APPLICATION OF MOL HARDWARE FOR RENDEZVOUS/RESUPPLY OPERATING MODE

CONTRACT

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PREPARED FOR

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INDEX

PAGE NO.

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1.0 INTRODUCTION

The Department of Defense Manned Orbiting Laboratory (MOL) Program interest in extended duration orbital manned systems is based upon numerous contracted and in-house studies performed over the past several years. Principal among the contracted efforts have been the SLOMAR, MODS, MTSS, OSS, and Phase Zero MOL studies. In-house studies have been continually pursued from the outset of the MOL conceptual design. The collective findings of these studies indicate that the basic MOL follow-on objectives of improvement in system economics, performance, and operating flexibility can be best achieved through utilization of a Rendezvous/Resupply mode. While the Baseline MOL program has as its objective 30 day mission duration, design provisions with the Baseline have been made to permit growth to 60 day mission duration. Thus, all practicable provisions have been made in the MOL Baseline hardware for effective application of the rendezvous mode in future growth versions of the program, and extensive systems planning has resulted in a specific preferred concept for possible implementation. With the initiation of the MOL Phase II, Engineering Development Program, it is now logical to conduct a preliminary design and engineering study of the MOL growth concept to provide sufficient planning information on which timely funding and schedule decisions can be made with high confidence.

Apart from the fundamental basis for this effort, as outlined above, additional interest by the National Aeronautics and Space Agency and the President's Scientific Advisory Committee in the long-term Bioastronautics testing potential of the MOL hardware has led to considerable attention to this aspect. In view of the inherent capability of the projected MOL follow-on system to accomplish extended Bioastronautics testing, and of the economic advantage which might accrue from such application, NASA requested the MOL SPO to furnish technical and economic information on second generation MOL systems concepts. Consequently, MOL planning information was submitted to NASA, and description of possible alternative system applications was briefed to NASA and PSAC personnel. Therefore, elements of the preferred Rendezvous/Resupply applications concept, and extensions of the concept for accomplishment of prolonged Bioastronautics testing, are included in this document for guidance.

2.0 OBJECTIVES AND APPROACH

The objective of this study is to obtain preliminary analytic and design substantiation of a specific concept for application of MOL Baseline end-items to a possible follow-on Rendezvous/Resupply system.

The study shall be conducted in such depth and detail as to form an adequate basis for schedule and cost estimates, and shall be oriented toward definition of total system problems as well as particular hardware interfaces. The Contractor's study efforts shall primarily be confined to delineation of the system concept summarized in Section 7.0.

Conduct of the study shall be over a period of five months. The study schedule and milestone dates are shown in Table I. Task numbers shown on the schedule relate to those tasks identified in Section 4.0.

Overall management of the study is the responsibility of the Manned Orbiting Laboratory Systems Program Office (MOL/SPO).

Technical Direction for this study will be the responsibility of Aerospace Corporation. Periodically, during conduct of the study, meetings between the Contractor and MOL/SPO/Aerospace will be held for this purpose.

The Study Contractor shall conduct the study to the requirements as stated in this Work Specification. The Contractor also shall define the management structure for this procurement and appoint a study Project Manager for direct contact with the designated Air Force Project Officer.

3.0 SCOPE

The concept to be considered for this study involves a maximum application of hardware and software developed in the initial MOL Program. Major features of the concept include a relatively low-cost Rendezvous/Resupply Vehicle (RRV), derived from Baseline subsystems, which consists of: A Gemini B, propulsion, electrical power, life support, spares, and docking hardware. The function of the RRV is to furnish logistic support and crew rotation at approximately sixty day intervals to a Rendezvous Initial Vehicle (RIV) comprised of a modified Laboratory and Mission Module which are maintained on-orbit.

3.1 OPERATIONAL MODES

Three modes of Rendezvous/Resupply system utilization shall be considered:

(a) Continuous MOL Baseline mission operations. (mode A)

(b) Continuous MOL Baseline mission operations, combined with Bioastronautics Testing for up to one year orbital stays. (mode B)

(c) Primary mission to be long duration Bioastronautics testing, with launches conducted from ETR. (mode C)

3.2 ORBITING VEHICLE CONFIGURATION

The vehicle configurations studies shall include, but not necessarily be limited to, the following reference baselines:

(a) In Mode A, the RIV will consist of a single compartment laboratory with provisions for RRV docking. The RIV will be launched unmanned. The RRV will provide logistic support to the baseline mission operations for approximately sixty day intervals.

(b) In Mode B, the RIV will contain dual laboratory compartments with provisions for RRV docking. The RIV will be launched unmanned. The RRV will provide support of the baseline mission in combination with prolonged Bioastronautics testing for approximately sixty day intervals.

(c) In Mode C, the baseline military mission equipment and provisions are deleted, and the basic RRV and RIV vehicles are configured to most efficiently accommodate long duration Bioastronautics testing.

4.0 TASKS

The following study tasks shall be performed for each of the three modes of Rendezvous/Resupply utilization as defined in Section 3.1.

4.1

Define the operational requirements for each of the three defined modes of operation, including representative Bioastronautics test equipment. The scope of this definition effort will be restricted to a review of the baseline mission operations and the long term Bioastronautics testing operations in order to identify those requirements which significantly impact the basic configuration of the Rendezvous Orbiting Vehicle.

4.2

Perform a survey of possible system configurations which utilize MOL hardware as a basis and which satisfy the operational requirements defined in Task 4.1. The system concept defined in Section 7.0 shall be used as a base point.

4.3

Select the most promising configurations. Development risk and cost, compatibility with logical system evolution, flexibility, system performance, orbit duration/resupply variables, etc., will be defined for each configuration analyzed. The results of this task will be approved by the MOL System Program Office prior to further study.

4.4

Establish the operational requirements for the selected concept. This will include crew rotational requirements, launching requirements, and program support requirements. Analysis will be performed to establish the overall function distribution to segments of the total system. From this, major interfaces will be identified.

