternate location, and display in each habitable compartment.

Warning parameters include O_2 storage, N_2 storage, dump and relief valve, contamination monitor, coolant H_2O circulation, radiator control, radiator recirculation, propellant, compartment pressure, partial O_2, and fire.

3.2.6.2.1 The Space Station shall be divided into at least two pressurized habitable volumes so that any damaged module can be isolated as required. Accessible modules will be equipped and provisioned so that the crew can safely continue a degraded mission and take corrective action to either repair or replace the damaged module.

Long term refuge is provided in either the GPL or the Crew/Operations Modules. Each is equipped with an independent EC/LS system, command-control capability, docking port for logistics, fault detection/isolation, and food, water, and supplies.

3.2.6.2.2 Sensors shall be installed to provide fire warnings in sensitive or danger areas. Fire suppressant techniques such as fire extinguishers or automatic isolation and decompression of module compartments shall be provided.

Every known precaution will be taken to reduce fire hazards since there is no detection, extinguishing and suppressant system to avoid all crew risk. Sources of ignition will be minimized and use of flammable material will be reduced to the least quantity possible. Egress hatches between modules will provide the crew with immediate egress to a safe compartment. Hard covers will be preinstalled on wires and wire supports. The electrical system will incorporate other safety features such as bonding and circuit protection.

These design features will be augmented with emergency lighting, caution and warning, etc. The OCS will continually monitor critical operations and alert the crew when a safety problem arises.

3.2.6.2.6 Pressure hatch design shall provide a means of visual verification that proper closure has been accomplished.

3.7.1.3.9.2 A minimum of two airlocks, each having a two-man capability, shall be provided.

Three EVA airlocks will normally be available to the crew. Planned EVA is through the GPL airlock. Alternates are located in the Log M and power module as indicated in Figure 3-17. Other design features are: (1) hatches are operable by one man, (2) hatches are operable from either side, (3) positive closure indication, (4) windows in each hatch, and (5) pressure-equalizing valve in hatch.

3.2.6.3.2 Personnel escape routes shall be provided in all hazardous situations. A design goal shall be to provide alternate escape routes that do not terminate into a common module area.

Refuge/retreat precedence is outlined in Table 3-16.

Escape routes which are mutually exclusive from all hazardous areas and from all habitable volumes are as follows:

Crew/Operations Module:	4 routes
GPL:	2 routes
Power/Subsystem Module:	4 routes
Log Module:	2 routes
RAM's:	2 routes

These routes are shown schematically in Figure 3-18.

3.3.2.2.7 All materials selected for use in habitability areas shall be nontoxic, nonflammable, and nonexplosive to the maximum extent possible.

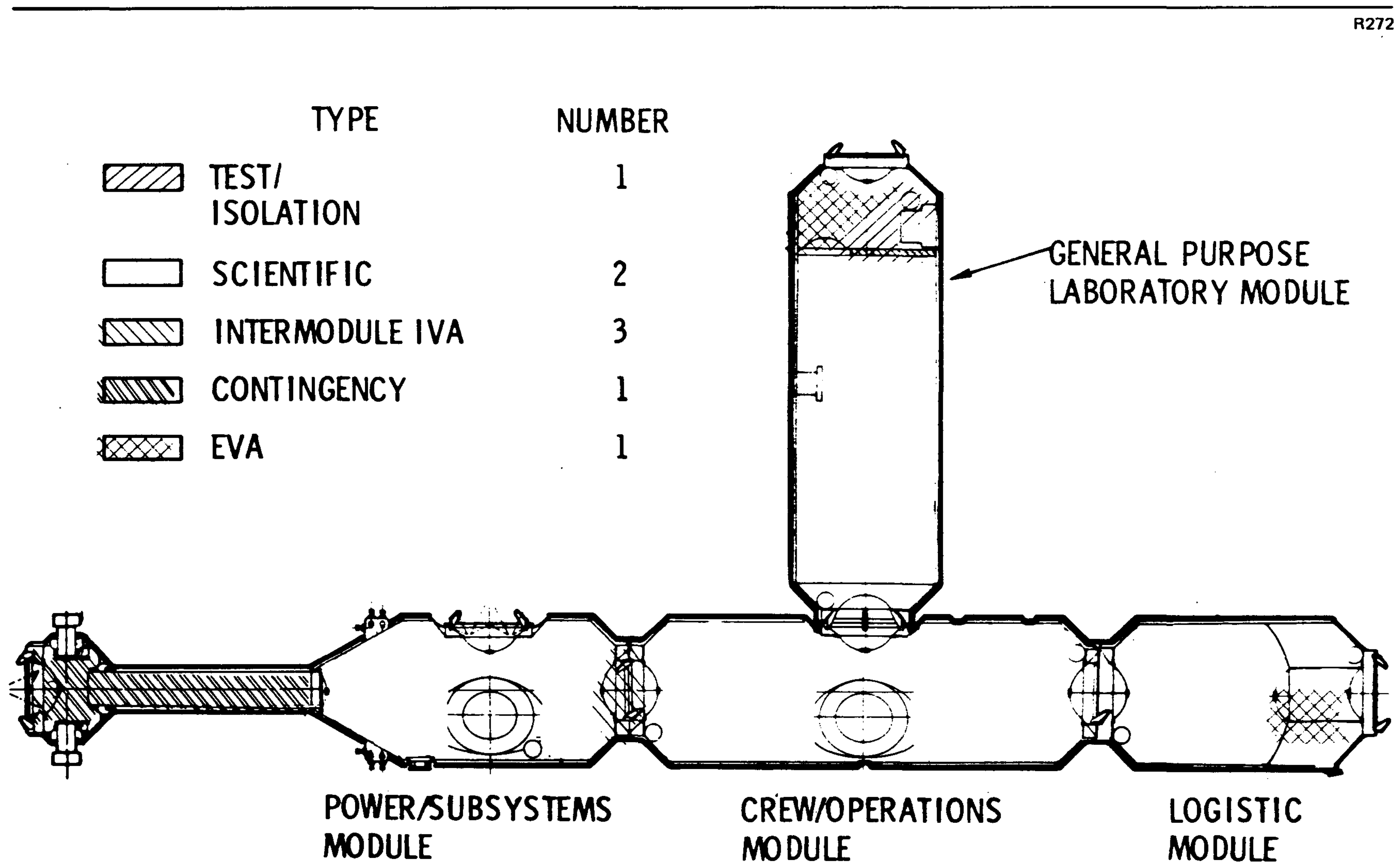


Figure 3-17. Integrated SS Airlock Summary

Table 3-16

REFUGE/RETREAT PRECEDENCE

1ST ORDER - TO CREW/OPERATIONS MODULE OR GPL

- EACH FULLY EQUIPPED TO OPERATE WITH LITTLE IF ANY DEGRADATION
- NO SPECIAL SHUTTLE FLIGHT LIKELY

2ND ORDER - TO POWER MODULE OR LOGISTICS MODULE

- 96-HOUR LIFE SUPPORT
- AIRLOCK AVAILABLE
- SHUTTLE FLIGHT PROBABLY REQUIRED

3RD ORDER - TO ATTACHED RAM'S

- 96-HOUR LIFE SUPPORT
- REQUIRES EVA TRANSFER OR SHUTTLE RESCUE

A summary of design requirements developed to meet the above specification follows:

A. Water only in EC/LS inside loops.
B. No cryogens in habitable areas.
C. No hydrogen onboard.
D. Hydrazine stored outside pressurized areas.
E. Contamination detection and control system.
F. Isolation chamber.
G. Backup redundancy.

3.7.1.3.1.1 The EC/LS system will provide a shirtsleeve environment within the habitable areas during the buildup, activation, and module replacement period. In addition to meeting the above specification, a requirement was established that no compromise of safety during buildup and activation would be permitted. To meet this general requirement, the following features were incorporated in the system design.

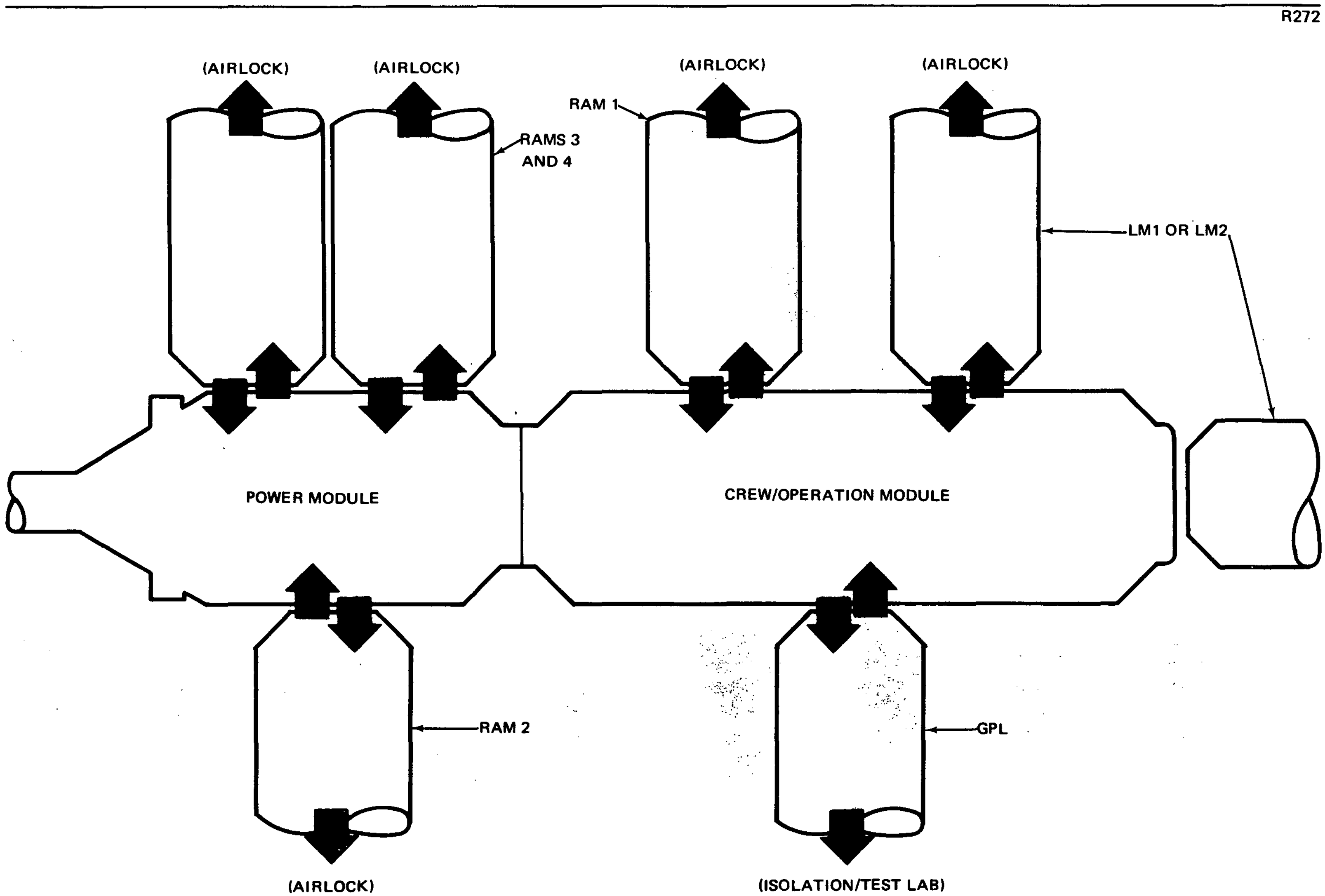


Figure 3-18. Crew Escape Routes

A. No EVA required.
B. Minimum activation crew.
C. Initial entry in pressure suits.
D. Verification of life-critical functions prior to entry.
E. No manning until all life-critical functions are fully operational.
F. Orbiter attached while buildup crew in SS module.
G. Caution and warning system active.
H. Remote activation of pressure lines.

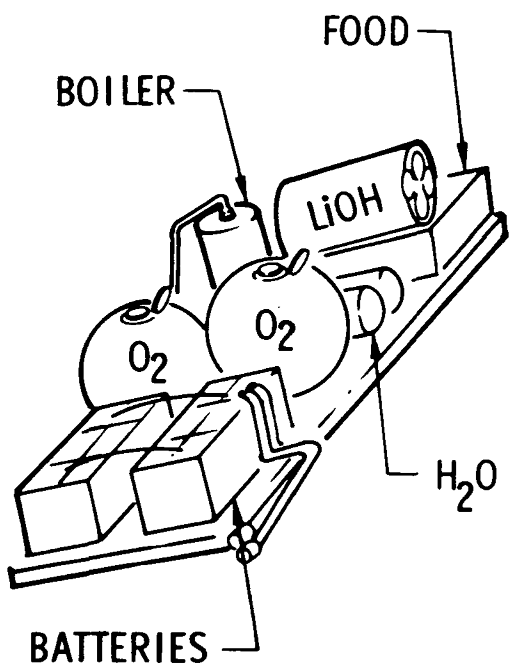
Another safety requirement was to locate pressure vessels and explosives away from crew areas, preferrably in unpressurized areas. The following design implementation resulted: propellants stored in unpressurized areas of Power/Subsystems Modules and Logistics Module, GO_2 located in Logistics and Power/Subsystems Modules cryogens for experiments located in test and isolation chamber (GPL), and no volatile fluids in habitable areas.

3.7.1.4.3 Provisions and habitable facilities shall be adequate to sustain the entire crew for a minimum of 96 hours during an emergency situation requiring Shuttle rescue.

In addition to the primary and backup EC/LS systems, a third level of emergency backup is provided in the form of 3-man pallets, as shown in Figure 3-19.

The basic two-man pallet may be located in any module wherein crew members could become isolated and would provide sufficient supplies for a maximum of four days. The O_2 supply supplements the normal O_2 stored in multitank reservoirs and would only be used if the crew members were isolated from the normal supply because of a catastrophic occurrence. The food, batteries, and temperature control equipment provide for a similar situation. The water and LiOH (used for CO_2 removal) would be used under similar circumstances and could also be used if the primary water recovery unit or CO_2 recovery unit fails. Under these latter circumstances, the crew could continue normal operations throughout the Space Station while repairs were being accomplished. It is unlikely that this mode would be needed because most repairs could be made before CO_2 levels or water quantity become critical.

R272



3-MAN PALLET

PROVISION	REQUIREMENT	WEIGHT (LB)
OXYGEN	METABOLIC O_2	52
WATER	CREW INTAKE + COOLING	142
FOOD	2700 KCAL DIET	30
LiOH	MAINTAIN 7.6 mmHg PCO_2	42
BATTERIES	960 WATT-HR	50
WATER BOILER	1600 BTU/HR COOLING	7
MISC. SUPPLIES		5
PALLET/PACKAGING		25
	TOTAL	353

Figure 3-19. 96-Hour Emergency Provisions

The pallets are distributed as follows:

GPL:	2
Power Subsystems Module	1
Crew/Operations Module	0
Logistics Module	1
RAM	1

Although no detailed specifications exist for space suits, the following requirements were established to ensure maximum crew safety during IVA/EVA:

A. Suit for each crewman plus two spares.

B. Four EVA/IVA suits.

2 individually fitted suits in Logistics Module.

2 backup suits in GPL.

C. Four grossly fitted suits for research personnel.

2 in Power/Subsystems Module.

2 in Crew/Operations Module.

D. Umbilical connectors located in every pressurizable compartment.

Safety requirements for module interfaces were as follows:

A. Hydrazine connectors and lines vented overboard.

B. Electrical lines separated from flammable fluids.

C. Hydrazine lines separated from oxidizer line.

D. Shutoff controls on both sides of interfaces.

E. Redundant lines separated.

F. Fluid lines purged overboard prior to mating and disconnecting.

G. Shirtsleeve access.

3.2.6.4.2 The allowable radiation limits for the crew are:

Organ	1 yr avg daily	30 day	Qtrly*	Yearly	Career
Skin (0.1 mm)	0.6	75	105	225	1200
Eye (3.0 mm)	0.3	37	52	112	600
Marrow (5.0 cm)	0.2	25	35	75	400

The radiation protection assembly provides the crew with protection against adverse radiation exposure. The solar-flare environment and the trapped-proton environment are expected to contribute the majority of the dose. The critical allowable dose is the dose on the BFO (blood-forming organs). The maximum allowable dose is 35 rem over a 90-day period.

The primary protective measure is spacecraft shielding along with onboard equipment. Our analysis shows that when a man-model is combined with a Space Station model, the resultant dose is 9.4 rem to the BFO over a 90-day period.

The radiation protection assembly requirements are primarily for monitoring and measuring the extent and kind of radiation exposure to ensure crew safety and for further analytic investigations. The equipment shall include onboard and extravehicular dosimetry which will be linked to the caution and warning systems as required.

Additional details regarding long-life assurance and safety are presented in Section 7, MP-01, MSS Mission Analysis.

*May be allowed for two consecutive quarters with six months restriction from further exposure to maintain yearly limit.

APPENDIX A

EXPERIMENT CREW OPERATIONS

Prepared by

MARTIN MARIETTA CORPORATION

Denver Division

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

PRECEDING PAGE BLANK NOT FILMED

Section 1
EXPERIMENT CREW TIMELINES

This document presents the flight crew requirements for both experiments and experiment modules for the Modular Space Station. The crew skills and time requirements are defined for each Functional Program Element, experiment subgroup, and experiment module. Crew mission requirements are included which provide compatible skill mixes and cross-training implications.

Crew size requirements for specific experiment programs are not included in this task, but can be compiled using this basic data with the WICK resources allocation computer program.

The crew operations for the experiments and modules are categorized under three major activity headings - SETUP, OPERATE, and SHUTDOWN. The activities included under each heading are as follows:

Function	Typical Activities
SETUP	
Initial Setup/Activation	Remove Launch locks, prep for operation, align, calibrate
Periodic Setup	Align, calibrate, check out, deploy
Service	Install film, supply consumables
OPERATE	
Initiate Operation	Turn on, start data taking, initial monitor, deploy
Monitor/Control	Observe operation of system/experiment during data taking operation, control equipment operation
SHUTDOWN	
Shutdown	Turn off, retract, de-activate, terminate, package, stow
Service	Resupply film and other consumables

Function	Typical Activities
Reconfigure	Exchange equipment, change settings
Process data	Develop film, reduce data
Evaluate data	Quality check, evaluate performance
Maintenance	
Scheduled	Inspection, replace time sensitive equipment, clean
Unscheduled	Remove and replace/repair failed hardware

The crew skills, referred to by number codes in various parts of this report, are listed in Table 1, Crew Skills.

Table 1

CREW SKILLS

1.	Biological Technician	15.	Optical Scientist
2.	Microbiological Technician	16.	Meteorologist
3.	Biochemist	17.	Microwave Specialist
4.	Physiologist	18.	Oceanographer
5.	Astronomer/Astrophysicist	19.	Physical Geologist
6.	Physicist	20.	Photo Geologist
7.	Nuclear Physicist	21.	Behavioral Scientist
8.	Photo Technician/Cartographer	22.	Chemical Technician
9.	Thermodynamicist	23.	Metallurgist
10.	Electronic Engineer	24.	Material Scientist
11.	Mechanical Engineer	25.	Physical Chemist
12.	Electromechanical Technician	26.	Agronomist
13.	Medical Doctor	27.	Geographer
14.	Optical Technician	28.	Hydrologist

Table 1

CREW SKILLS (Continued)

29.	Pilot/Navigator	31.	Electromechanical Engineer
30.	EVA Backup/Subject (any skill)	32.	Life Science Technician

PRECEDING PAGE BLANK NOT FILMED

Section 2.0
CREW REQUIREMENTS - EXPERIMENTS

The crew skill and time requirements for the experiments are based on the January 1971 Blue Book, the Experiment Requirements Summary, Rev. 1 (Greenbook), and subsequent analysis. The crew requirements for each subgroup and FPE are presented in Appendix A and supercede the Greenbook where conflicts exist.

For ease in reference, the crew timelines (Appendix A) have been added to the Operational Sequences submitted as part of task 2.2.1-b. The time requirements are totaled for each skill and are listed in average manhours per day. A summary of the experiment skill and time requirements is shown in Table 2.

2.1 GROUND RULES AND ASSUMPTIONS

a) All crew times for the subgroups were estimated considering only the requirements of that subgroup. The mode of accommodation and the impact of concurrent operation with other subgroups or experiments have not been considered.

b) All EVA times include three hours prep and post EVA activities.

c) At the FPE level, crew times have taken commonality of activities into consideration where several experiments within the FPE could be conducted and monitored concurrently. Where sequential operations are required, the total FPE crew times are the sum of the subgroup requirements.

d) EVA is always performed with two men. The second man is identified as "EVA Backup" when specific skill is not required.

Table 2

EXPERIMENT SKILL AND TIME REQUIREMENTS

FPR/ SUBGROUP (Crew Time Requirements)	Average Manhours Per Day Per Skill* 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
A-1 X-Ray Astronomy					3.0																										
A-2 Advance Stellar Astronomy					4.8																										
A-2A 2-Meter Telescope					4.8																										
A-3 Advanced Solar Astronomy					20.3 (Flare Day) 10.4 (Non-Flare Day)																										
A-3A 1.5M Photoheliograph, XUV Spectrometer, X-ray Grazing Telescope					10.1 (Non-Flare Day) 19.7 (Flare Day)																										
A-3B Solar Coronagraph					0.4 (Non-Flare Day) 0.6 (Flare Day)																										
A-3C Photoheliograph					4.1																										
A-3D X-ray Spectroheliograph					4.1	If operated concurrently - skill 5, 10.2 hr/day (average)																									
A-3E XUV Spectrometer					4.1																										
A-4 Intermediate Size UV Telescopes					7.1																										
A-4A 0.94M Narrow Field					4.0																										
A-4B 0.3M Wide Field					7.9																										
A-4C Small UV Survey					2.8																										
A-5 High Energy Stellar Astronomy					1.9																										
A-5A Lower Energy Experiment					1.5																										
A-5B Higher Energy Experiment					1.5																										
A-6 Infrared Astronomy					8.3																										
P-1 Space Physics Research Lab						2.8						2.9																		0.25	
P-1A Atmospheric and Magnetospheric Science						0.5						1.0																		0.1	
P-1B Cometary Physics						0.04						0.04																			
P-1C Meteoroid Science (exclusive of TMP)						0.5						0.15																		0.15	
P-1D Thick Material Meteoroid Penetration						0.1																									
P-1E Small Astronomy Telescope						1.9						1.9																			
P-2 Plasma Physics and Environmental Perturbations Lab						3.6						3.6																	1.3		
P-2A Wake Measurements from Station and Booms						0.7						0.7																			
P-2B Wake Measurements from Subsatellite						0.7						0.7																	0.5		

*For Corresponding Skill Titles, See Table 1

Table 2

EXPERIMENT SKILL AND TIME REQUIREMENTS (Continued)

FPE/ Subgroup (Crew Time Requirements)	Average Manhours Per Day Per Skill*																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
P-2C Plasma Resources						0.7						0.7																			
P-2D Wave Particle Interactions						0.9						0.9																	0.8		
P-2E Electron and Ion Beam Interaction						0.7						0.7																			
P-3 Cosmic Ray Physics Lab						3.2						1.3																		Min	
P-3A Lab Without TAD						3.2						1.3																		Min	
P-3B Lab with 1/2 TAD						3.2						1.3																		Min	
P-3C Plastic/Nuclear Emulsions (only)												Min																			
P-4 Physics and Chemistry Lab						2.4			0.6			8.5													1.7						
P-4A Airlock and Boom Experiments						1.4						2.6													0.2						
P-4B Flame Chemistry and Laser						0.4			1.1			6.6													3.1						
P-4C Test Chamber Experiments						2.2			0.2			6.4																			
ES-1 Earth Observation Facility								1.5		0.6		1.4		0.9		0.7		0.8	1.6	0.9						1.9	0.6	0.6			
ES-1A Meteorology and Atmospheric Science										0.6		0.25		0.75		0.5		0.6													
ES-1B Land Use								0.9				0.9		Min					0.7							0.2	0.8				
ES-1C Pollution								Min				0.3		0.3		0.1		0.1										0.1			
ES-1D Resource Recognition								0.1				0.3		0.2					0.2	0.1						0.2					
ES-1E Disasters								0.4				0.2		Min		Min			0.3	0.2						0.3		0.3			
ES-1F Ocean Resources												0.3		0.3		0.5		0.5													
ES-1G Minimum Payload								0.7				1.8		1.3		0.4		0.3	1.0									1.0			
C/N-1 Communication/Navigation Research facility										8.2		2.0		3.2			5.3														
C/N-1A Experiments 1-7										3.2		0.4		1.2			1.7														
CN/1B Experiments 1-7, 12, 13										3.8		0.8		1.2			2.8														
MS-1 Materials Science and Manufacturing	0.5		0.1			0.1				0.1		2.6		0.1									1.9	1.5							
MS-1 III A	0.5		0.1			0.1				0.3		0.8											0.5	0.6							
MS-1 III B										0.2		0.6											0.4	0.3							
MS-1 III C										0.2		0.8											0.6	0.3							
MS-1 III D										0.1		0.3		0.1									0.1	0.2							
MS-1 III E										0.1		0.2											0.4	Min							
T-1 Contamination Measurements						1.8						1.0																		0.5	
T-1A Experimental						1.3						0.8																		0.3	
T-1B Monitor						0.5						0.3																		0.3	

*For Corresponding Skill Titles, See Table 1

Table 2

EXPERIMENT SKILL AND TIME REQUIREMENTS (Continued)

FPE/ Subgroup (Crew Time Requirements)	Average Manhours Per Day Per Skill*																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
T-2 Fluid Management									2.7			2.3																			
T-2A Long-Term Storage of Cryogenics									2.0			0.1																			
T-2B Short-Term Cryogenics									4.8			1.3																			
T-2C Slush Propellant									2.3			0.4																			
T-2D Non-Cryogenics (1)									1.9			3.2								Operate for 30 Days Only											
T-2E Non-Cryogenics (2)									Min			12.8	(2 Men, 6.4 Hr/Day, Average)																		
T-3 Extravehicular Activity												13.2	(3 Men, 4.1 Hr/Day, Average)																		
T-3A Astronaut Maneuvering Unit												6.9	(3 Men, 2.3 Hr/Day, Average)																		
T-3B Maneuverable Work Platform												6.3	(3 Men, 2.1 Hr/Day, Average)																		
T-4 Advanced Spacecraft		0.5							0.2	0.9	2.5	3.7											Min								
T-4A Long-Duration									0.2			1.5											0.1								
T-4B Medium-Duration		0.8									1.7	12.0	(2 E/M Techs)																		
T-4C Short-Duration										2.0	1.0	7.6	(2 E/M Techs)																		
T-5 Teleoperation										2.0	1.4	7.1																			
T-5A Initial Flight Experiment										0.1	0.1	0.3																			
T-5B Functional Manipulation										1.7	1.2	6.6																			
T-5C Ground Control										0.2	0.1	0.2																			
LS-ST/A Minimal Medical Research Facility																								(3 Subjects, 2.4 Hr/Day, Ave)						7.2	
LS-ST/B Life Science (LS) Facility													10.0													Skill 32 - 5.0 Hr				2.0	
LS-ST/C Interim L.S. Facility													10.0													Skill 32 - 5.0 Hr				2.0	
LS-ST/D Dedicated L.S. Facility													10.0													Skill 32 - 20.0 Hr				2.0	

*For Corresponding Skill Titles, See Table 1

Section 3.0

CREW REQUIREMENTS - EXPERIMENT MODULES

The crew requirements for the experiment modules were derived for each different type module. A summary of the module requirements is provided in Table 3, Module Crew Requirements.

3.1 GROUND RULES AND ASSUMPTIONS

a) All pressurizable portions of the modules are pressurized prior to launch and will only require "top off" in orbit.

b) All free flying modules will dock to the Station for service/maintenance once per 60 days.

c) EVA for maintenance is based on the failure rates and repair times for the components external to the pressure shell. The free flying module used as a basis for EVA estimates includes a pressurizable subsystems chamber and sensor chamber and requires 14.0 hours EVA each for two men every 90 days. Assuming that approximately one-third of the equipment requiring maintenance is located in the subsystems chamber, one-third in the sensor chamber, and one-third in the experiment chamber, the EVA time is adjusted directly with the volume of pressurizable area. The maintenance time for each type module and the EVA portion is shown below. All EVA times include three hours prep and post EVA activities.

Configuration	Maintenance Time (Hours/Man)	EVA Time (Hours/Man)
Subsystem and Sensor Chambers Pressurizable	26	14
Subsystem Chamber Pressurizable	39	27
No Pressurization	53	53
Fully Pressurizable	26	7

Table 3
MODULE CREW REQUIREMENTS

Crew Skill / Experiment Module	Pilot/ Navigator	Electromechanical Engineer	Electromechanical Technician	Total Crew Time	Remarks
		Manhours Per 90 Days			
FF1-A1	9	64 (27 EVA)	60 (27 EVA)	133 (54 EVA)	NOTE (1) All crew times are for subsequent 90 day periods; i.e. "One Time" tasks are not included.
FF2-A2	9	77 (53 EVA)	65 (53 EVA)	151 (106 EVA)	
FF3-A2A	9	52 (14 EVA)	51 (14 EVA)	112 (28 EVA)	NOTE (2) Major variables affecting module crew times are EVA requirements and volume pressurizable.
FF4-A3 (Includes A3A, A3B)	9	64 (27 EVA)	60 (27 EVA)	133 (54 EVA)	
FF5-A3C, A3D, A3E	9	64 (27 EVA)	60 (27 EVA)	133 (54 EVA)	
FF6-A5A	9	52 (7 EVA)	51 (7 EVA)	112 (14 EVA)	
FF7-T2A	9	51 (7 EVA)	48 (7 EVA)	108 (14 EVA)	
FF8-T2B, T2C, T2D, T2E	9	51 (7 EVA)	48 (7 EVA)	108 (14 EVA)	
AM1 Thru AM12	-	54 (20 EVA)	64 (20 EVA)	118 (40 EVA)	
DM1-P3, P3A, P3B	-	48 (20 EVA)	48 (20 EVA)	96 (40 EVA)	
DM2-ES1	-	54 (20 EVA)	64 (20 EVA)	118 (40 EVA)	

d) Crew time for pumpdown or pressurization is assumed as 1 manhour regardless of volume.

e) An automatically mated pressurization umbilical connector between the station and all modules is assumed. All other connectors are assumed manual.

f) Maintenance times are higher for the attached modules than for the free flyers since the redundant systems on the free flyers will not be repaired under the existing maintenance policy.

Section 4

CREW MISSION REQUIREMENTS

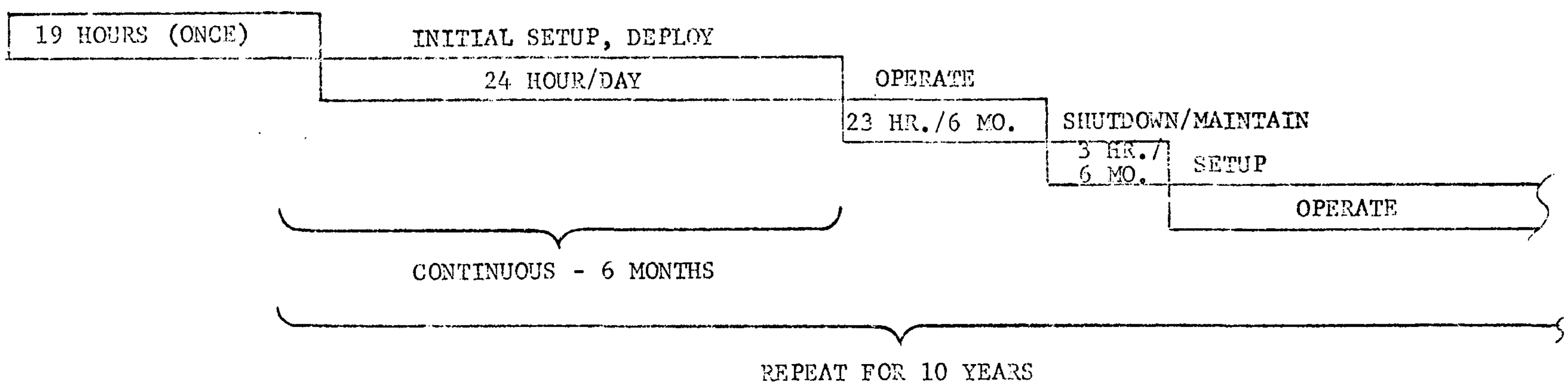
Determination of crew size and skill mix are directly dependent on the experiment program which is flown and is therefore not a part of this report. The 32 skills identified on Table 1 must be combined in such a way as to minimize the number of crewmen and still retain the skills required to accomplish the experiment program. In attempting to combine skills into a limited number of crewmen, the compatibility of skills must be considered. To assist in identifying the cross-training requirements, Table 4 lists the skills which are compatible and would require minimal cross-training. Skill levels, i.e., scientist, engineer, specialist, are noted by the crew titles in Table 4.

TABLE 4 COMPATIBLE SKILL COMBINATIONS

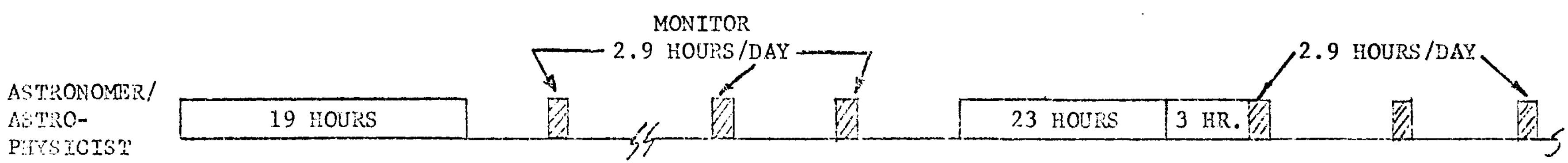
CODE	SKILL	CREWMAN
3	BIOCHEMISTRY	BIOSCIENTIST
4	PHYSIOLOGY	
1	BIOLOGY (TECHNICIAN)	
2	MICROBIOLOGY (TECHNICIAN)	
32	LIFE SCIENCE (TECHNICIAN)	
5	ASTRONOMY/ASTROPHYSICS	ASTROPHYSICIST
6	PHYSICS	
7	NUCLEAR PHYSICS	
	ENGINEERING	ELECTROMECHANICAL ENGINEER
10	ELECTRONIC	
11	MECHANICAL	
31	ELECTROMECHANICAL	
29	PILOT/NAVIGATION	
	TECHNICIAN/SPECIALIST	
12	ELECTROMECHANICAL	
17	MICROWAVE	
30	EVA BACKUP	
13	MEDICINE (M.D.)	AEROMEDICAL SPECIALIST
21	BEHAVIORAL SCIENCES	
23	METALLURGY	MATERIAL PROCESS SPECIALIST
24	MATERIAL SCIENCE	
9	THERMODYNAMICS	

CODE	SKILL	CREWMAN
15	OPTICS SCIENCE	OPTICAL SYSTEMS ENGINEER
14	OPTICS (TECHNICIAN)	
8	PHOTOGRAPHY/CARTOGRAPHY (TECHNICIAN)	
	GEOLOGY	EARTH RESOURCES SPECIALIST
19	PHYSICAL	
20	PHOTO	
26	AGRONOMY	
27	GEOGRAPHY	
16	METEOROLOGY	EARTH PROCESSES SPECIALIST
18	OCEANOGRAPHY	
28	HYDROLOGY	
25	PHYSICAL CHEMISTRY	CHEMICAL ENGINEER
22	CHEMISTRY (TECHNICIAN)	
30	ANY SKILL	SUBJECT

A-1 X-RAY ASTRONOMY

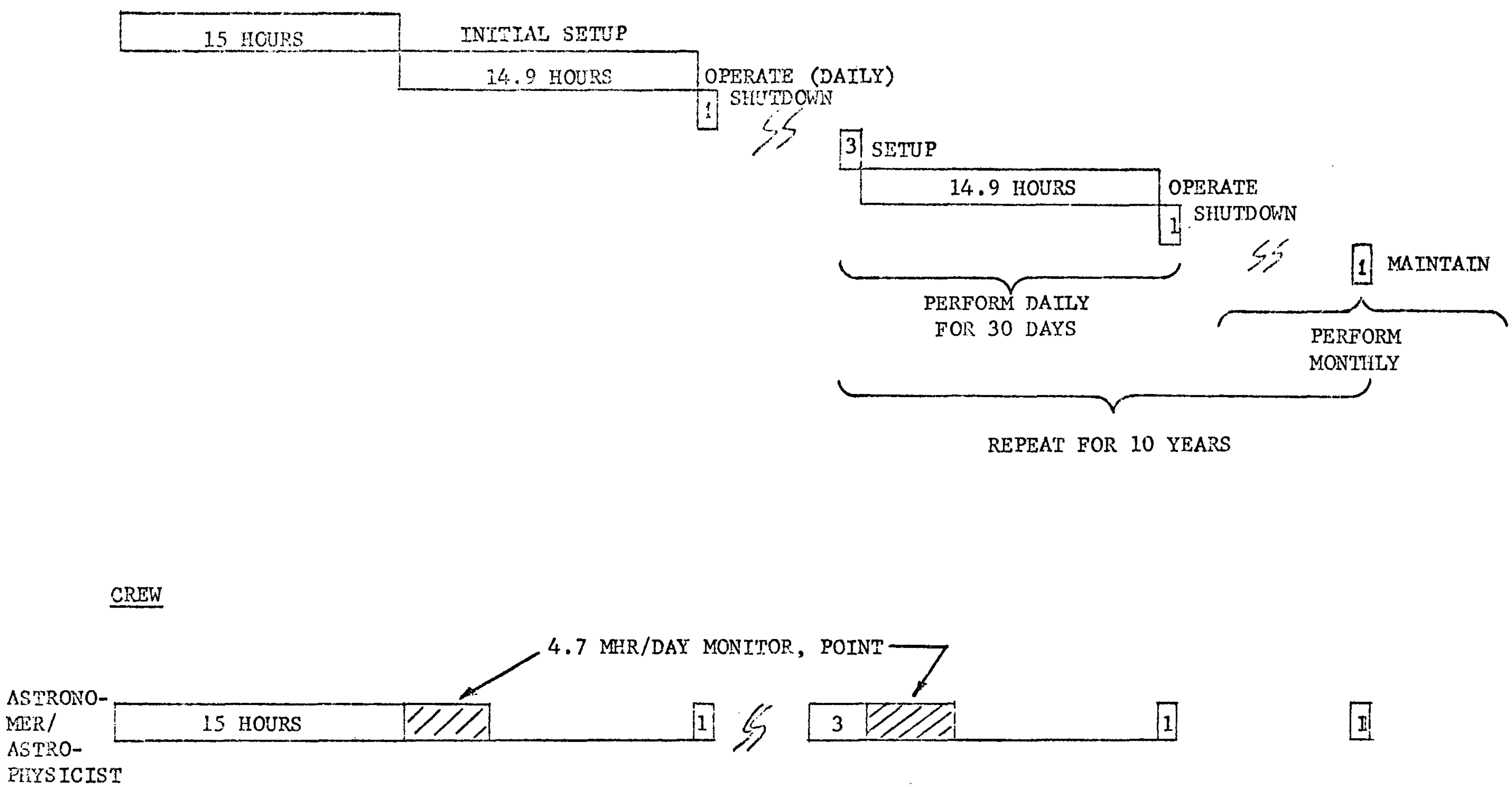


CREW



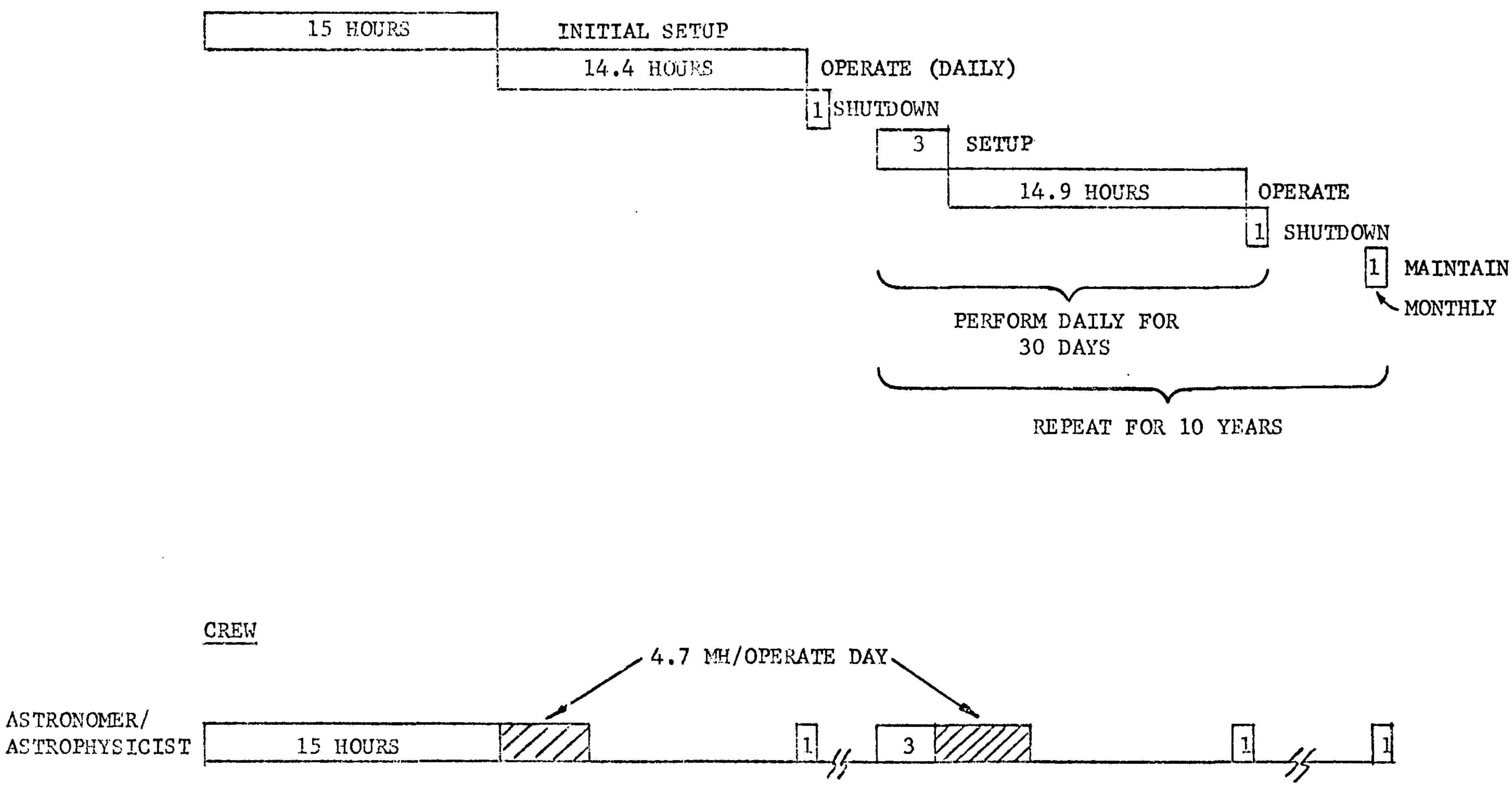
TOTAL - ASTRONOMER/ASTROPHYSICIST = 3.0 MHR/DAY (AVE.)

A-2 ADVANCED STELLAR ASTRONOMY



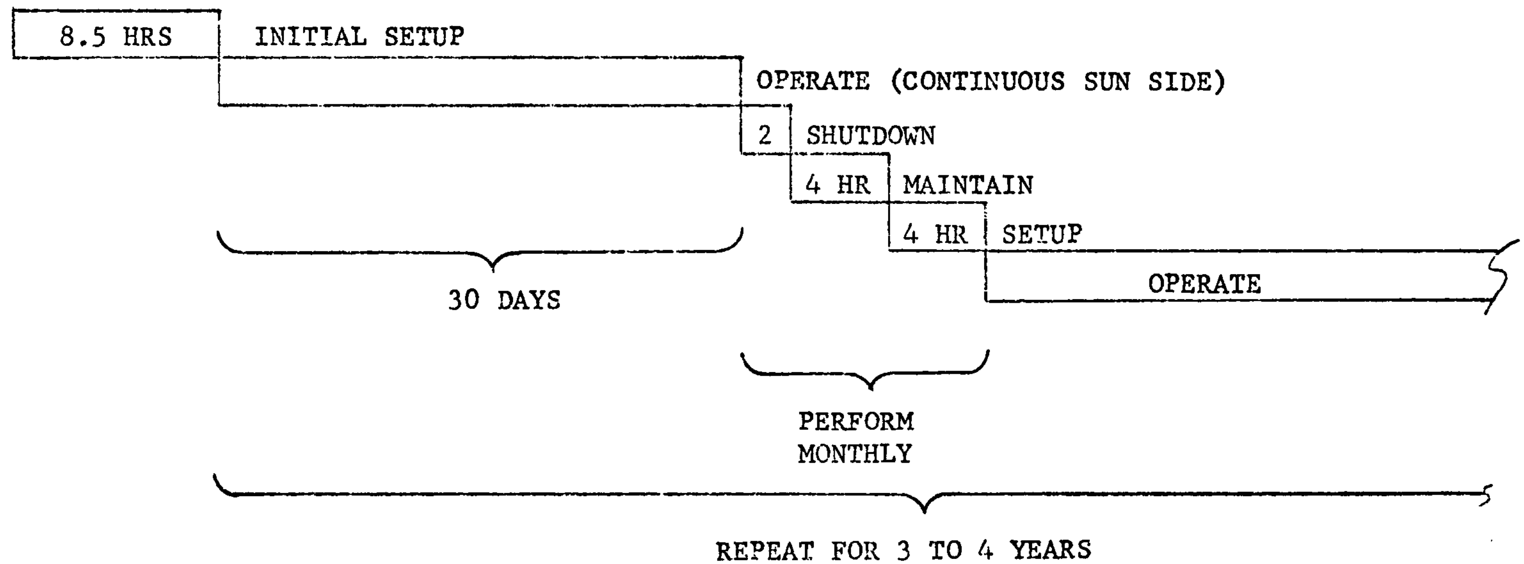
TOTAL - ASTRONOMER/ASTROPHYSICIST - 4.8 MHR/DAY (AVE.)

