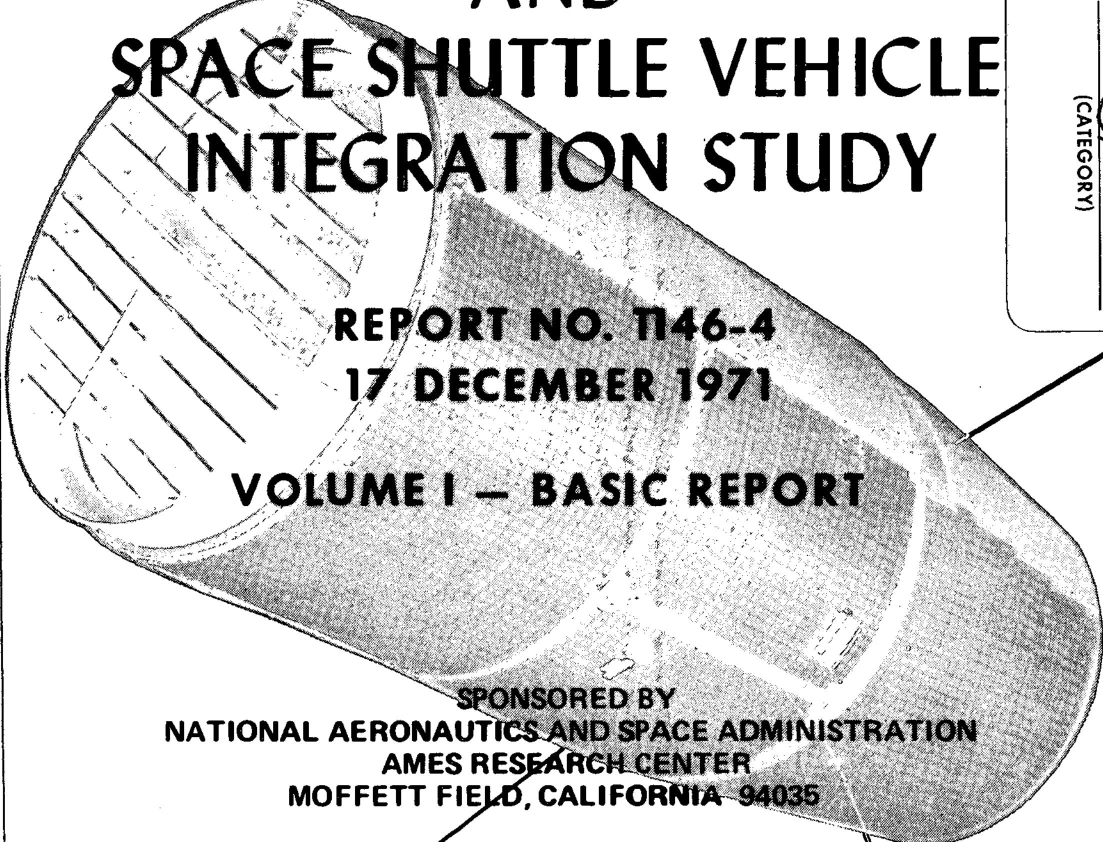
FINAL PROGRESS REPORT

BIORESEARCH MODULE DESIGN DEFINITION AND SPACE SHUTTLE VEHICLE INTEGRATION STUDY



REPORT NO. T146-4
17 DECEMBER 1971

VOLUME I — BASIC REPORT

SPONSORED BY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA 94035

CONTRACT NAS2-6524

VOUGHT MISSILES AND SPACE COMPANY

DALLAS, TEXAS 75222

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LTV AEROSPACE CORPORATION
DALLAS, TEXAS 75222

NASA CR-XXXXX

FINAL PROGRESS REPORT

BIORESEARCH MODULE DESIGN DEFINITION AND SPACE SHUTTLE VEHICLE INTEGRATION STUDY

VOLUME I - BASIC REPORT

By A. L. Lang, Jr.