4.5

Perform a preliminary design analysis to establish basic design characteristics of the Rendezvous Initial Vehicle (RIV) and the Rendezvous Resupply Vehicle (RRV). The approach to be taken will be one of utilizing the MOL hardware to the greatest extent possible. The design analysis performed will be limited to those areas where significant design modifications to the basic MOL hardware are required. Major modifications will be identified. Design analysis will be performed to determine the design/development feasibility and the most promising approach in the following specific areas:

(a) Vehicle subsystem life extension limited to major critical subsystems. Analysis will include the aspects of maintenance/replacement/repair, redundancy, design modification, and new design.

(b) Evaluation of utilization of single and dual pressurized compartment for the RIV.

(c) Docking structure design and compatibility with basic vehicle structure. Rendezvous and docking dynamics analysis will not be a part of this study effort. Necessary impact data will be assumed based upon published general studies.

(d) Vehicle control system for Resupply Vehicle will be analyzed to define a basic design compatible with the operational requirements and the previously established rendezvous requirements (Item (c) above).

4.6

Define a feasible preliminary plan for the design-development evolution of the RIV and RRV. This plan will include:

(a) Definition of major development and system test requirements.

(b) Major development facility requirements beyond those planned for the basic MOL program.

(c) Development and acquisition schedule. Information will be limited to major program milestones and long lead time or schedule risk items.

(d) Program costs will be estimated and presented in terms of Baseline MOL Program cost elements.

4.7

Define major program operational requirements to include facility requirements, gross simulation requirements, AGE requirements, and estimated program operations cost.

4.8

Provide a preliminary definition of equipment, test procedures, and timelines for Bioastronautic testing during prolonged orbital stay.

(a) Physiological tests.

(b) Psychological tests.

(c) Artificial gravity and/or exercise devices.

4.9

Provide results of the study in the following end items:

(a) Mid-Study Briefing

(b) Final Study Briefing

(c) Final Summary Report

4.10

In the foregoing tasks, results of the study effort shall include at least the following information, as applicable to the task:

(a) Description of vehicles, the vehicle subsystems and their operation.

(b) Preliminary design layouts of vehicle configurations identifying equipment locations and major mechanical/structural interfaces.

(c) System level block diagrams and functional schematics.

(d) Mass properties and c.g. location estimates.

5.0 GROUND RULES

5.1

System to perform baseline MOL mission, with possible addition of complimentary payload elements. Possible use of system for long term Bioastronautics testing.

5.2

WTR launch site; sunsynchronous orbit inclination; 80 N. M. perigee and optimized apogee altitude (except Mode C).

5.3

Five minute launch window (for purposes of sizing Resupply Vehicle).

5.4

Two man operating crew, with possible growth to four.

5.5

Sixty-day nominal minimum resupply cycle.

5.6

Hardware and software to be derived from Baseline MOL system. (Including T-III C (U)).

5.7

Initial (RIV) Vehicle launched unmanned for DOD or Combined Missions only; will not be required to perform mission operations in the unmanned mode.

5.8

Gemini B capability to return data will be utilized.

5.9

Normal crew transfer to be Intra-Vehicular (I. V.), except E. V. A. may be considered for crew-rotation on the combined basic and extended duration bioastronautics test mission.

5.10

EVA for maintenance/repair/replacement of components external to pressurized compartment.

5.11

Minimum assistance by crew in post-docking connections of RRV to RIV. (i. e., desire automatic sequences of high reliability for RRV/RIV interface connectors.)

5.12

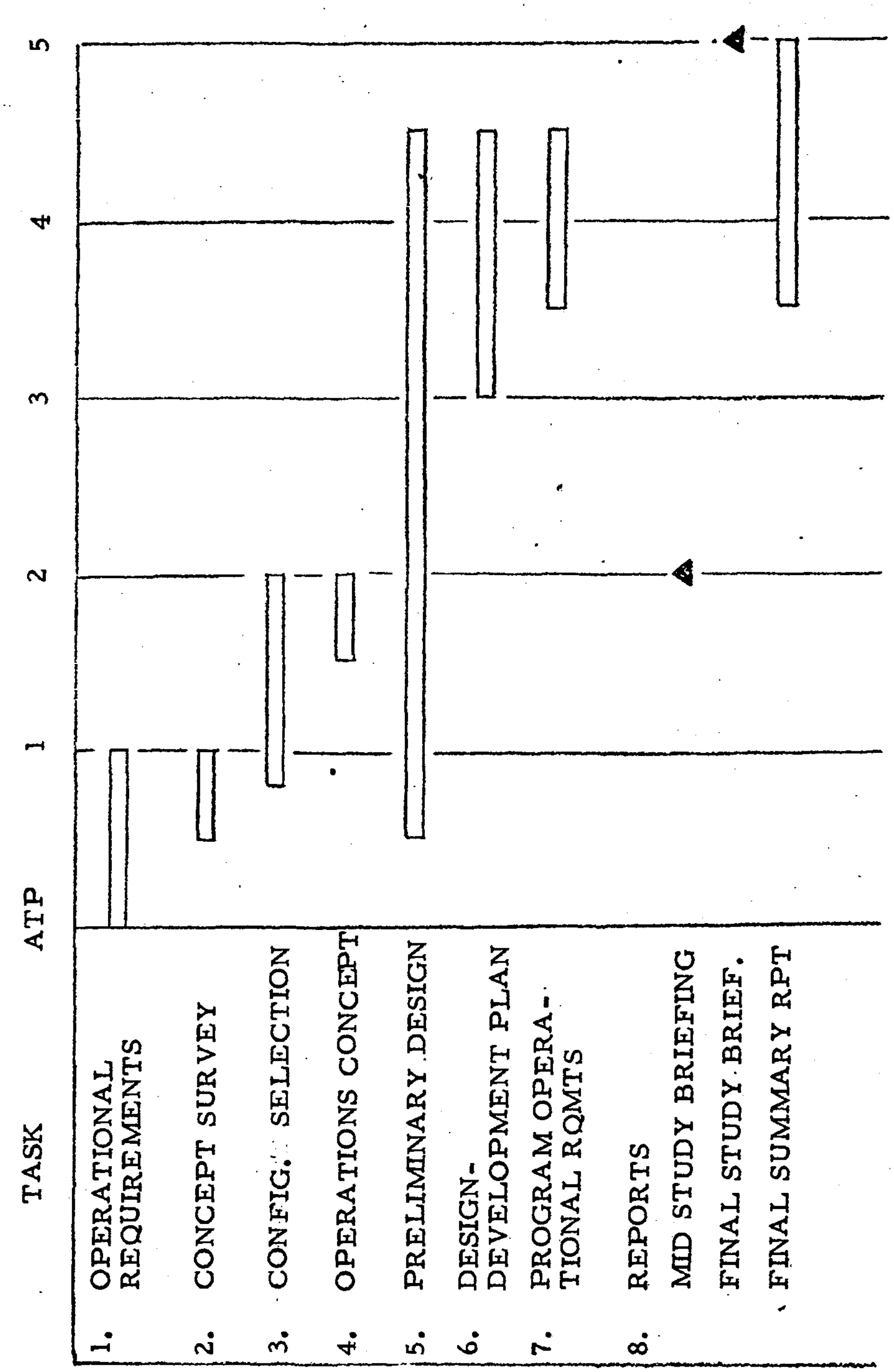
Maintain a high probability of mission success. The approaches for extending subsystem life on-orbit shall not appreciably reduce subsystem reliability from the 30 day baseline development levels.