A-2A TWO METER TELESCOPE

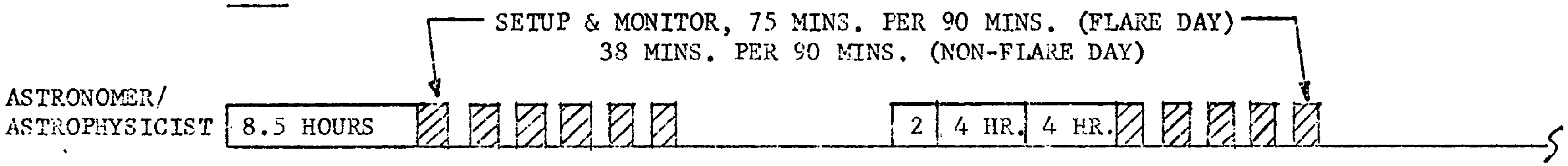


TOTAL - ASTRONOMER/ASTROPHYSICIST - 4.8 MH/DAY (AVE.)

A-3 ADVANCED SOLAR ASTRONOMY



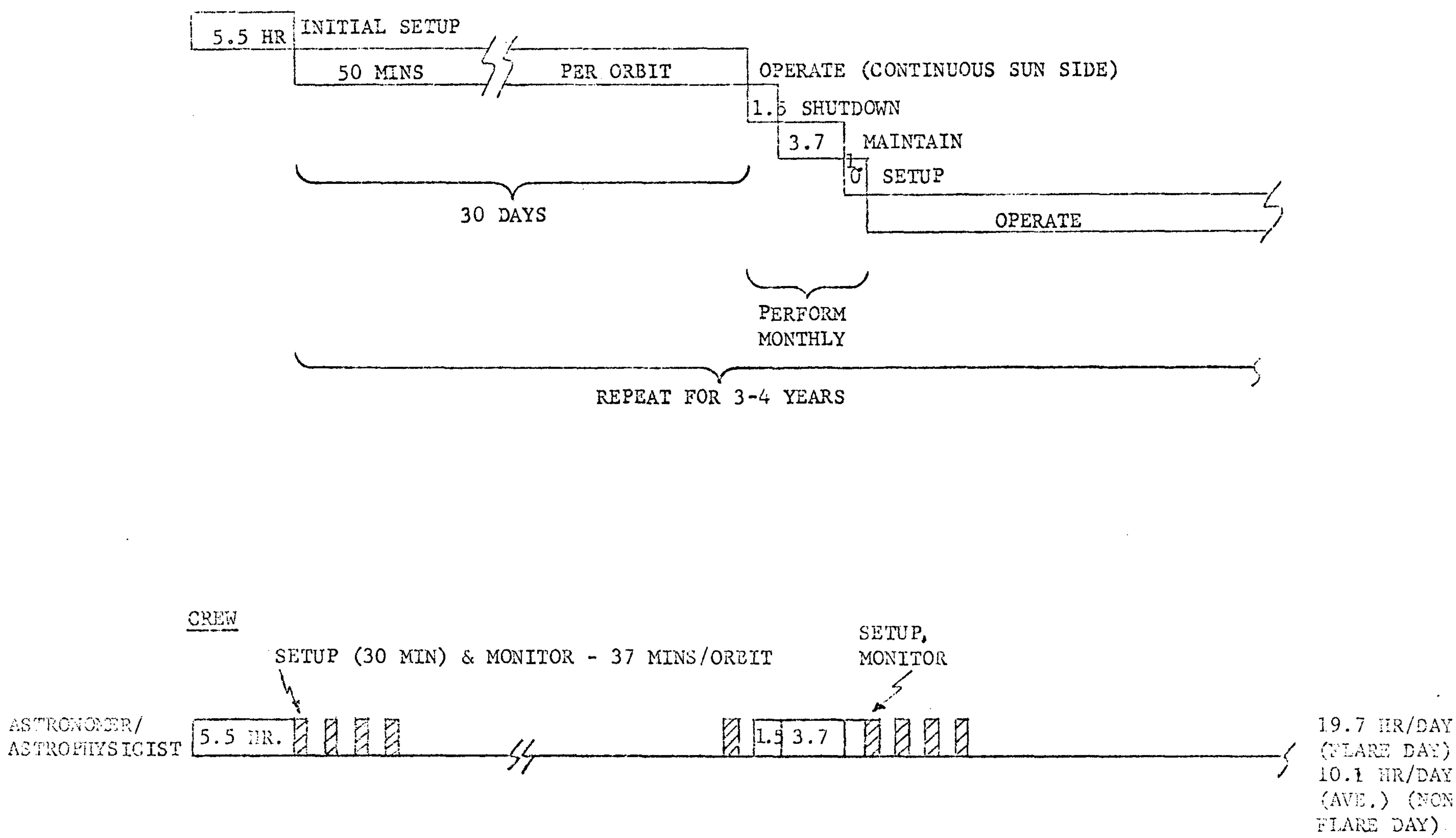
CREW



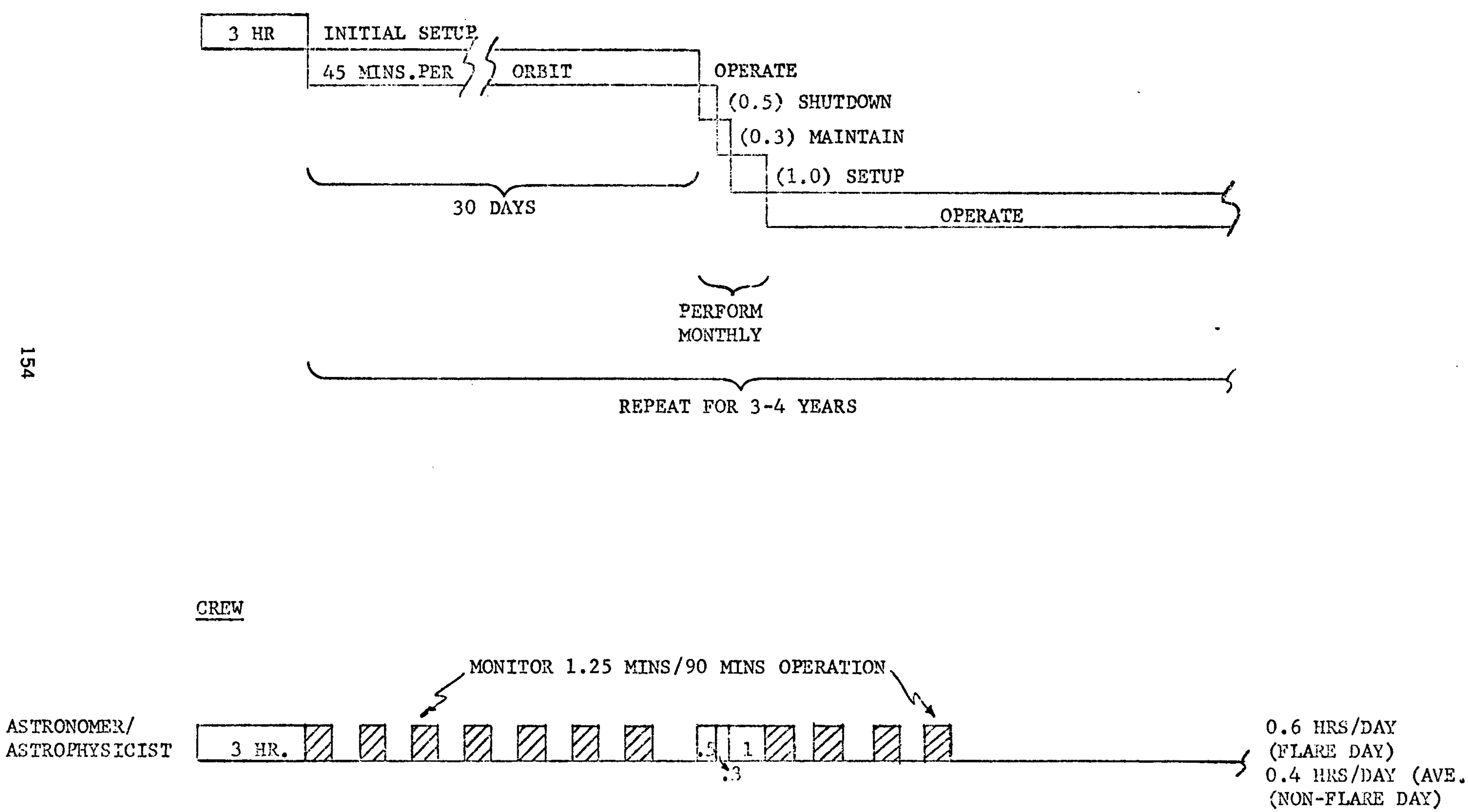
TOTAL - 20.3 HOURS - FLARE DAY*
10.4 HOURS - NON-FLARE DAY

*ESTIMATE ONE FLARE DAY PER MONTH

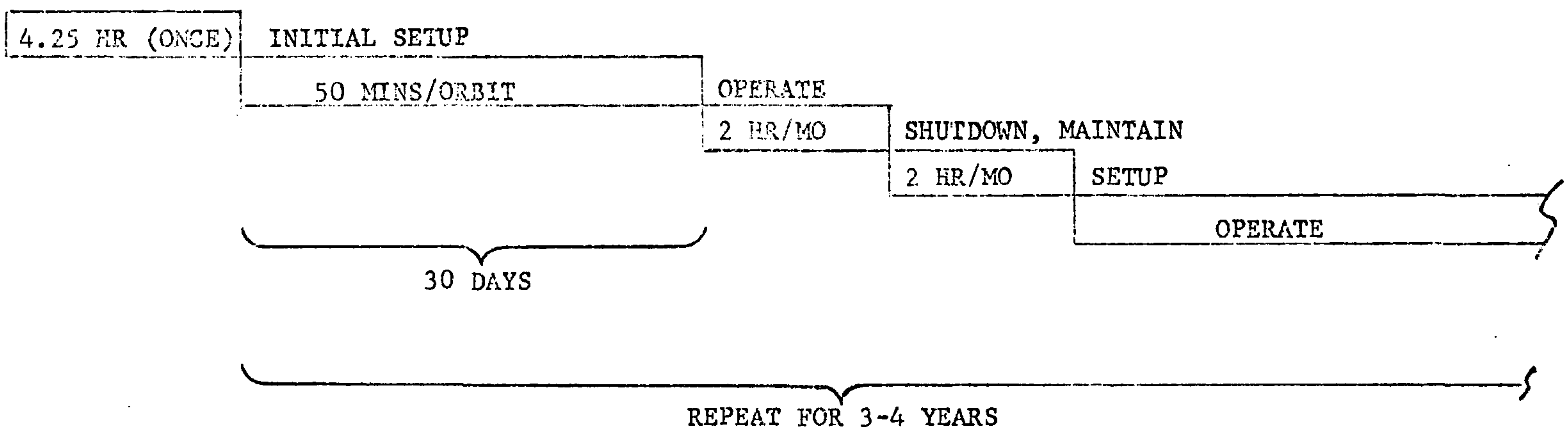
A-3A 1.5 M PHOTOHELIOGRAPH, XUV SPECTROMETER, X-RAY GRAZING TELESCOPE



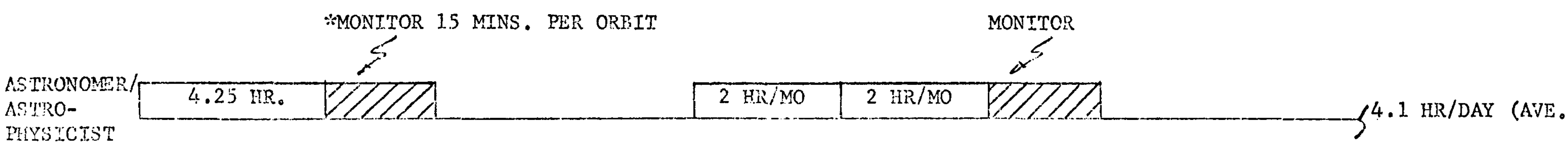
A-3B SOLAR CORONAGRAPH



A-3C PHOTOHELIOGRAPH

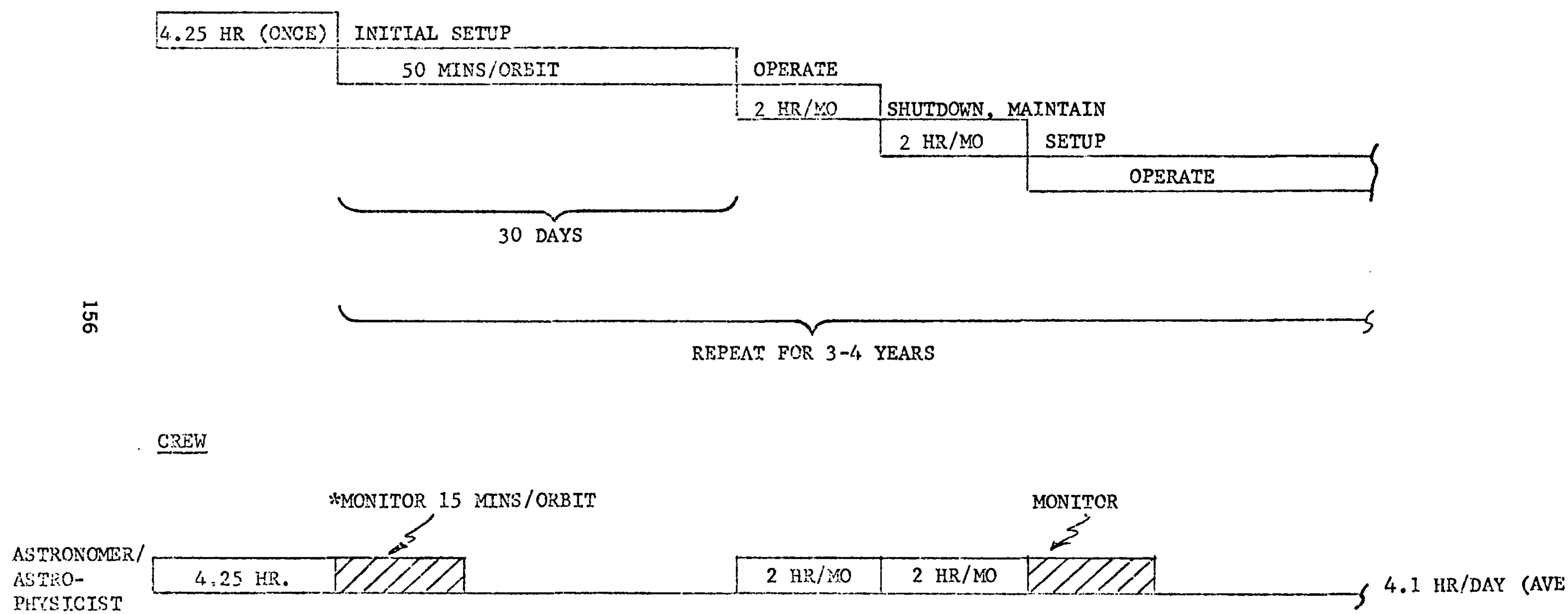


CREW



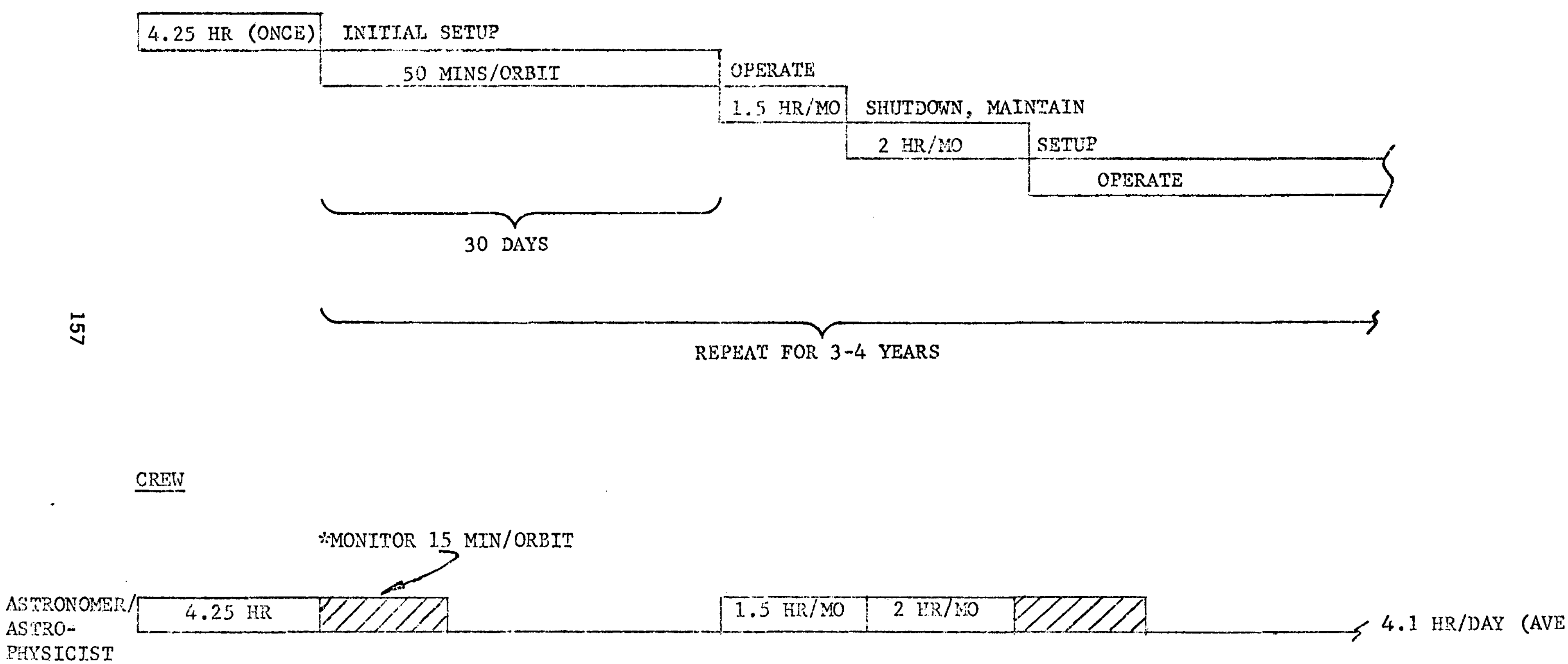
*If A-3C, A-3D, and A-3E are operated concurrently, monitor time for all three instruments is 37 minutes per orbit, total.

A-3D X-RAY SPECTROHELIOGRAPH



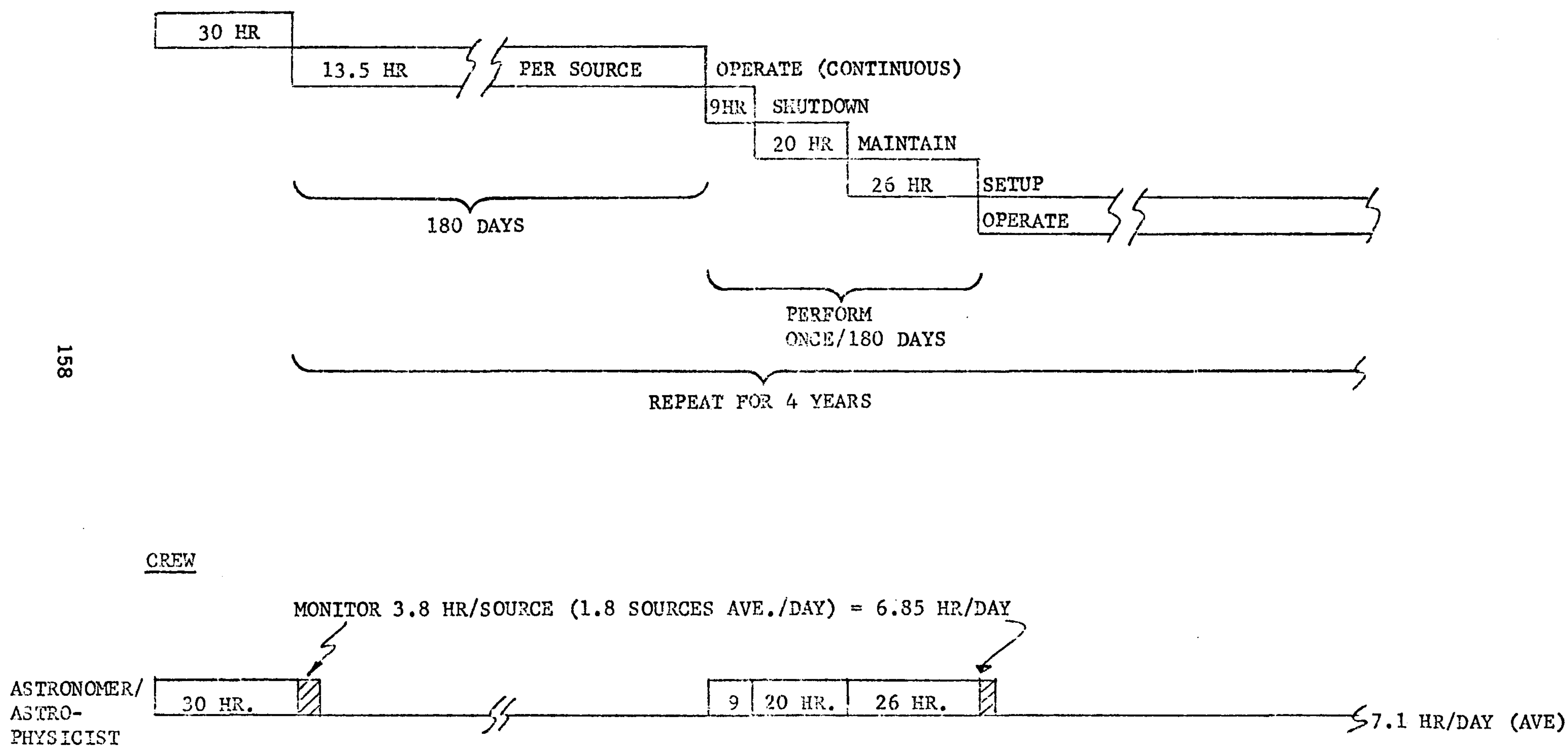
*If A-3C, A-3D, and A-3E are operated concurrently, total monitor time for all three instruments is 37 mins/orbit.

A-3E XUV SPECTROMETER

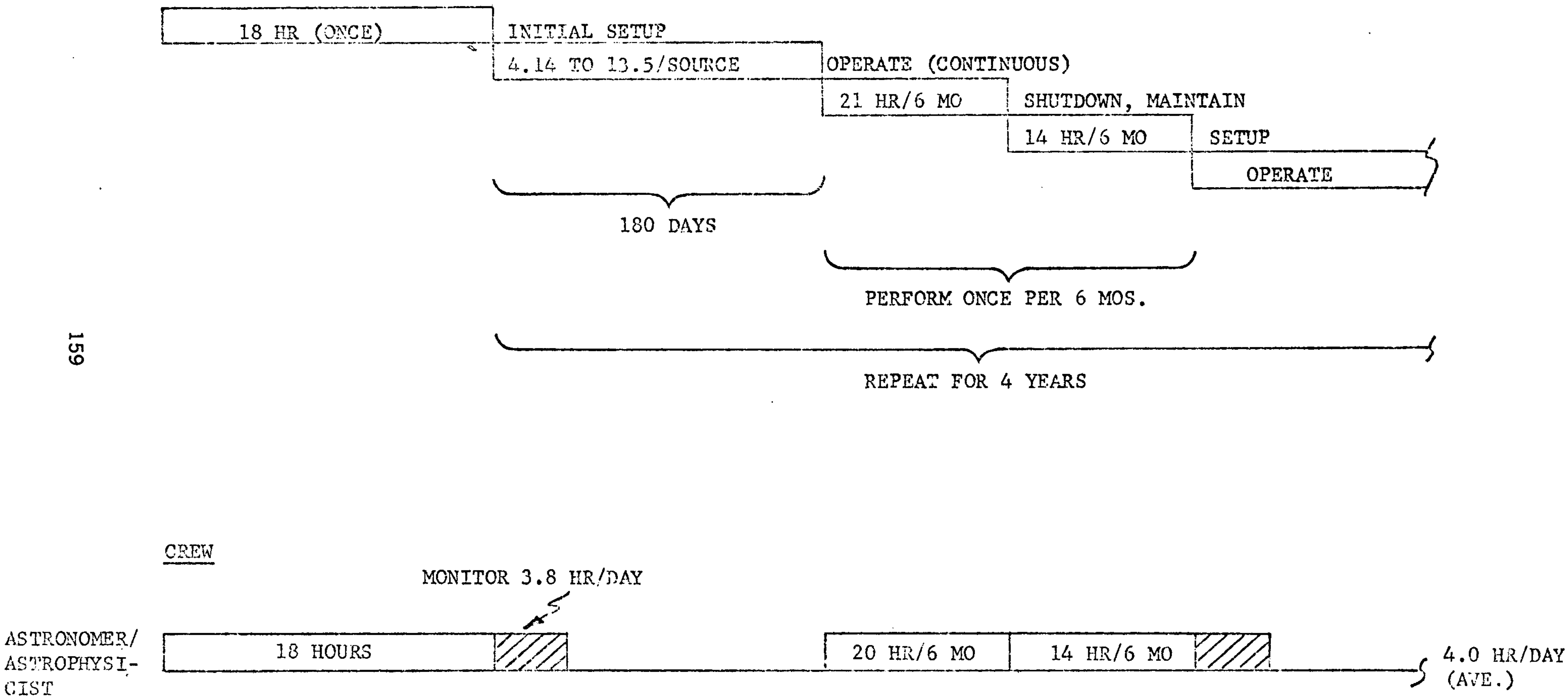


*If A-3C, A-3D, and A-3E are operated concurrently, total monitor time for all three instruments is 37 mins/orbit