Prepared under Contract No. NAS2-6524 by

VOUGHT MISSILES AND SPACE COMPANY
LTV AEROSPACE CORPORATION
Dallas, Texas 75222

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FOREWORD

This Final Progress Report for the "Bioresearch Module Design Definition and Space Shuttle Vehicle Integration Study", NASA Contract NAS2-6524, is provided in accordance with Article IV of the contract schedule. The six-month period of performance of this contractual work was 4 June 1971 through 4 December 1971. During this period two Design Reviews were conducted, the first at the Grand Prairie, Texas facility of Vought Missiles and Space Company, LTV Aerospace Corporation; the second at the National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California. These reviews are reported in separate volumes:

"Bioresearch Module First Design Review," 26, 27 August 1971, LTV/VMSC Report No. T146-2

"Bioresearch Module Second Design Review," 5 November 1971, LTV/VMSC Report No. T146-3.

The material presented at the Design Reviews plus the results of all contractual studies are included in this Final Progress Report. The report is submitted in two volumes:

Volume I - Basic Report

Volume II - Appendices

Cost analyses presented in Sections 4.6 and 4.7 of Volume I are submitted as separate attachments.

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CONTENTS (Continued)

FINAL PROGRESS REPORT

BIORESEARCH MODULE DESIGN DEFINITION AND

SPACE SHUTTLE VEHICLE INTEGRATION STUDY

By A. L. Lang, Jr.
Vought Missiles and Space Company
LTV Aerospace Corporation

SUMMARY

Preliminary designs of the Bioexplorer spacecraft, developed in an earlier study program, are analyzed and updated to conform to a new specification which includes use of both the Scout and the Space Shuttle Vehicle for launch. The updated spacecraft is referred to as Bioresearch Module. It is capable of supporting a variety of small biological experiments in near-earth and highly elliptical earth orbits. The baseline spacecraft design is compatible with the Scout launch vehicle. Inboard profile drawings, weight statements, interface drawings, and spacecraft parts and Aerospace Ground Equipment lists are provided to document the design.

The baseline design is analyzed to determine the design and cost impact of a set of optional features. These include reduced experiment power and thermal load, addition of an experiment television monitor, and replacement of VHF with S-band communications. The impact of these options on power required, weight change and cost is defined.

Considerable study is devoted to use of the Space Shuttle Vehicle to launch and retrieve the Bioresearch Module. The investigations include missions analysis, on-orbit servicing and maintenance, interfaces, potential cost savings and test program reductions, and impact of using both the Scout and the Space Shuttle Vehicle. It is shown that the Bioresearch Module is compatible with both launch vehicles, but that additional hardware is necessary to support the Space Shuttle Vehicle launches.

To provide planning for subsequent phases of the Bioresearch Module program a development plan is presented. This includes equipment lists for flight hardware and Aerospace Ground Equipment, test program items, schedule, and costs for baseline and optional hardware and flight operations.

INTRODUCTION

The Bioresearch Module is a small scientific spacecraft capable of supporting a 45 kg (100 lb) biological experiment in near-earth or highly elliptical earth orbit for a period of six months. The spacecraft is capable of providing either zero or artificially-induced gravity environments for the experiments, accomplished by modular variation of components for the various missions. The biological problems to be studied in a space environment are the stability of circadian systems divorced from geophysical cues, and gravity preference following prolonged exposure to zero or reduced gravity. The experiment package is a government furnished item to be installed in the spacecraft just prior to flight.

The Bioresearch Module was originally designed as a Bioexplorer spacecraft (Contract NAS2-6028, Reference 1) which would be low cost, non-recoverable and capable of supporting, with minimum integration and recurring cost, a variety of small biological experiments as noted above. The preliminary designs developed under the Bioexplorer study program clearly demonstrated that the mission goals could be achieved. These were a low cost, modularized spacecraft maintaining simple spacecraft/experiment interfaces, and a high degree of commonality between mission type designs. The Bioexplorer studies, reported in References 2, 3 and 4, included trade studies, preliminary designs, performance analyses, test and operations plans, and a complete spacecraft development plan.