5.13

Assume Rendezvous Resupply system to be ready for operational use in early 1973.

6.0 SCHEDULES

TABLE I - STUDY SCHEDULE
(MONTHS)



7.0 CONCEPT DESCRIPTION

7.1 Foreword

Periodic resupply of and crew rotation to an Orbiting Vehicle, utilizing a low cost resupply vehicle, has been selected as the most promising approach to a cost effective MOL follow-on program. This section contains a summary of system concepts intended to furnish Contractor guidance.

7.2 Rendezvous Initial Vehicle

The Rendezvous Initial Vehicle (RIV) concept consists of a modified Laboratory Module and a Mission Module as depicted in Figure 1. The modifications to the Laboratory Module include adding a pressurized compartment, that has only selected subsystems remaining, to the forward end of the existing pressurized compartment; removing the DRV, its supports and launch tube from the pressure compartment, and removing half the cryogenic tanks, and one fuel cell from the unpressurized compartment. The required docking system hardware, interface connections for operation of the system, and ascent fairing accommodations are part of the docking plane modifications. The added pressure compartment is to be utilized primarily for storage and operation of items connected with crew activities such as vehicle maintenance, bio testing, physical conditioning and recreation. Other items such as sleep and food preparation and consumption stations may be included in this compartment.

It is intended that the RIV vehicle be launched in the unmanned mode and be capable of orbit storage in a stabilized condition for periods of not less than 30 days. Following docking to a Resupply Vehicle, the RIV is to be activated for operation in a manned mode. At the end of each resupply period, the RIV will be returned to the stored mode for replacement of the RRV and crew.

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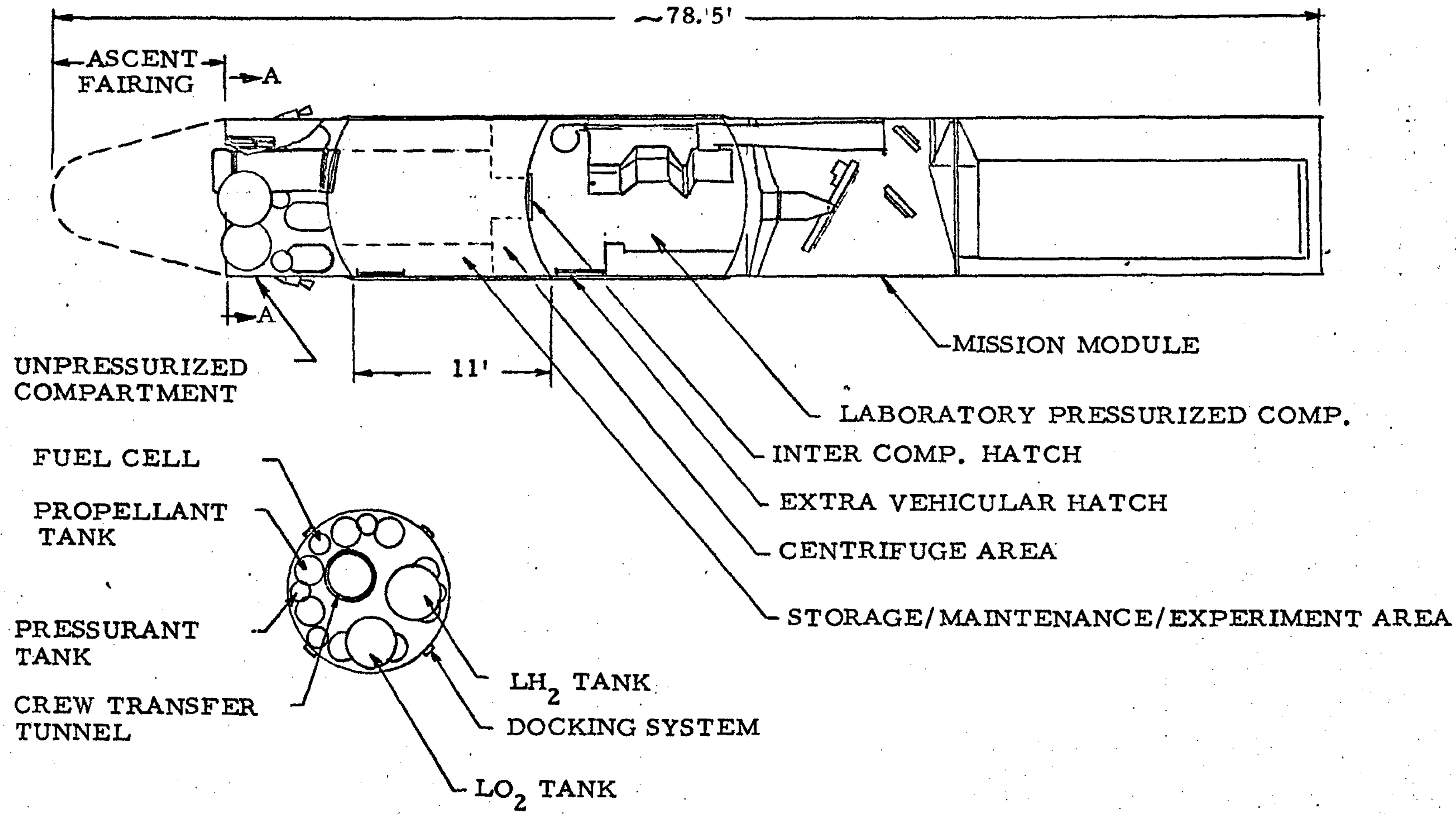
FIGURE 1