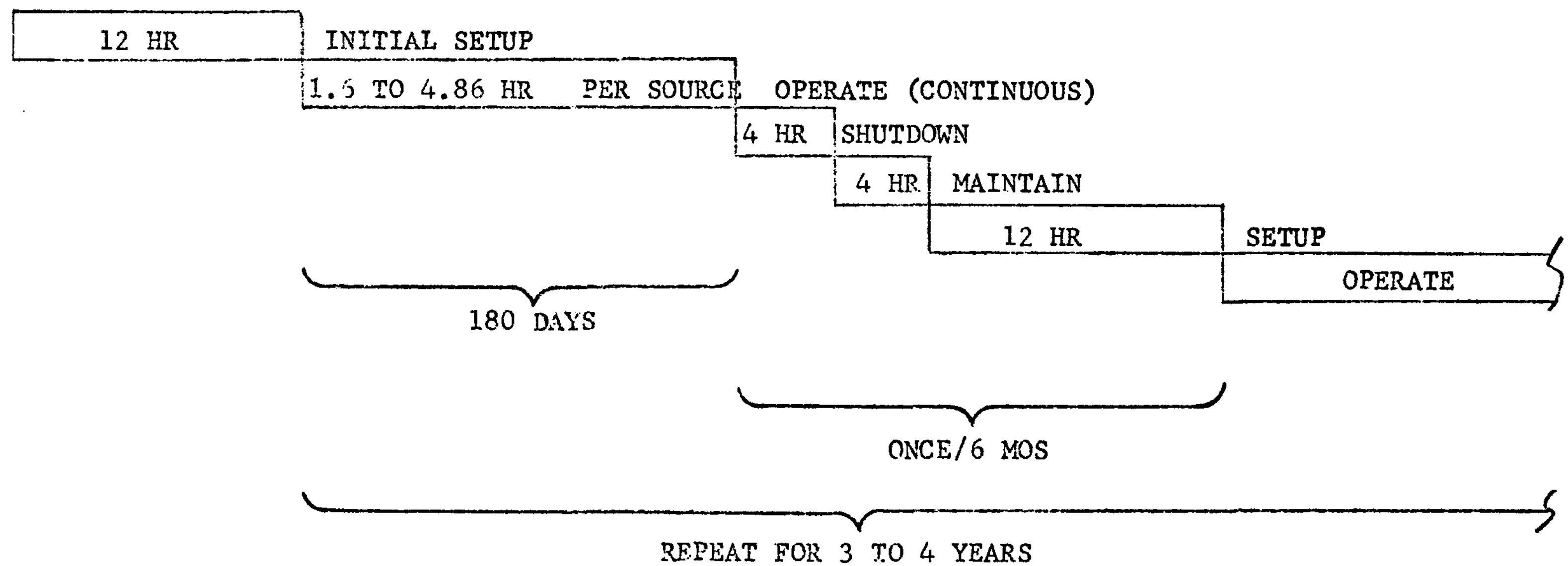
A-4 INTERMEDIATE SIZE UV TELESCOPES



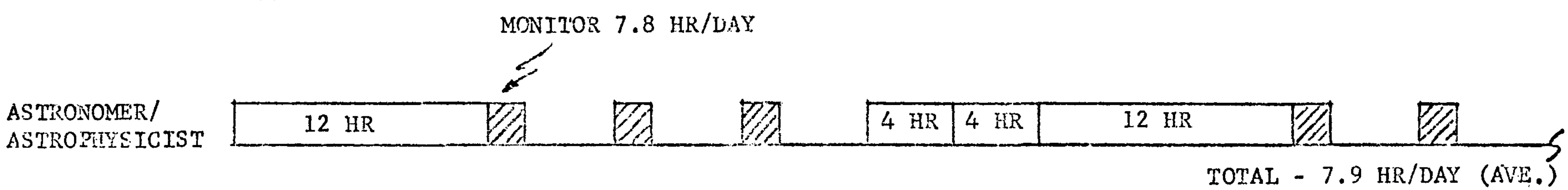
A-4A 0.94 M NARROW FIELD UV TELESCOPE



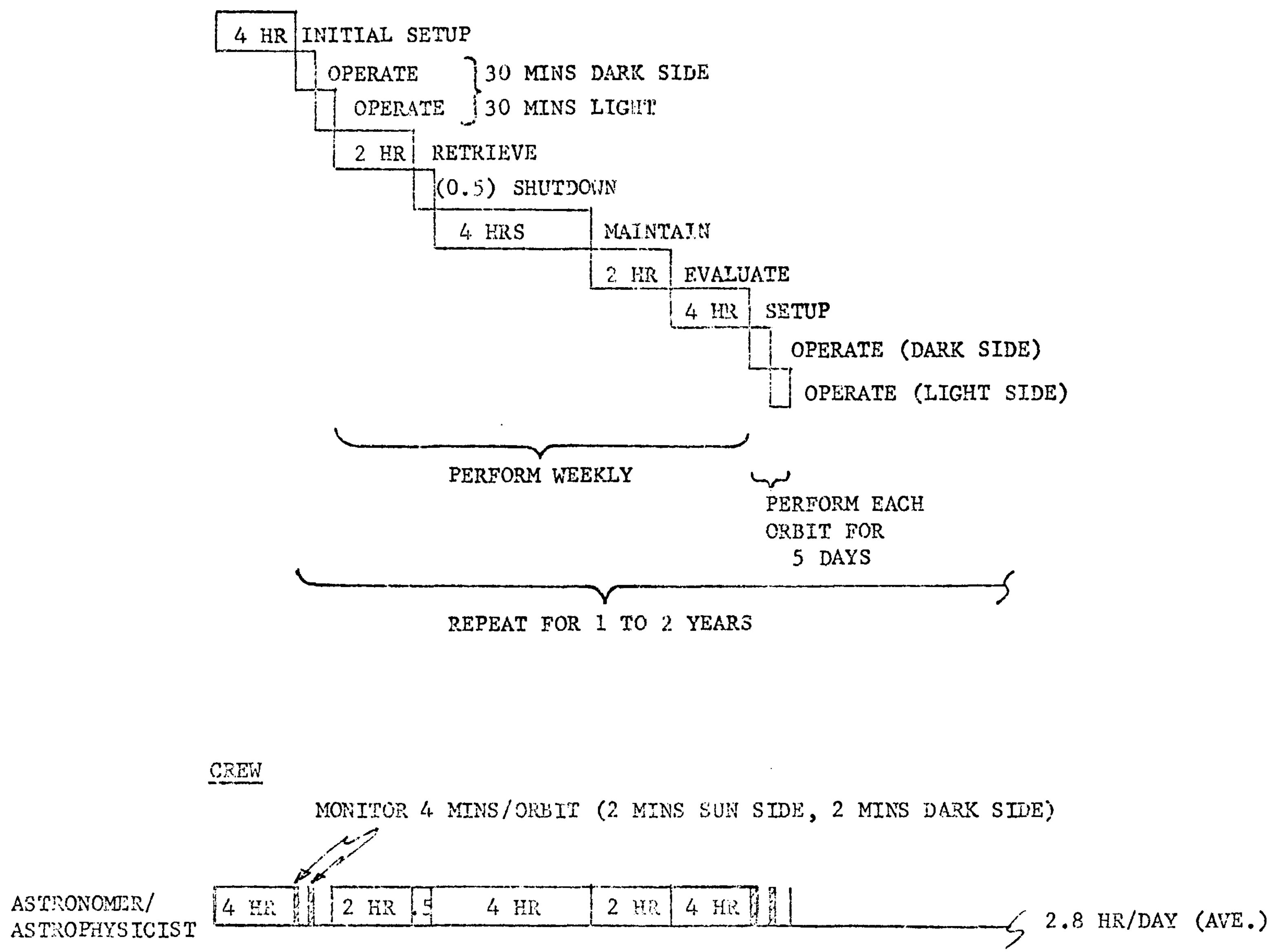
A-4B 0.3 M WIDE FIELD UV TELESCOPE



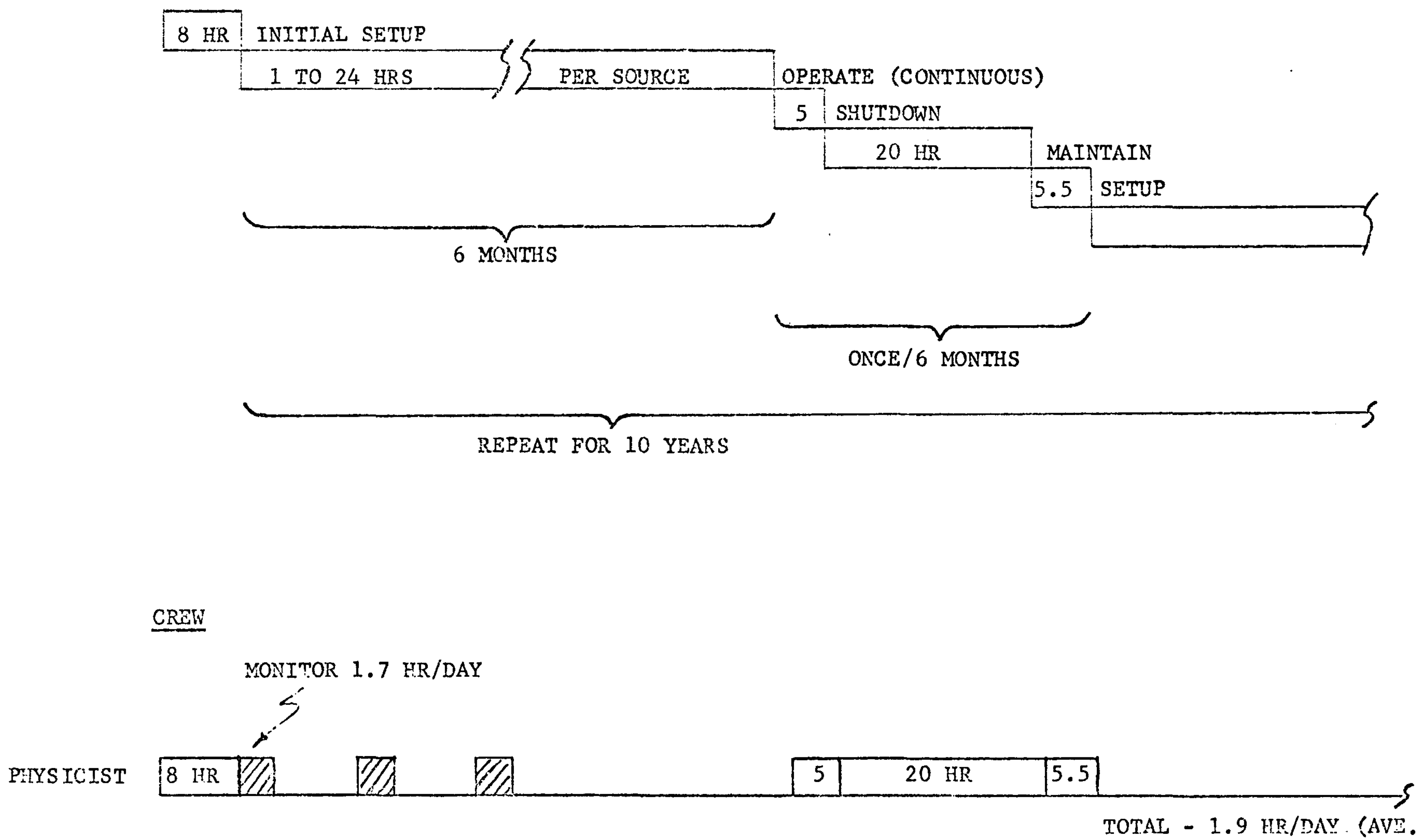
CREW



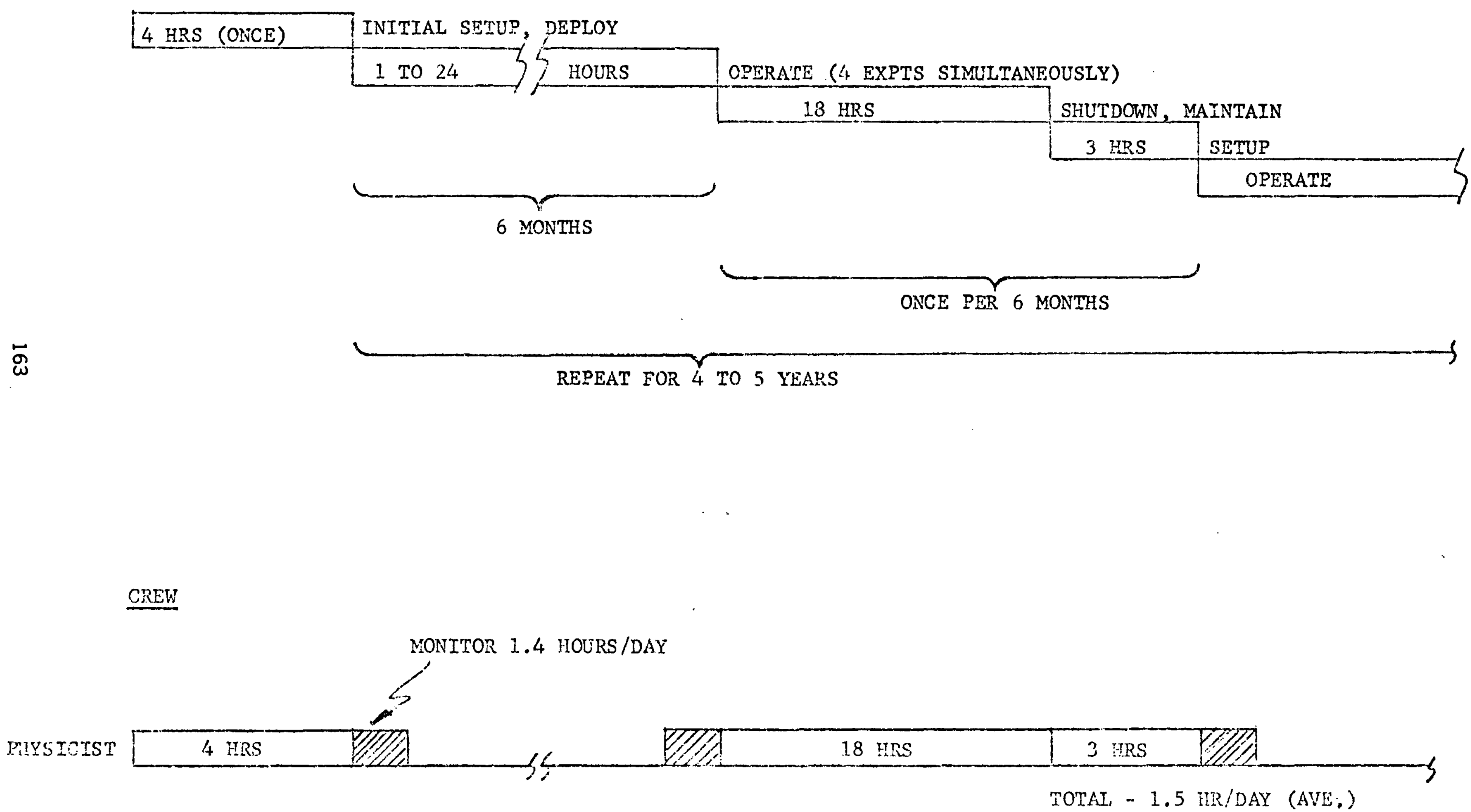
A-4C SMALL UV SURVEY TELESCOPES



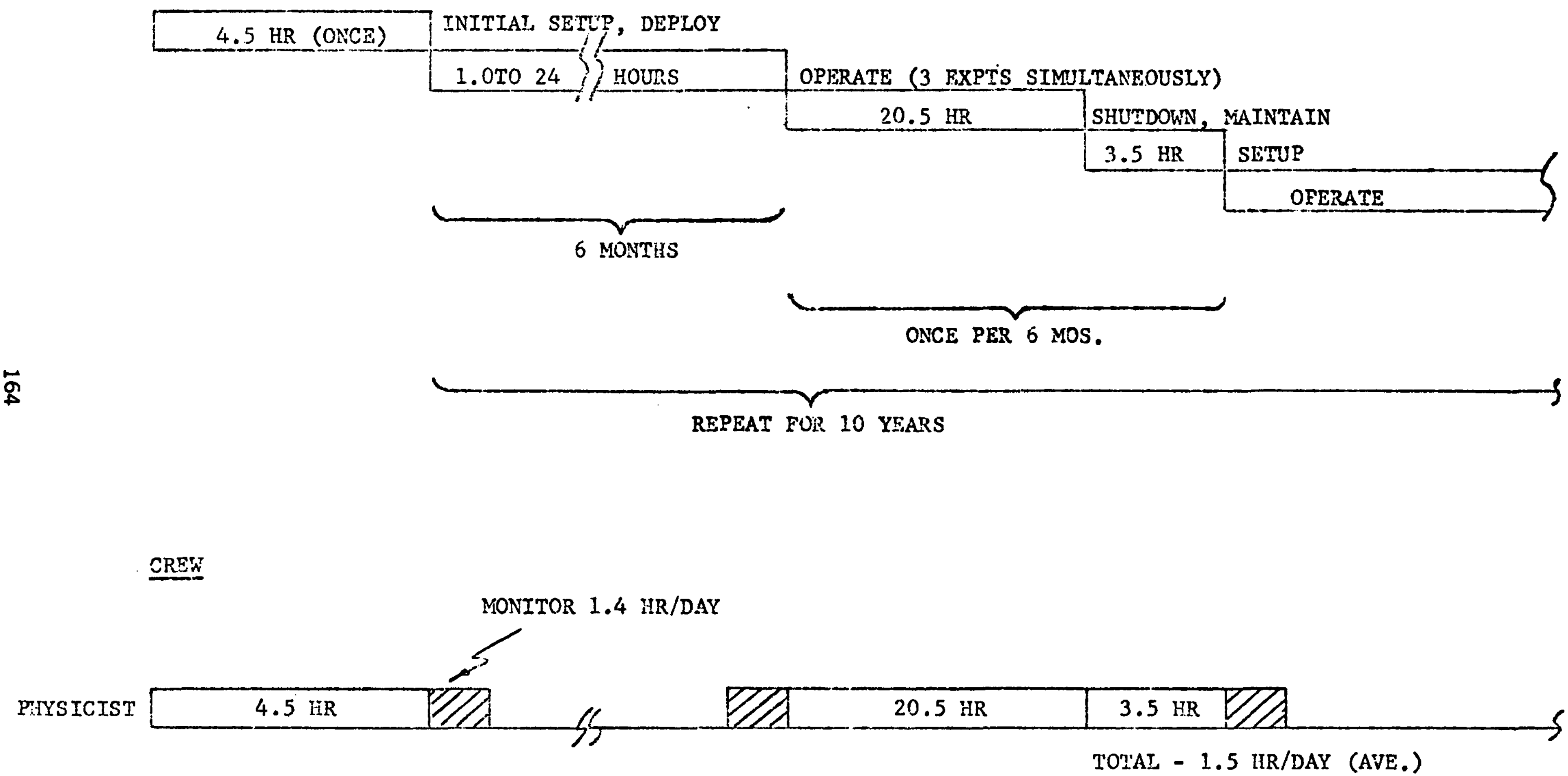
A-5 HIGH ENERGY STELLAR ASTRONOMY



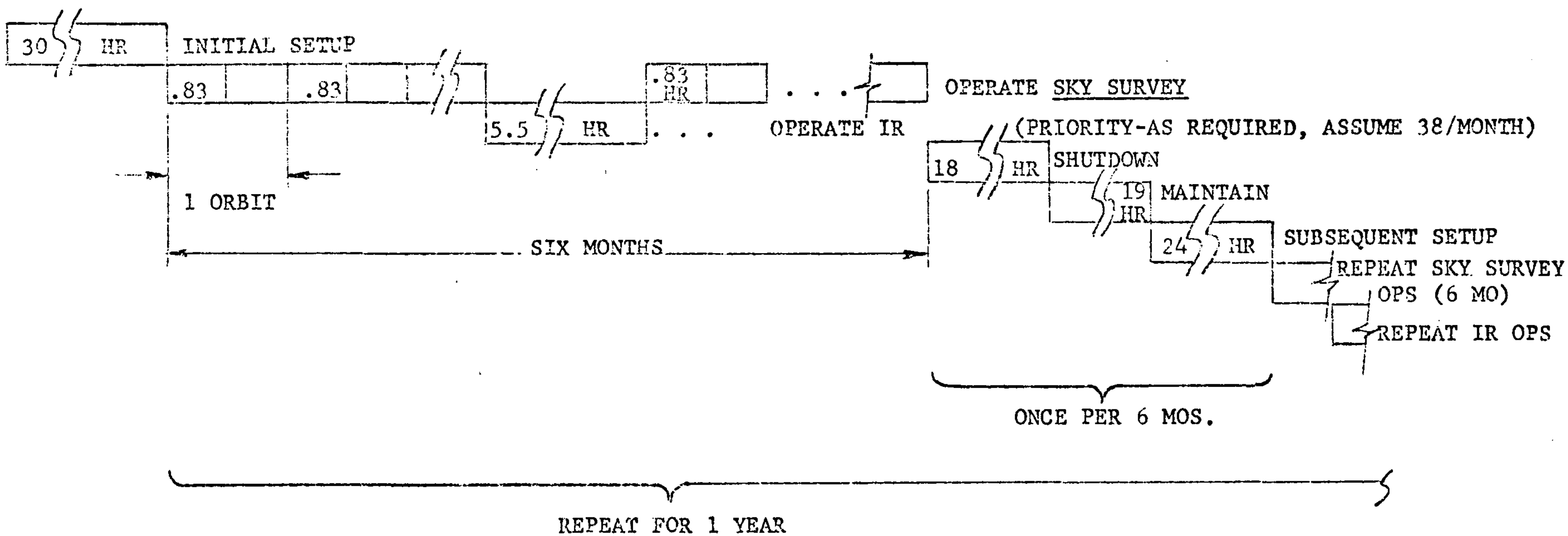
A-5A LOWER ENERGY EXPERIMENT



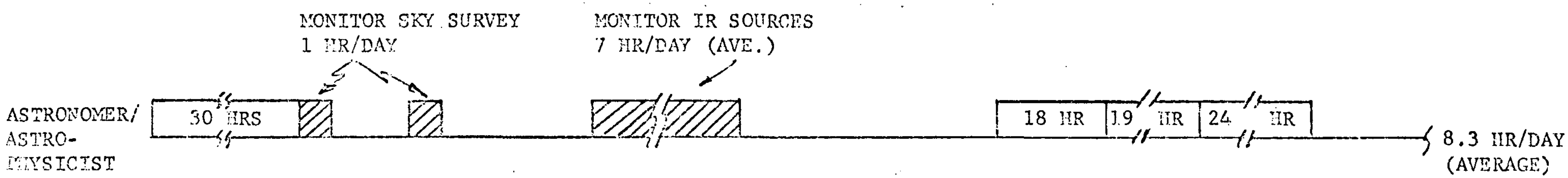
A-5B HIGHER ENERGY EXPERIMENT



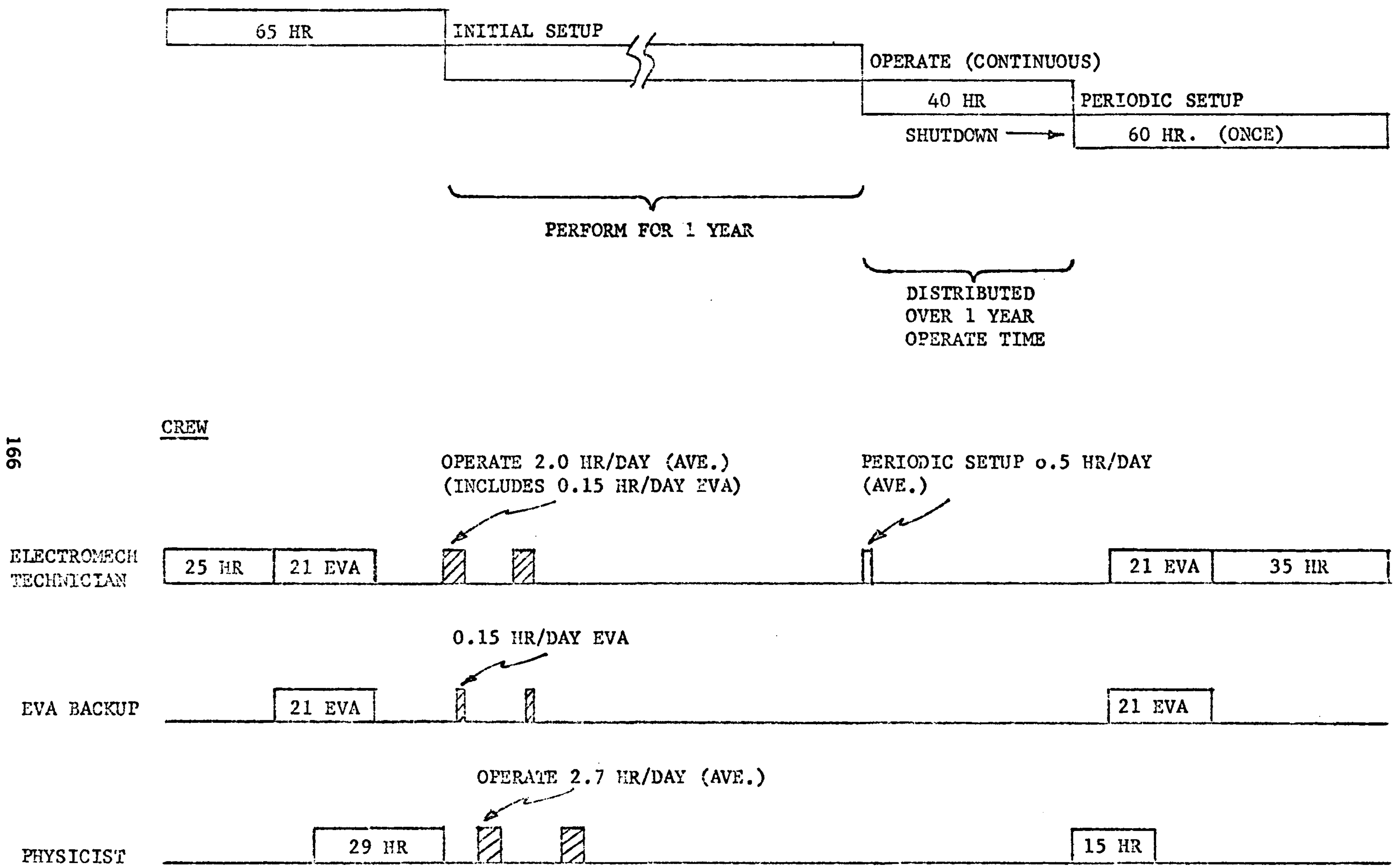
A-6 INFRARED ASTRONOMY



CREW

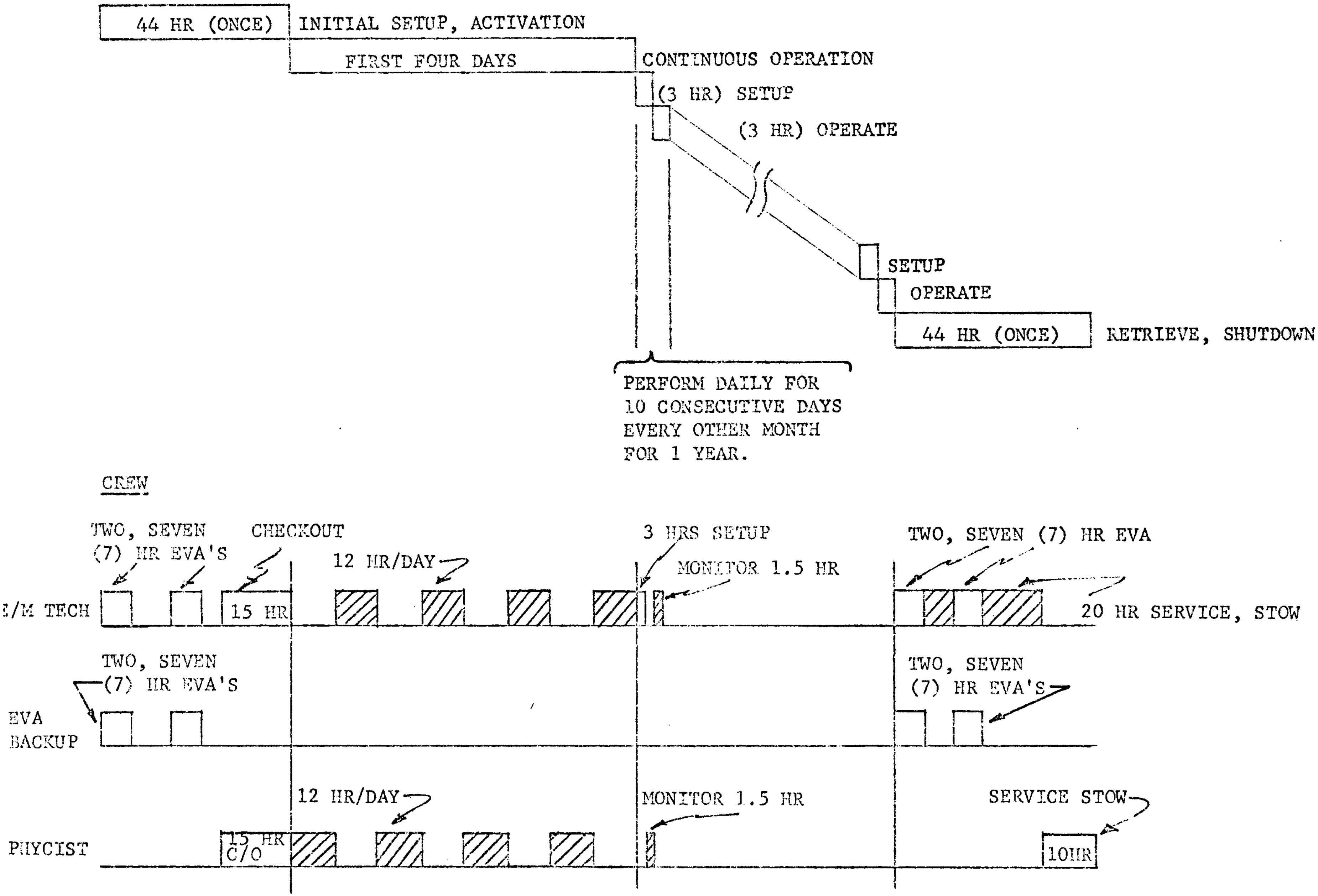


P-1 SPACE PHYSICS RESEARCH LAB



TOTAL - E/M TECHNICIAN - 2.9 HR/DAY (AVE.)
EVA BACKUP - 0.25 HR/DAY (AVE.)
PHYSICIST - 2.8 HR/DAY (AVE.)

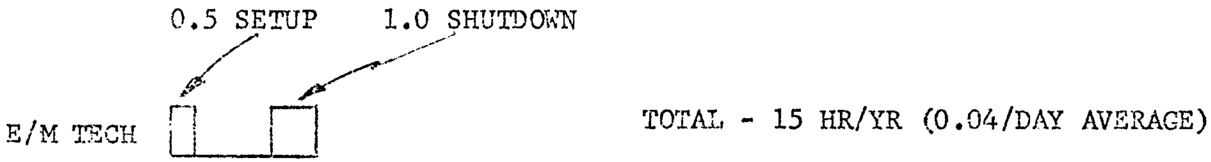
P-1A ATMOSPHERIC & MAGNETOSPHERIC SCIENCE

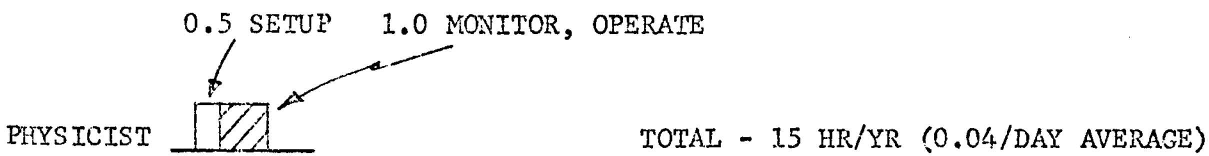


TOTAL - PHYSICIST - 0.5 HR/DAY (AVERAGE)
E/M TECH - 1 HR/DAY (AVERAGE)
EVA BACKUP - 0.1 HR/DAY (AVERAGE)

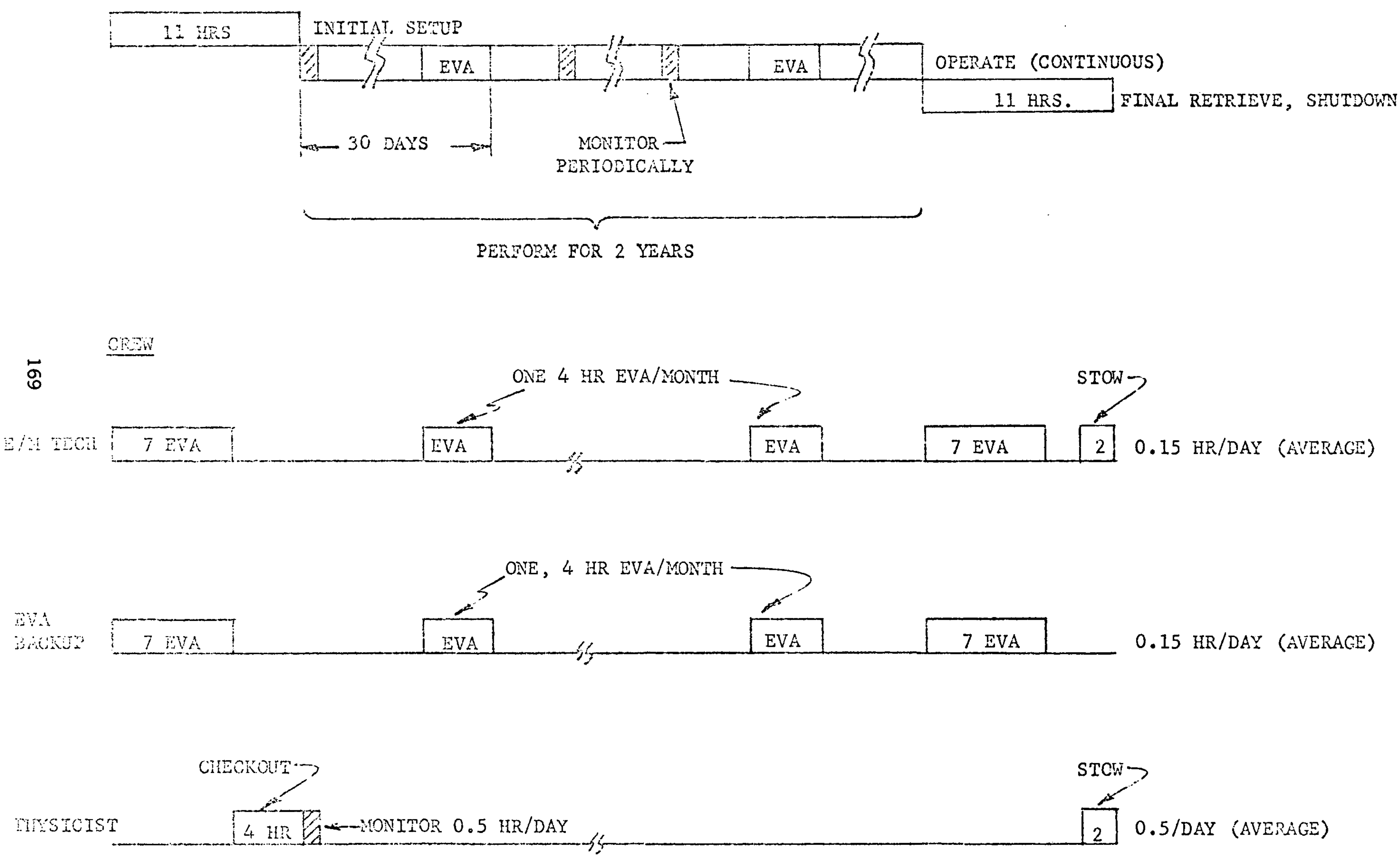
P-1B COMETARY PHYSICS

CREW

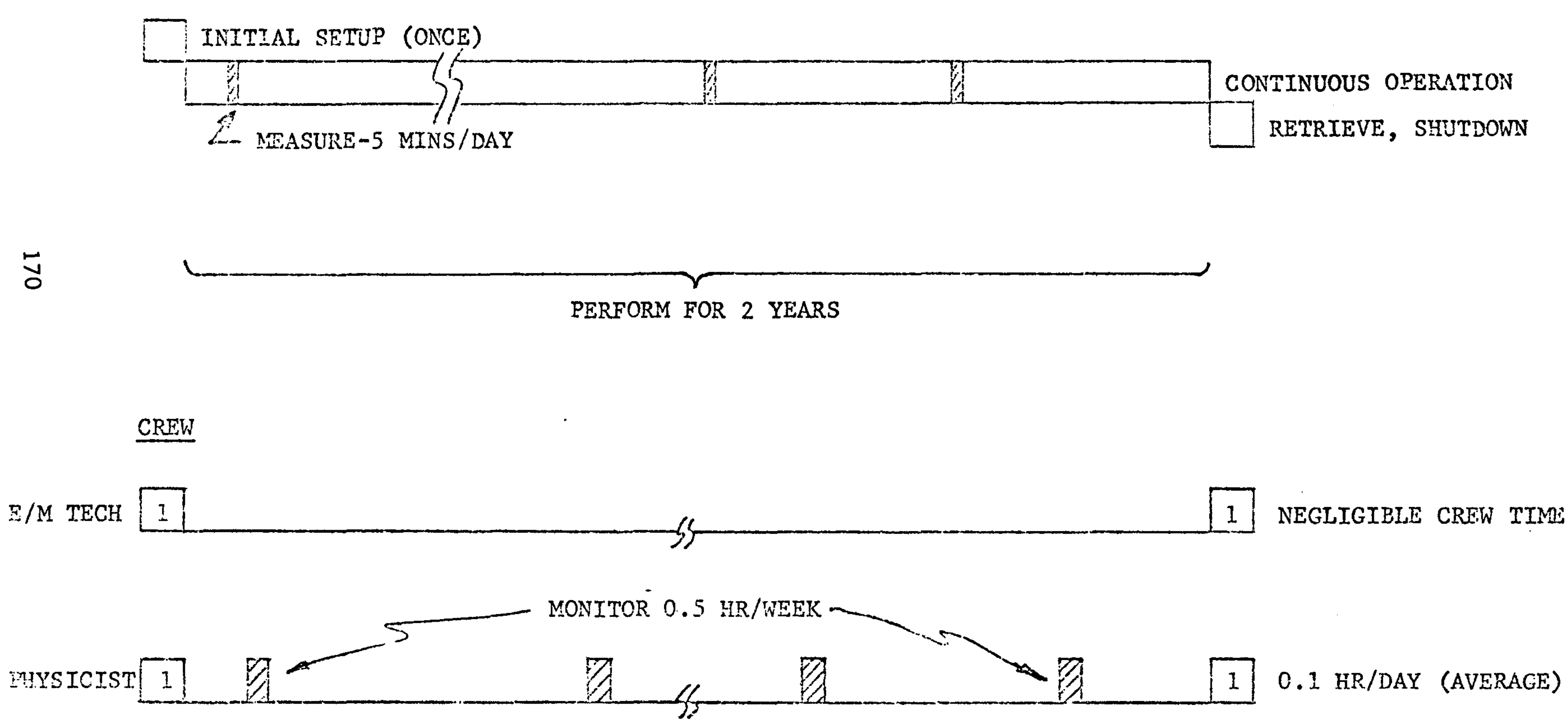




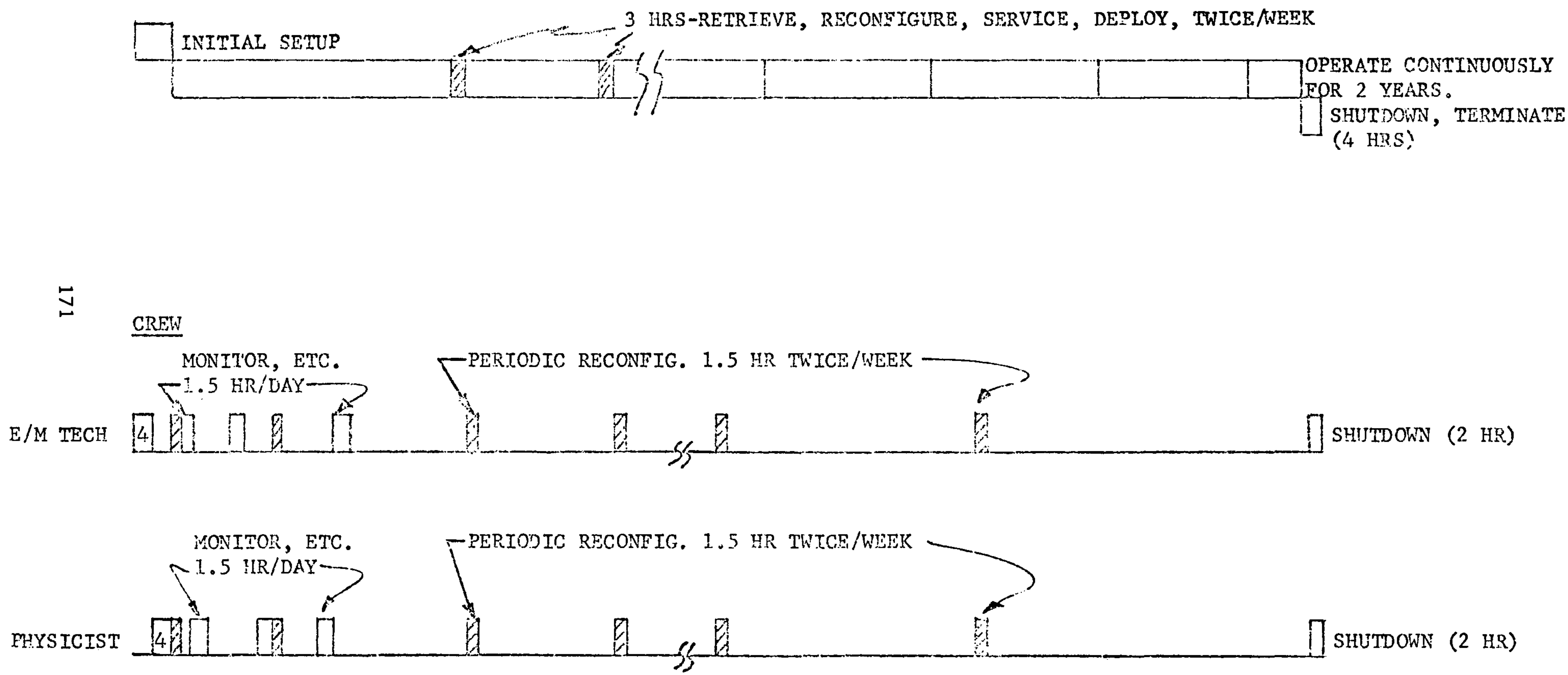
P-1C METEOROID SCIENCE (EXCLUSIVE OF THICK MATERIAL PENETRATION)



P-1D THICK MATERIAL METEOROID PENETRATION

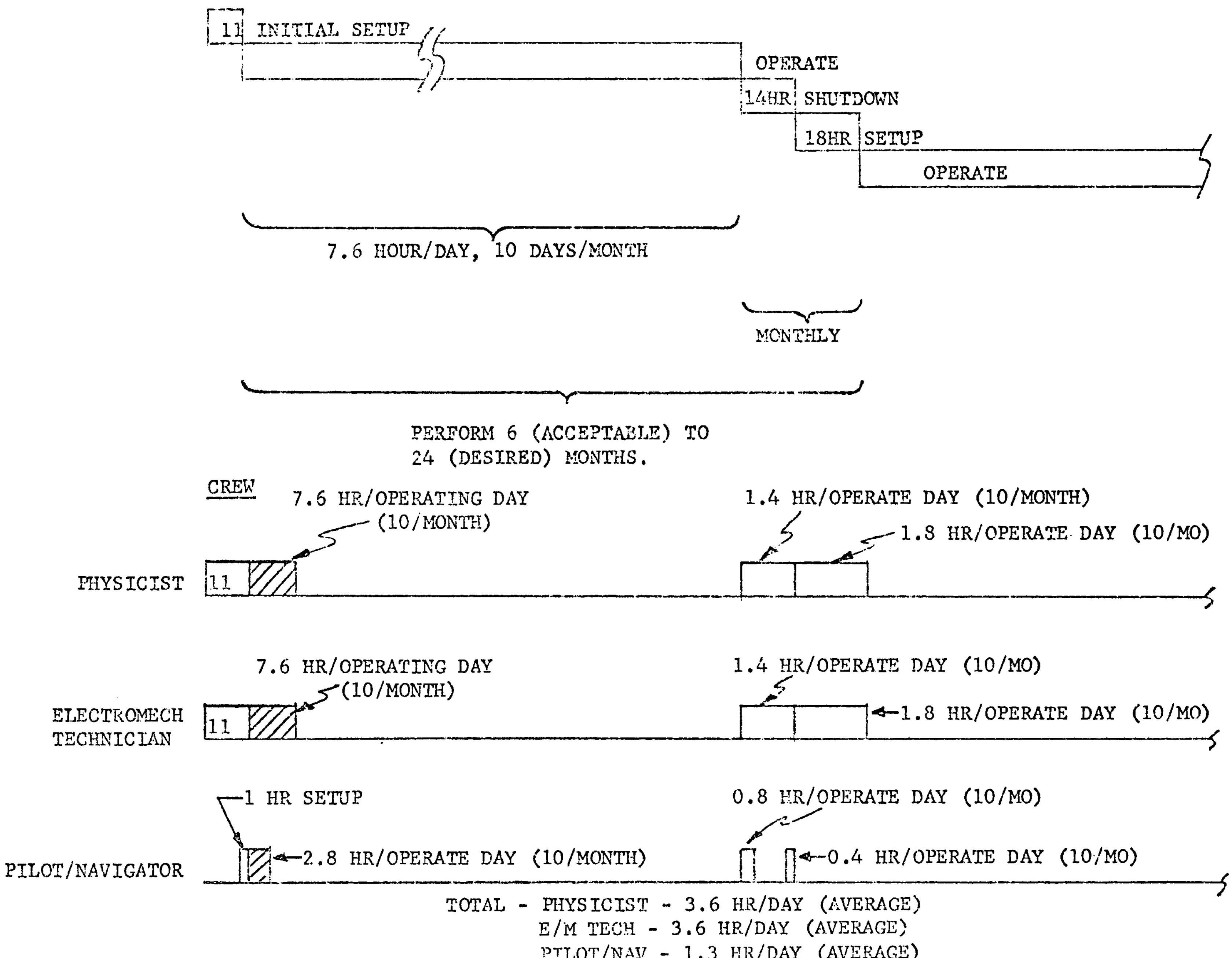


P-1E SMALL ASTRONOMY TELESCOPE

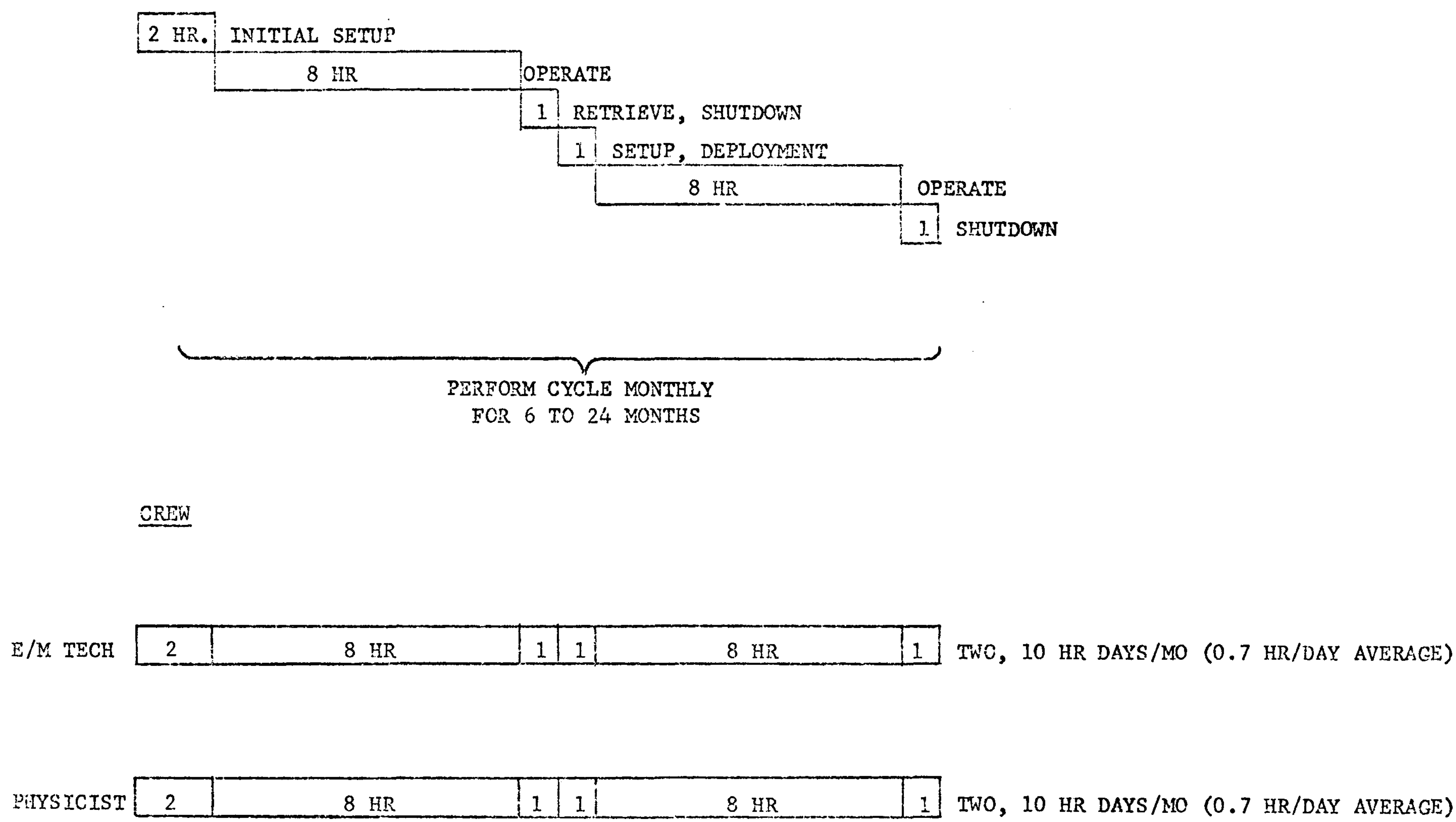


TOTAL - ELECTROMECH TECH - 1.9 HR/DAY (AVERAGE)
PHYSICIST - 1.9 HR/DAY (AVERAGE)

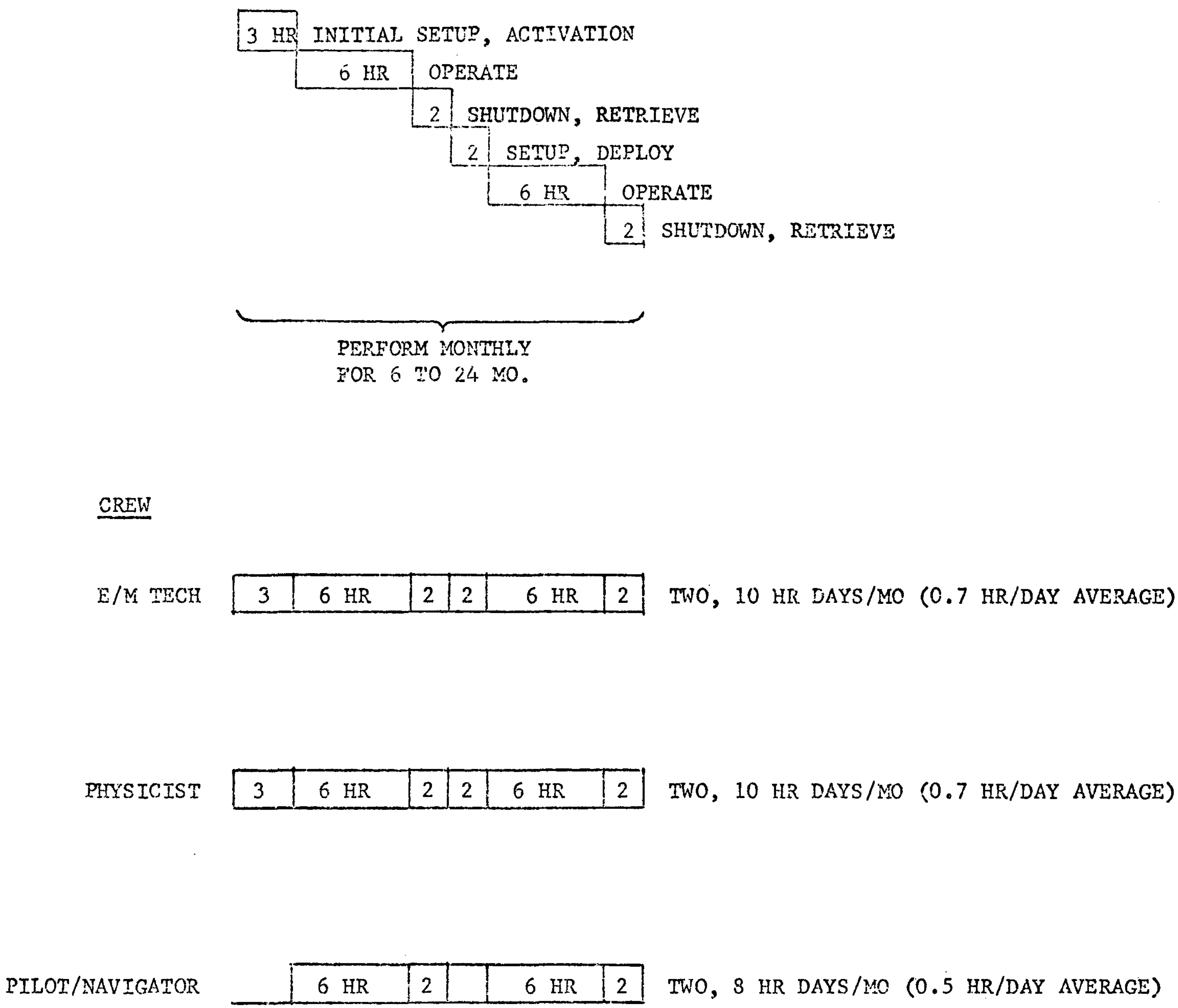
P-2 PLASMA PHYSICS & ENVIRONMENTAL PERTURBATION LAB



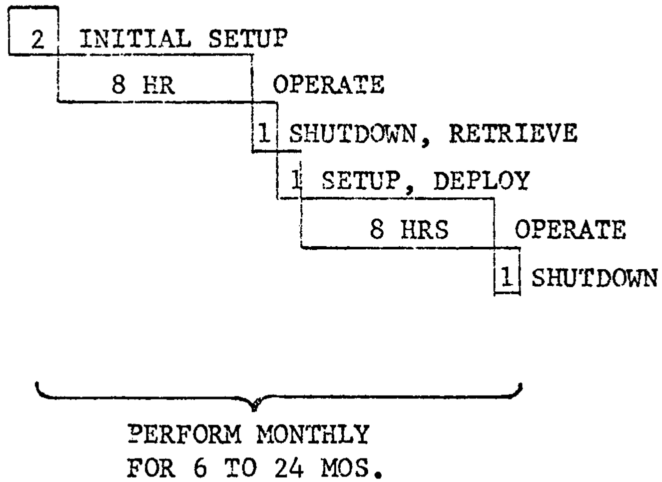
P-2A WAKE MEASUREMENTS FROM STATION & BOOMS



P-2B WAKE MEASUREMENTS FROM SUBSATELLITE



P-2C PLASMA RESOURCES



CREW

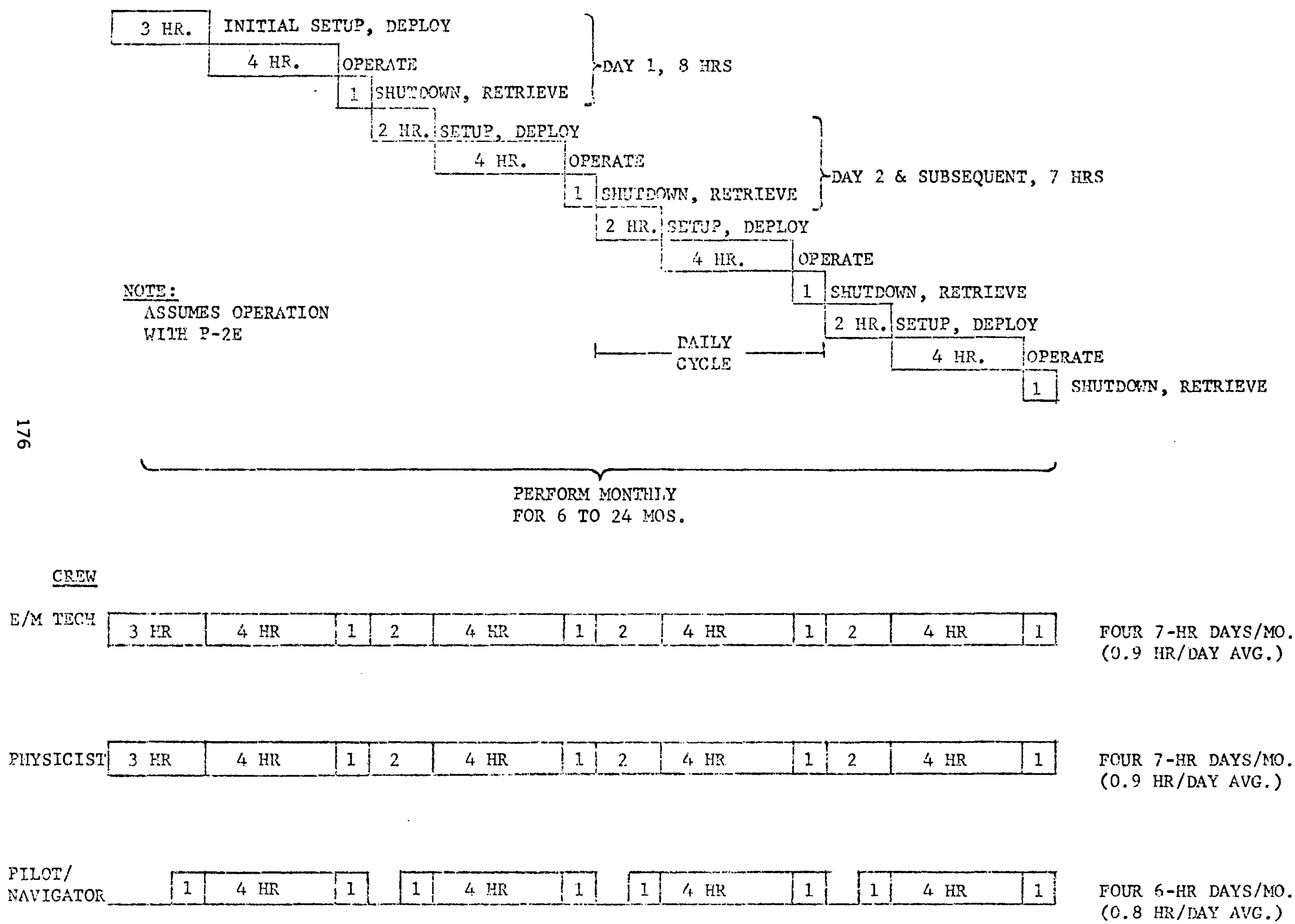
E/M TECH 

TWO, 10 HR DAYS/MO (0.7 HR/DAY AVERAGE)

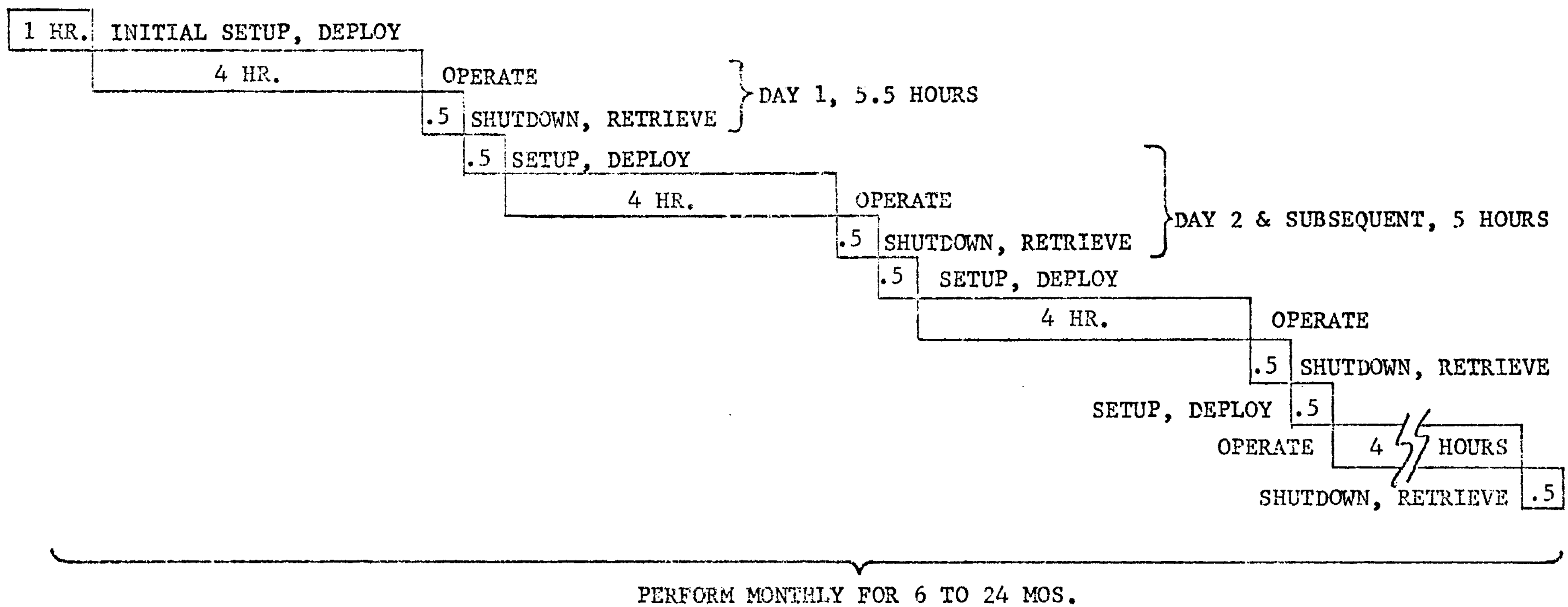
PHYSICIST 

TWO, 10 HR DAYS/MO (0.7 HR/DAY AVERAGE)