RENDEZVOUS INITIAL VEHICLE CONFIGURATION

(DUAL COMPARTMENT LABORATORY)



VIEW A-A

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FIGURE 2

RENDEZVOUS/RESUPPLY VEHICLE - "VERTICAL" DRV ARRANGEMENT

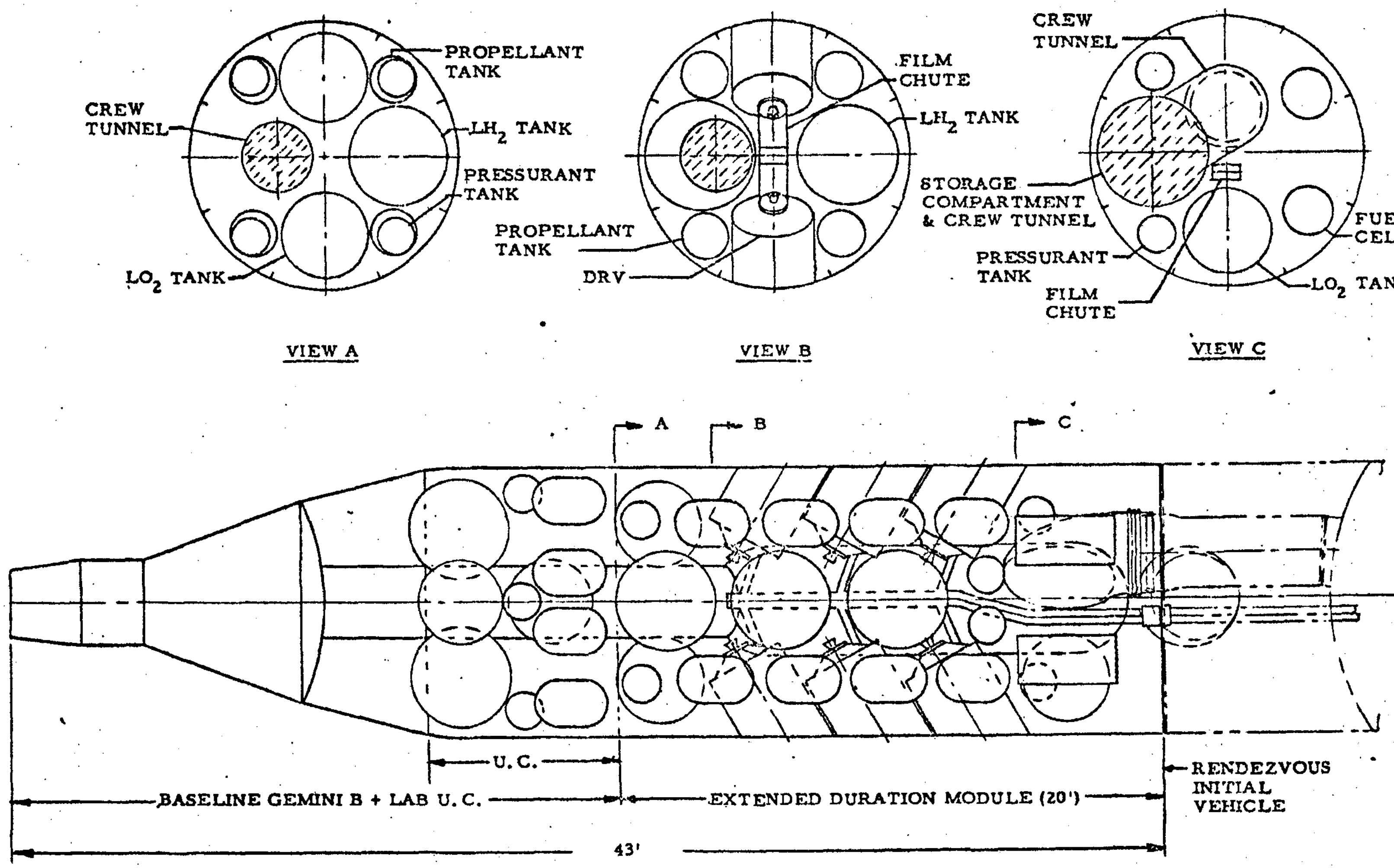

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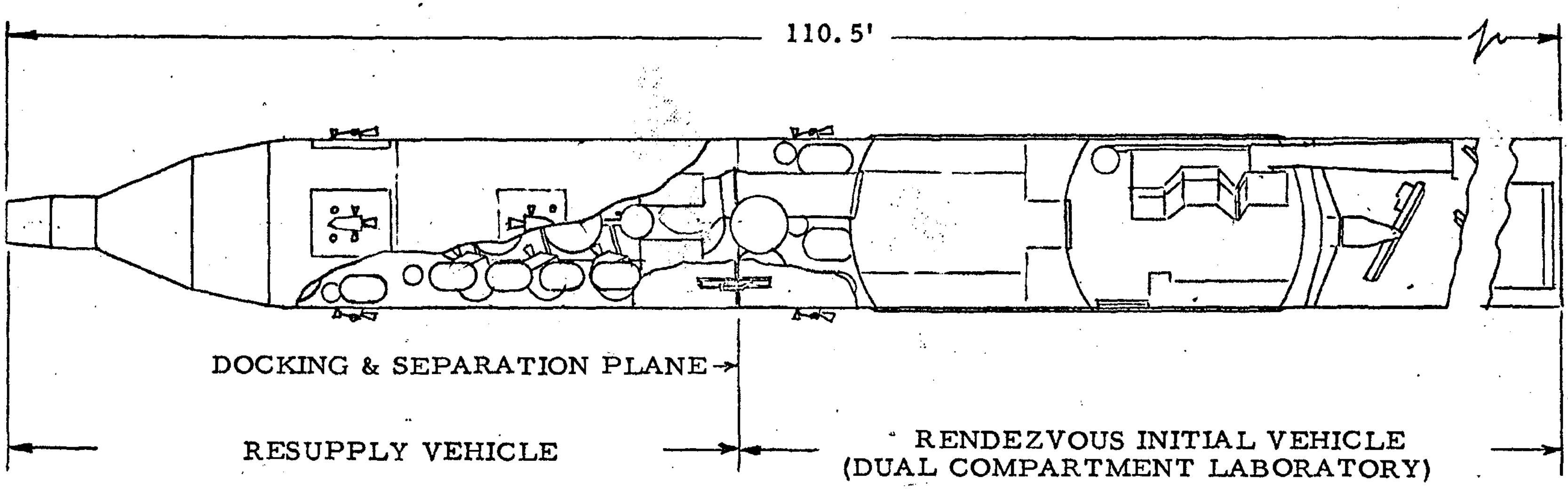
FIGURE 3

RENDEZVOUS ORBITING VEHICLE FUNCTIONS

(NOMINAL 60 DAY RESUPPLY CYCLE)



RRV FUNCTIONS

- CREW TRANSPORT VEHICLE
- ACTS PROPULSION
- PRIME POWER SYSTEM
- LIFE SUPPORT EXPENDABLES
- DATA RETURN SYSTEM
- SUBSYSTEM SPARES/REPLACEMENTS

RIV FUNCTIONS

- LIFE SUPPORT SYSTEM
- ATTITUDE CONTROL REFERENCE/ ELECTRONICS
- COMMUNICATIONS AND DATA HANDLING
- ENVIRONMENTAL CONTROL
- HRO SYSTEM

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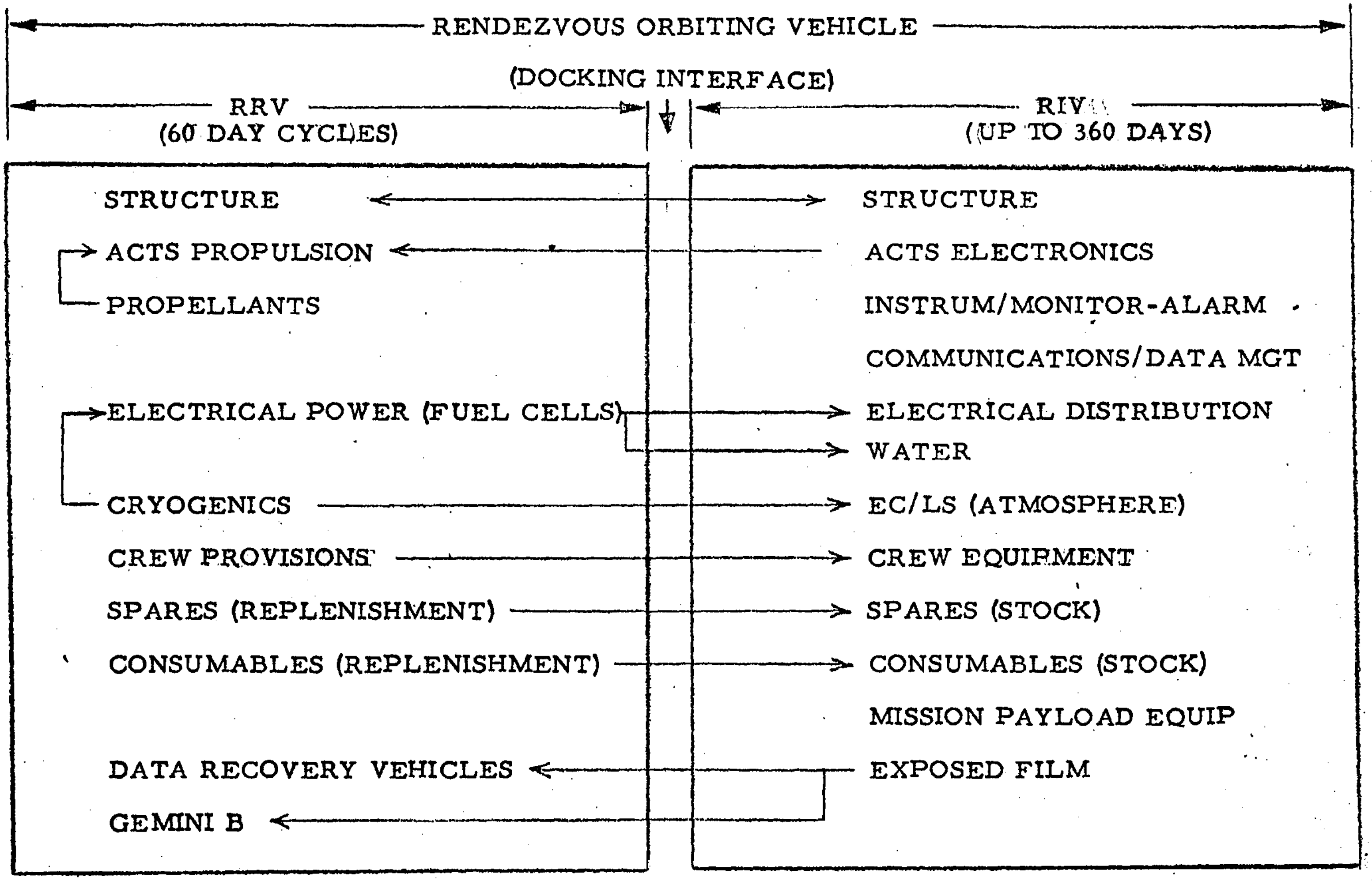
FIGURE 4

ROV SUBSYSTEM RELATIONSHIP



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7.3 Rendezvous Resupply Vehicle

The Rendezvous Resupply Vehicle (RRV) concept consists of a Gemini B, a modified Laboratory Unpressurized Compartment, an Extended Duration Module, and subsystems developed for the Baseline Manned and Automatic vehicles. A pictorial representation of the RRV is shown on Figure 2.