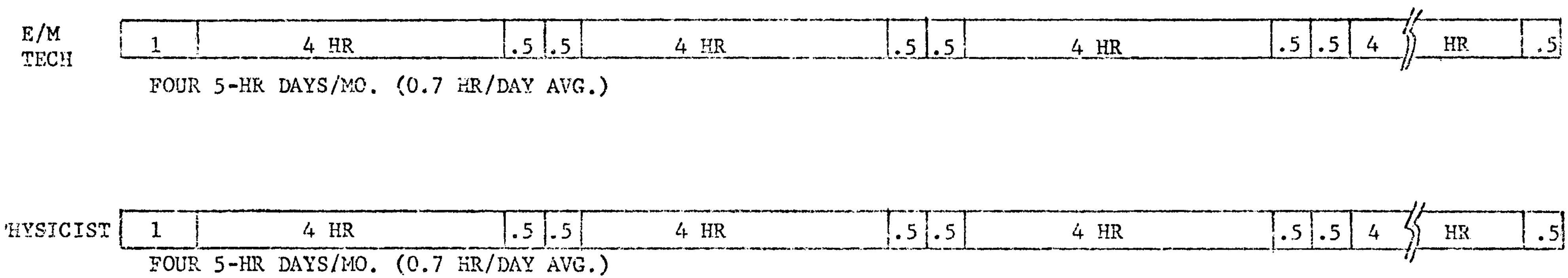
P-2D WAVE PARTICLE INTERACTIONS



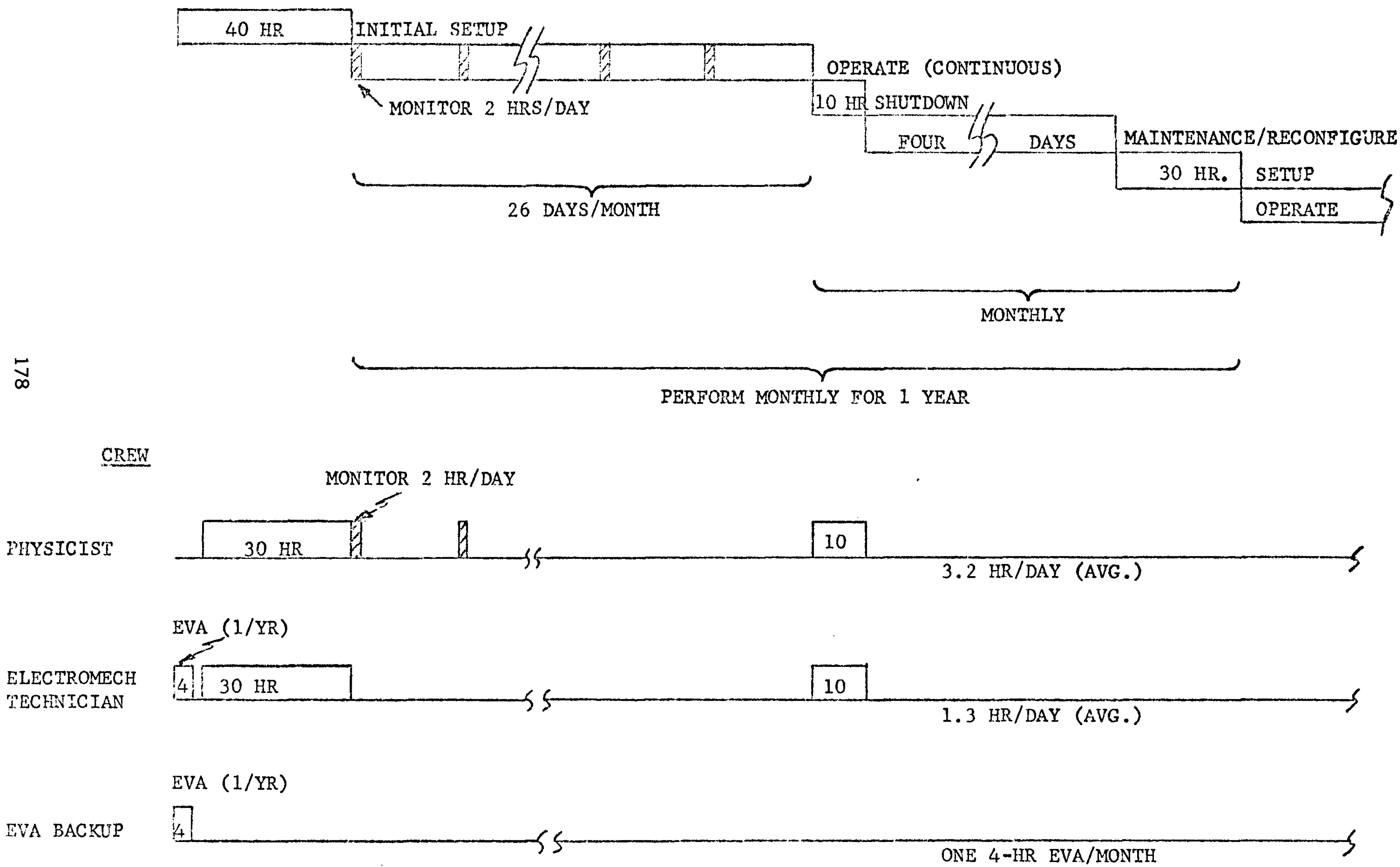
P-2E ELECTRON & ION BEAM INJECTION



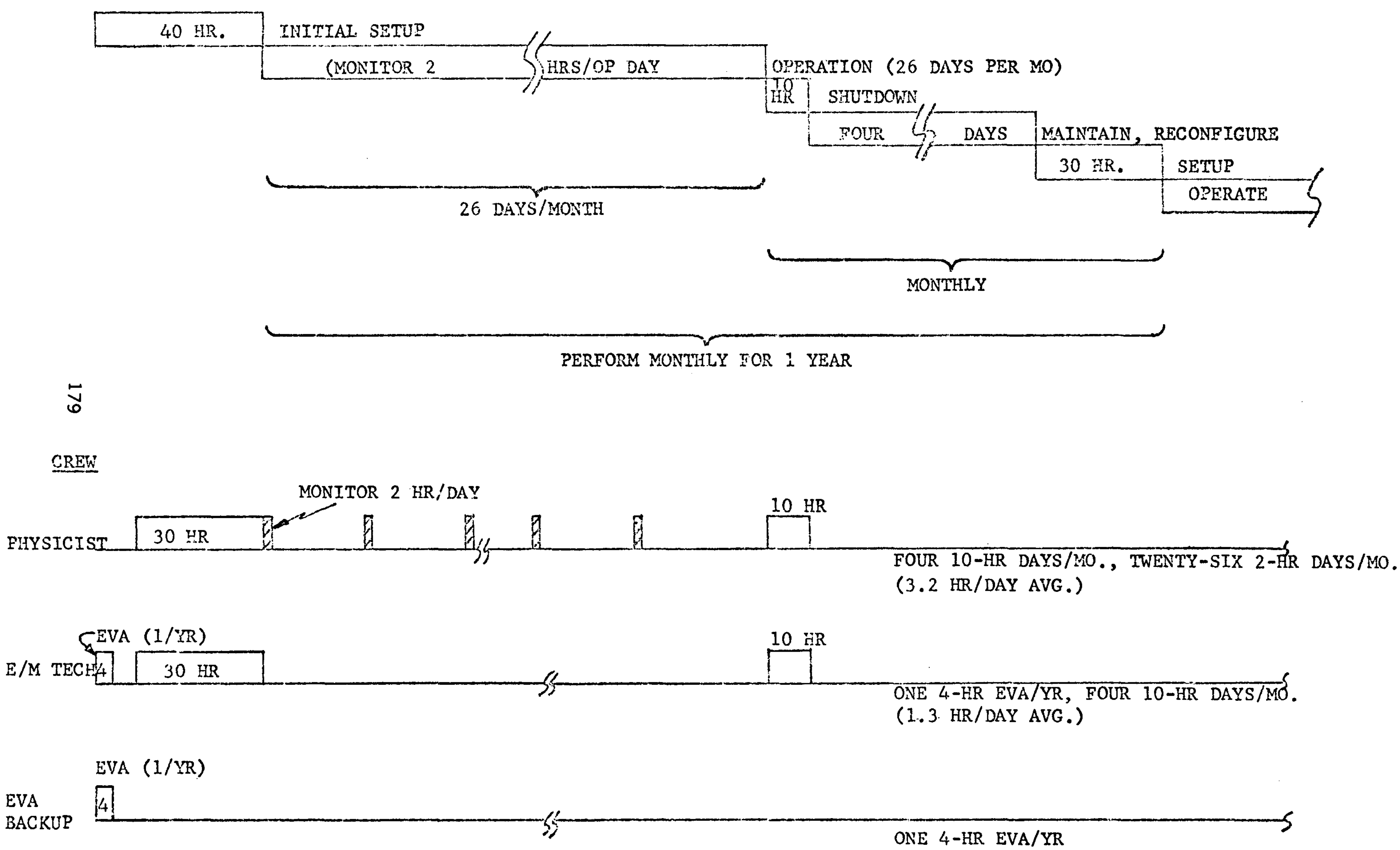
CREW



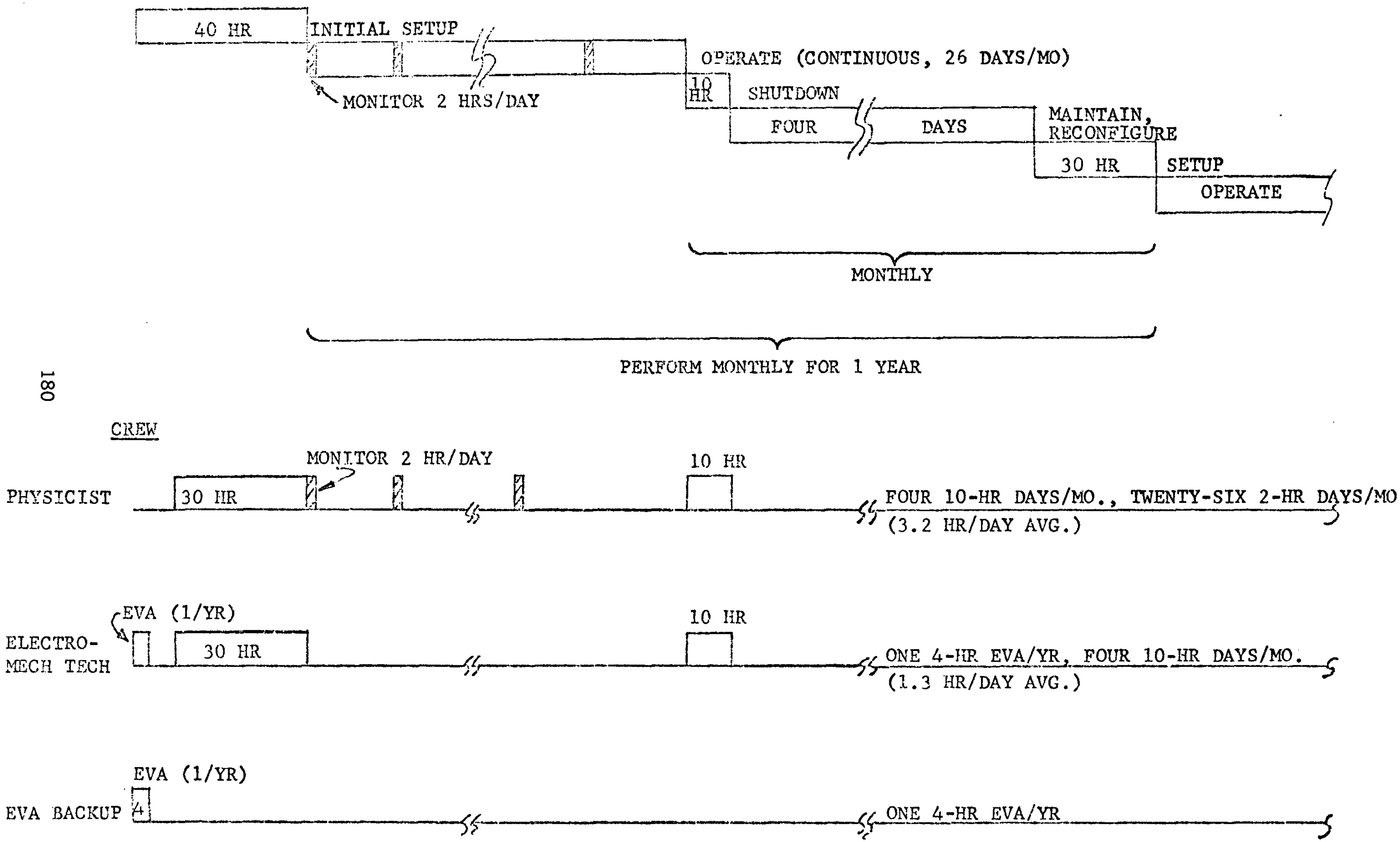
P-3 COSMIC RAY PHYSICS LAB



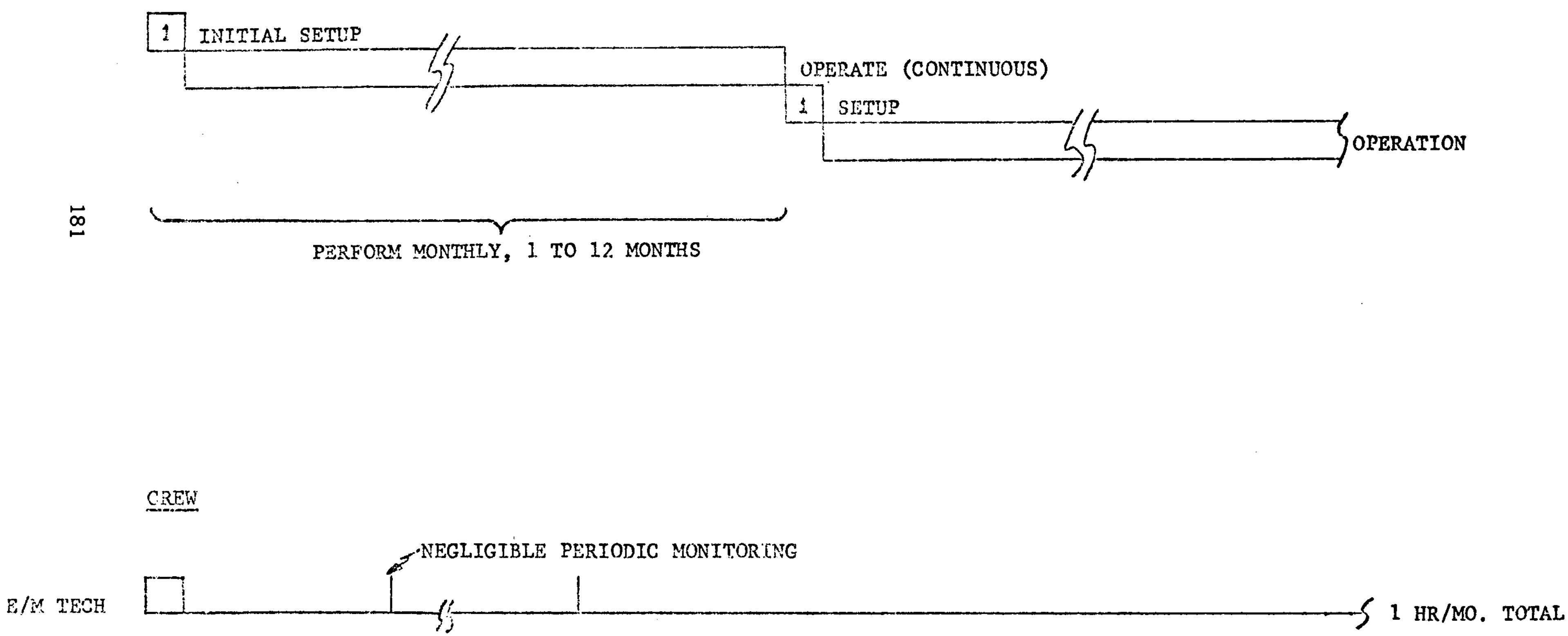
P-3A LAB WITHOUT TOTAL ABSORPTION DEVICE



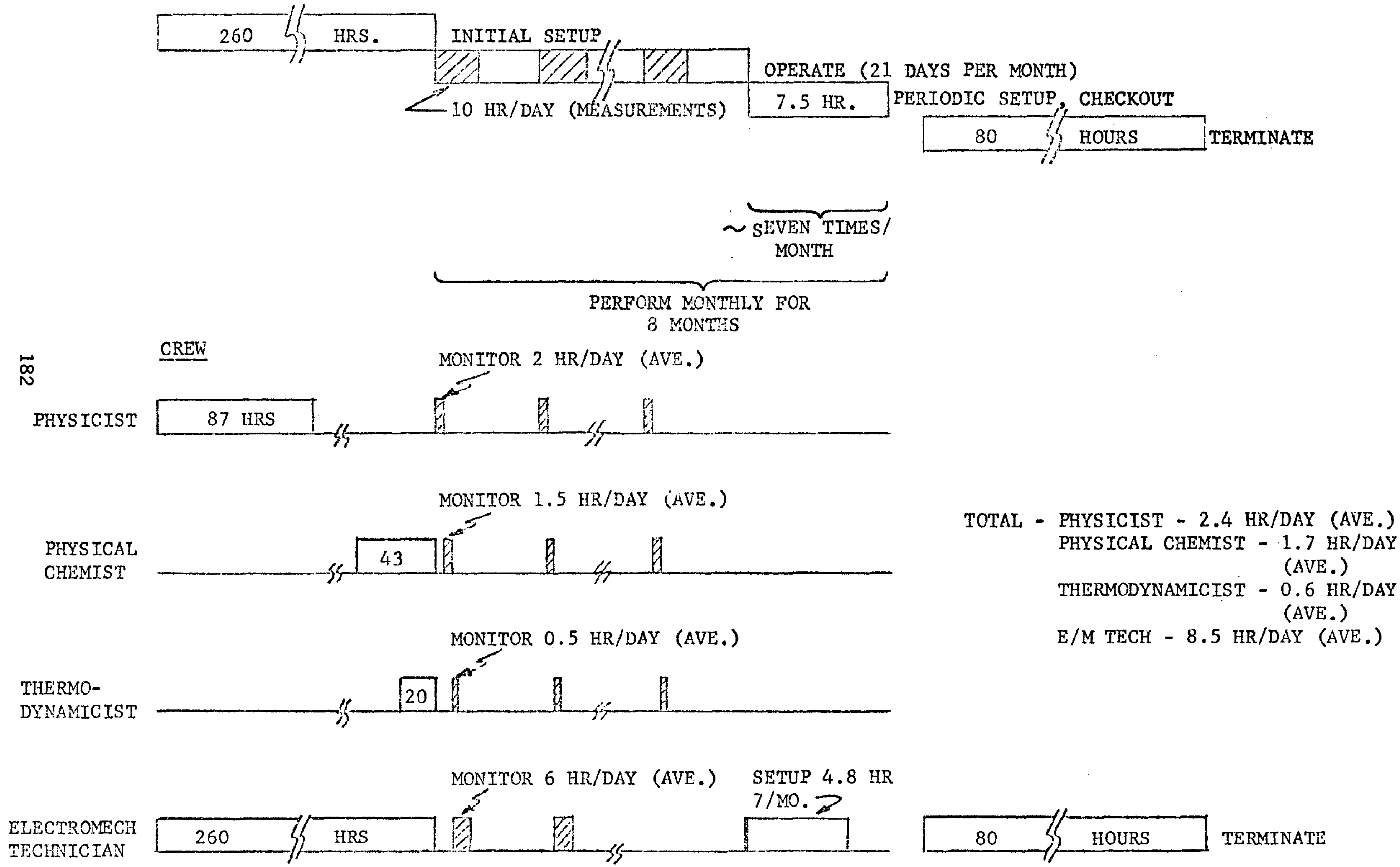
P-3B COSMIC RAY PHYSICS LAB WITH 1/2 TOTAL ABSORPTION DEVICE



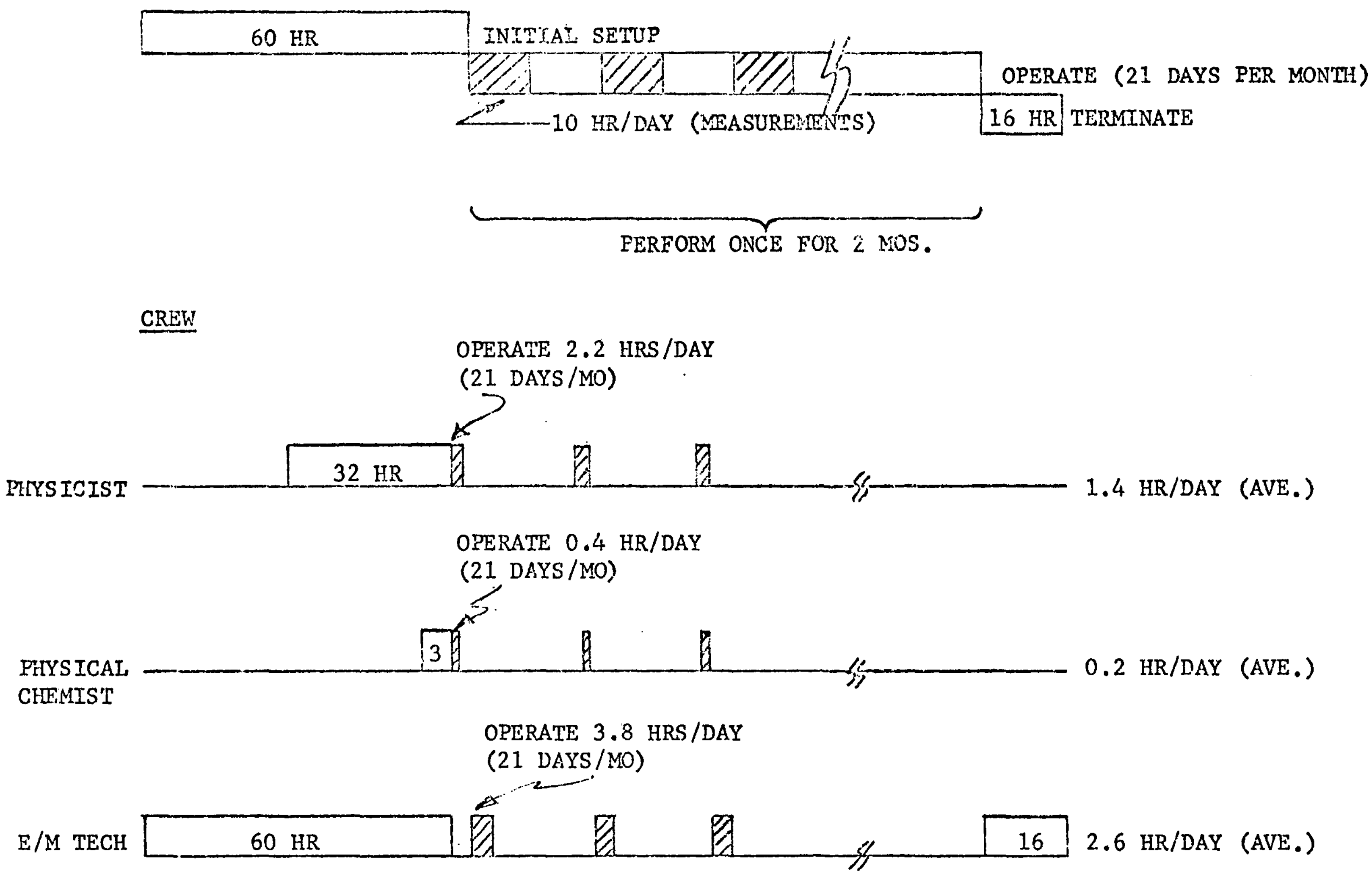
P-3C PLASTIC/NUCLEAR EMULSIONS ONLY



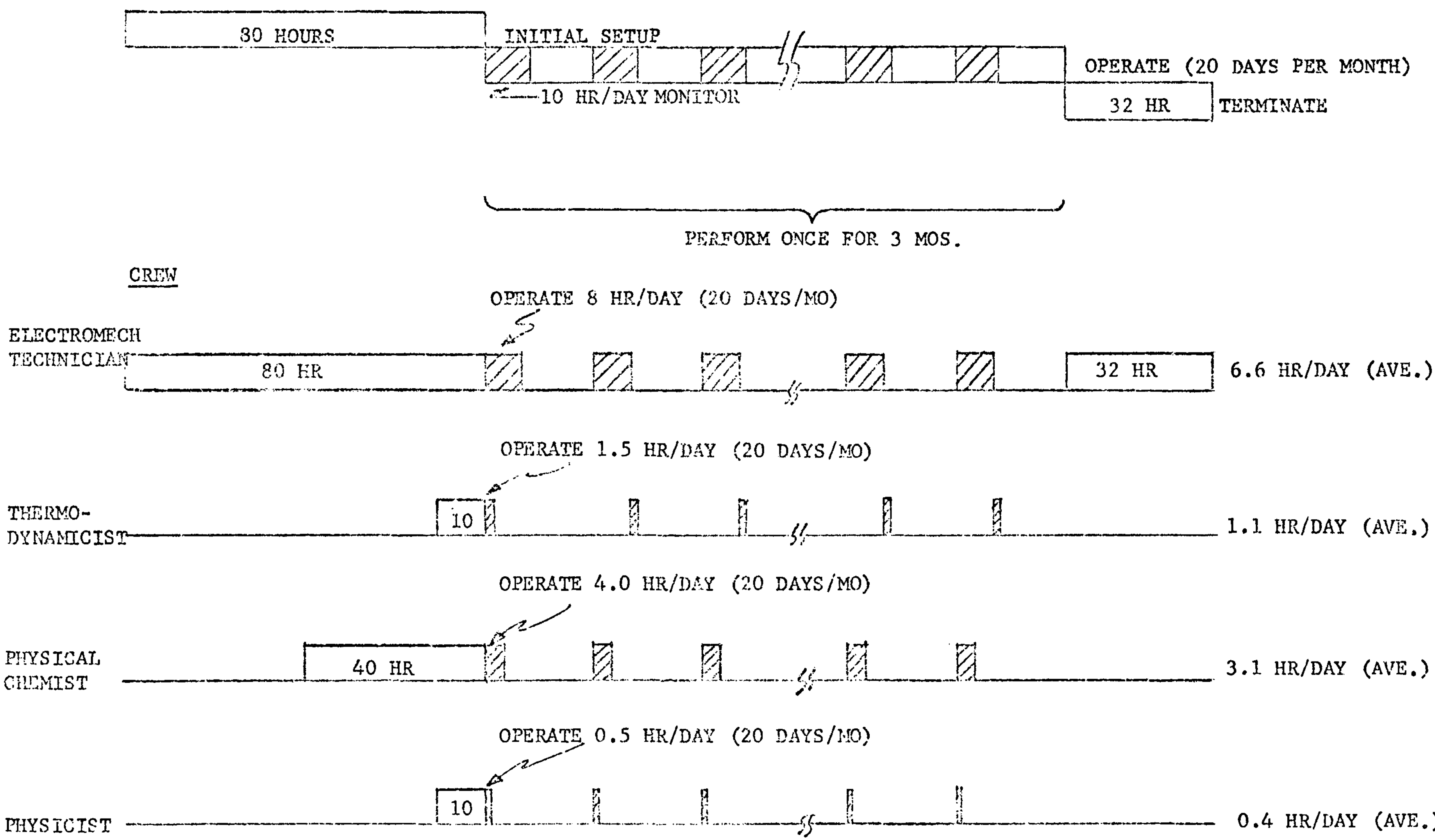
P-4 PHYSICS AND CHEMISTRY LAB



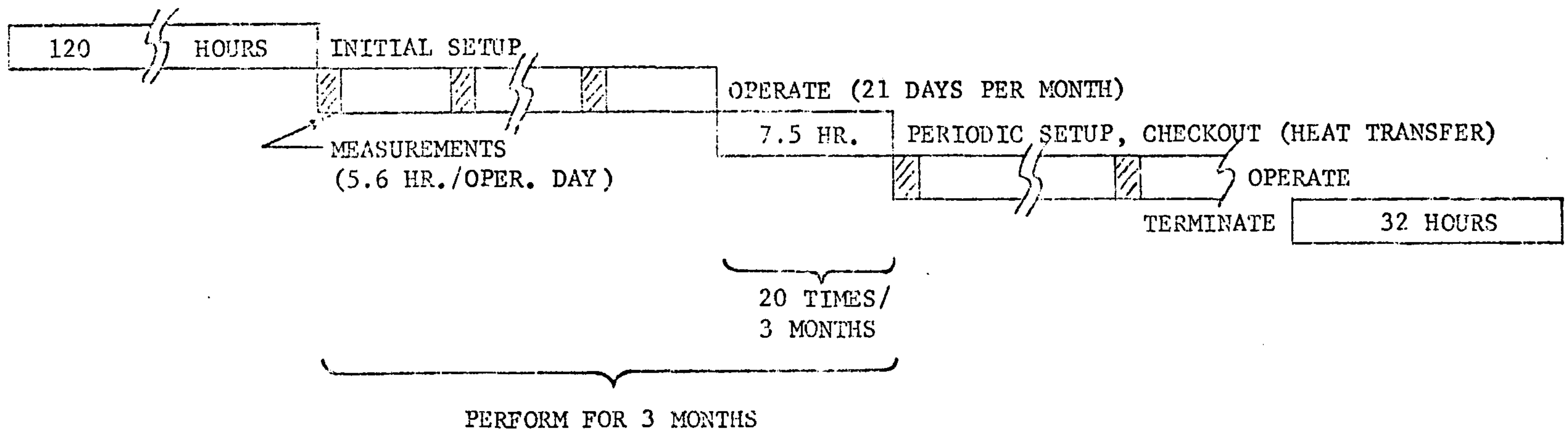
P-4A AIRLOCK & BOOM EXPERIMENTS



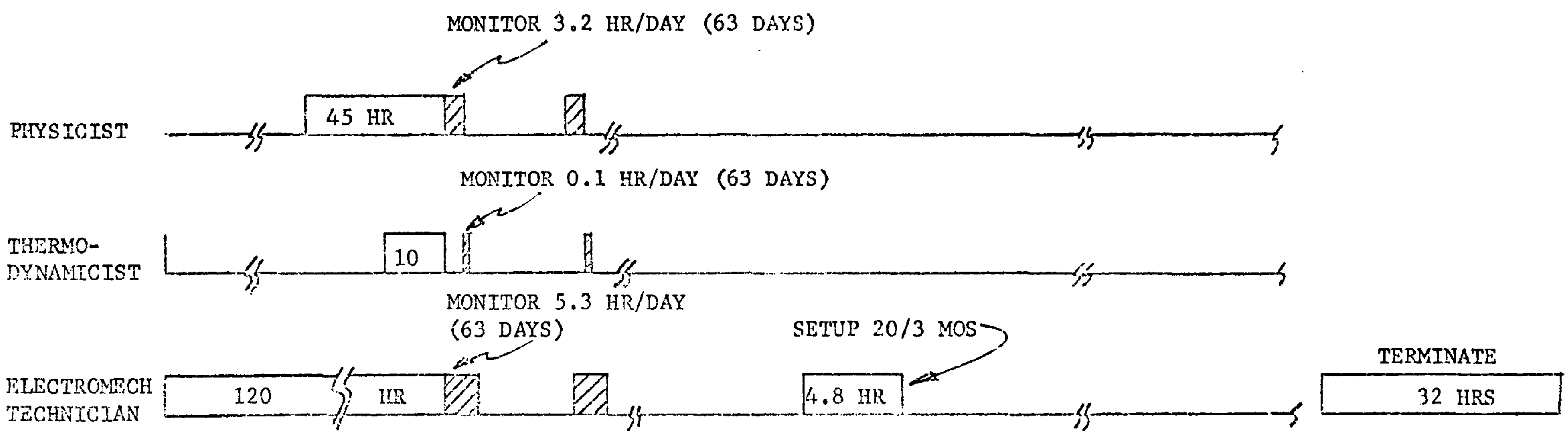
P-4B FLAME CHEMISTRY & LASER EXPERIMENTS



P-4C TEST CHAMBER EXPERIMENTS

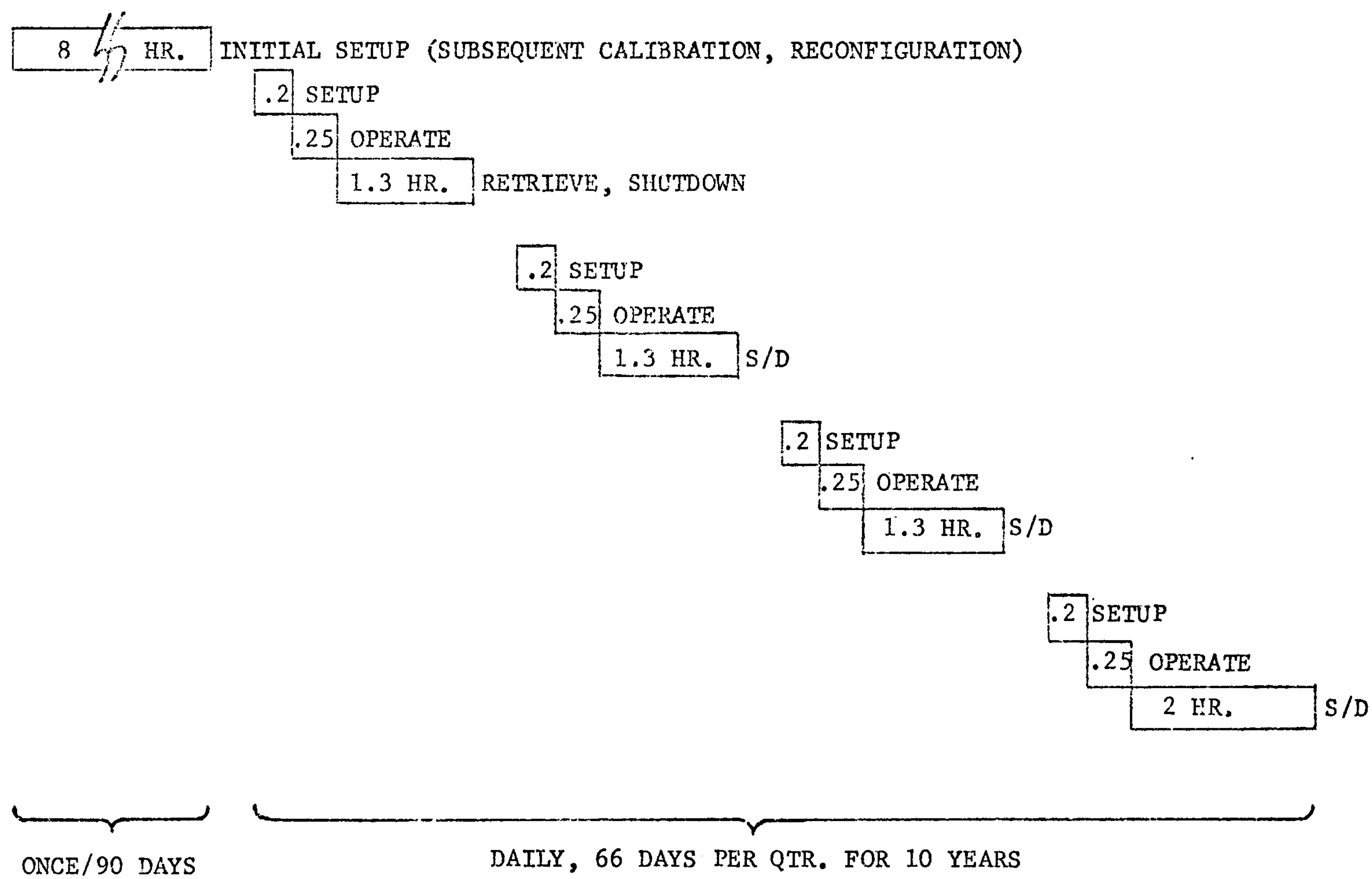


CREW



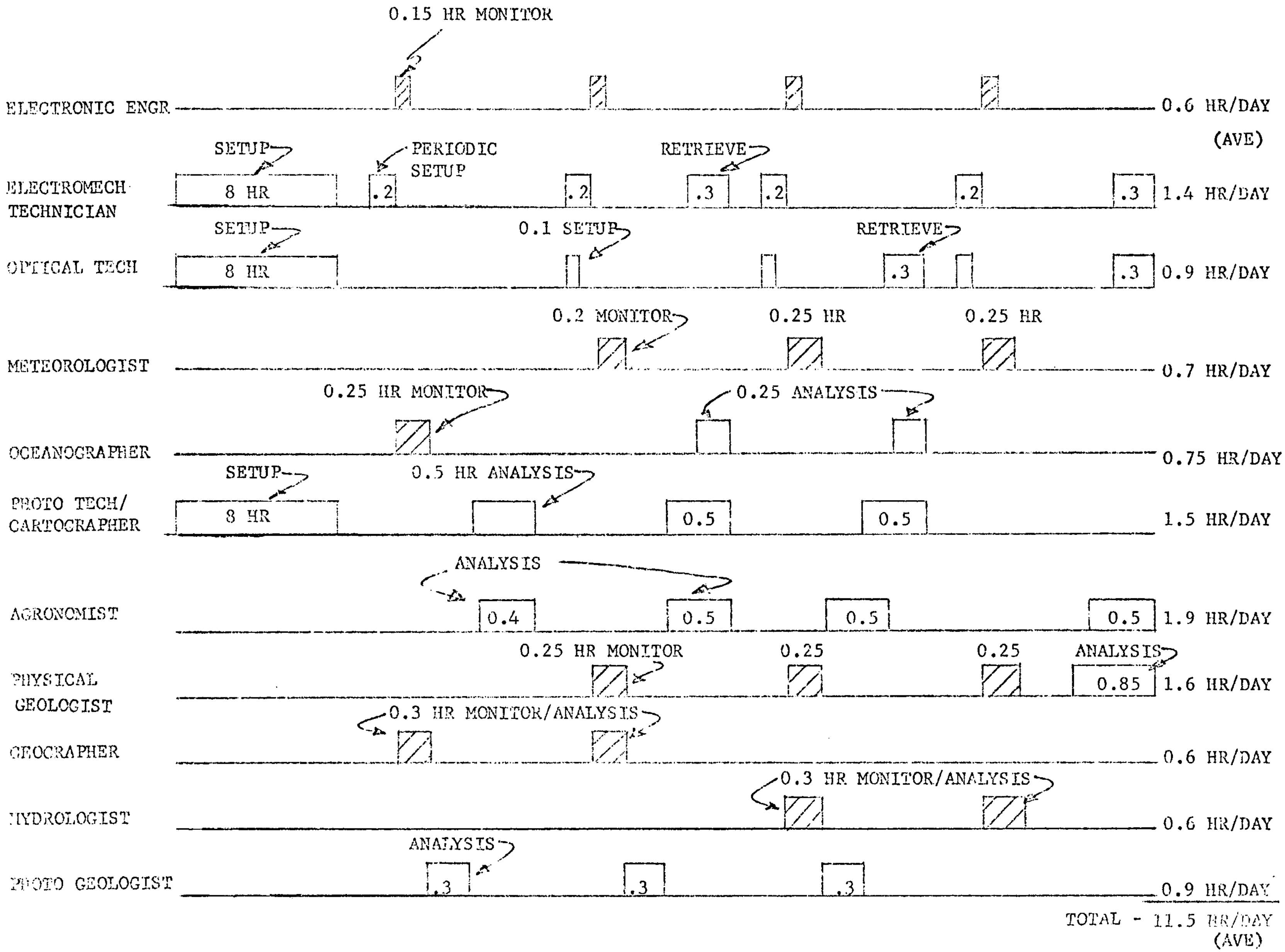
TOTAL - PHYSICIST - 2.2 HR/DAY (AVE.)
THERMODYNAMICIST - 0.2 HR/DAY (AVE.)
E/M TECH - 6.4 HR/DAY (AVE.)