Modifications to the Unpressurized Compartment are those necessary to permit a structural and equipment interface with the Extended Duration Module. The Extended Duration Module consists of a structural shell, and the extended duration elements of the Power System, Propulsion System, Cryogenic Tank System, and Data Recovery System. Other components include the Crew Transfer Tunnel and Storage Compartment, Docking System, and their associated supporting structure and interconnections. All items of equipment are Baseline derived except the Docking System, and certain interface connections associated with the crew transfer tunnel, power, O_2 gas and fluid lines.

It is intended that the Resupply Vehicle be capable of providing mission support for the crew and vehicle systems for at least sixty days of continuous operation in a nominal orbit of 96.4^{o}, at an 80 N.M. perigee with an optimized apogee altitude.

7.4 Rendezvous Orbiting Vehicle

The Rendezvous Orbiting Vehicle (ROV) is the on-orbit assembled vehicle system consisting of a RIV and a RRV in the docked/operating mode. The ROV configuration and the principle system element functions related to the RRV/RIV are illustrated in Figures 3 and 4.

Activities of the crew in the normal operating mode are to be "shirtsleeve." This is accommodated by the pressurized interconnecting tunnel in the RRV for transfer of crew equipments, food, spare parts, and film from the RRV and the dual pressurized compartment RIV. The dual compartment laboratory RIV permits crew activity to be isolated with reconnaissance mission operation conducted from the aft compartment and other activities, such as rest, recreation, repair, or bio-testing to be performed in the forward compartment.

Following a nominal sixty day duty period, the crew is to be relieved and the system expendables replenished by a new RRV.

7.5 Mission Scenario

A nominal Rendezvous Mission operations scenario is depicted in Figure 5. The initial launch timing is selected to permit optimum acquisition of the RIV by the RRV. Each resupply launch will be made such that the new RRV arrives at the ROV before exhaustion of prior RRV expendables. With the new RRV in a station keeping mode, the RIV is placed in a stored mode, after which the prior RRV disengages from the RIV, permitting the new RRV to dock. The RIV is then reactivated by the new RRV, and the prior RRV Gemini B is returned from orbit.

7.6 Potential Long Duration Bioastronautics Testing

7.6.1 Combined Mission Approach

The system configuration concept described in the foregoing appears to have a direct potential application to acquisition of long duration bioastronautics data. In this case, the forward pressurized compartment might be used as a substantially equipped bioastronautics test facility, and test data could be obtained in parallel with accomplishment of the basic MOL mission objectives. Figure 6 illustrates possible utilization of the basic RRV and RIV vehicles in a Combined Mission Mode. The operations procedures would entail unique crew exchange techniques, in order to build up individual crew member time on orbit. An approach which would permit the attainment of durations up to one year on orbit, based upon progressive analysis of accumulated bio-test data, is summarized in Figure 7.

FIGURE 5

RENDEZVOUS AND RESUPPLY OPERATIONS
(CONTINUOUS MANNED)

FLIGHT TIME LINE	FUNCTION
−T	LAUNCH RIV VEHICLE AND STORE
TO	
T = 0	LAUNCH RESUPPLY VEHICLE #1
	o RENDEZVOUS WITH RIV
	o DOCK RRV #1 WITH RIV
	o OPERATE ROV SYSTEM
60	LAUNCH RESUPPLY VEHICLE #2
	o RENDEZVOUS WITH ROV (STATION KEEP)
	o PLACE RIV IN INTER-DOCK MODE
	o SEPARATE EXPENDED RRV #1
	o RETURN RRV #1 CREW + DATA
	o DOCK RRV #2 WITH RIV
	o OPERATE ROV SYSTEM
120	REPEAT WITH RRV #3 AND SUBSEQUENT
ETC.	MISSION TERMINATION
	o PREPARE SYSTEM FOR DISPOSAL
	o SEPARATE EXPENDED RRV
	o RETURN RRV CREW + DATA
	o DISPOSE OF RIV

VEHICLE CONFIGURATION

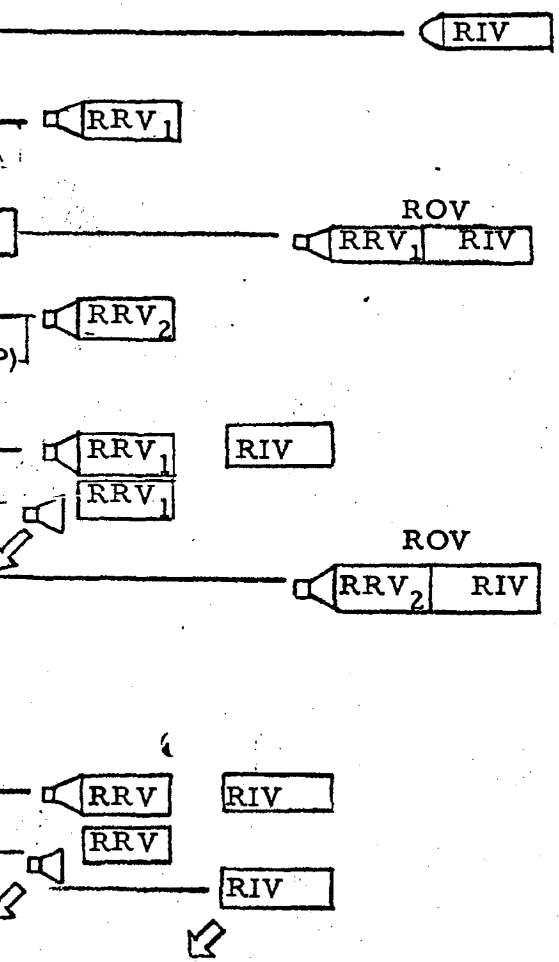
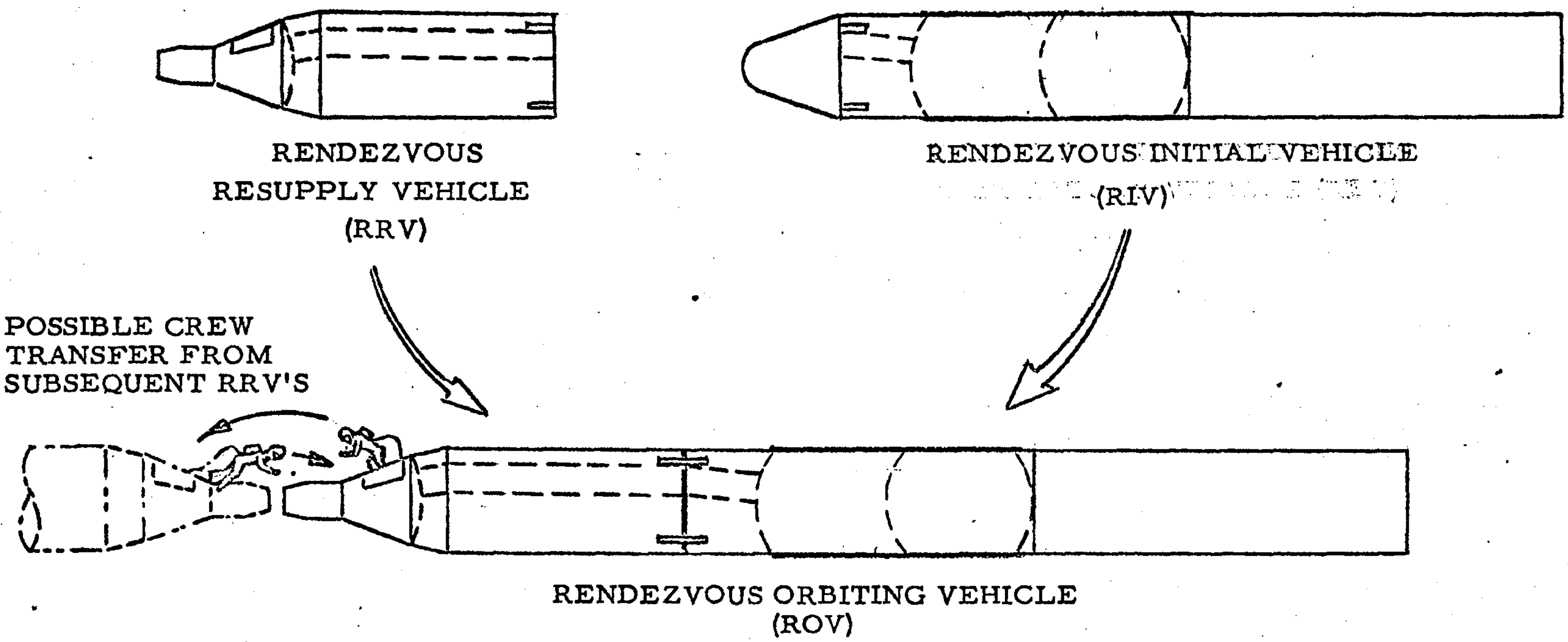


FIGURE 6
2 MAN DUAL COMPARTMENT LABORATORY CONFIGURATION

(COMBINED MISSION)



RRV FUNCTIONS

- CREW TRANSPORT VEHICLE
- ACTS PROPULSION
- PRIME POWER
- LIFE SUPPORT EXPENDABLES
- DATA RETURN SYSTEM
- SUBSYSTEM SPARES/REPLACEMENTS

RIV FUNCTIONS

- LIFE SUPPORT SYSTEM
- ATTITUDE CONTROL REF. ELECTRONICS
- COMMUNICATIONS AND DATA HANDLING
- ENVIRONMENTAL CONTROL
- PERFORMANCE DATA

FIGURE 7

POTENTIAL BIOASTRONAUTICS TEST PROGRAM

(TWO MAN - DUAL COMPARTMENT LABORATORY)

LAUNCH		ACCUMULATED TIME (MONTHS)	CREW ON-ORBIT TIME (MONTHS)		TEST DATA * (MONTHS)
RIV	RRV		A	B	
1	1	2	2	2*	2
	2	4	4*	2	4
	3	6	2	4	-
	4	8	4	6*	6
	5	10	6	2	2
	6	12	8*	4*	8, 4
2	7	14	2	2	-
	8	16	4*	4	4
	9	18	2	6	-
	10	20	4	8	-
	11	22	6*	10	6
	12	24	2*	12*	2, 12

TEST DATA TOTALS

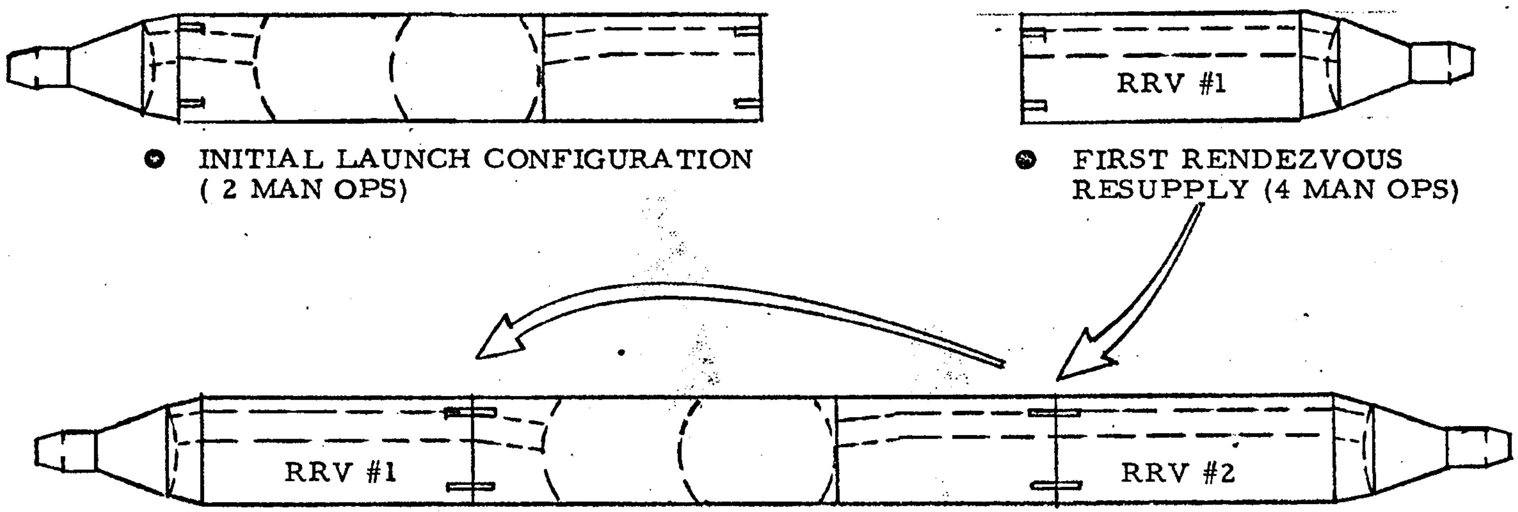
3 MEN @ 2 MONTHS
3 MEN @ 4 MONTHS
2 MEN @ 6 MONTHS
1 MAN @ 8 MONTHS
1 MAN @ 12 MONTHS