ES-1 EARTH OBSERVATION FACILITY

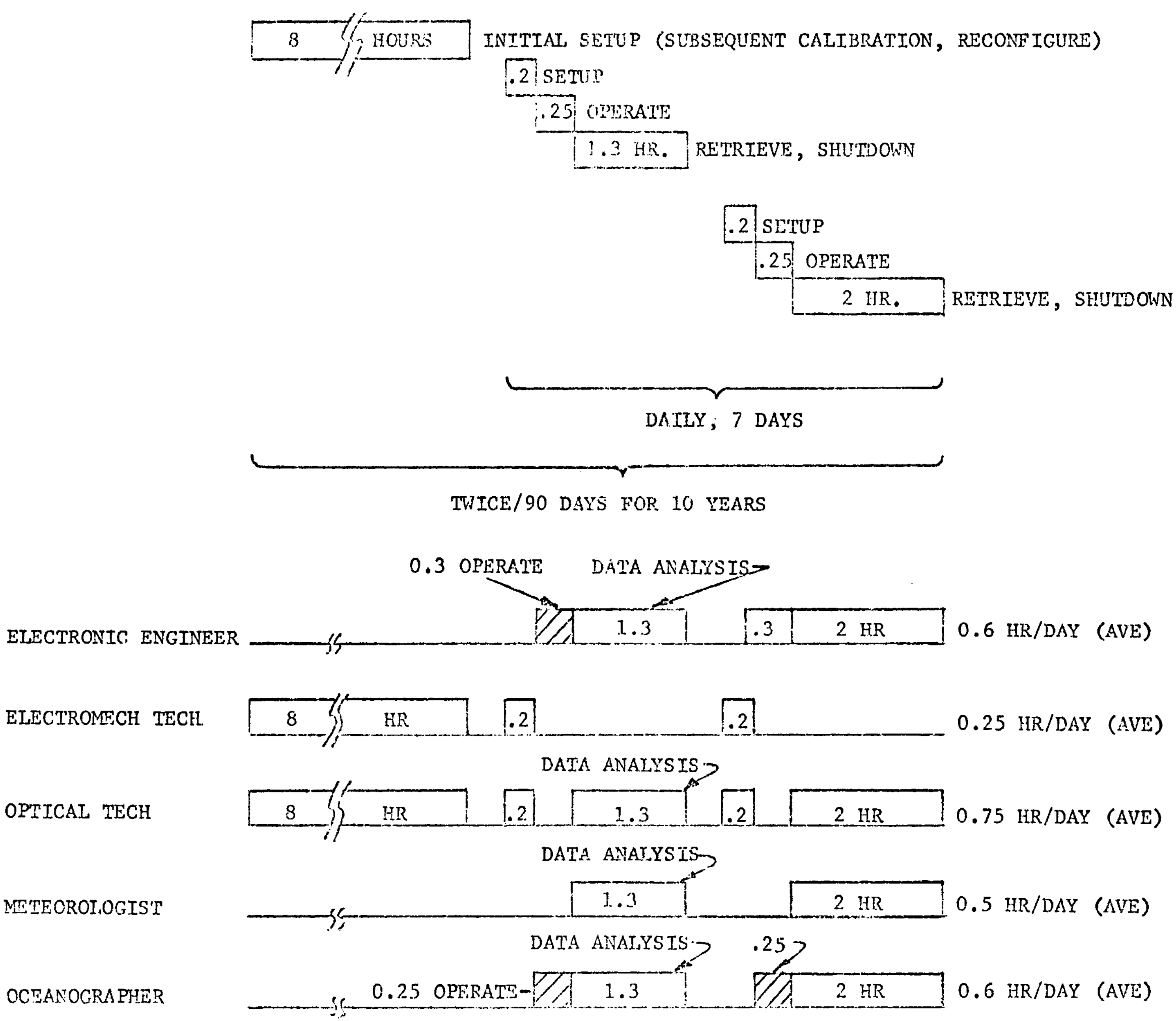


ES-1 EARTH OBSERVATION FACILITY

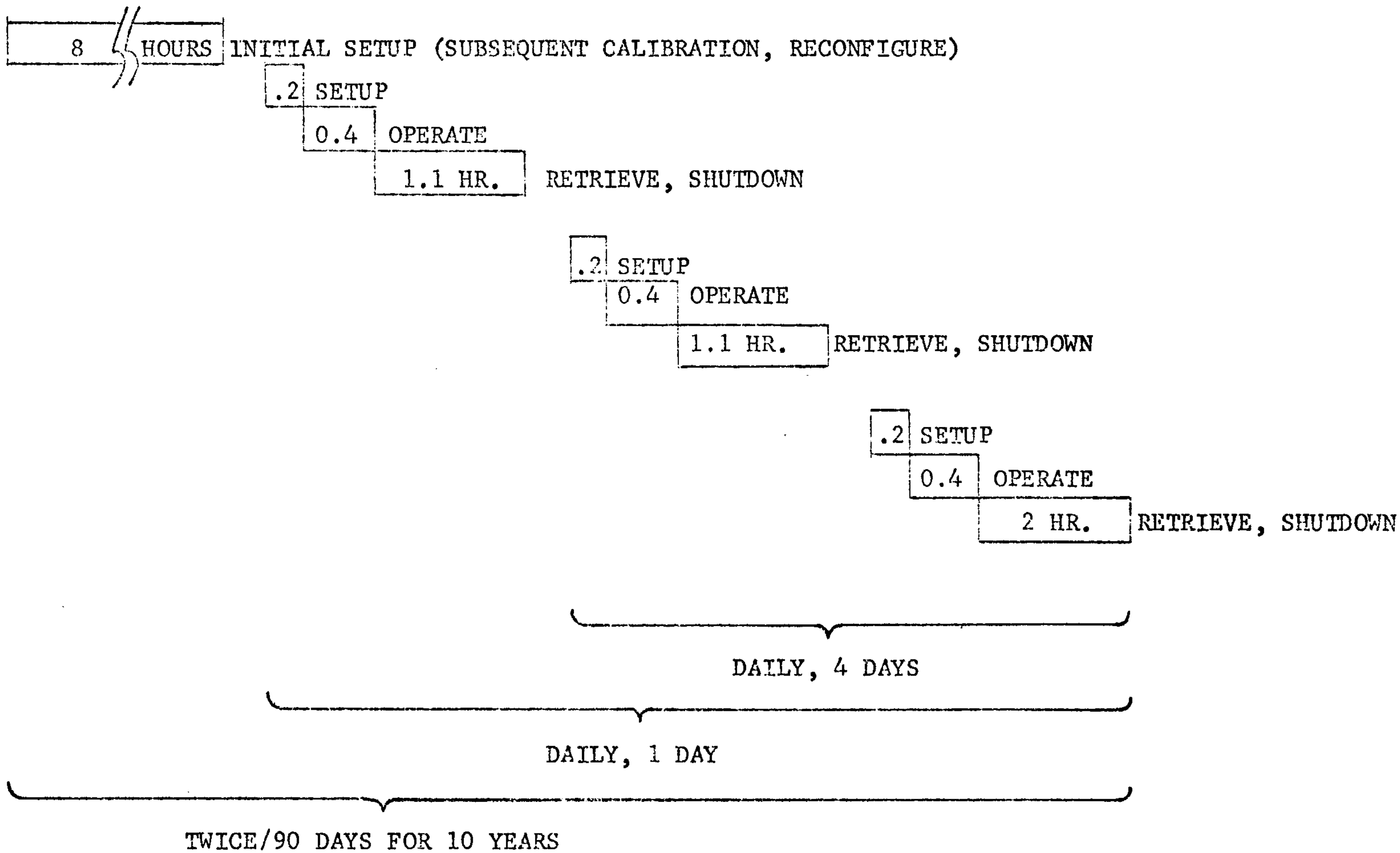
CREW



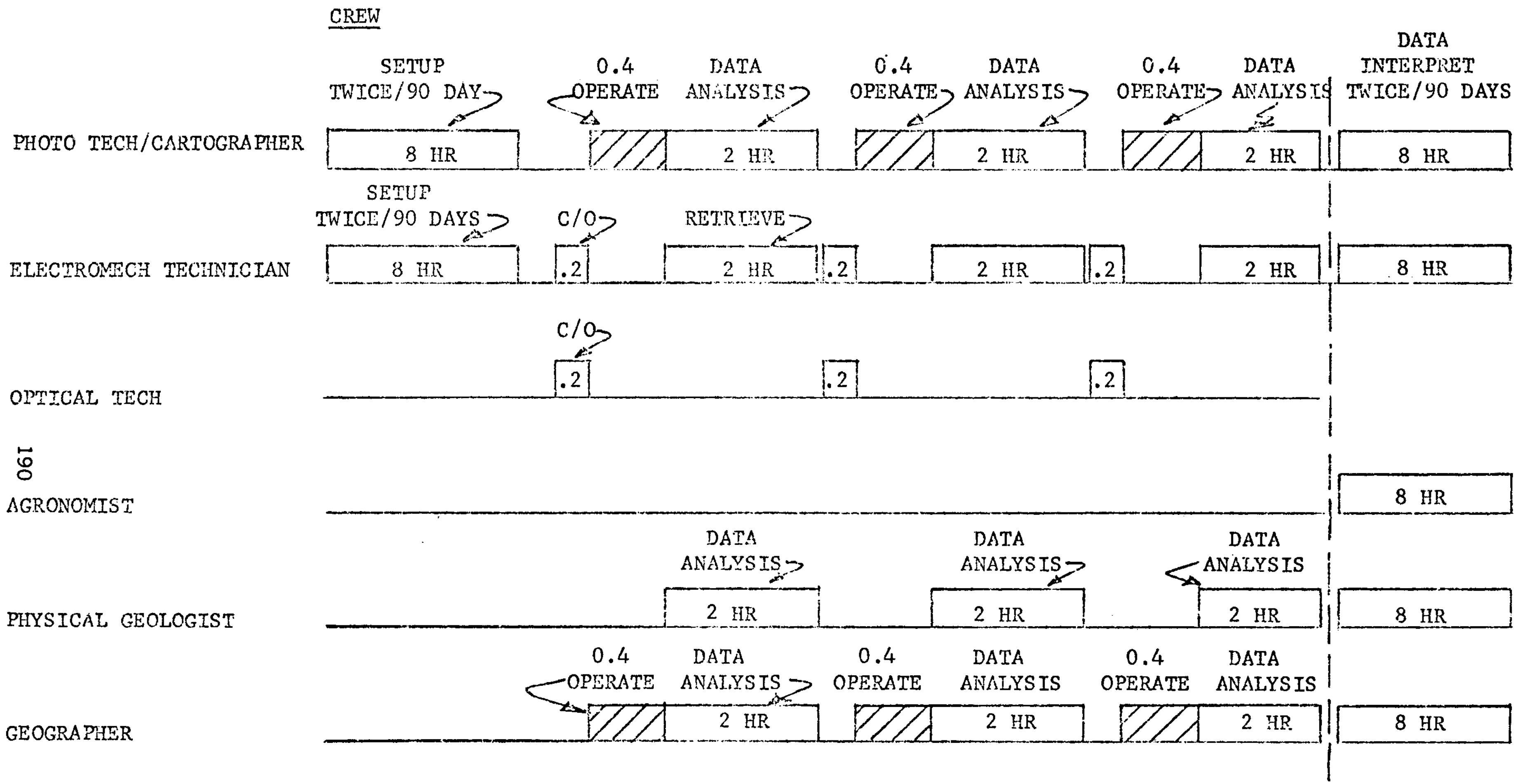
ES-1A METEOROLOGY & ATMOSPHERE



ES-1B LAND USE

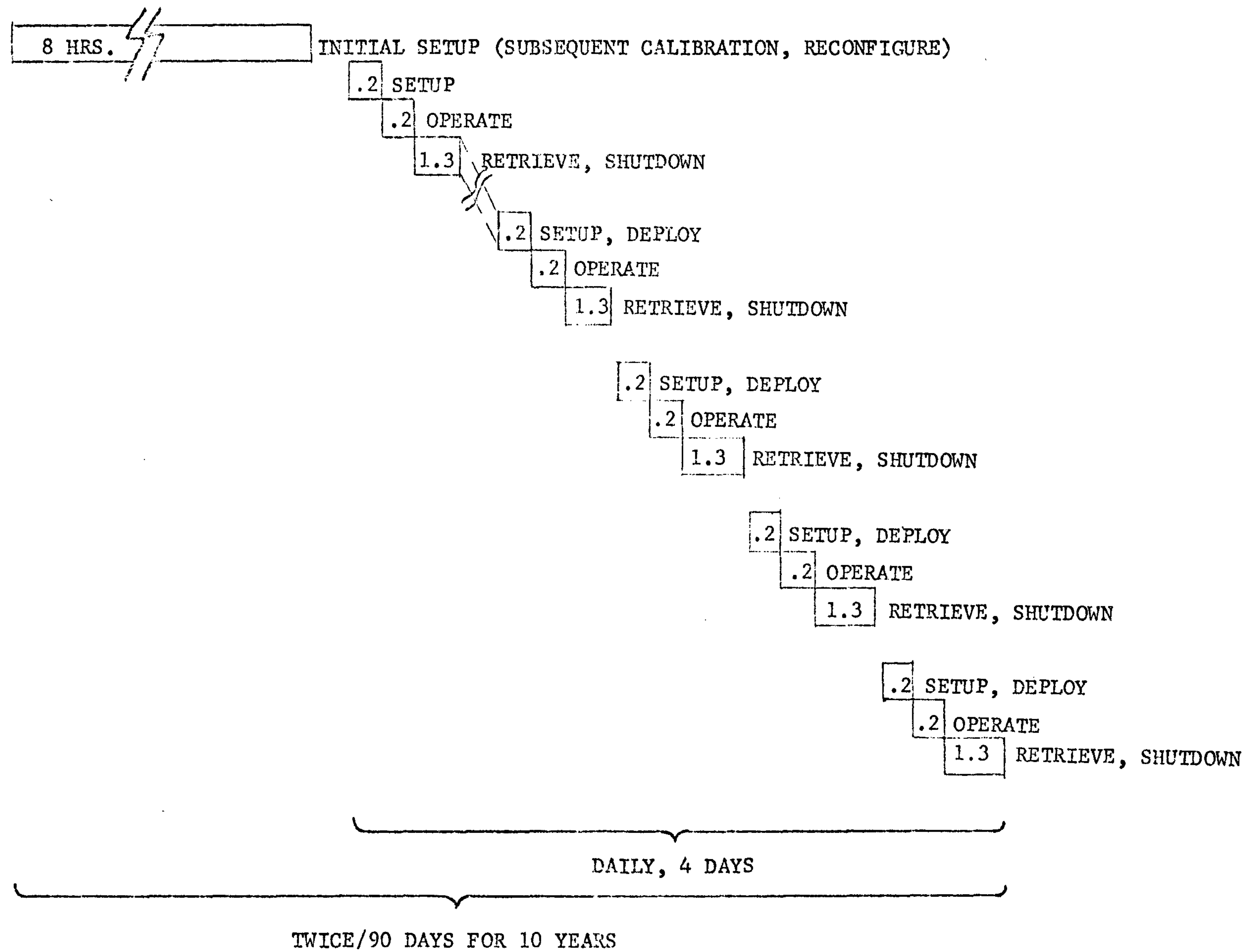


ES-1B LAND USE



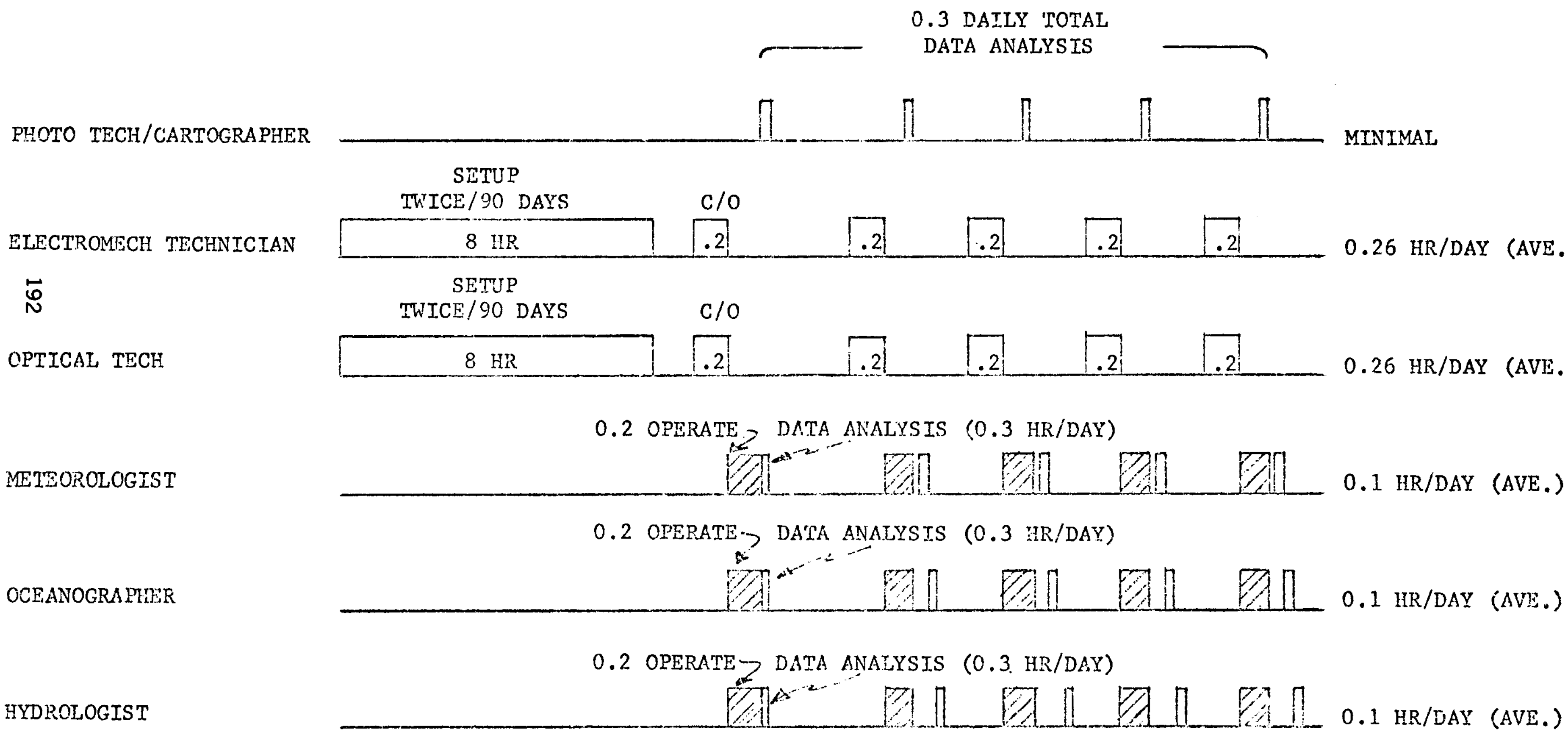
TOTAL - PHOTO TECH/CARTOGRAPHER - 0.9 HR/DAY (AVE.)
E/M TECH - 0.9 HR/DAY (AVE.)
OPTICAL TECH - MINIMAL
AGRONOMIST - 0.2 HR/DAY (AVE.)
PHYSICAL GEOLOGIST - 0.7 HR/DAY (AVE.)
GEOGRAPHER - 0.75 HR/DAY (AVE.)

ES-1C POLLUTION

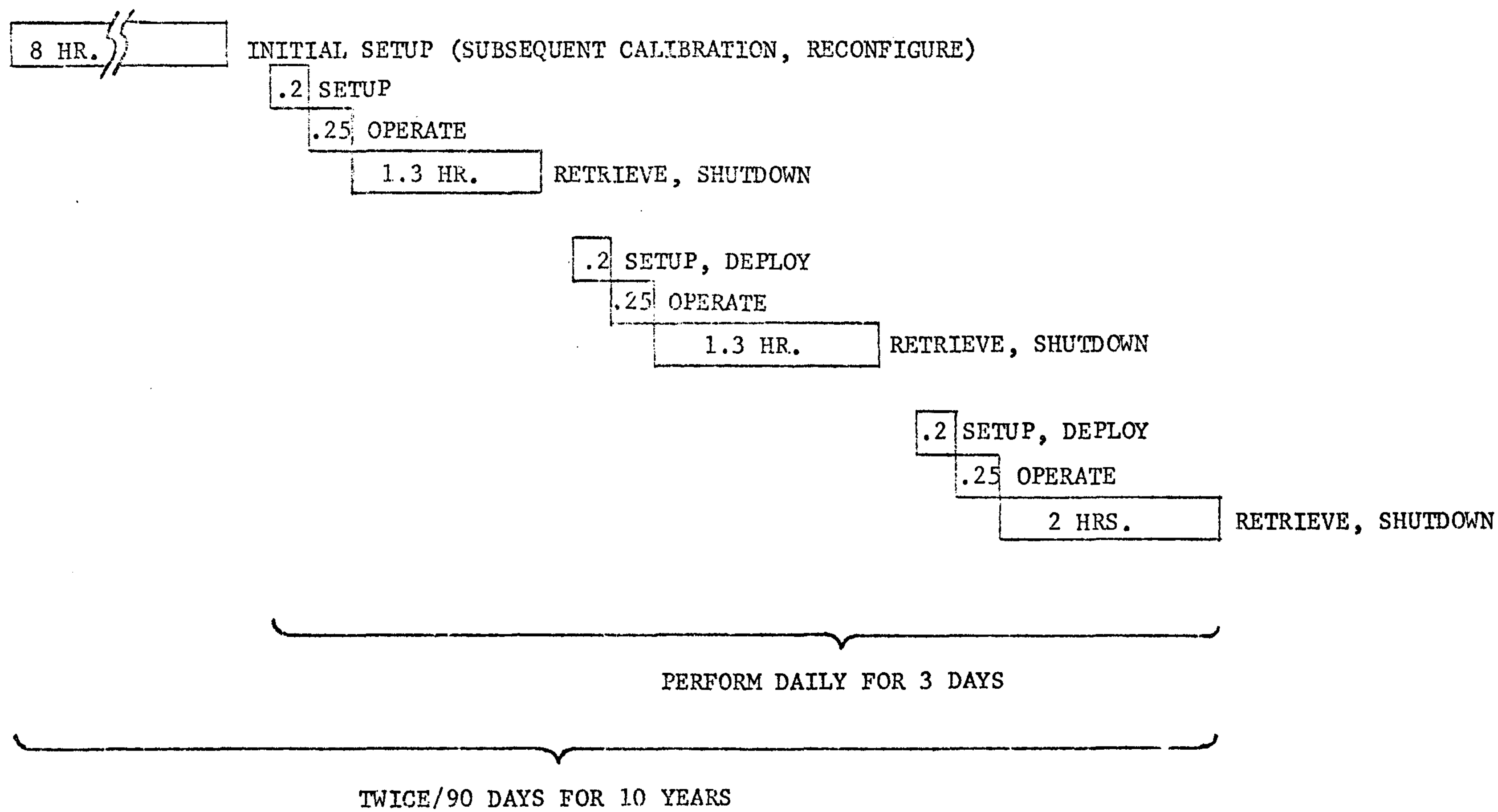


ES-1C POLLUTION

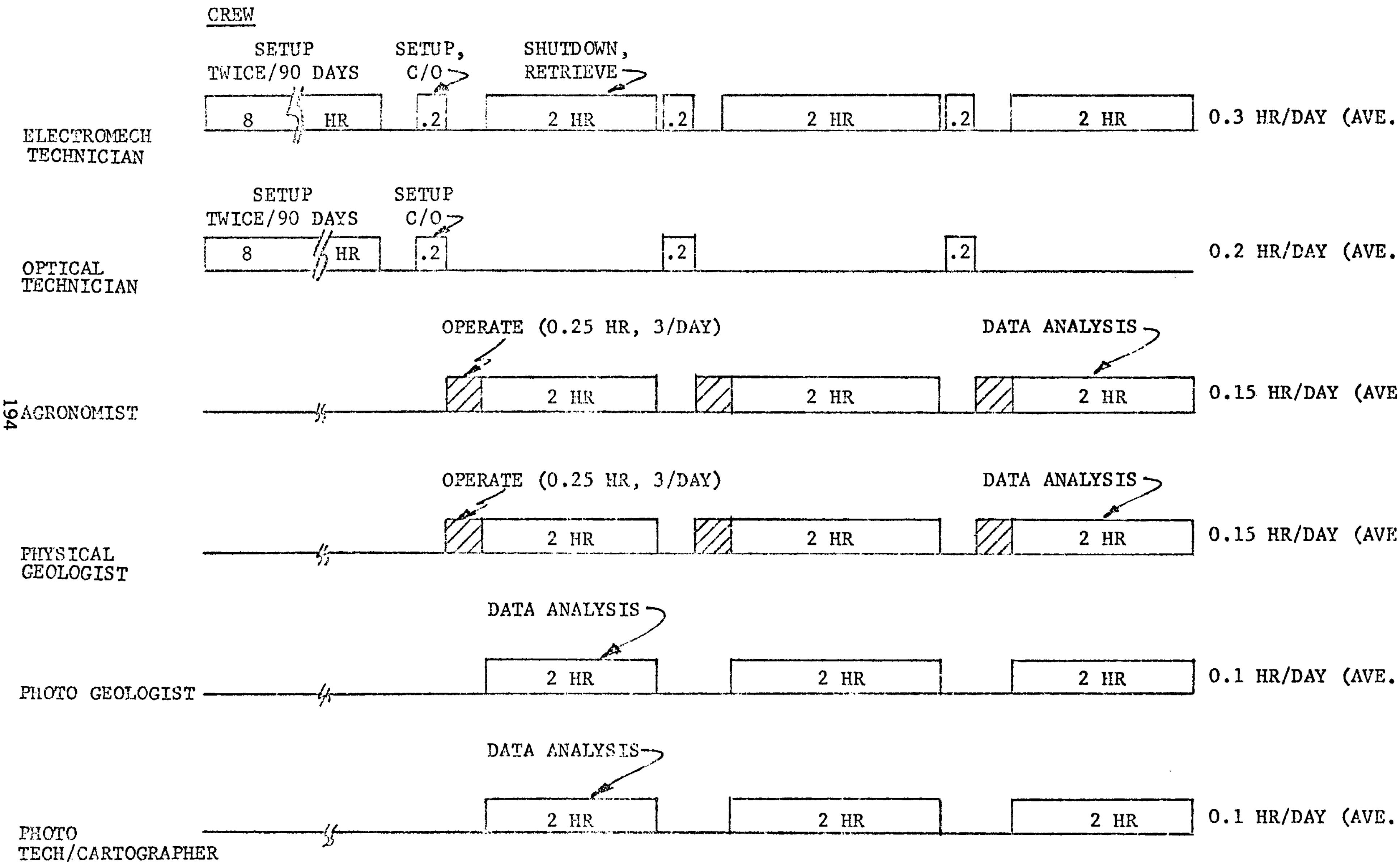
CREW



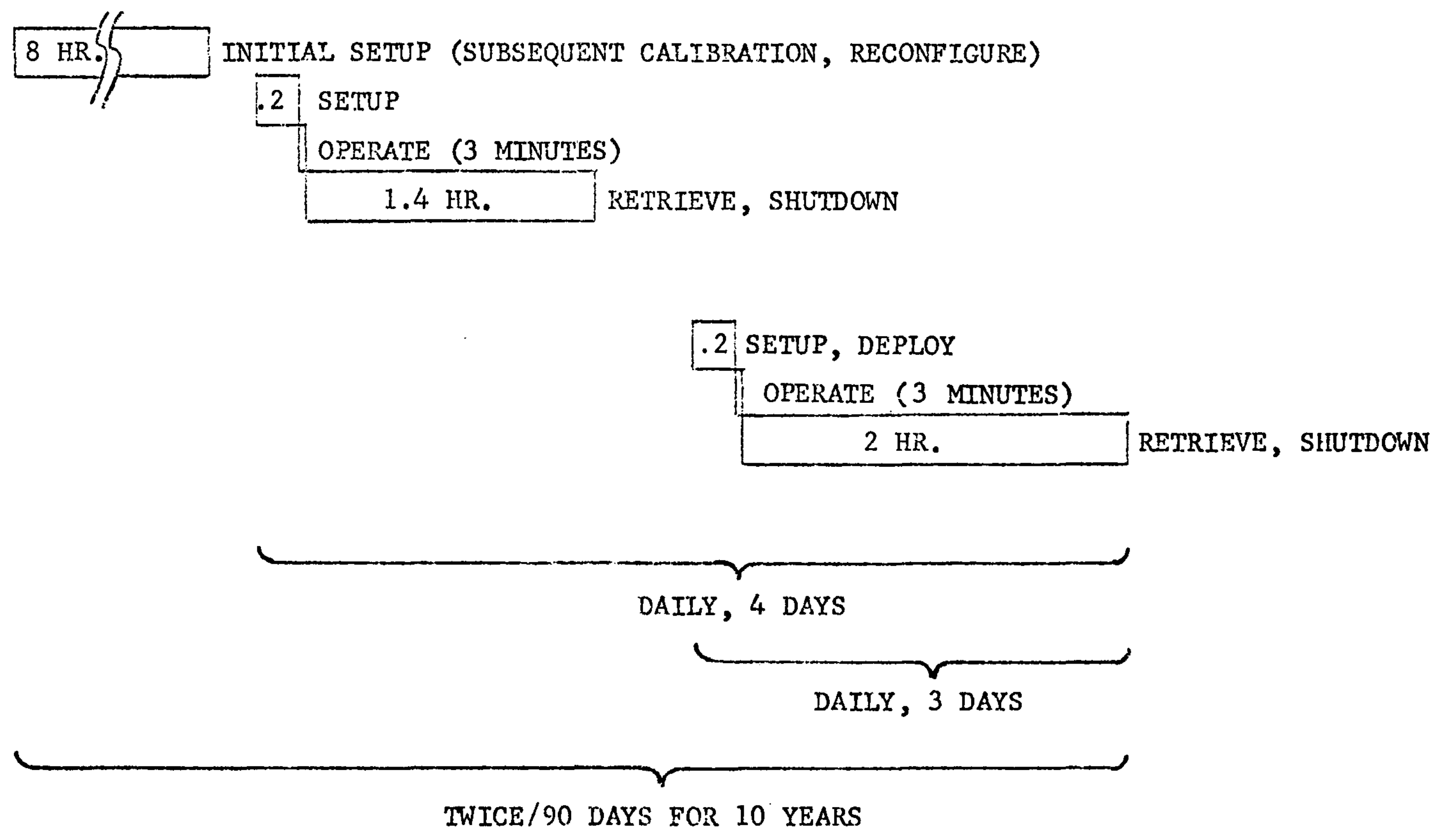
ES-1D RESOURCE RECOGNITION

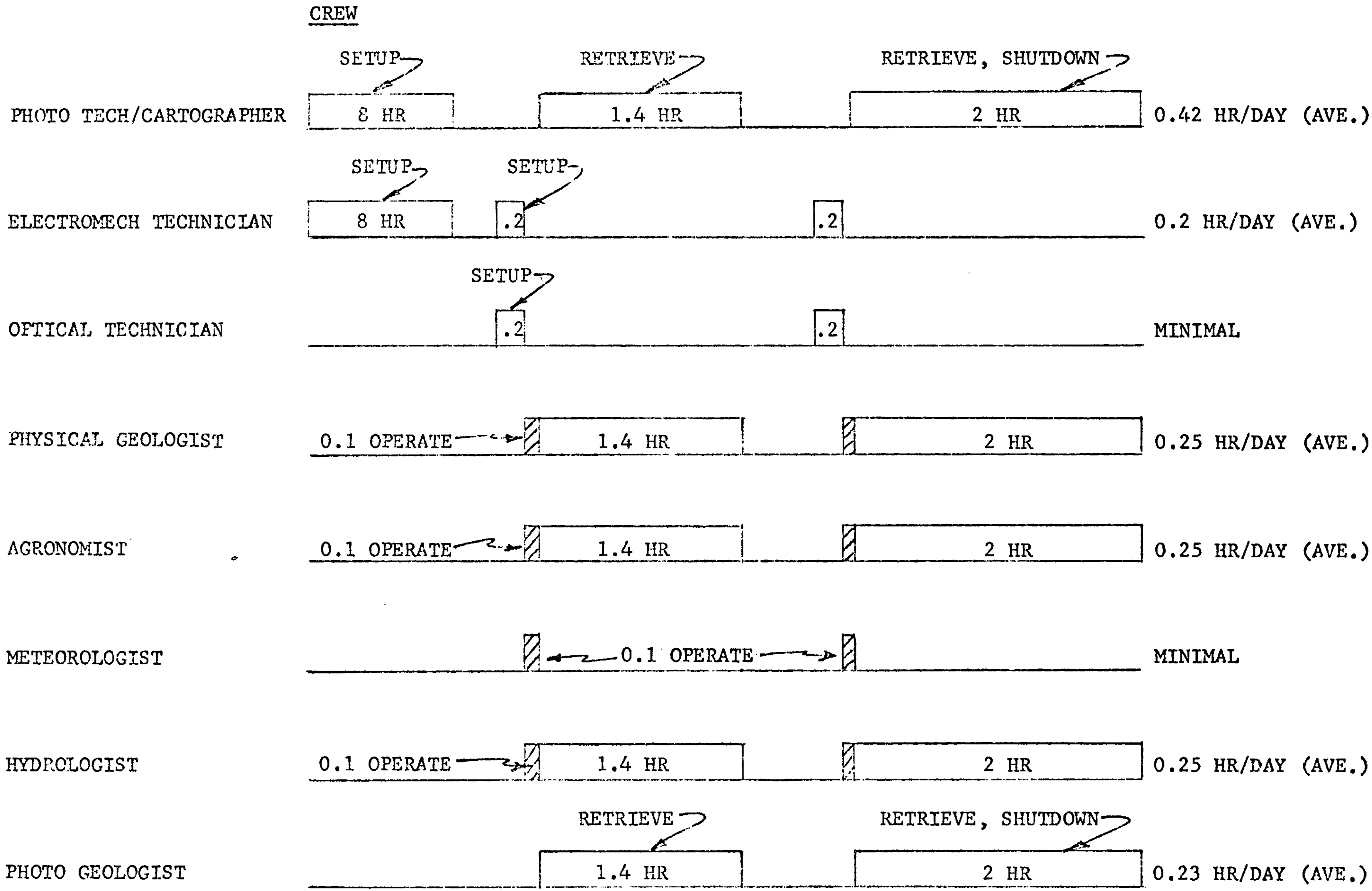


ES-1D RESOURCE RECOGNITION



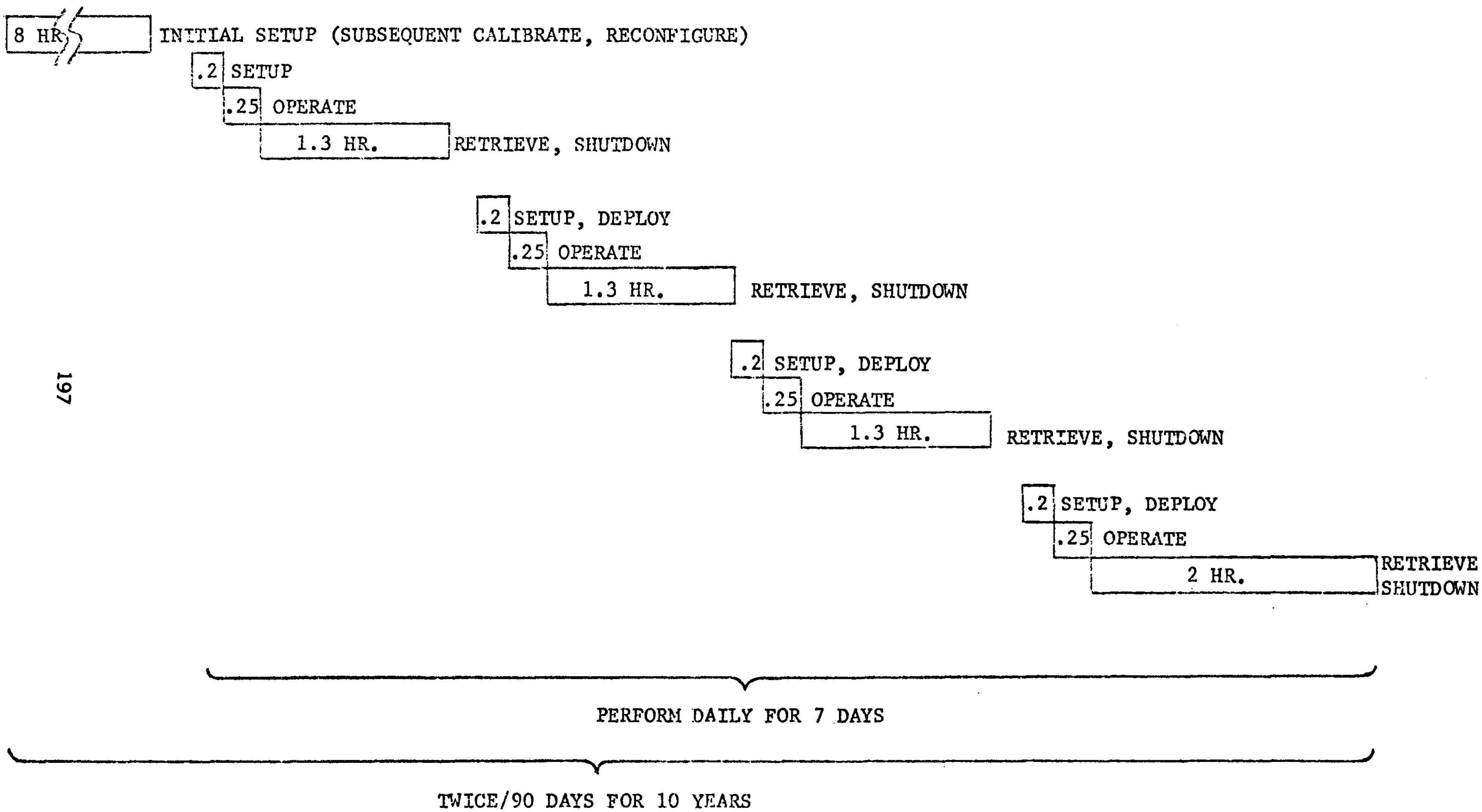
ES-1E DISASTERS





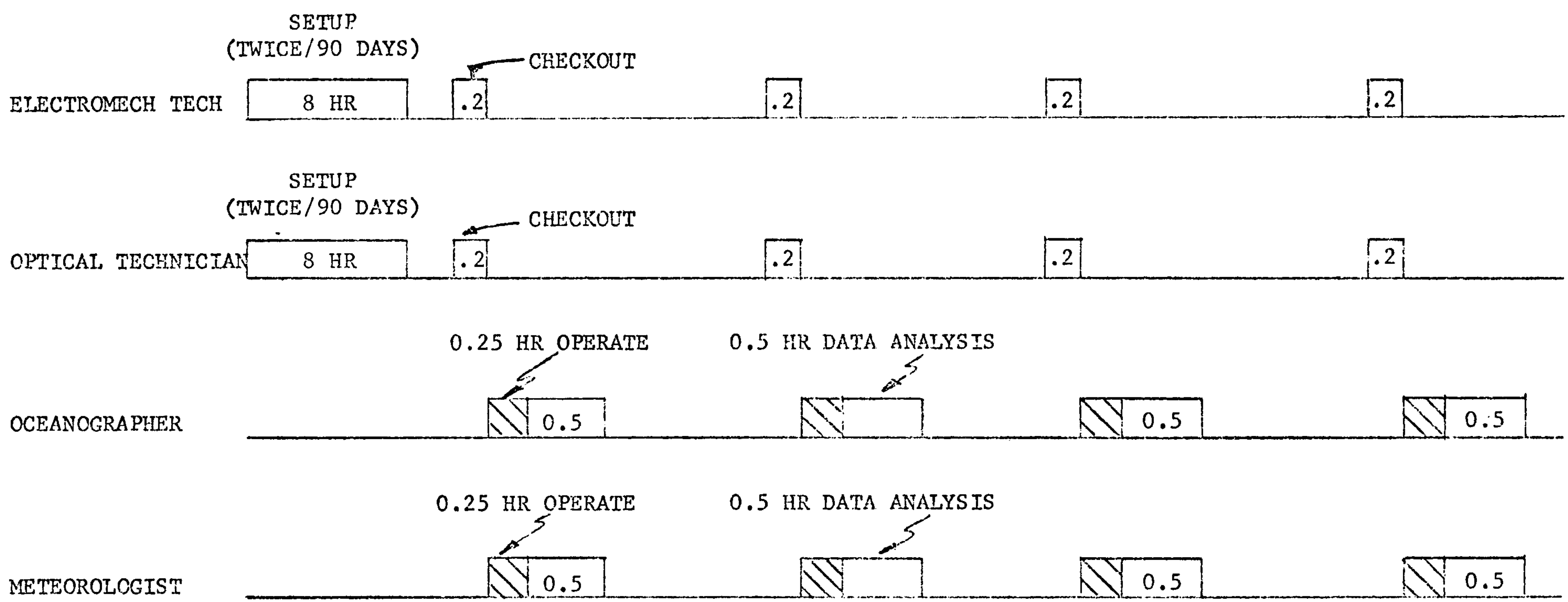
CREW
PHOTO TECH/CARTOGRAPHER
SETUP
8 HR
RETRIEVE
1.4 HR
RETRIEVE, SHUTDOWN
2 HR
0.42 HR/DAY (AVE.)
ELECTROMECH TECHNICIAN
SETUP
8 HR
SETUP
.2
.2
0.2 HR/DAY (AVE.)
OPTICAL TECHNICIAN
SETUP
.2
.2
MINIMAL
PHYSICAL GEOLOGIST
0.1 OPERATE
1.4 HR
2 HR
0.25 HR/DAY (AVE.)
AGRONOMIST
0.1 OPERATE
1.4 HR
2 HR
0.25 HR/DAY (AVE.)
METEOROLOGIST
0.1 OPERATE
MINIMAL
HYDROLOGIST
0.1 OPERATE
1.4 HR
2 HR
0.25 HR/DAY (AVE.)
PHOTO GEOLOGIST
RETRIEVE
1.4 HR
RETRIEVE, SHUTDOWN
2 HR
0.23 HR/DAY (AVE.)

ES-1. OCEAN RESOURCES



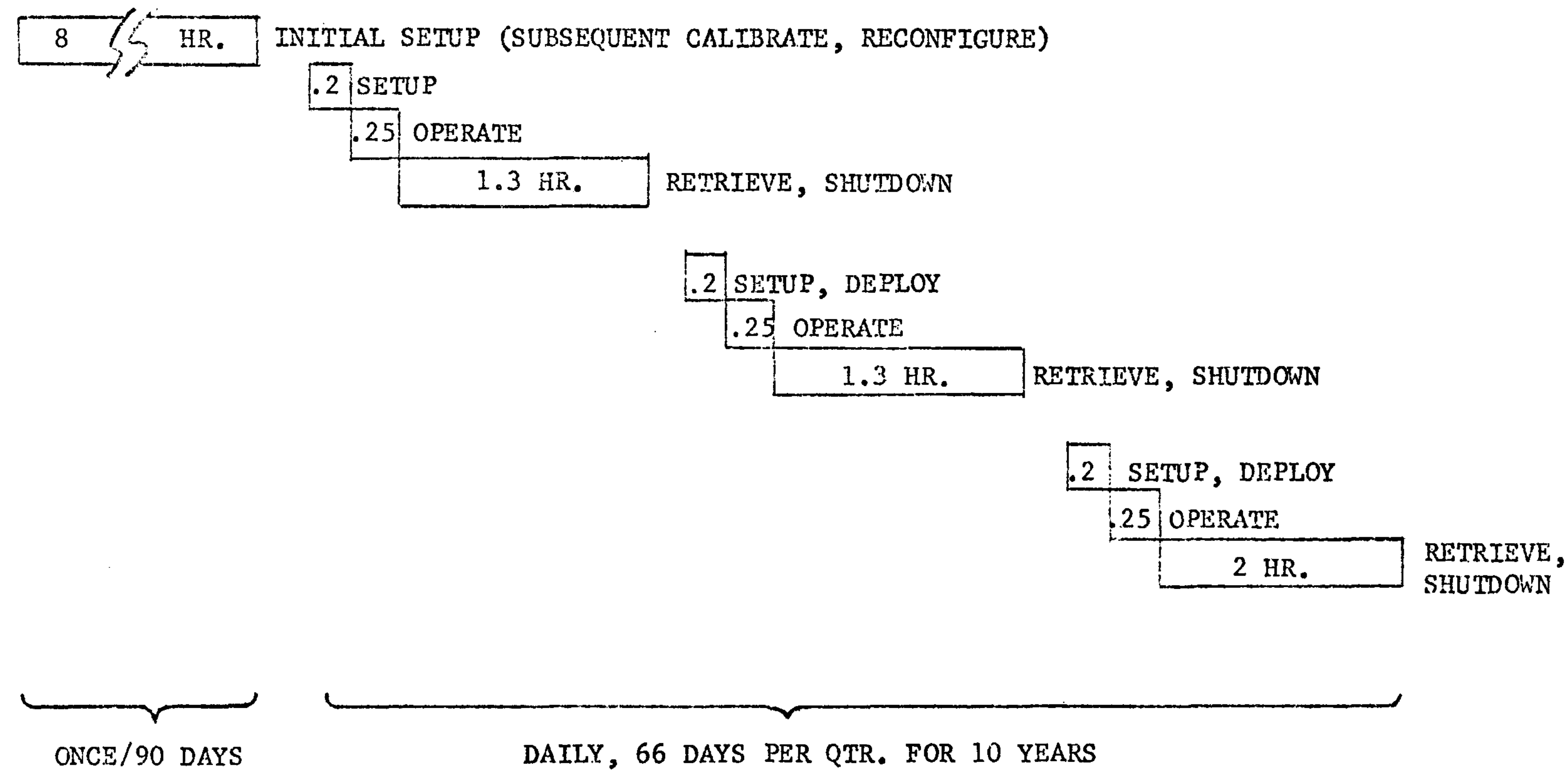
ES-1F OCEAN RESOURCES

CREW

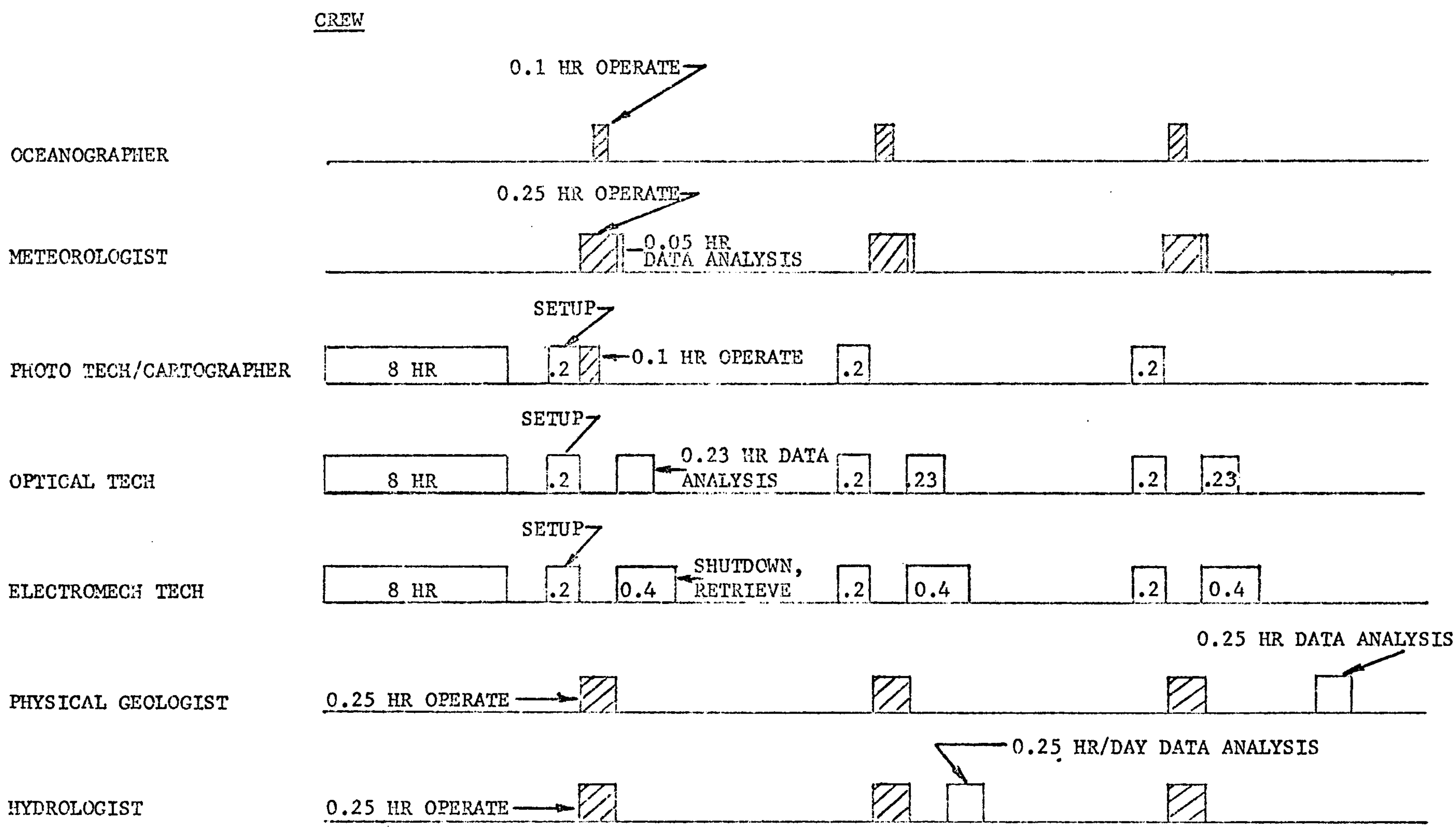


TOTAL - E/M TECH - 0.3 HR/DAY (AVE.)
OPTICAL TECHNICIAN - 0.3 HR/DAY (AVE.)
OCEANOGRAPHER - 0.46 HR/DAY (AVE.)
METEOROLOGIST - 0.46 HR/DAY (AVE.)