7.6.2 Primary Biomedical/Experiments Mission Approach

Possible application of MOL-derived hardware to missions primarily oriented toward extended physiological and psychological testing is illustrated in Figure 8. In this concept, basic mission payload equipment is replaced by a modified mission module structure, and provisions for docking and crew transfer are made at both ends of the Orbiting Vehicle. The system is configured for four man crew operations. A nominal mission scenario for this concept is shown in Figure 9, and a possible crew rotation procedure is summarized in Figure 10.

FIGURE 8

4 MAN DUAL COMPARTMENT LABORATORY



- ON-ORBIT CONFIGURATION (4 MAN OPS)

RRV FUNCTIONS

- ACTS PROPULSION
- PRIME ELECTRICAL POWER
- LIFE SUPPORT EXPENDABLES
- EXPERIMENTS
- SPARE EQUIPMENT

LABORATORY FUNCTIONS

- LIFE SUPPORT/ENVIRONMENTAL CONTROL
- ACTS - REFERENCE
- COMMUNICATIONS/DATA
- BIO-MEDICAL EQUIPMENT
- EXPERIMENTS

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FIGURE 9

4 MAN - DUAL COMPARTMENT CONCEPT
POSSIBLE RENDEZVOUS/RESUPPLY OPERATIONS

TIME LINE (DAY)	FUNCTION	CREW	CONFIGURATION
0-60	LAUNCH ROV & OPERATE	2	
60	LAUNCH RRV #1	2	
	RENDEZVOUS WITH ROV	4	
	DOCK & OPERATE ROV SYSTEM		
120	LAUNCH RRV #2	2	
	RENDEZVOUS WITH ROV		
	SEPARATE RRV #1 & STATION KEEP		
	DOCK RRV #2 ON P/L COMPARTMENT		
	SEPARATE GEMINI #1 & RETURN		
	DOCK RRV #1 ON ROV/GEM I. F.	4	
	OPERATE ROV SYSTEM		
180	LAUNCH RRV #3 & SUBS. (REPEAT RRV SEQUENCE)		SAME AS RRV #2 CONFIG.

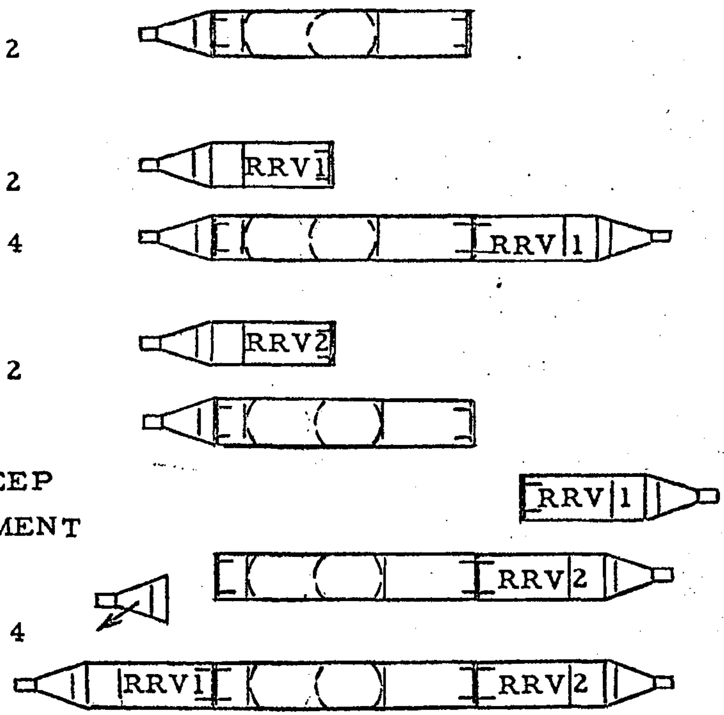

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FIGURE 10

POTENTIAL BIOASTRONAUTICS TEST PROGRAM

(FOUR MAN - DUAL COMPARTMENT LABORATORY)

LAUNCH		ACCUMULATED TIME (MONTHS)	CREW ON-ORBIT TIME (MONTHS)				TEST DATA * (MONTHS)
RIV	RVV		A	B	C	D	
1	1	2	2	2	2	2*	2
	2	4	4	4	4*	2	4
	3	6	6	6*	2	4	6
	4	8	8	2	4	6	-
	5	10	10	4	6	8	-
	6	12	12*	6*	8*	10*	12, 6, 8, 10

TEST DATA TOTALS

1 MAN @ 2 MONTHS
1 MAN @ 4 MONTHS
2 MEN @ 6 MONTHS
1 MAN @ 8 MONTHS
1 MAN @ 10 MONTHS
1 MAN @ 12 MONTHS