ES-1G MINIMUM PAYLOAD

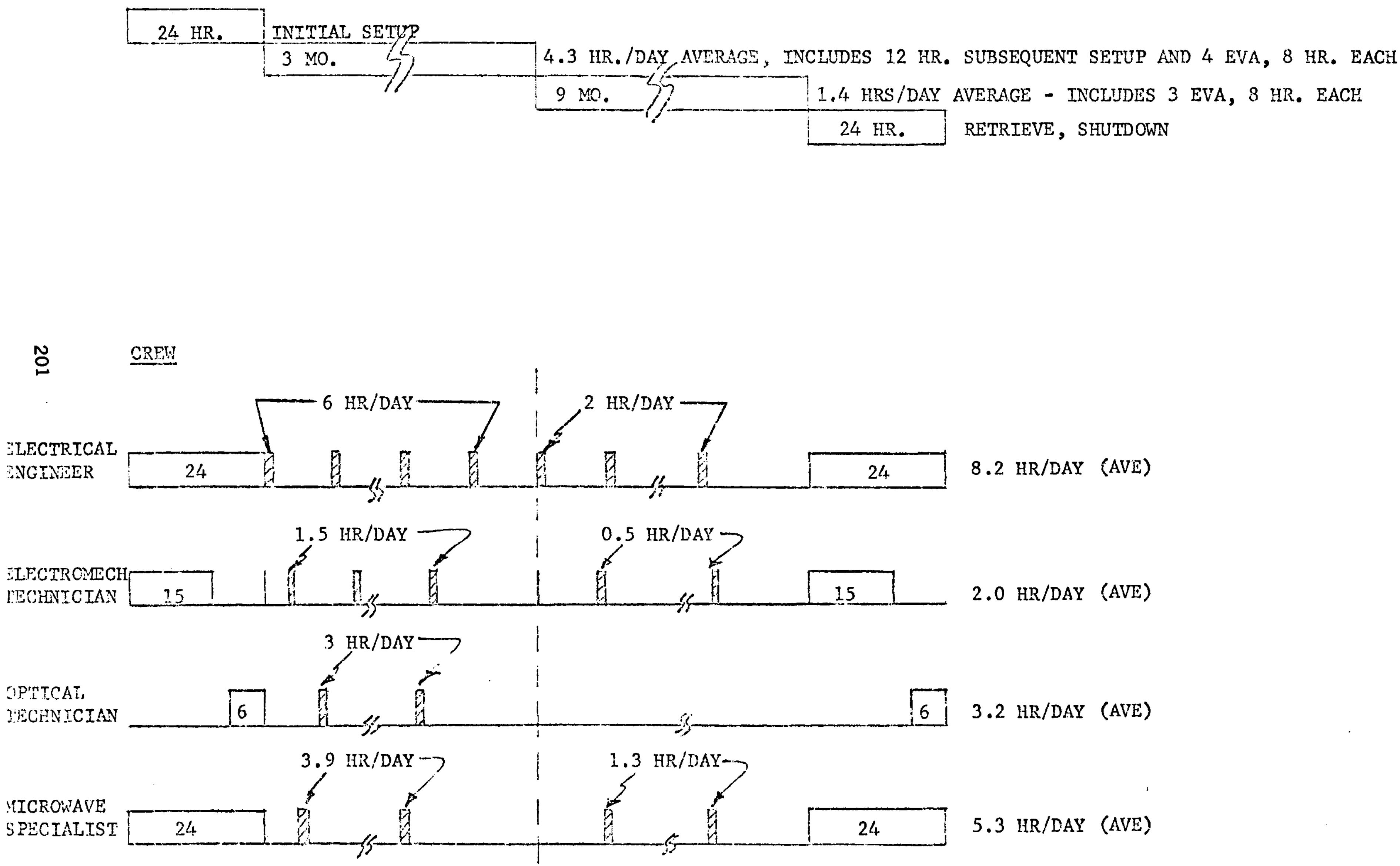


ES-1G MINIMUM PAYLOAD

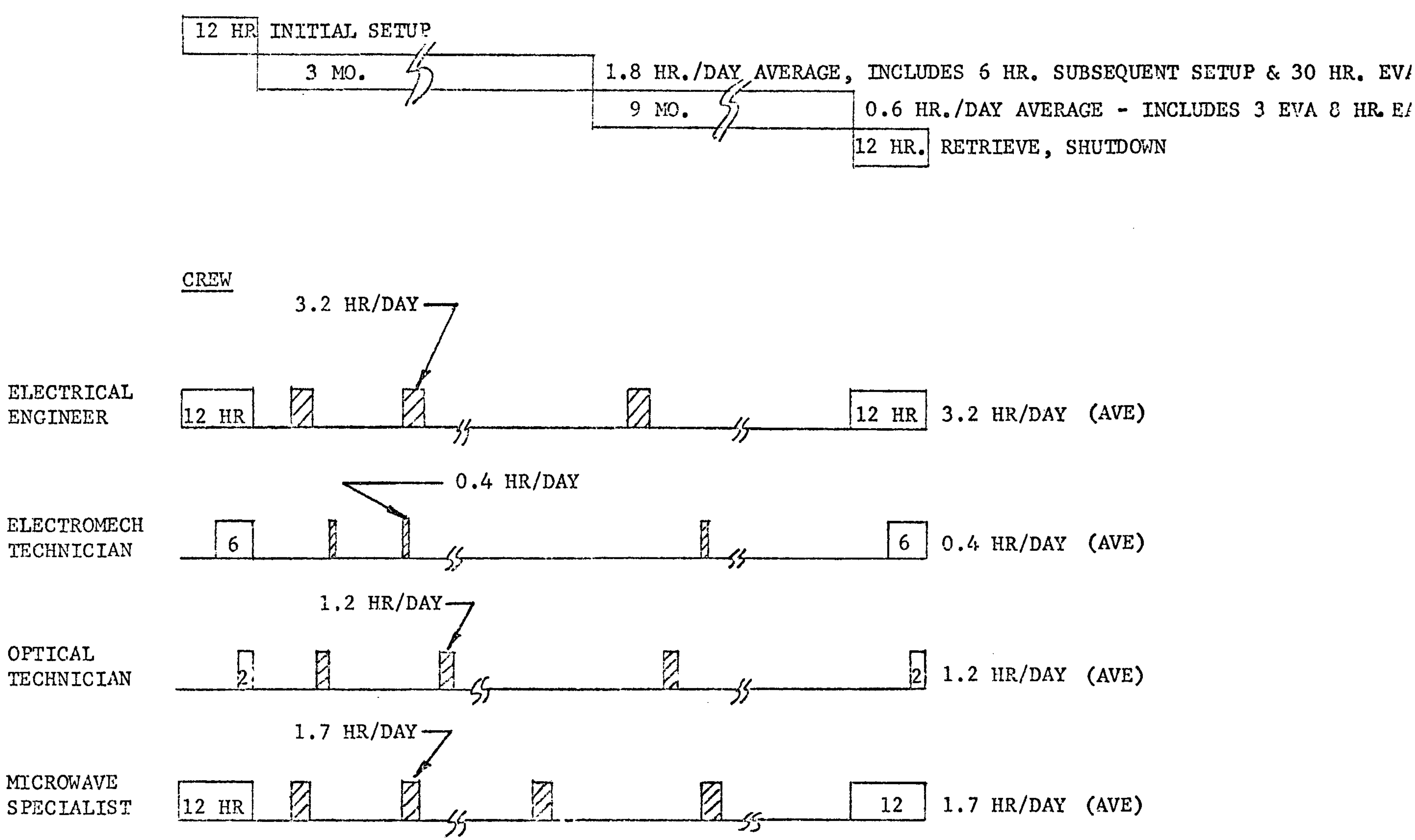


TOTAL - OCEANOGRAPHER - 0.3 HR/DAY (AVE.)
METEOROLOGIST - 0.4 HR/DAY (AVE.)
PHOTO TECH/CARTOGRAPHER - 0.7 HR/DAY (AVE.)
OPTICAL TECHNICIAN - 1.3 HR/DAY (AVE.)
E/M TECHNICIAN - 1.8 HR/DAY (AVE.)
PHYSICAL GEOLOGIST - 1.0 HR/DAY (AVE.)
HYDROLOGIST - 1.0 HR/DAY (AVE.)

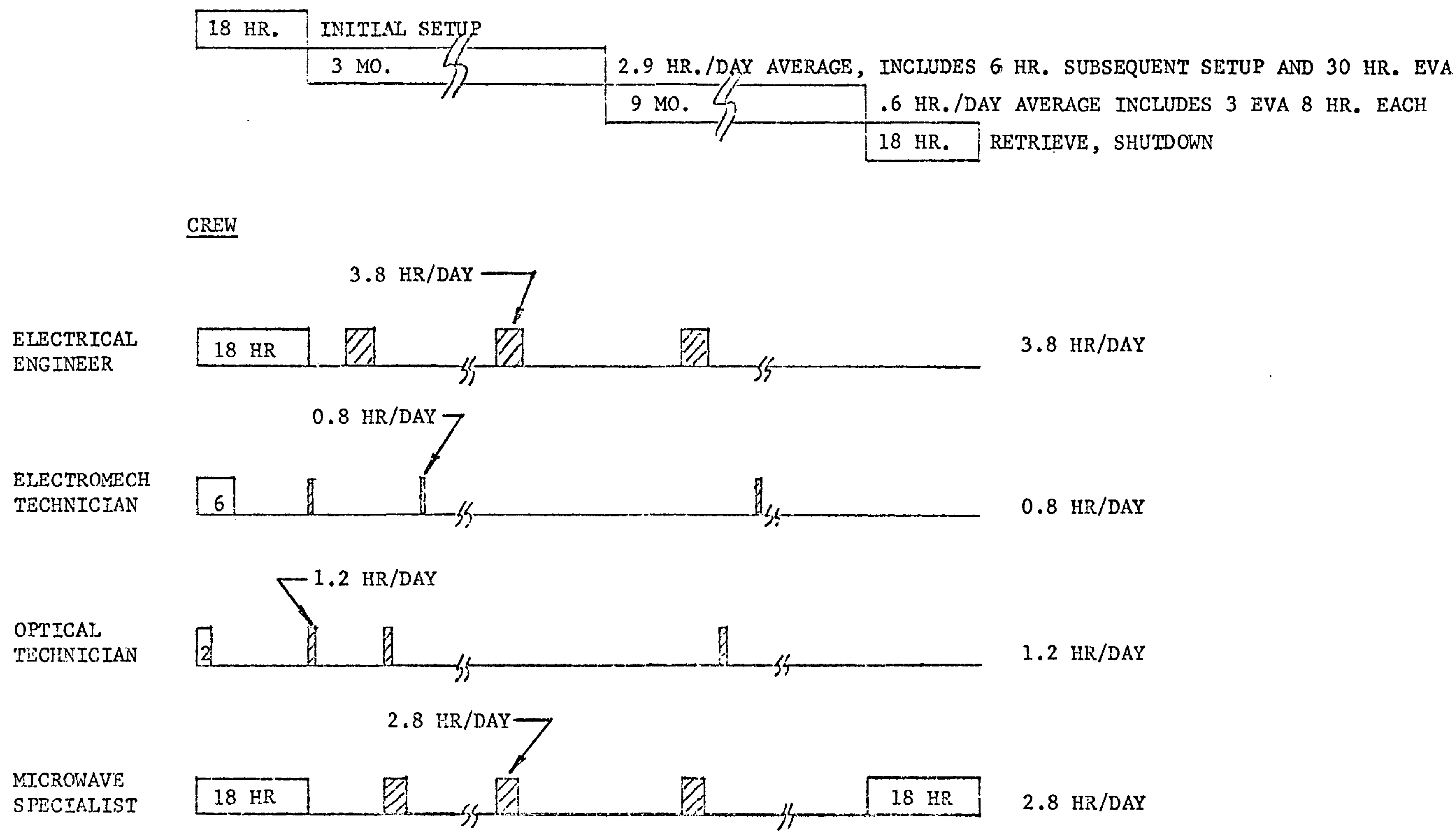
C/N-1 COMMUNICATION NAVIGATION RESEARCH FACILITY



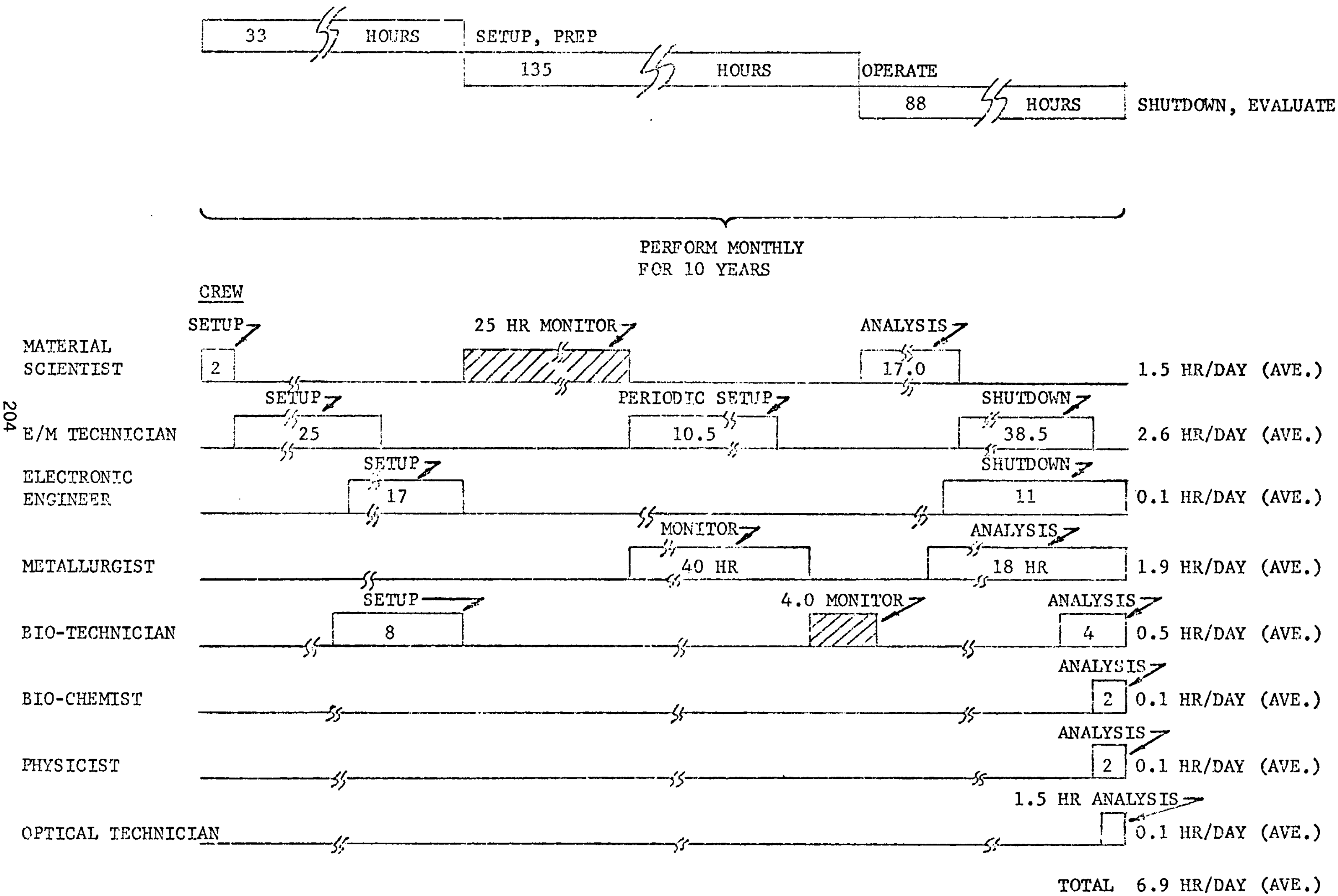
C/N-1A EXPERIMENTS 1 THRU 7



C/N-1B EXPERIMENT 1 THRU 7, 12, 13



MS-1 MATERIALS SCIENCE AND MANUFACTURING IN SPACE (MINIMUM PROGRAM)



MATERIALS SCIENCE AND MANUFACTURING

MS-1-III A

*MINIMUM

NOTE: EXPERIMENTS CAN BE OPERATED SIMULTANEOUSLY

2.0 INITIAL SETUP (EXPERIMENT 1)

8 HR. OPERATE

4HR. SHUTDOWN

1.5 SETUP (EXPERIMENT 2)

2.5 OPERATE

4.5 HR. SHUTDOWN

1 SETUP (EXPERIMENT 3)

6 HR. OPERATE

1.5 SHUTDOWN

.5 SETUP (EXPERIMENT 4)

3 HR. OPERATE

.5 SHUTDOWN

1 SETUP (EXPERIMENT 5)

6 HR. OPERATE

1 SHUTDOWN

1/DAY, ONCE* PER MONTH

2/DAY, 3 DAYS* PER MONTH

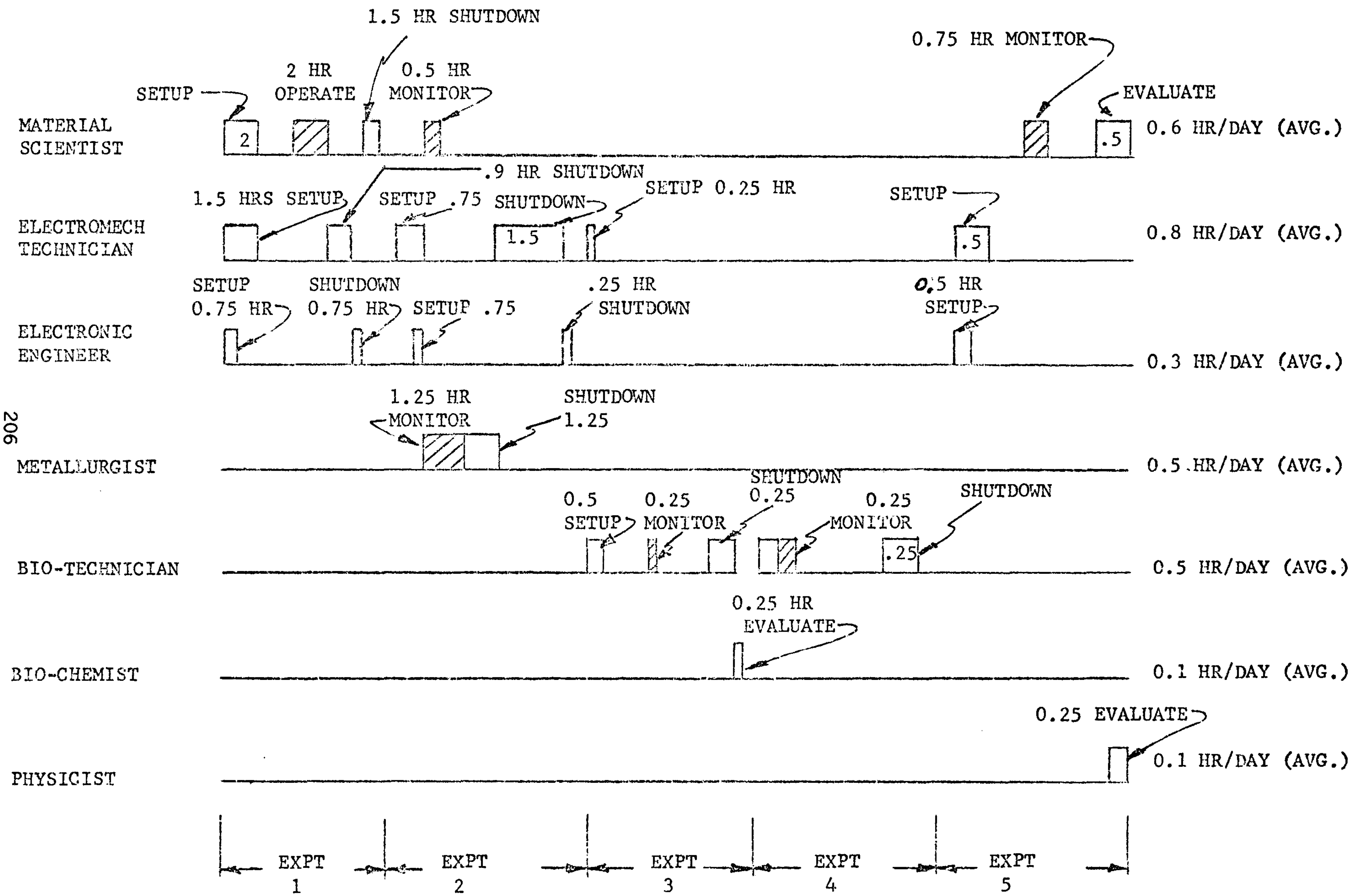
2/DAY, 4 DAYS* PER MONTH

2/DAY, 4 DAYS* PER MONTH

2/DAY, 4 DAYS* PER MONTH

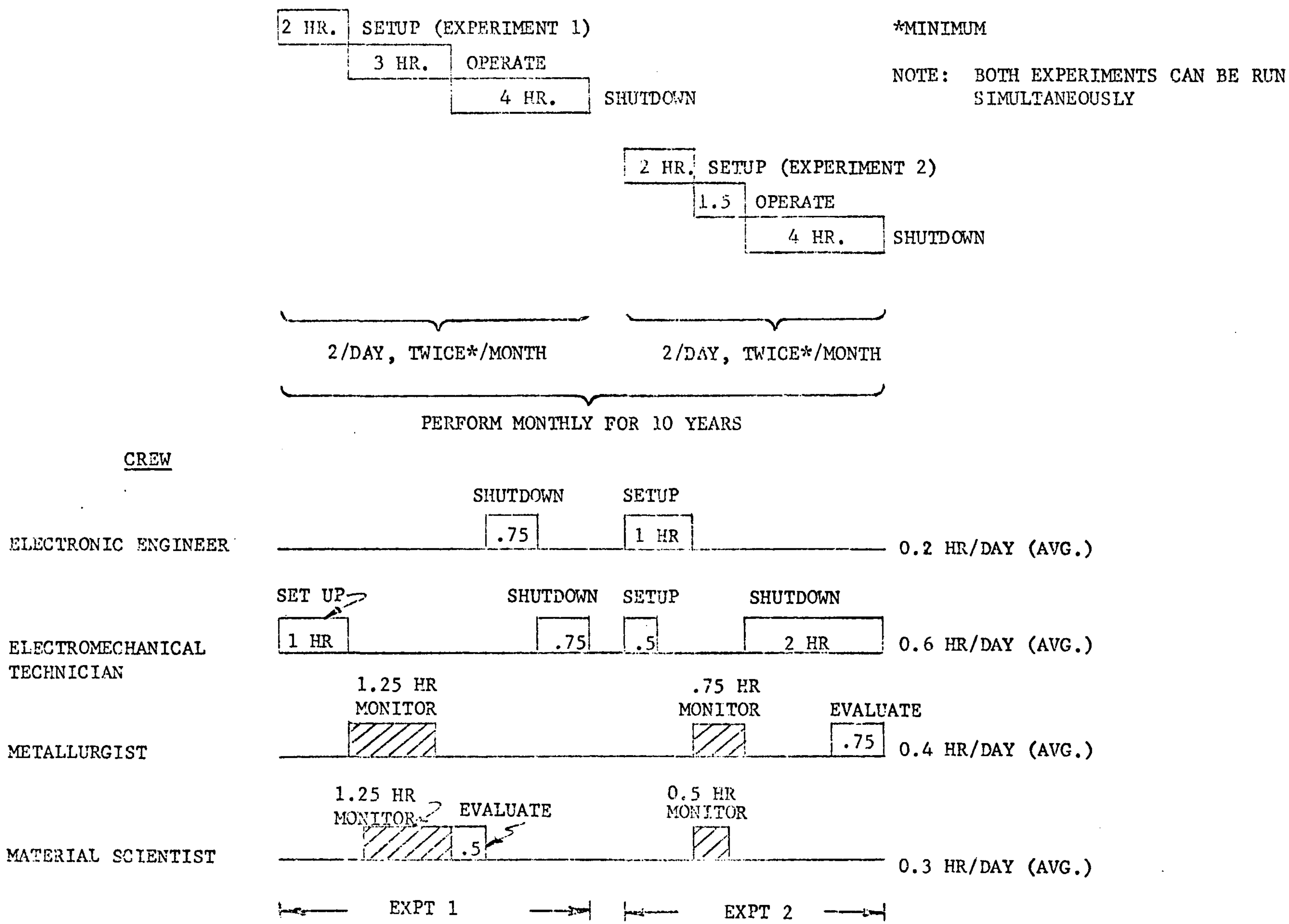
PERFORM MONTHLY FOR 10 YEARS

MS-1-IIIA CREW



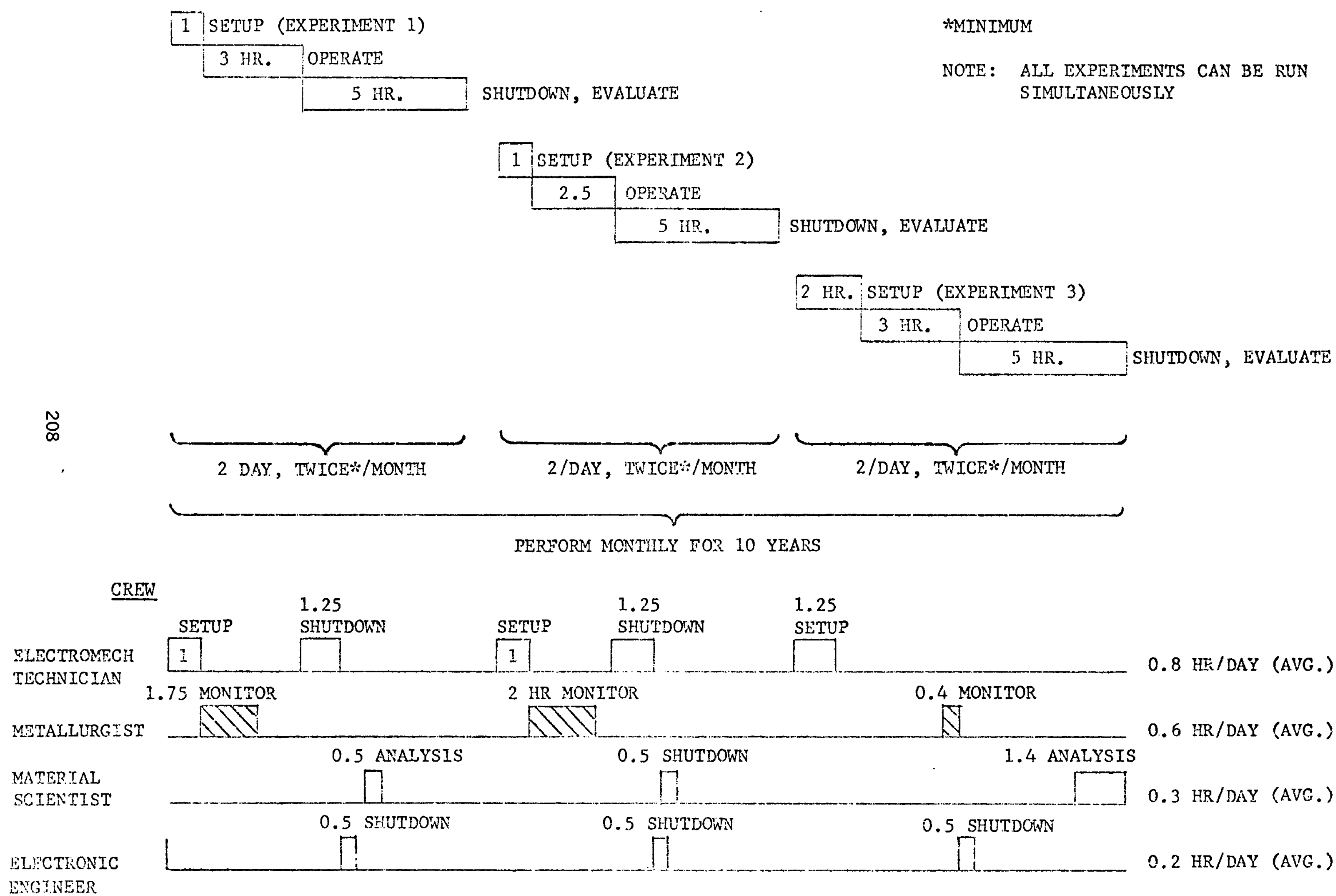
MATERIALS SCIENCE & MANUFACTURING

MS-1-III B



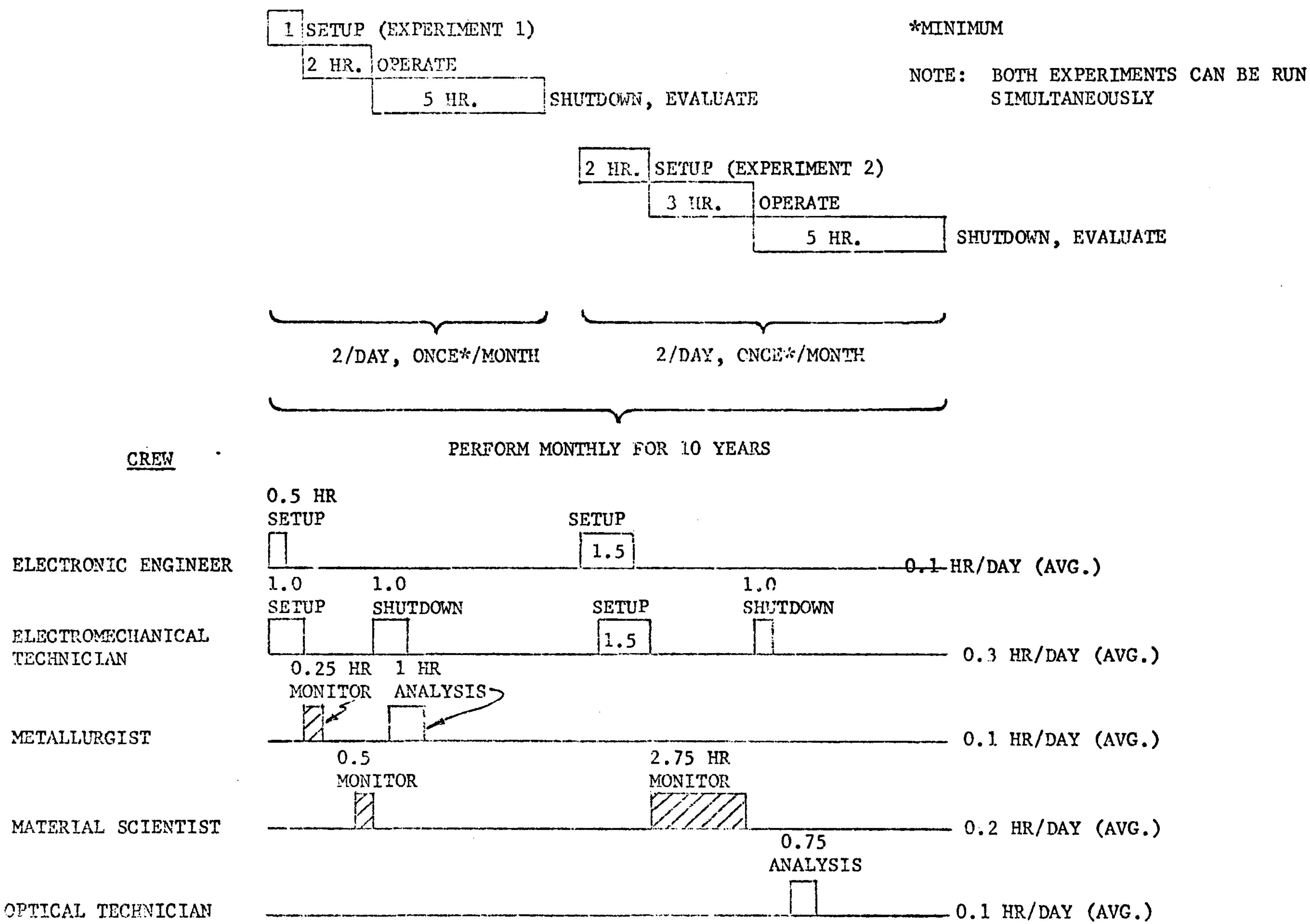
MATERIALS SCIENCE & MANUFACTURING

MS-1-III C



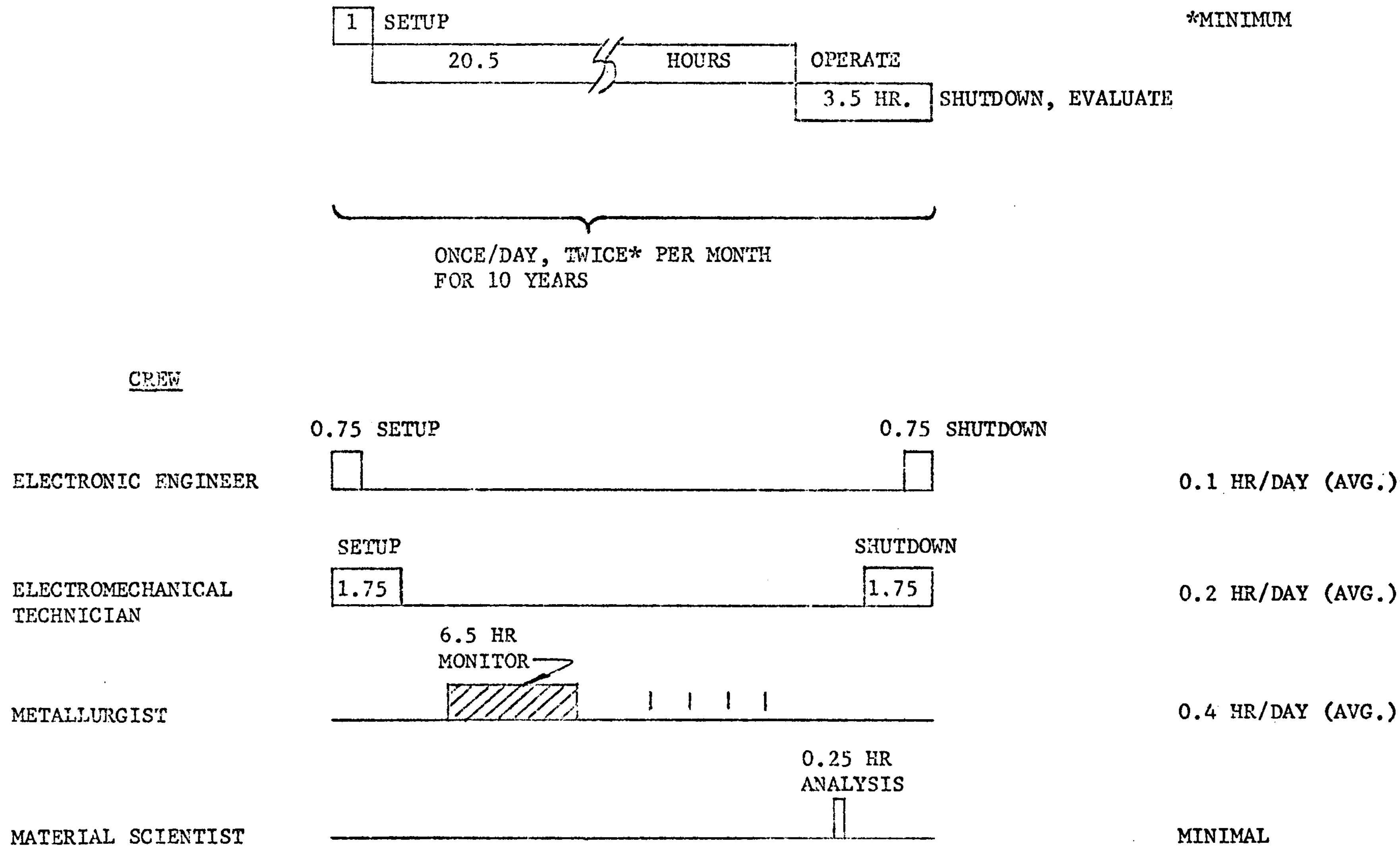
MATERIALS SCIENCE & MANUFACTURING

MS-1-III D

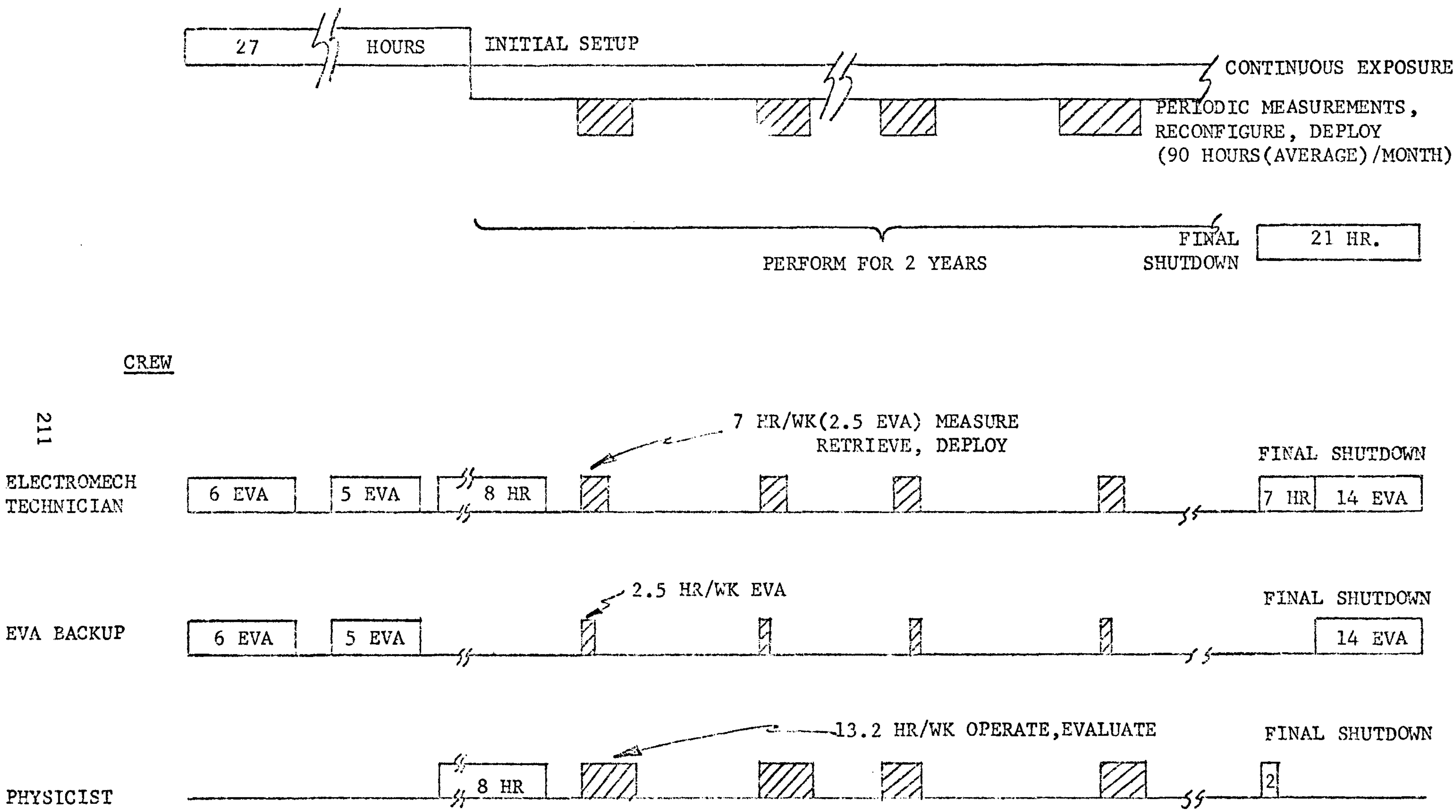


MATERIALS SCIENCE & MANUFACTURING

MS-1-III E

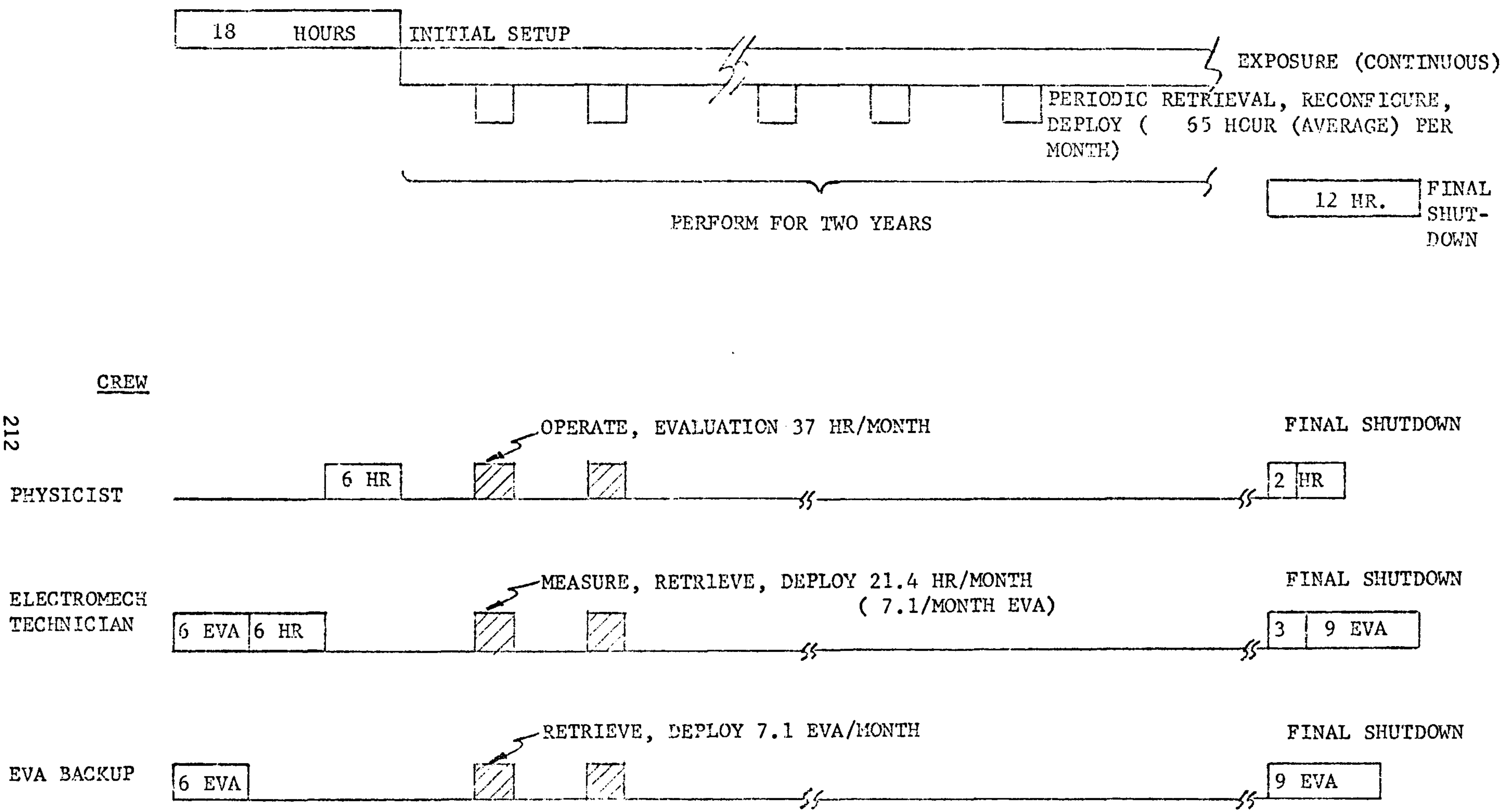


T-1 CONTAMINATION MEASUREMENTS



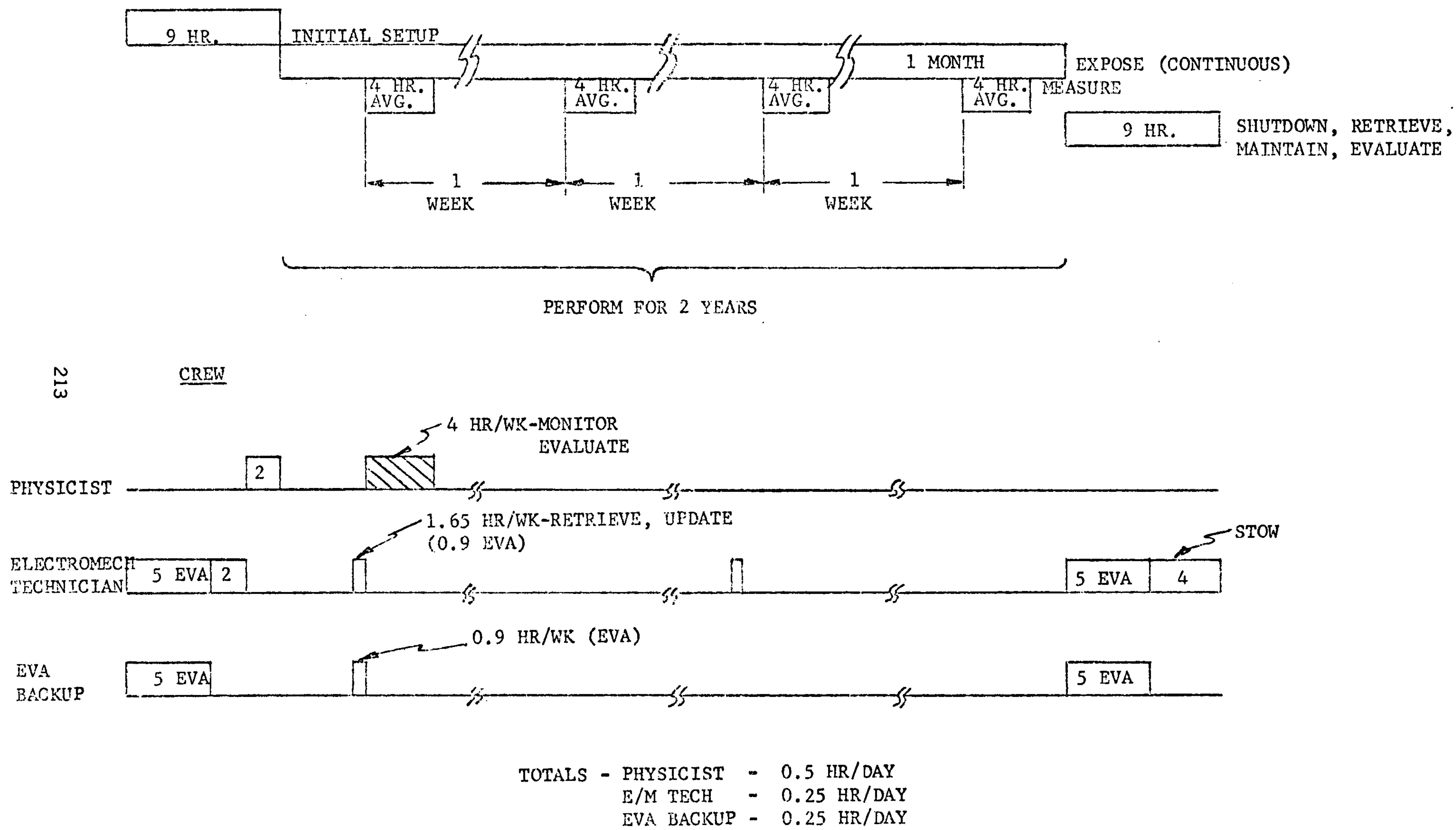
TOTAL - E/M TECH - 1.0 HR/DAY (AVG.)
EVA BACKUP- 0.5 HR/DAY (AVG.)
PHYSICIST - 1.75 HR/DAY (AVG.)

T-1A EXPERIMENTAL

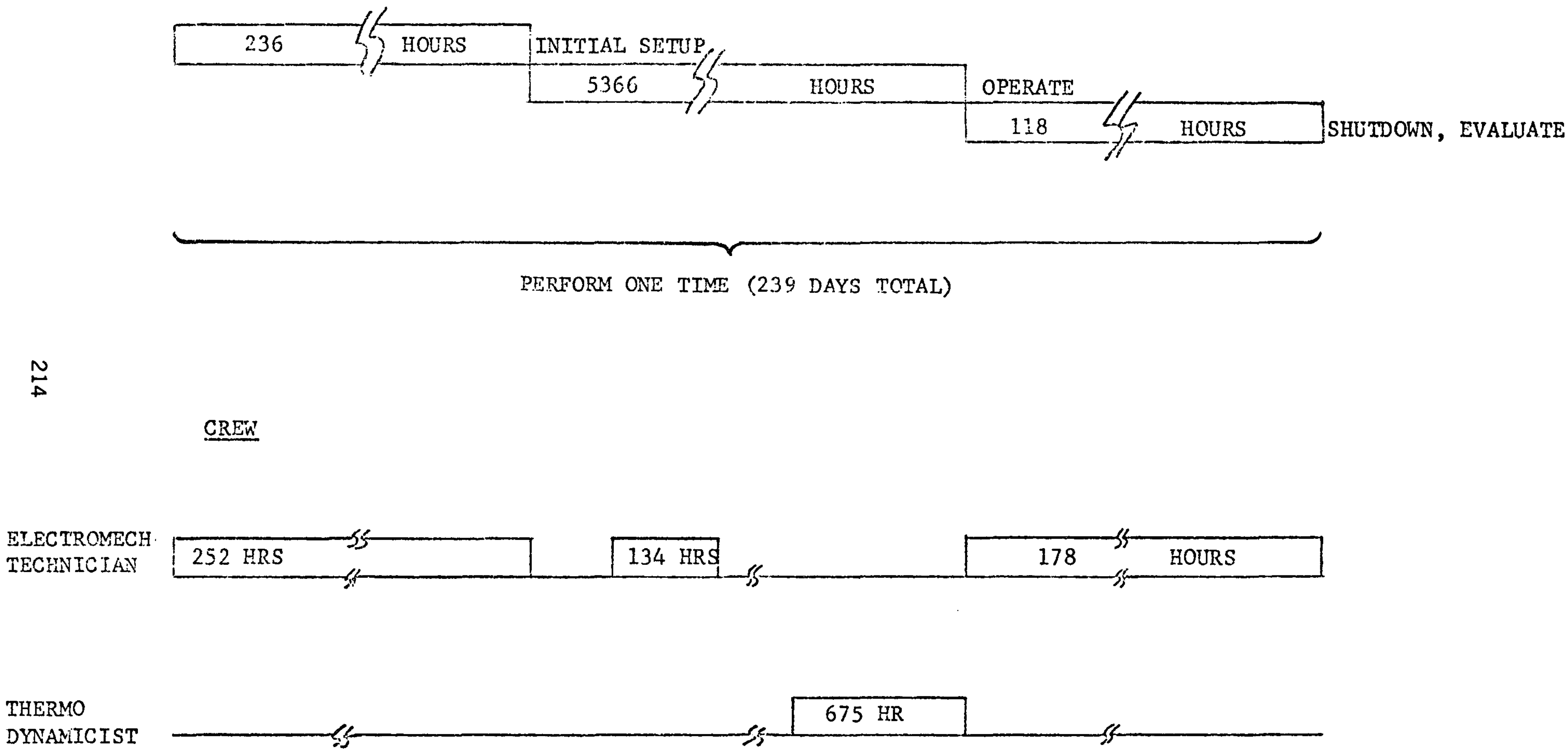


TOTALS - PHYSICIST - 1.25 HR/DAY
E/M TECH - 0.75 HR/DAY
EVA BACKUP - 0.25 HR/DAY

T-1B CONTAMINATION MEASUREMENTS

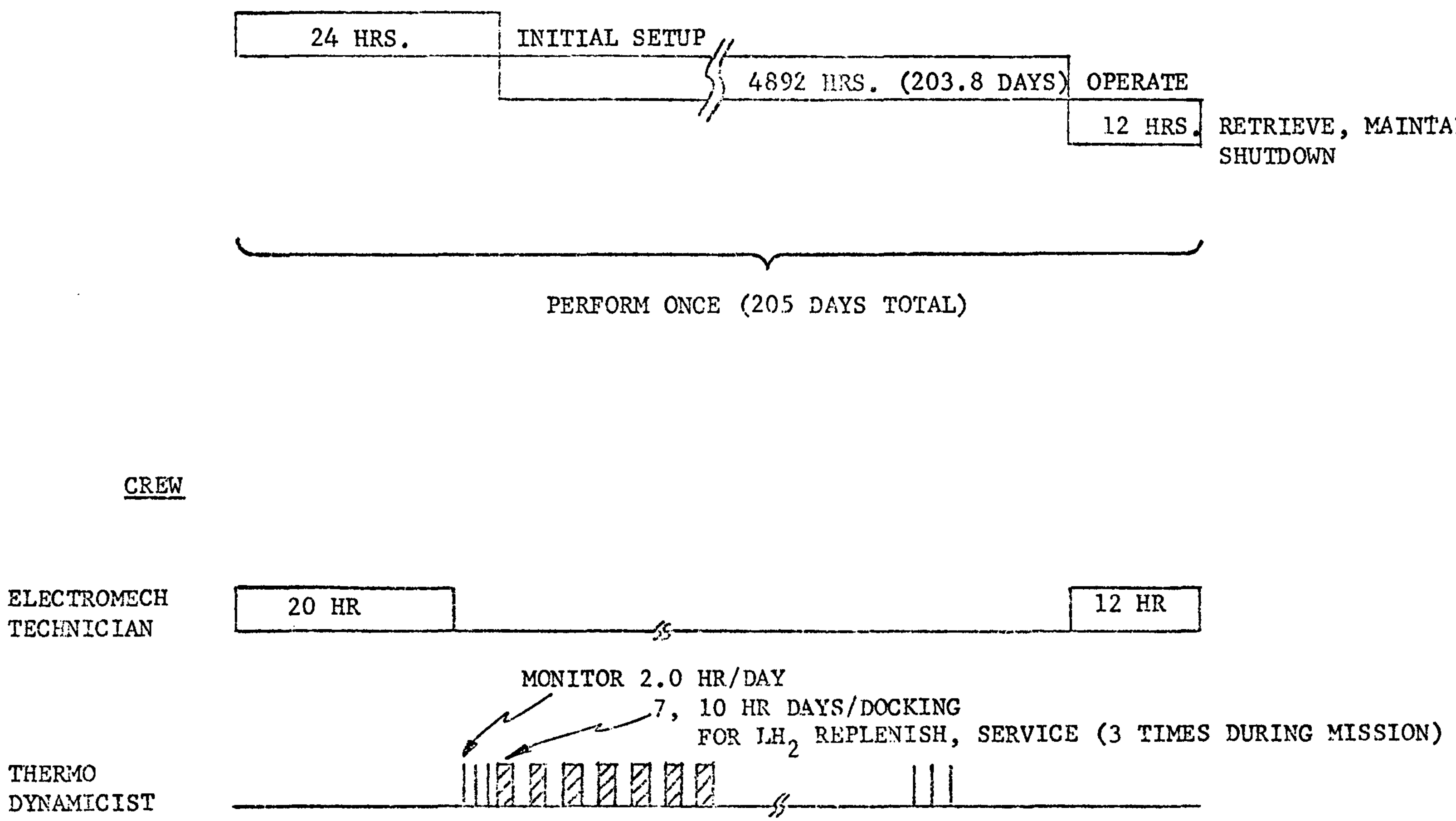


T-2 FLUID MANAGEMENT



TOTAL - E/M TECH - 564 HR/MISSION, 2.3 HR/DAY (AVG.)
THERMODYNAMICIST - 675 HR/MISSION, 2.7 HR/DAY (AVG.)

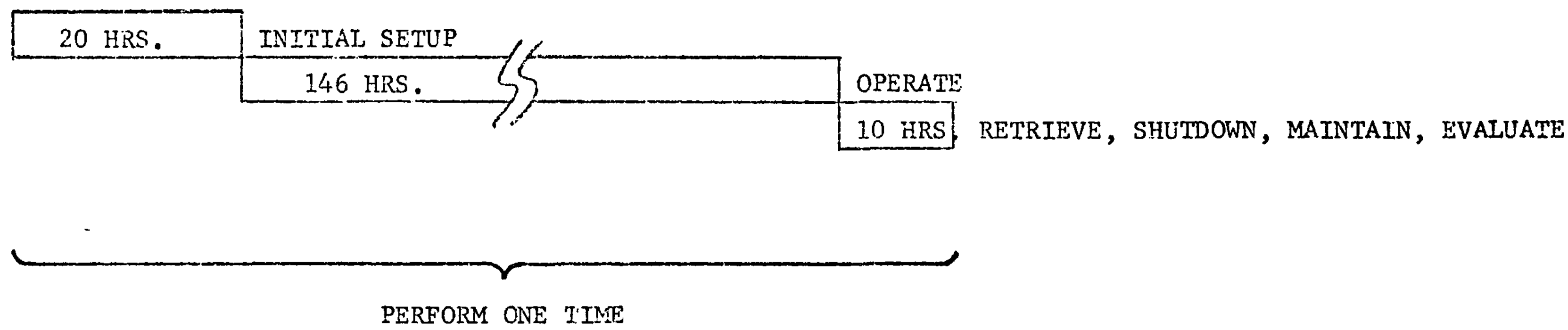
T-2A LONG TERM STORAGE OF CRYOGENICS



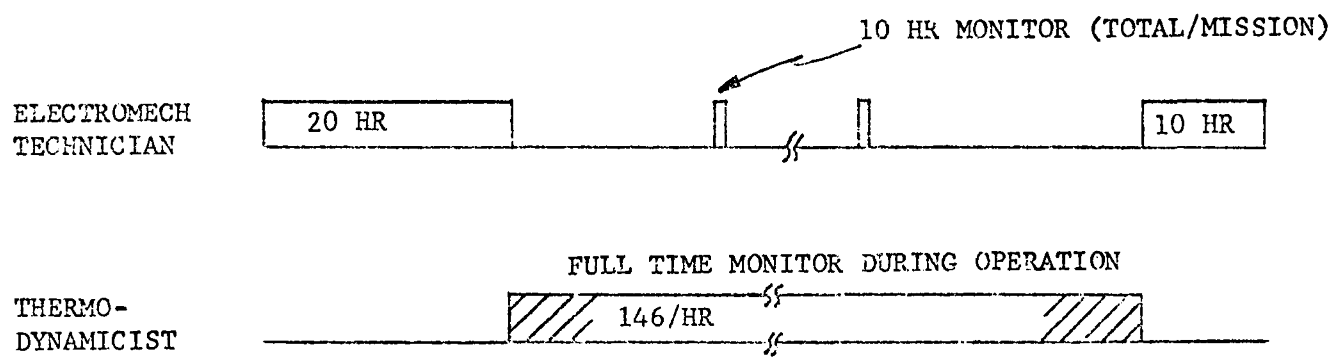
TOTAL - E/M TECH - 32 HRS/MISSION (0.13 HR/DAY, AVG.)
THERMODYNAMICIST - 400 HRS/MISSION (2.0 HR/DAY, AVG)

T-2B SHORT-TERM CRYOGENICS

NOTE: ASSUME T-2B THROUGH T-2E ARE COMPLETED IN ONE 30 DAY PERIOD.

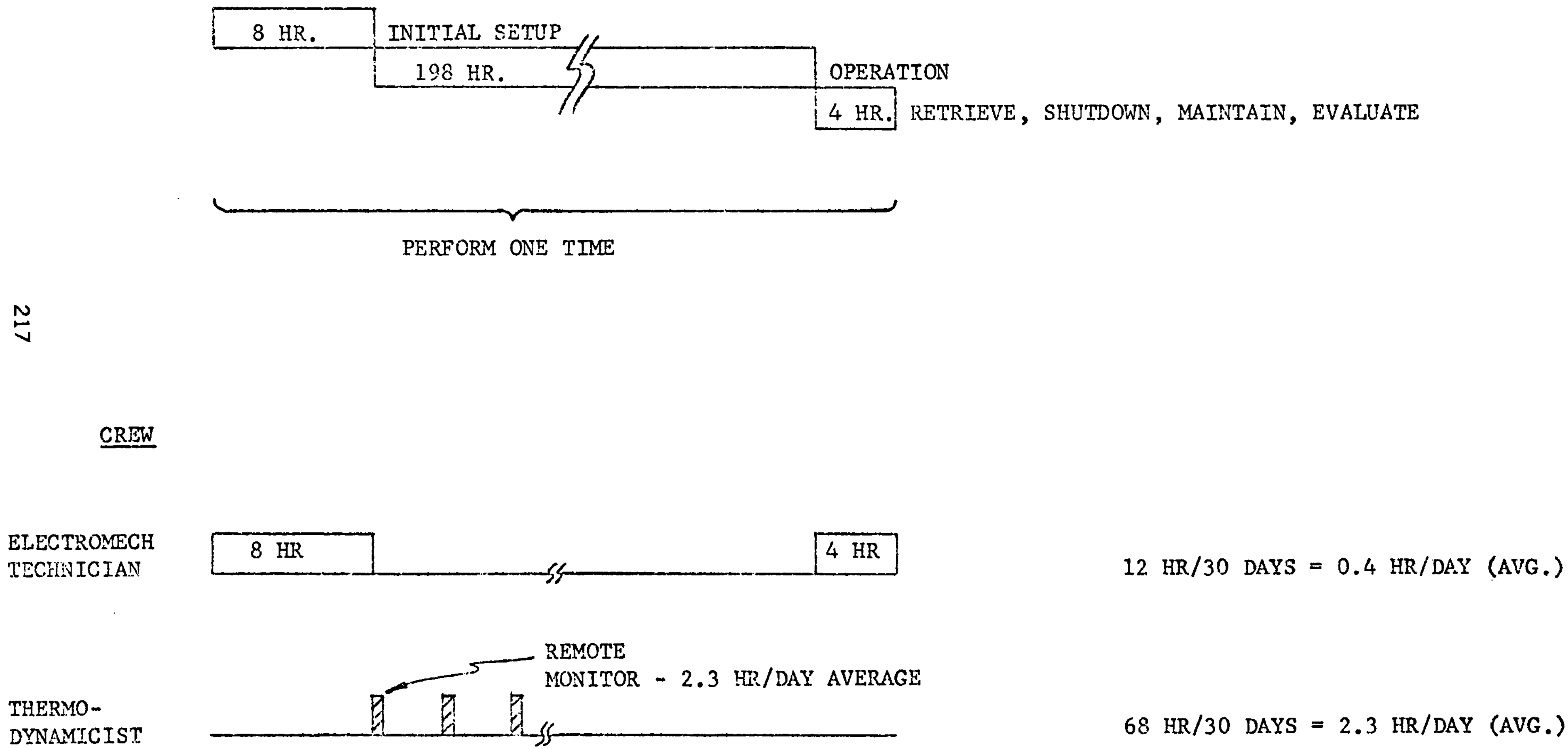


CREW

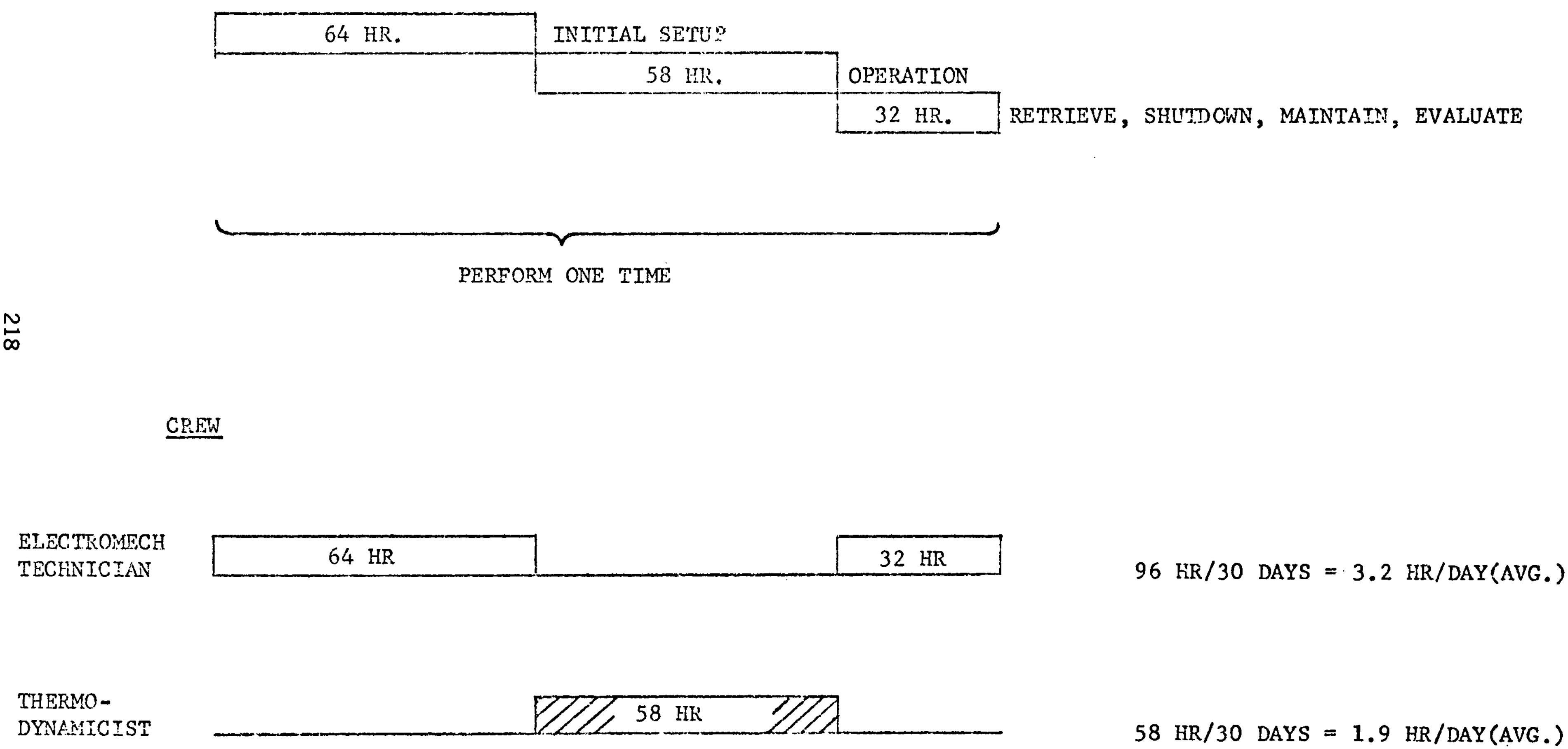


TOTAL - ELECTROMECH TECH - 40 HR/MISSION, 1.3 HR/DAY AVERAGE
THERMODYNAMICIST - 146 HR/MISSION, 4.8 HR/DAY AVERAGE

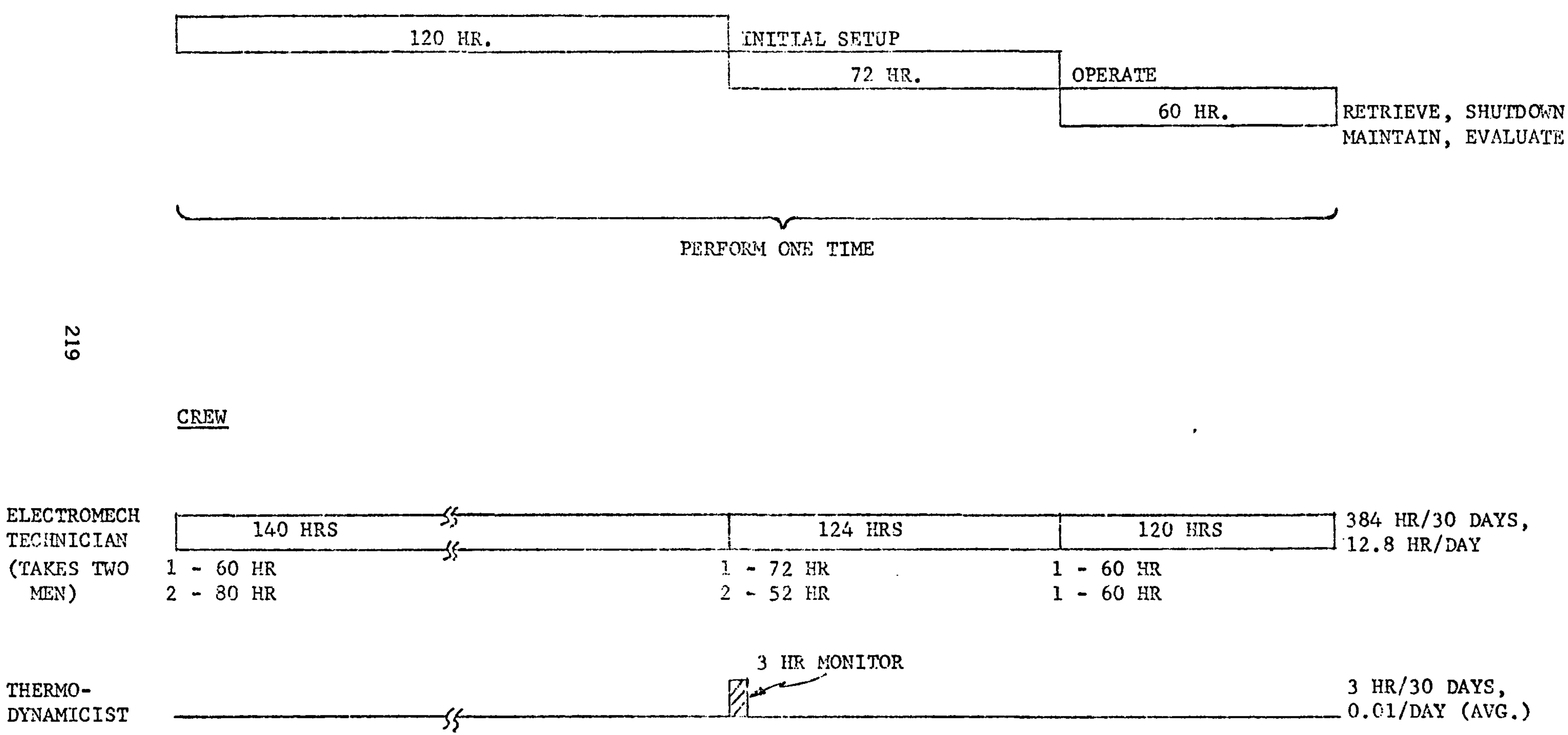
T-2C SLUSH PROPELLANT



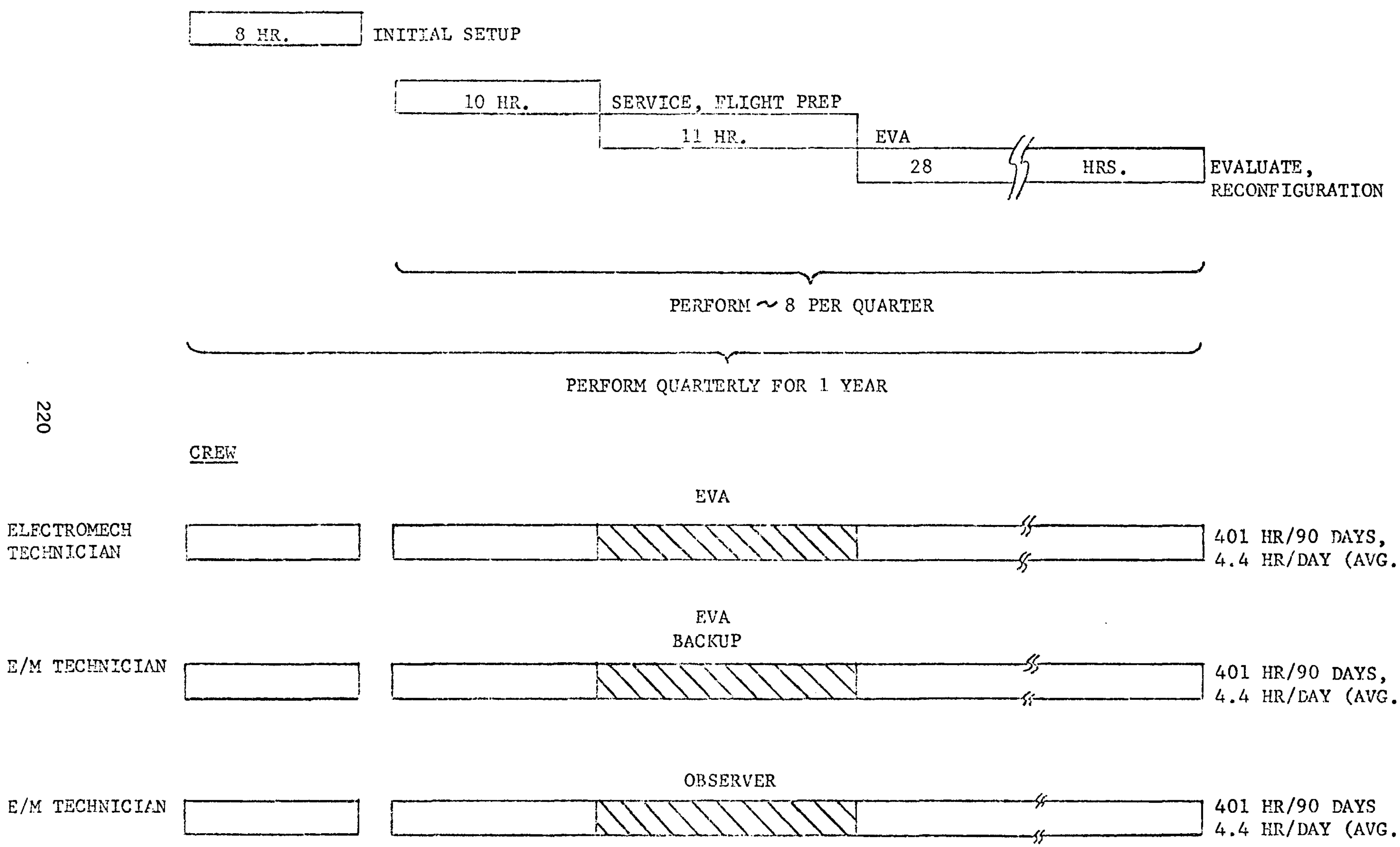
T-2D NON CRYOGENICS (1)



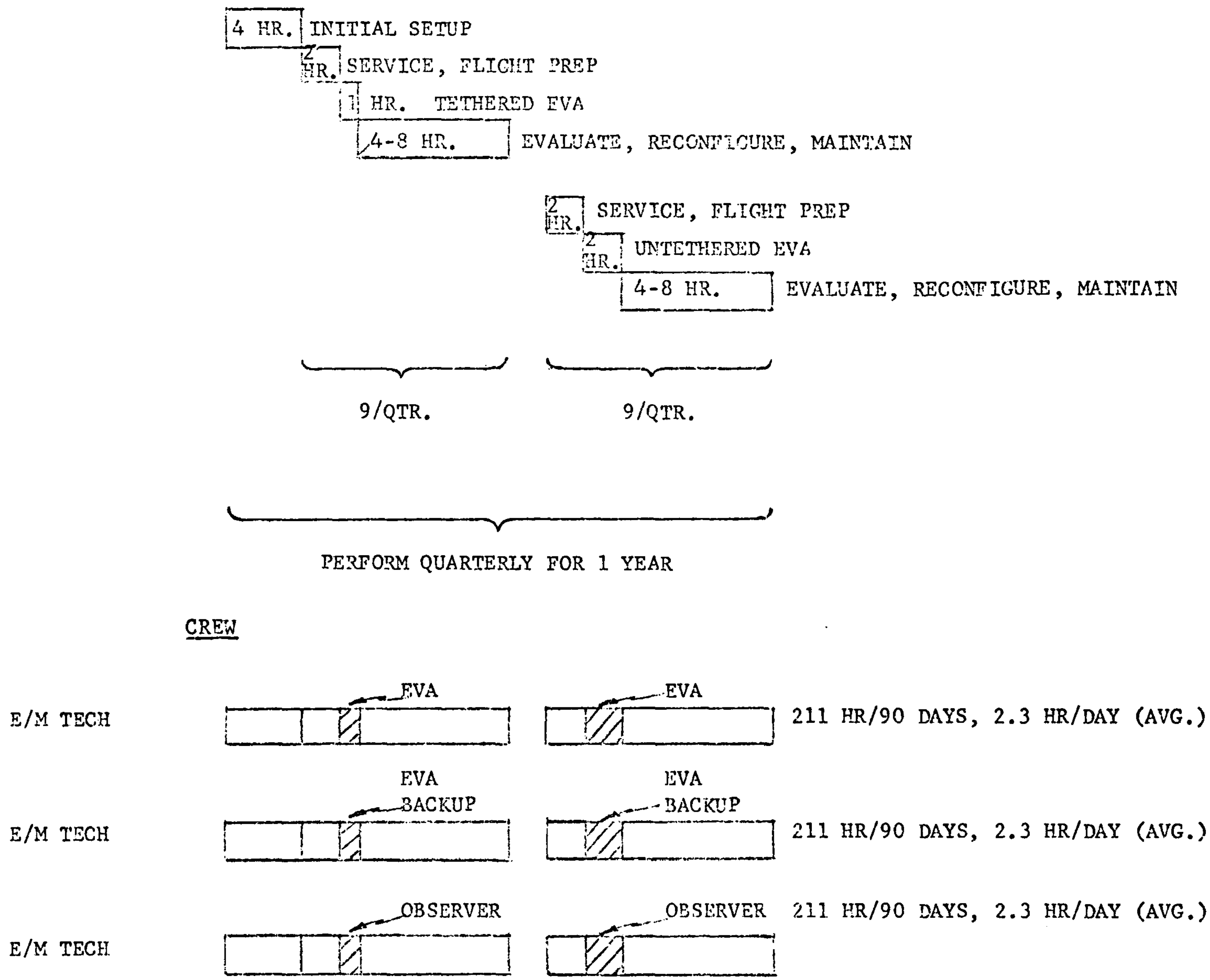
T-2E NON CRYOGENICS (2)



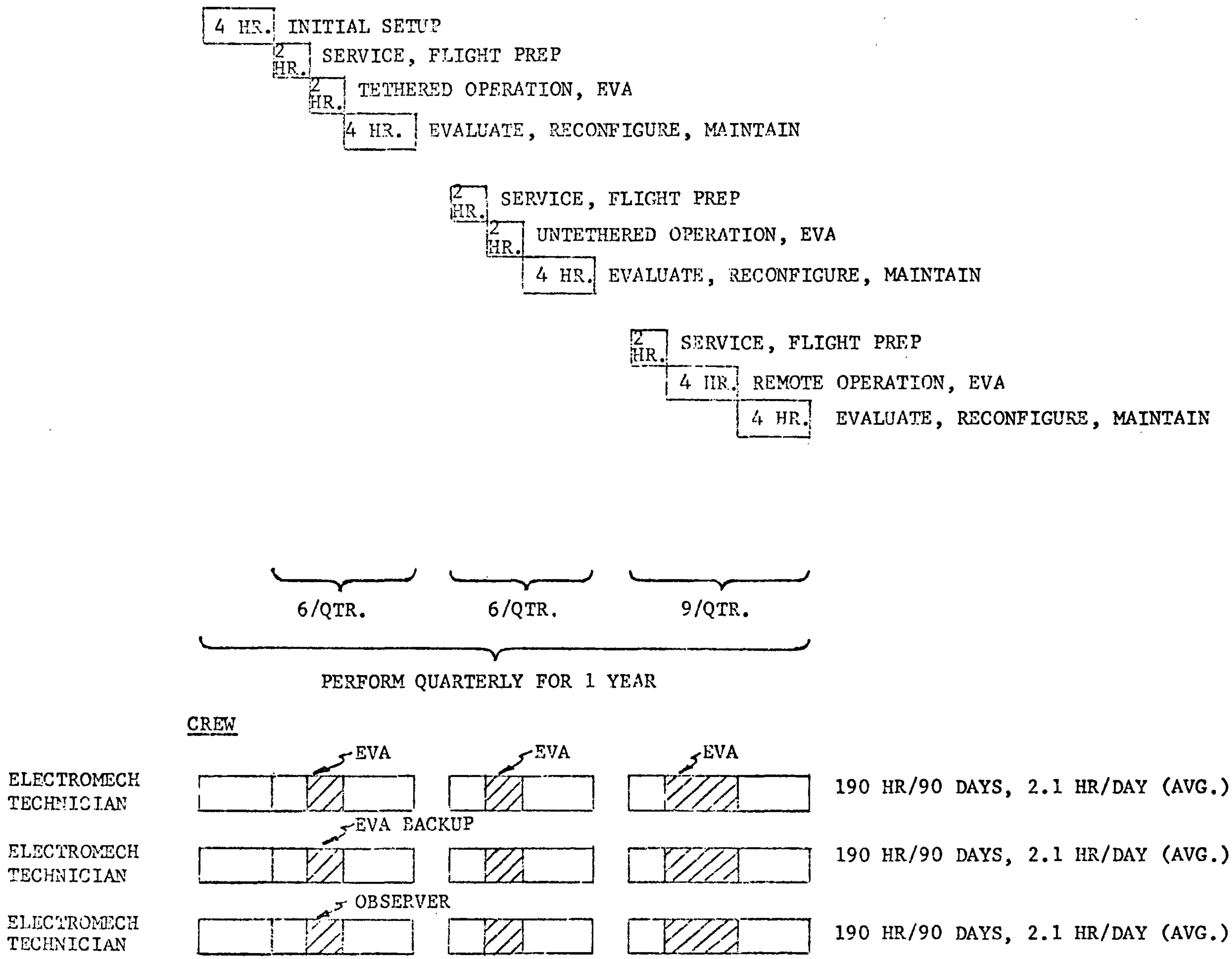
T-3 EXTRAVEHICULAR ACTIVITY



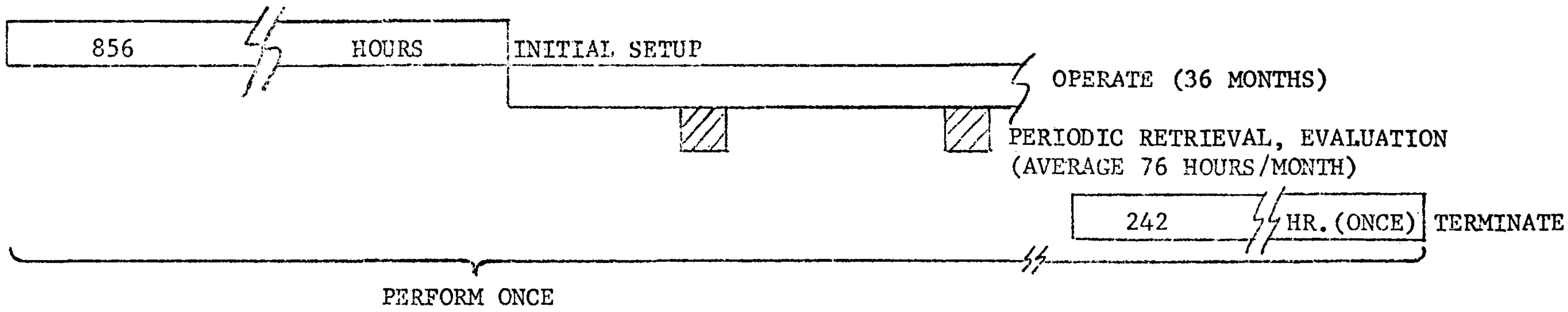
T-3A ASTRONAUT MANEUVERING UNIT



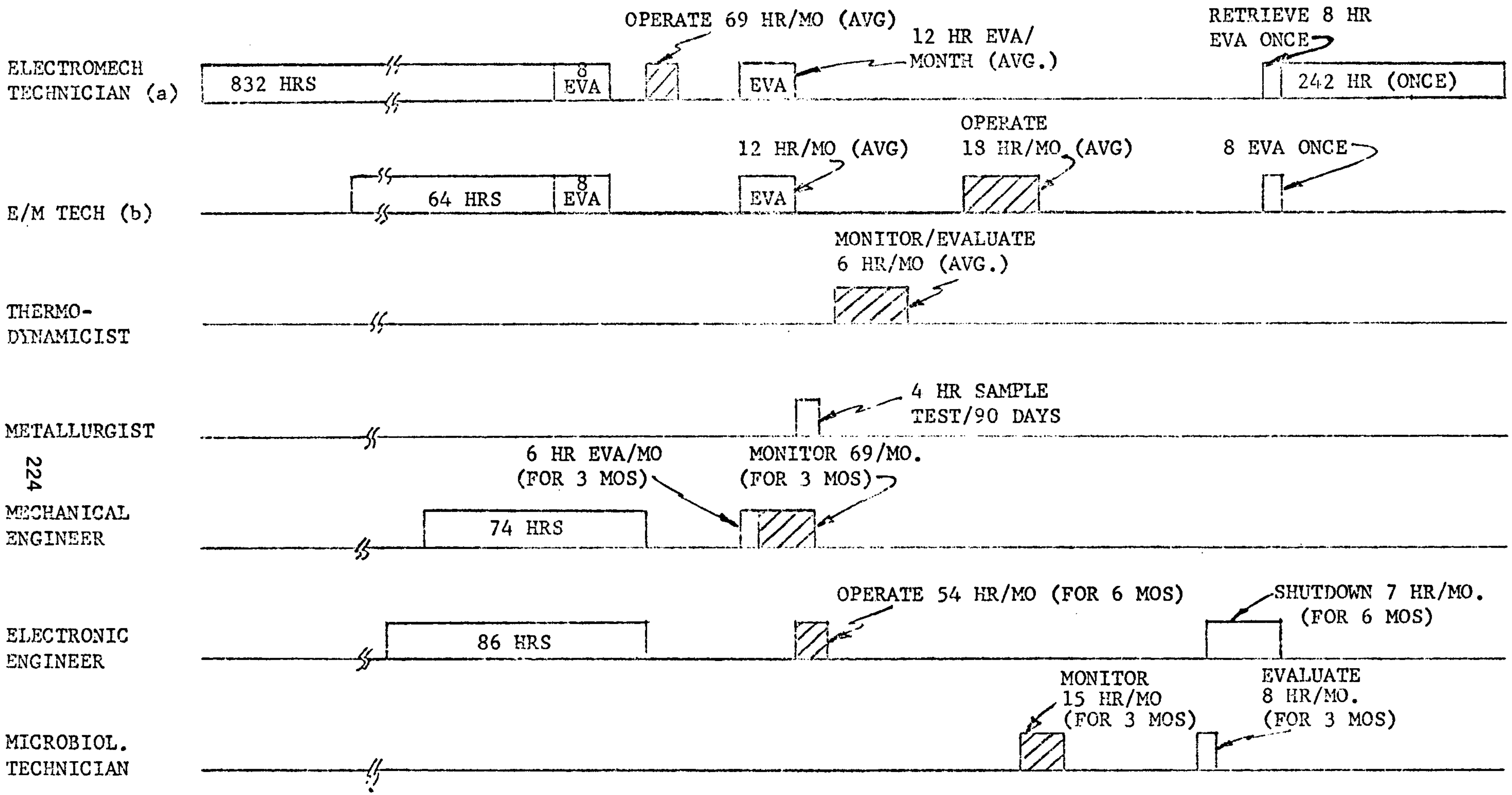
T-3B MANEUVERABLE WORK PLATFORM



T-4 ADVANCED SPACECRAFT SYSTEMS TEST

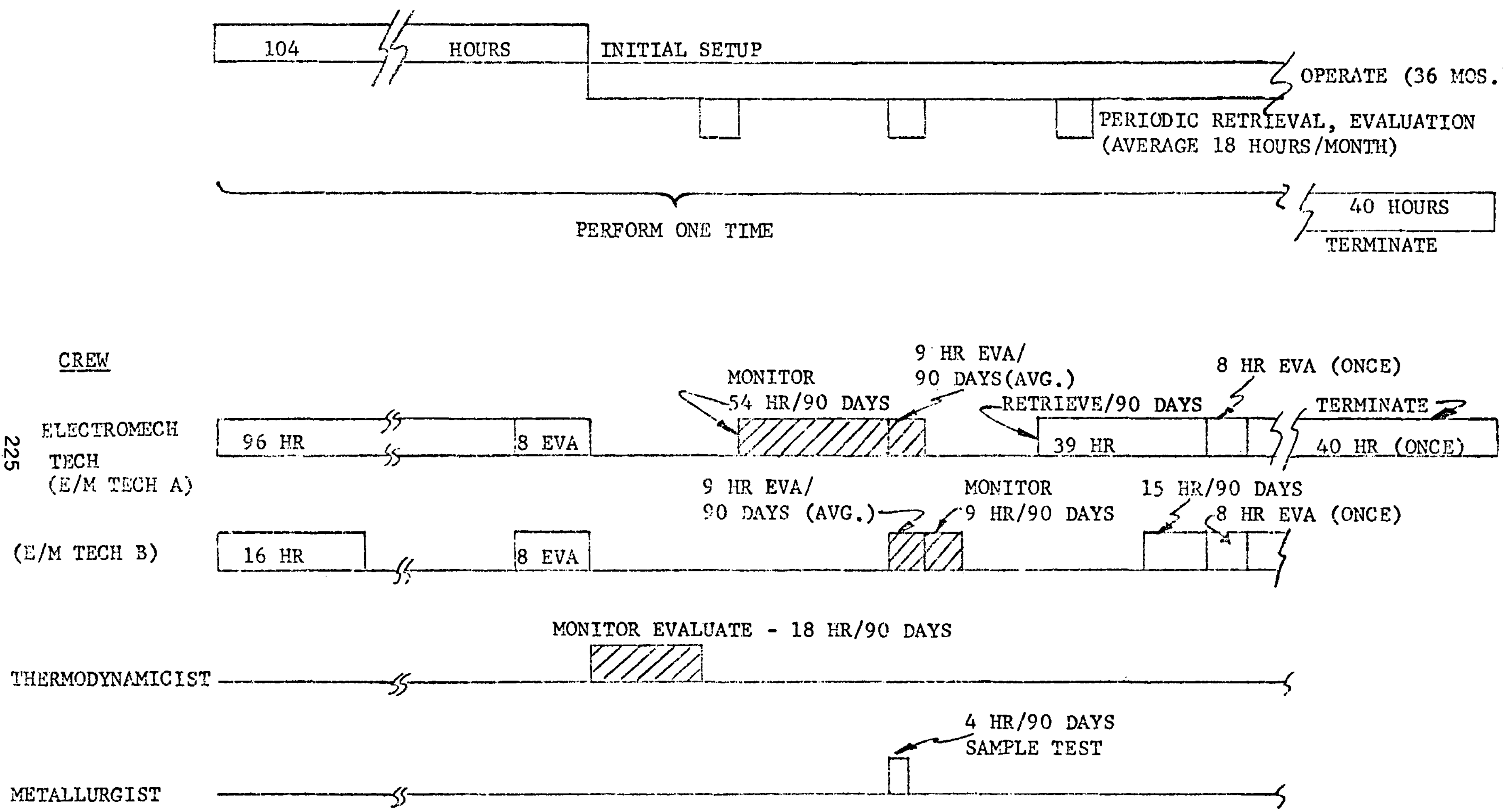


CREW



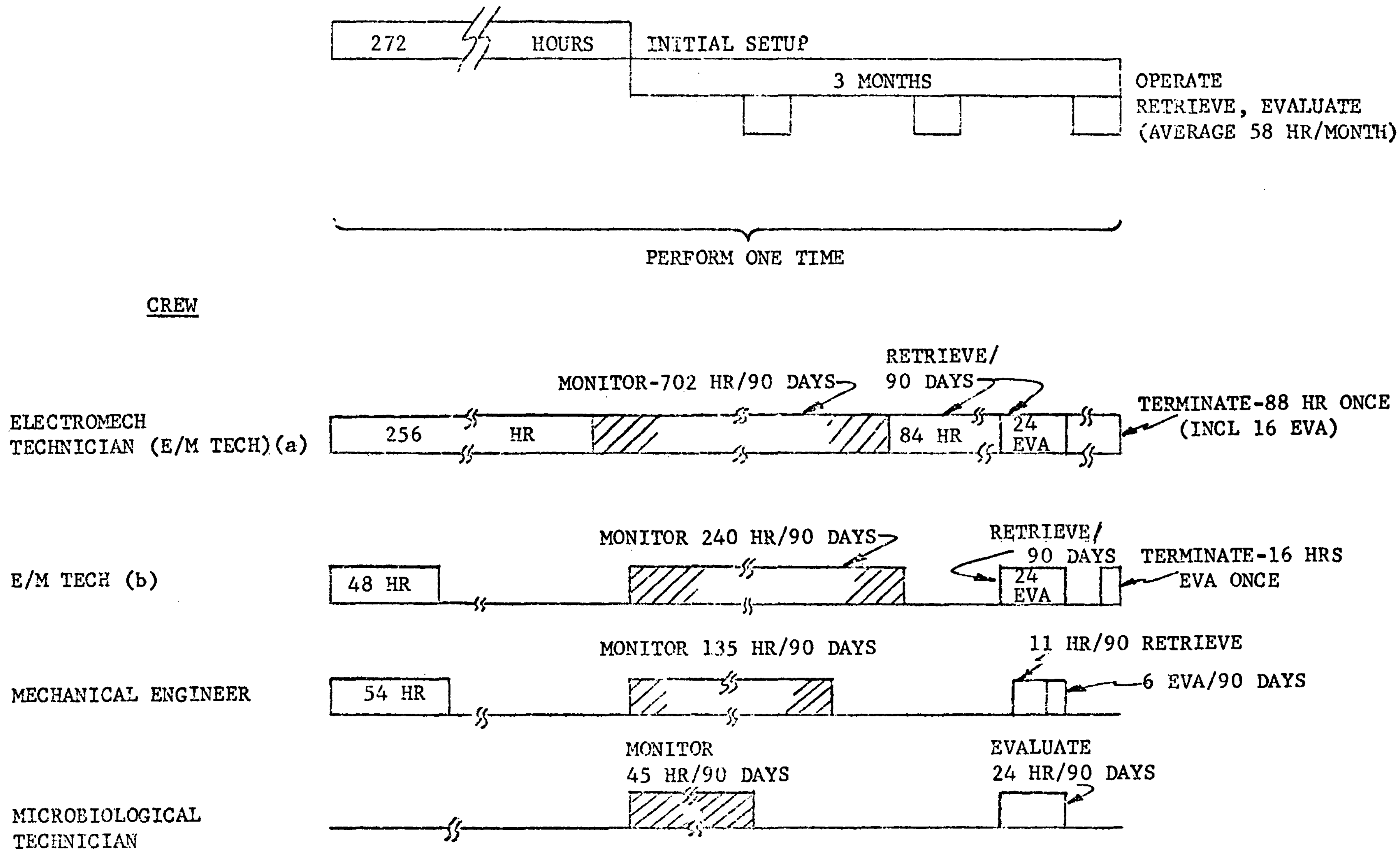
TOTAL - E/M Technician	-	3.7 hr/day (avg.)
Thermo-Dynamicist	-	0.2 hr/day (avg.)
Metallurgist	-	Minimal
Mechanical Engineer	-	2.5 hr/day (avg.)
Electronic Engineer	-	0.9 hr/day (avg)
Microbiology Technician	-	0.5 hr/day (avg)

T-4A LONG-DURATION



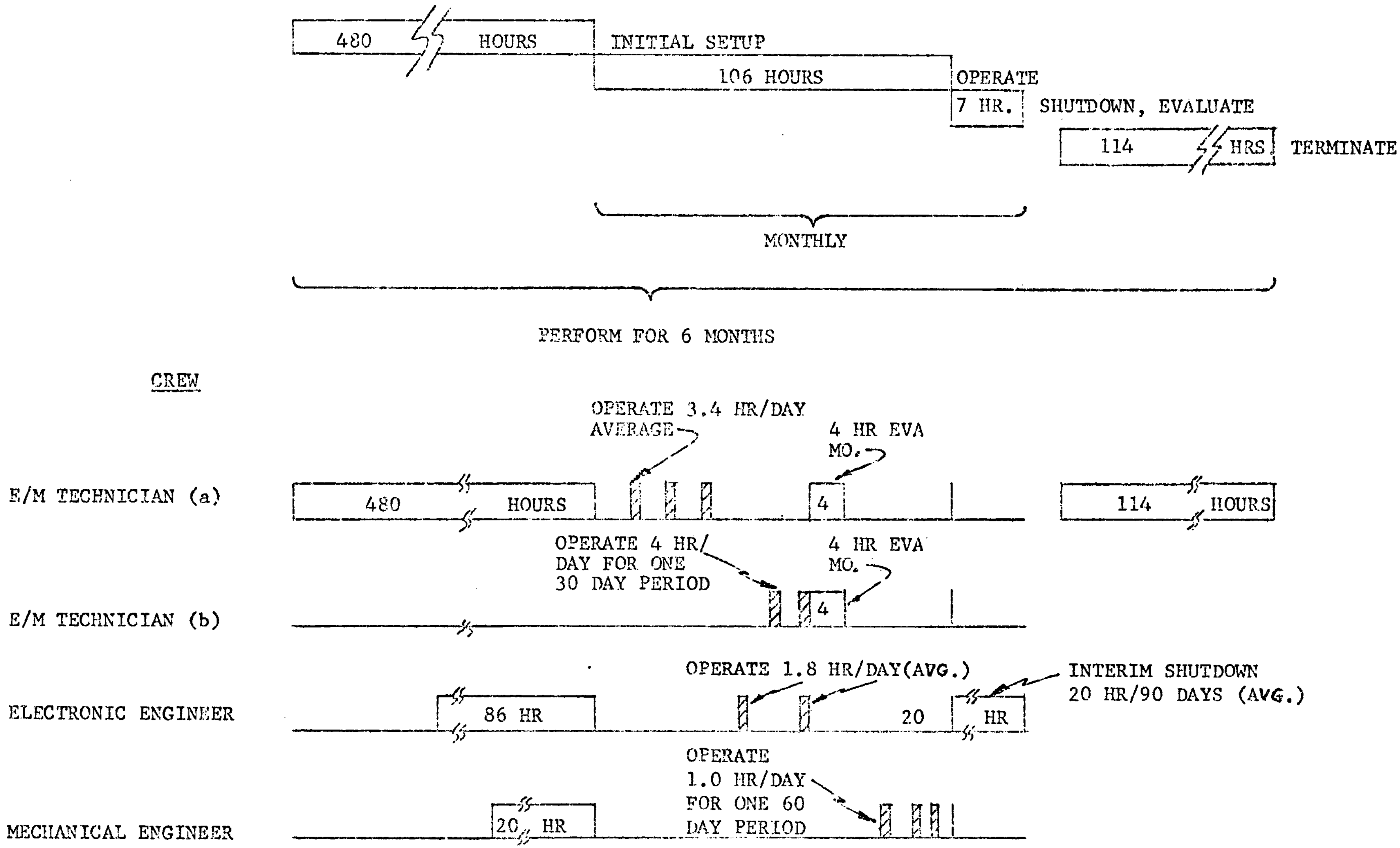
TOTALS: E/M TECH A - 1.1 HR/DAY (AVG.)
E/M TECH B - 0.4 HR/DAY (AVG.)
THERMODYNAMICIST - 18 HR/90 DAYS; 0.2 HR/DAY (AVG.)
METALLURGIST - 4 HR/90 DAYS; 0.1 HR/DAY (AVG.)

T-4B MEDIUM DURATION



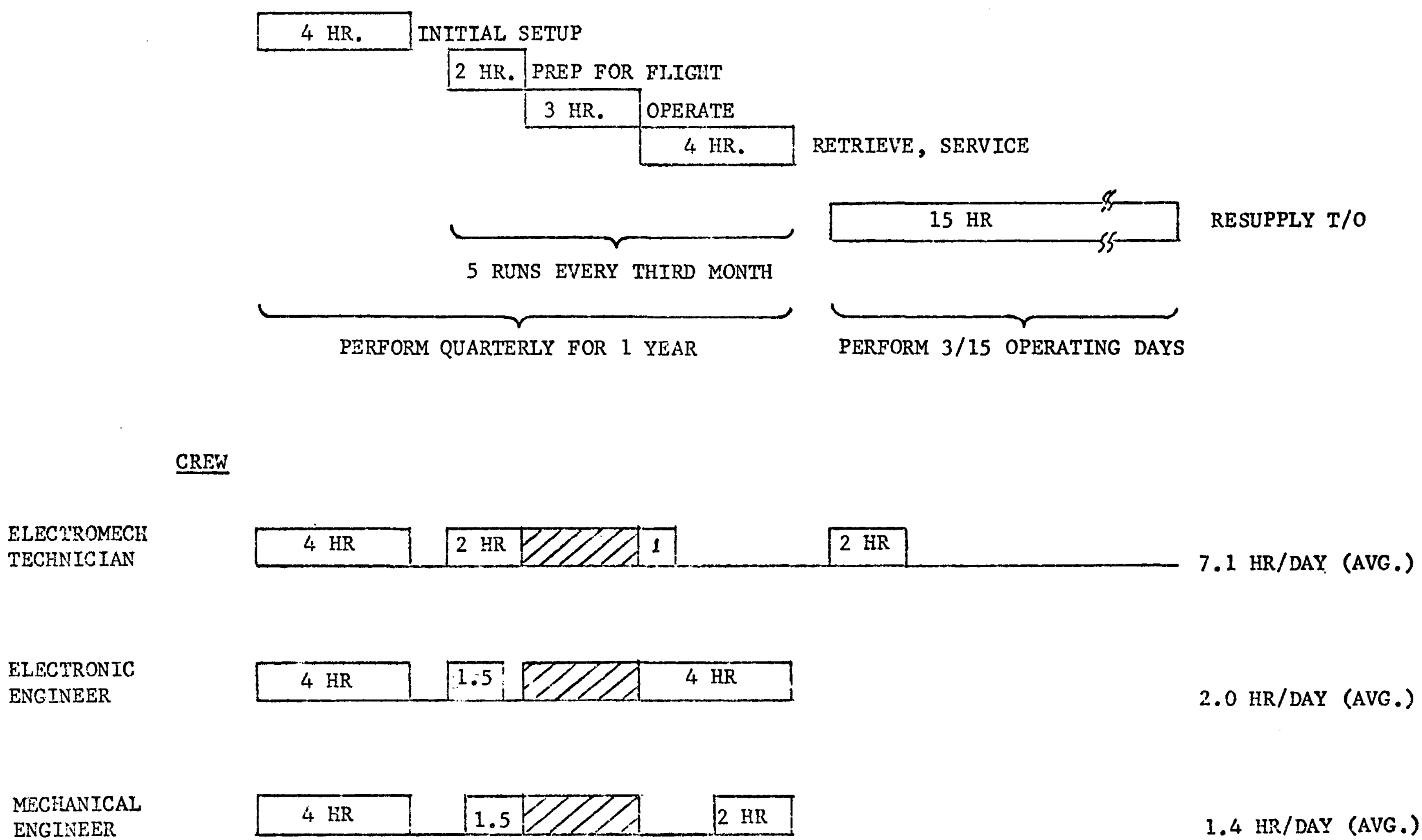
TOTALS - E/M TECH (a) - 9 HR/DAY (AVG.)
E/M TECH (b) - 3 HR/DAY (AVG.)
MECH ENGINEER - 1.7 HR/DAY (AVG.)
MICROBIOL TECH - 0.8 HR/DAY (AVG.)

T-4C SHORT DURATION

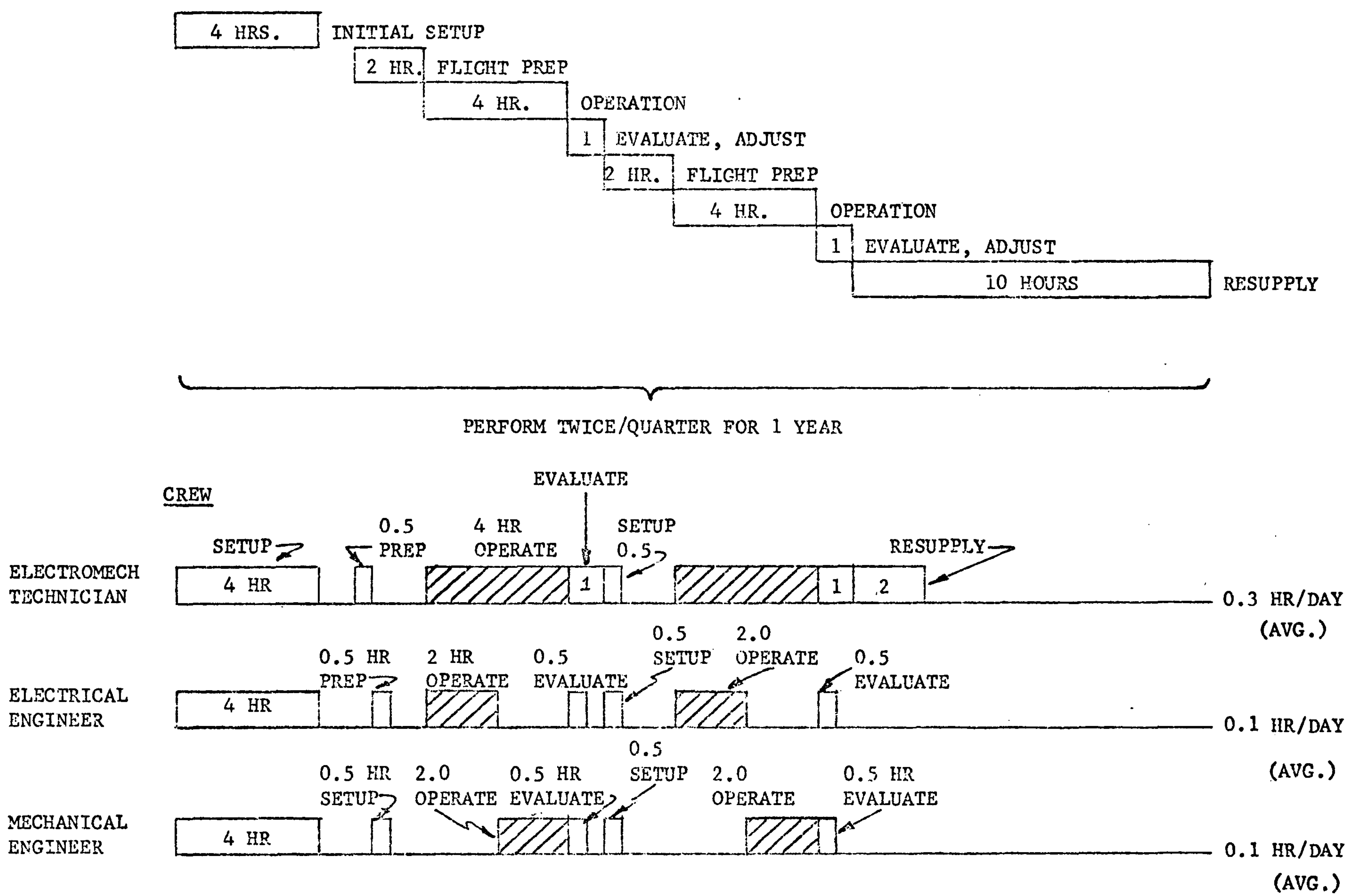


TOTAL E/M TECHNICIAN (a) - 3.5 HR/DAY (AVG.)
E/M TECHNICIAN (b) - 4.1 HR/DAY (AVG.)
ELECTRONIC ENGINEER - 2.0 HR/DAY (AVG.)
MECHANICAL ENGINEER - 1.0 HR/DAY (AVG)

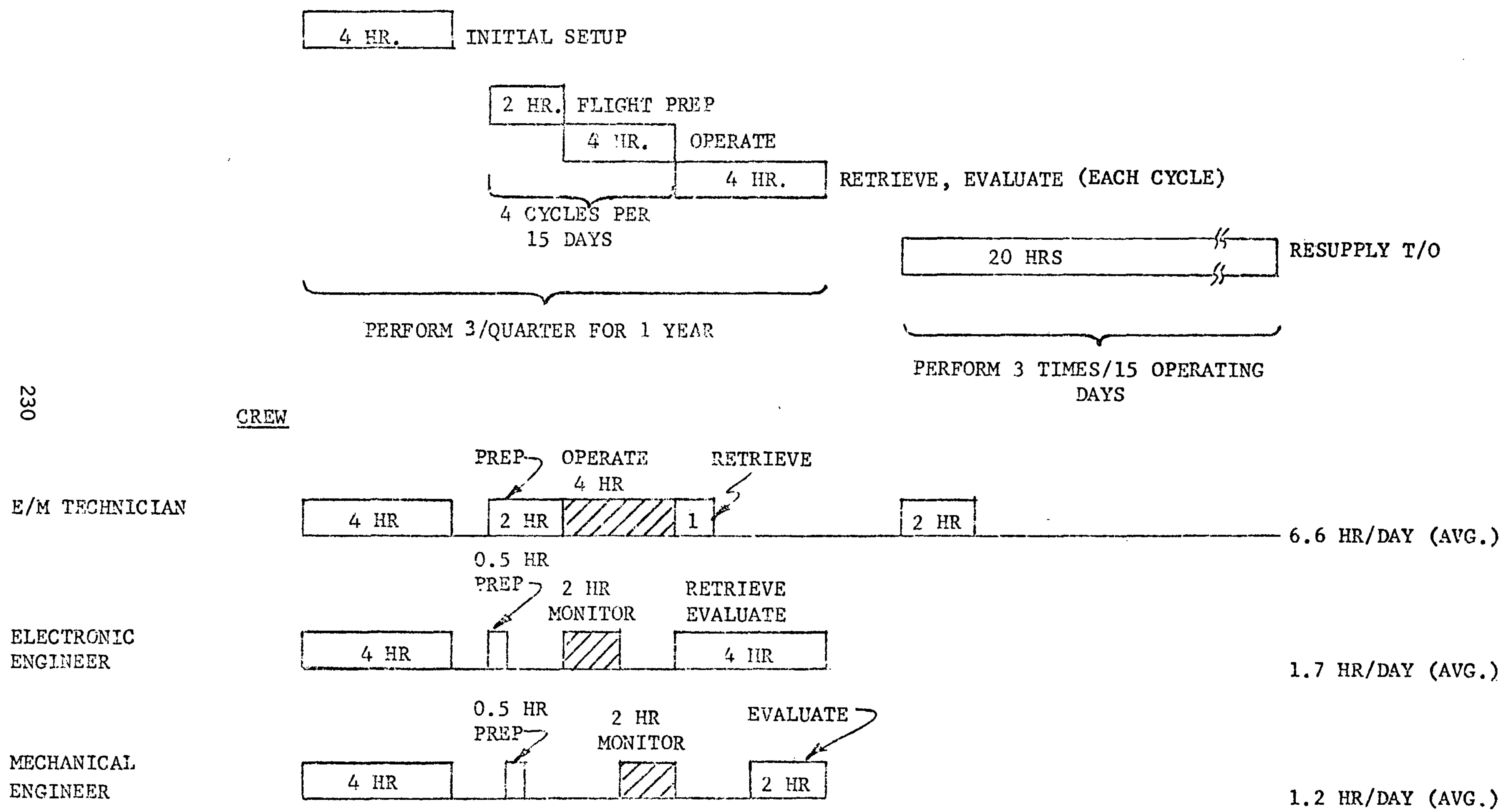
T-5 TELEOPERATION



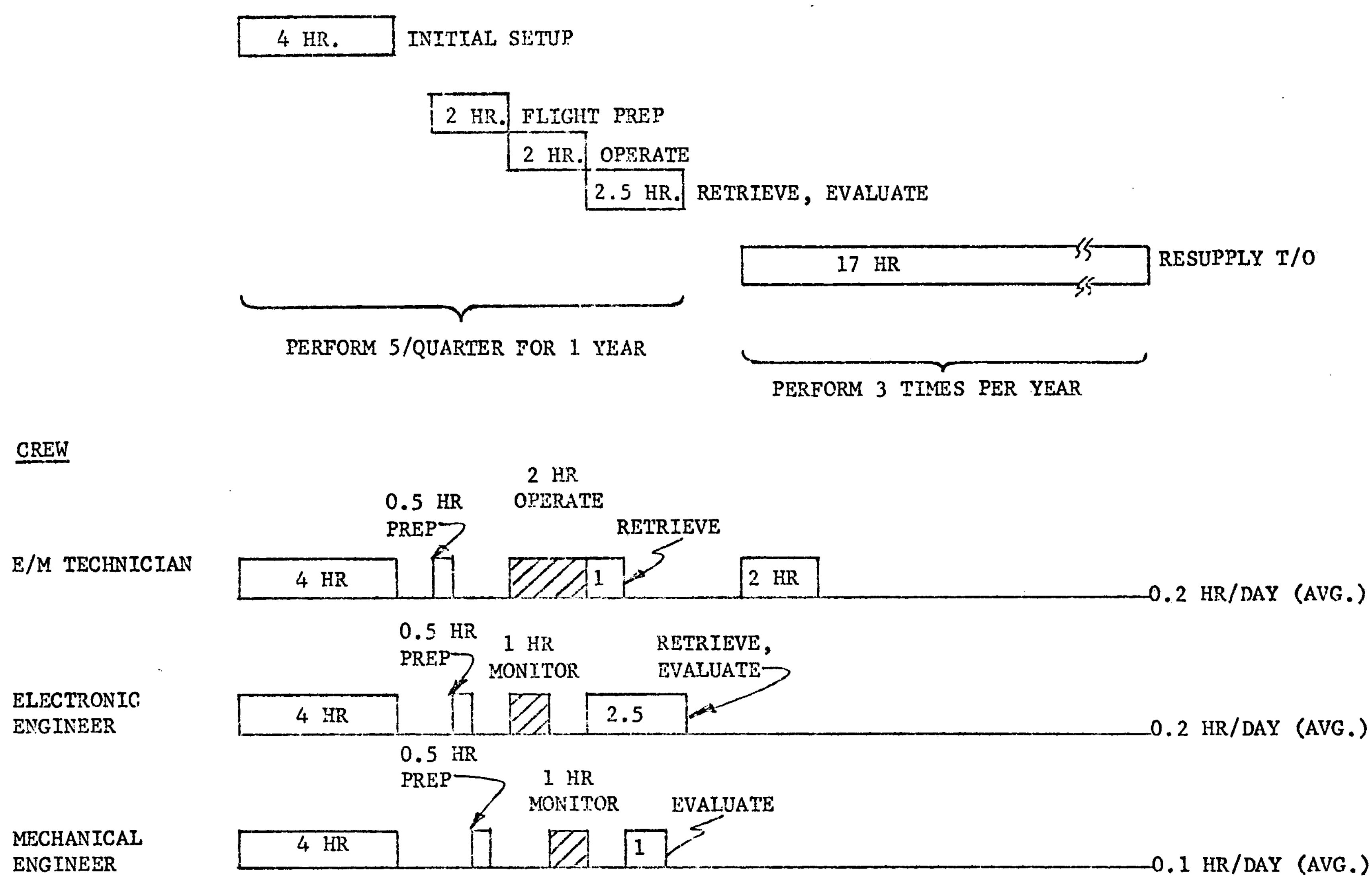
T-5A INITIAL FLIGHT EXPERIMENT



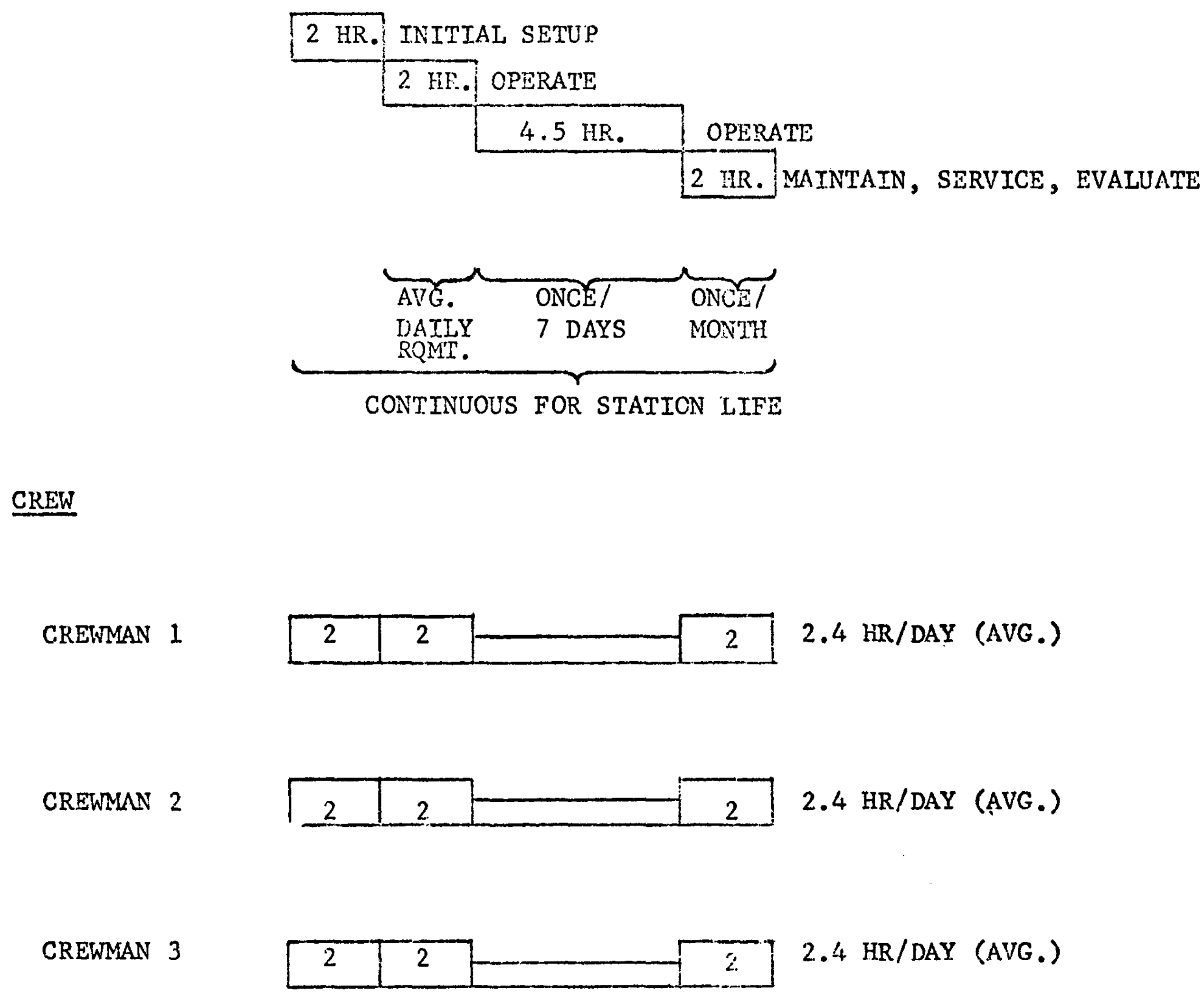
T-5B FUNCTIONAL MANIPULATION EXPERIMENT



T-5C GROUND CONTROL EXPERIMENT

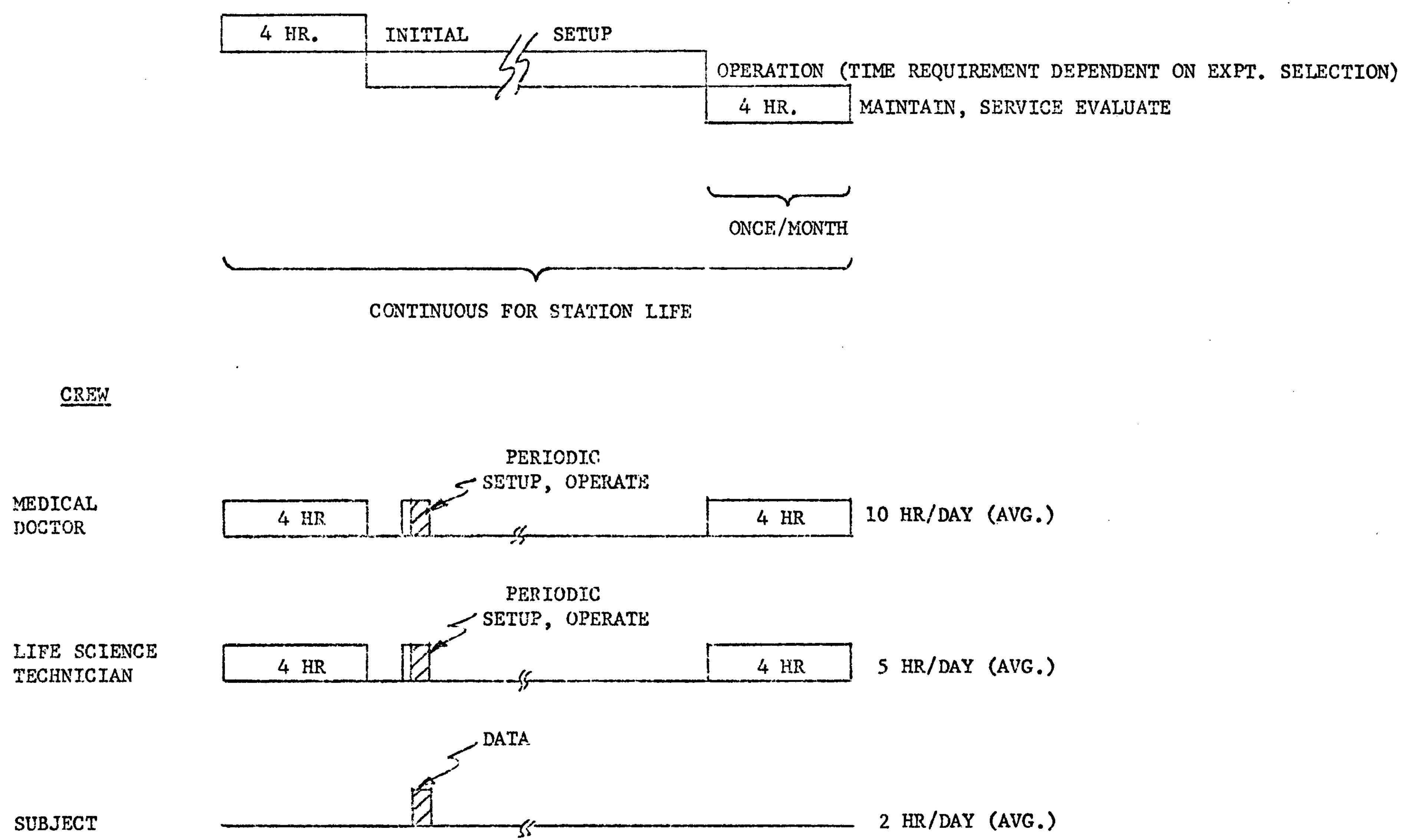


LS-ST/A MINIMAL MEDICAL RESEARCH FACILITY (STATION)

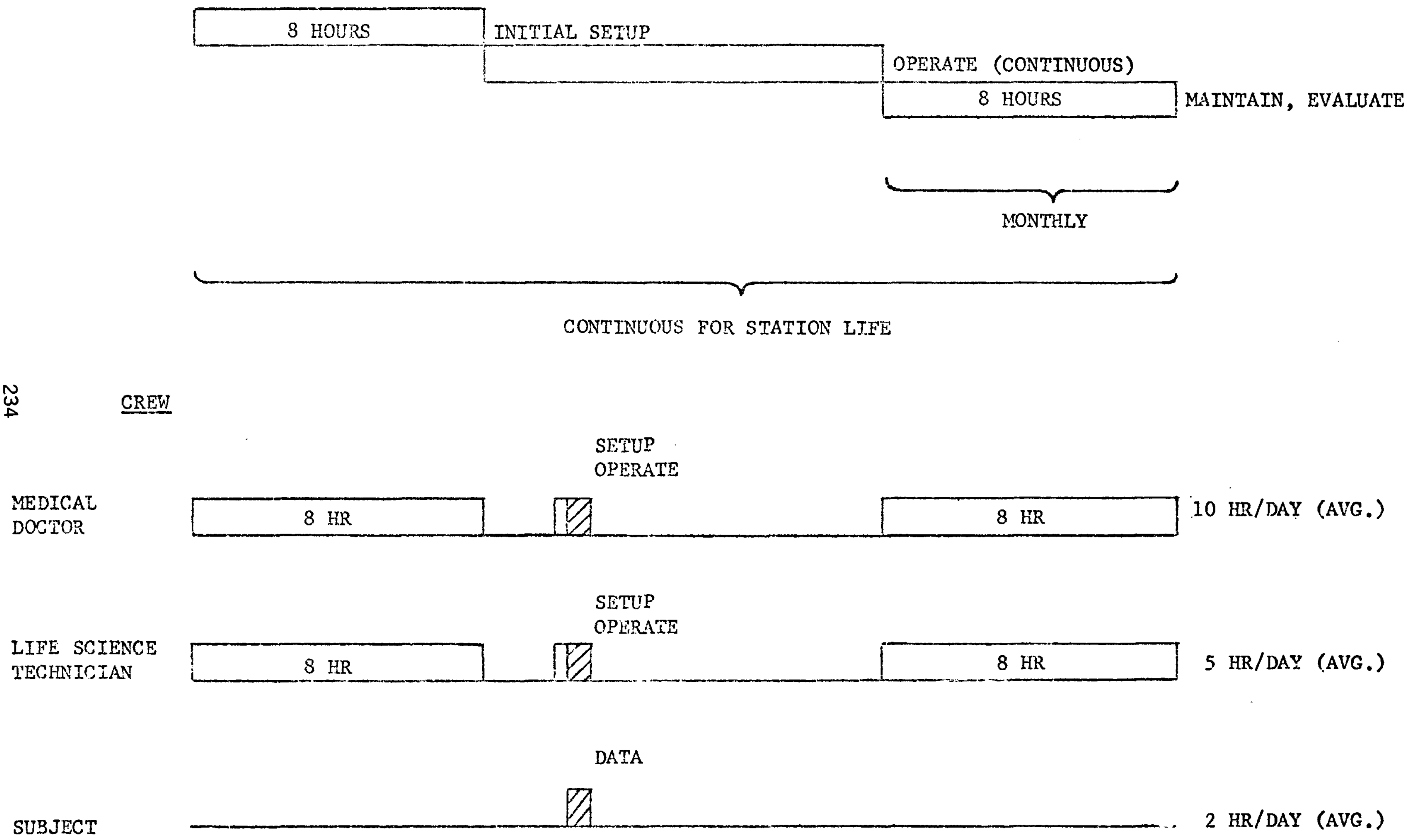


NOTE: NO MEDICAL DOCTOR REQUIRED - OPERATED BY SUBJECTS.

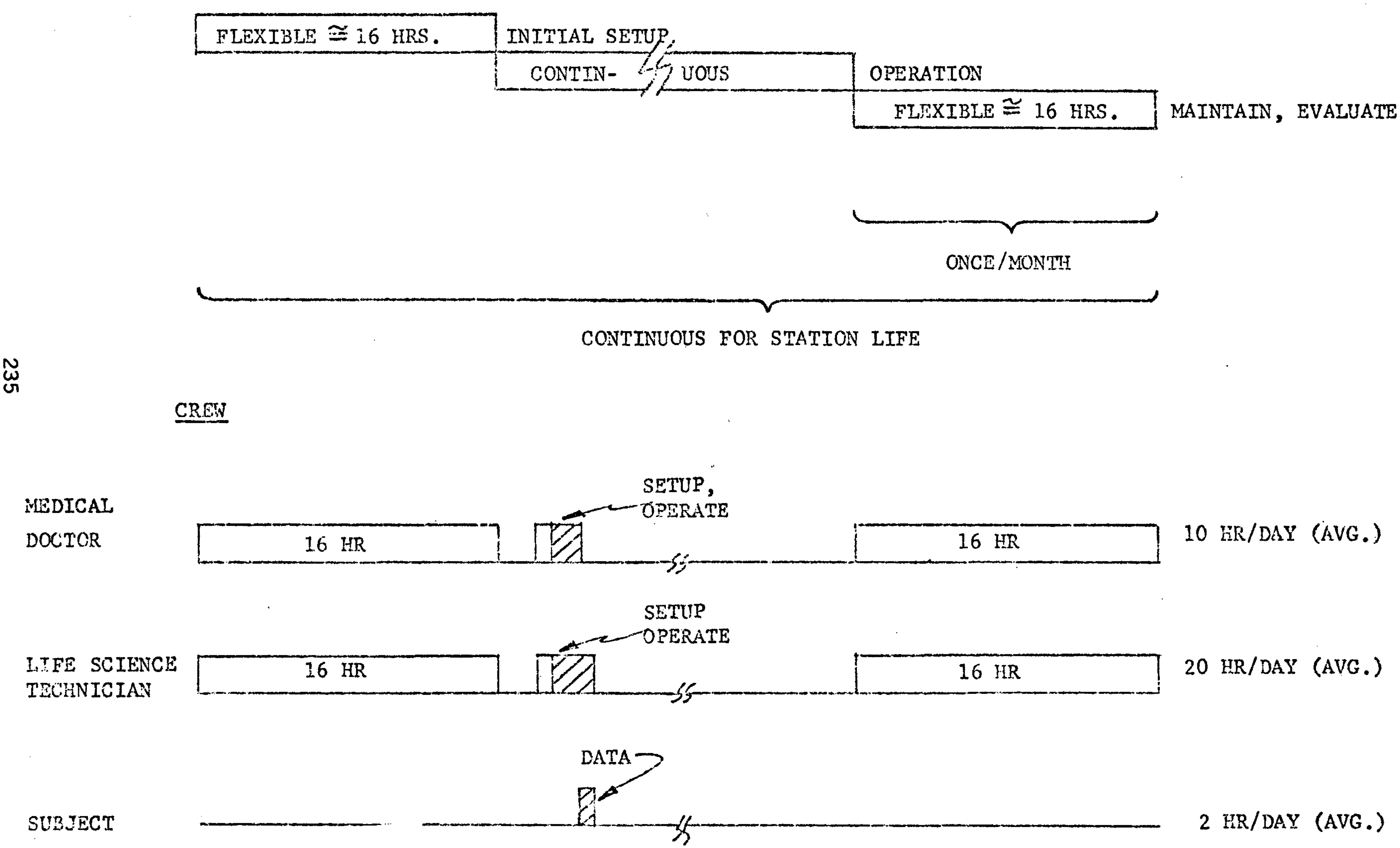
LS-ST/B LIFE SCIENCE FACILITY



LS-ST/C INTERIM LIFE SCIENCE FACILITY



LS-ST/D DEDICATED LIFE SCIENCE FACILITY



PRECEDING PAGE BLANK NOT FILMED

Section 5
CREW COMPOSITION REQUIREMENTS

The data in Table 5-1 summarizes the crew skill and time requirements for the experiments within each Functional Program Element (FPE). The times listed for each skill are totals for all tasks including Setup, Operate and Shutdown/Evaluate.

The EVA time requirements include preparation time and post-EVA activities in addition to the time required outside the spacecraft.

The crew skill requirements indicate a requirement for a particular skill and do not indicate the number of crewmen required.

Crew time per day indicates the time required for each skill during the period of experiment operation. Where the experiment operates continually, the crew time per day shown is a daily average. The crew times and skills for both the free flying, attached modules and integral experiments are provided. The free flying and attached modules are noted in the remarks column.

Table 5-1

CREW REQUIREMENTS

FPE (Requirements)	EVA ("Ours)	Skill Type	Crew Time (Hours Per Operating Day)	Crew Time (Hours Per Mission)	Remarks
A1 X-Ray Astronomy - Hl-Res Telescope - Large Area Telescope - Supplementary Exp	None	Astronomer/ Astrophysicist	3.0	90/30 days	Free-flying module
A2 Advanced Stellar Astronomy - 3-Meter Telescope	None Planned	Astronomer/ Astrophysicist	4.0	144 hrs/30 days	The total crew time of 448 hours/30 days includes 1 hours for maint and 447 hours for experiment operation. The 447 hours could be programmed from a remote location such as the ground Free-flying module
A3 Advanced Solar Astronomy - 1.5M Photoheliograph	None Planned	Astronomer/ Astrophysicist	0.30 min/orbit 0.333 min/orbit	16 orbit/day	30 min is set up time
- XUV Spectroheliograph	None Planned	Same	2.833 min/orbit		Duty cycle based on operating coronagraph for 45 min on sun side of orbit
- X-Ray Grazing Incidence	None Planned	Same	3.5 min/orbit		
- Solar Coronagraph	None Planned	Same	Sum side		Free-flying module
A4 Intermediate UV Tel - 0.94M Narrow Field	None	Astronomer/ 2.2 hrs Astrophysicist Source	4.0 hrs		Attached Module
- 0.3M Wide Field	None	Astronomer/ 1.6 hrs Astrophysicist Source	7.8 hrs		
A5 High Energy Stellar Astronomy (7 Experiments)	None	On-Orbit Physicist/Astronaut	1.9 hrs	Continuous 1.9 hrs/ day times number of days	Attached Module Time (hrs per mission) function of MSS mission duration plus 28 for maintenance
A6 Infrared Astronomy	None	Astronomer, Astromiysicist, Astronaut	8.3	2804	Mission of almost 1 year (337 days) to survey complete celestial sphere. Attached Module
P1 Space Physics Research Lab	6 each 7 hr EVAs per mission plus one 4 hr EVA/mo.	Electrotech Tech	2.9/day average	113 hr one time/yr plus 78.7 hr/mo for 1 yr	
	6 each 7 hr EVAs per mission plus one 4 hr EVA/mo	EVA Backup	0.23/day average	35 hr one time/yr plus 4 hr/mo for 1 yr	
	None	Physicist	2.77/day average	79 hr one time/hr plus 76.7 hr/mo for 1 yr	
Total	Six 7 hr EVAs per yr plus one 4 hr EVA/mo for 2 men		5.90/day average	227 hr one time/hr plus 159.4 hr/mo for 1 yr	

Table 5-1

CREW REQUIREMENTS (Continued)

FPE / Requirements	EVA ("Ours)	Skill Type	Crew Time (Hours Per Operating Day)	Crew Time (Hours Per Mission)	Remarks
P2 Plasma Physics and Environmental Perturbation Laboratory					
Station and 30-day Shuttle	None Planned	Physicist	10.8	108	Over a 10-day period single shift operation rest periods allowable
		Electromechanical Tech	10.0	108	approximately 10 hr work days required.
		Pilot/Navigation	4.0	40	
P3 Cosmic Ray Physics Laboratory	4 - once/year	Elec/Mech Tech	10 hrs - 4 days	40 hrs/mo	It is assumed that the EVA will be required for yearly magnht/dewar exchange. (
		Physicist	10 hrs - 4 days		
			2 hrs - 26 days	92 hrs/mo	(Decrease in dwar DLA to 5 ft to pass through airlock would shorten the interval.
					Attached Module
P4 Physics and Chemistry Lab				(Per 90 days)	
	Not required	6 Physicist	6 3.0	448	
		23 Physical Chemist	23 3.5	313	
		9 Thermo	9 1.0	98	
		12 Electromechanical Technician	12 17.2	1538	
SS1 Earth Observations Facility				(Per 90 days)	
			Station	Station	Attached Module
	0	Photo Tech/Cartog	12	120	
		Elec Engr	2.3	32	
		Elec Mech Tech	16.5	159	
		Official Tech	10.2	107	
		Oceanographer	5.2	77	
		Meteorologist	6.2	80	
		Acronomist	5.9	59	
		Phys Geologist	7.9	79	
		Photo Geologist	4.0	40	
		Geographer	4.6	46	
		Hydrology	2.4	32	
C/N-1 Comm/Nav					
Station (1 yr)	43	10-Elect Engr	1.2	437/year	Time allocated to a specific skill code may actually be worked by a different crew member under the cognizance of the skill code listed.
		12-Electroccn Tech	0.4	138/year	
		14-Optical Tech	0.3	110/year	
		17-Microwave Spec	1.1	397/year	
					Attached Module
MS-1 Materials Science and Manufacturing in Space	None		7.7	232/30 days	These times represent total crew time for total PFE. See subgroup crew for skill types and crew types for each subgroup.
T-1 Contamination Measurements	11.6/30 days (AVO)	Electrotech Tech	0.99 hr/day	29.7/30 day	11.6 hr EVA results from 23 hr/2 yr plus 10.4 hr/mo
	11.6/30 days (AVO)	EVA Backup°	0.51 hr/day	15.1/30 day	11.6 hr EVA results from 23 hr/2 yr plus 10.6 hr/mo
		Physicist	5.72/day	31.6/30 day	Higher EVA and Crew hours/day and assumes higher rate of experiment operation.

Table 5-1

CREW REQUIREMENTS (Continues)

Requirements FPE	EVA ("Ours)	Skill Type	Crew Time (Hours Per Operating Day)	Crew Time (Hours Per Mission)	Remarks
T-2 Fluid Management	None	Electrotech Tech	14 hrs 8 hrs	527 hrs/30 days 347 hrs/30 days	1209 manhours total Attached Module
T-3 EVA All Missions	48/30 days (AVE) 48/30 days (AVE) 48/30 days (AVE	Electromech Tech Electromech Tech Electromech Tech	16.5/3 days 16.5/3 days 16.5/3 days	161/30 days 161/30 days 161/30 days	
T-4 Advanced Spacecraft Systems Tests	14 hr/mo	Electromech Tech Electronic Engineer Mechanical Engineer Thermodynamicist Microbiological Tech Physical Chemist Metallurgist	21.7 hrs 0.8 hrs 2.3 hrs 0.7 hrs 0.8 hrs 0.3 hrs 0.1 hr	650/30 days 25/30 days 70/30 days 20/30 days 23/30 days 10/30 days 1/30 days	
T-5 Teleoperation	0	Electromech Tech	11.0	133/30 days	
Life Sciences LS-ST/D Dedicated Life Science Facility	(Experiment Dependent)	Medical Doctor Life Science	10 26	720/90 days 1440/90 days	Attached Module Calculated on the basis of 60 hr week peak days consist of 14 hrs