The Bioexplorer designs were developed as Scout-launched spacecraft for the near-earth orbits, and the highly elliptical orbit was to be achieved with a Delta launch vehicle. As a result of NASA's large effort in studies of the Space Shuttle Vehicle (SSV), and the preliminary designs developed for the Bioexplorer spacecraft, it became apparent that the Bioexplorer could be a candidate payload for the SSV. Accordingly, certain areas where additional design definition was required were identified in the statement of work for the Bioresearch Module study program (Contract NAS2-6524, Reference 5). The purpose of this contract was to devote further study effort to areas of spacecraft design, and to evaluate use of the SSV as a potential launch vehicle for the Bioresearch Module. Results of these studies are reported in this final progress report.

Scope

The scope of the Bioresearch Module study, as listed in the statement of work, is summarized as follows:

(1) Complete design definition of a Bioresearch Module as a Scout launched spacecraft to accomplish Missions I and II as

defined in the Specification (Reference 5).

(2) Preliminary definition of the design impact of using the Space Shuttle Vehicle to launch the Bioresearch Module for Missions I, II and III, and recover Missions I and II.

(3) Preliminary definition of the Space Shuttle Vehicle/ Bioresearch Module interfaces necessary to accomplish the missions defined.

(4) Funding, schedule and test plan for development and fabrication of spacecraft hardware, and support of four missions using the Scout launch vehicle.

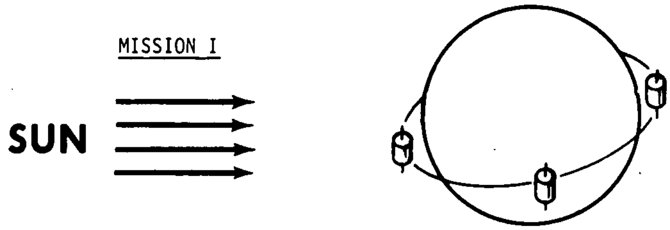
Bioresearch Module Missions

The Bioresearch Module missions are illustrated in Figure I-1. Mission I is a weightless experiment in near-earth orbit for six months. The studies resulted in a spacecraft weighing 148 kg (327 lb) which can be placed in the desired orbit by a Scout launch vehicle. Mission II is a variable g (spin-induced gravity) experiment in near-earth orbit for six months. The 156 kg (343 lb) spacecraft is also launched on a Scout vehicle. Mission III is a fixed g (spin-induced gravity at prelaunch selected rate) experiment in highly elliptic orbit for six months. The 152 kg (335 lb) spacecraft is deployed into an earth parking orbit by the SSV. By means of a velocity package it is then injected into its final orbit.

During the previous Bioexplorer study a quarter-scale model was constructed to illustrate the spacecraft configurations. The external appearance of the spacecraft has changed little as a result of the Bioresearch Module studies. Chief difference is a change in solar cell area, which is discussed later in this report. Therefore, Figures I-2, I-3, and I-4 are shown to illustrate the Bioresearch Module configurations. Figure I-2 shows the Mission I spacecraft with solar array on the sun-oriented side of the spacecraft. The forward louvers control temperature of the experiment cold plate. Figure I-3 shows the spinning Mission II spacecraft for which the spin axis is oriented normal to the earth-sun line. The small weights on extendible booms control spin rate. Figure I-4 shows the spinning Mission III for which the spin axis is also oriented normal to the earth-sun line. Dipole antennas are used for the longer range communications.

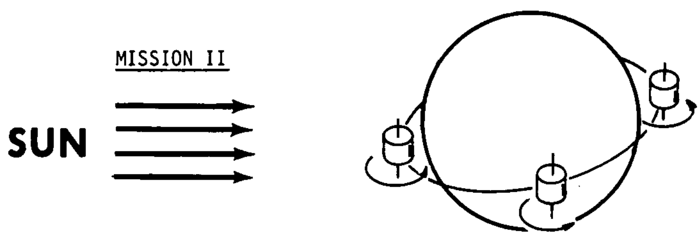
A fourth configuration, Mission I(S), is not shown. It is similar to Mission I, but longer to accommodate a special experiment.

MISSION I



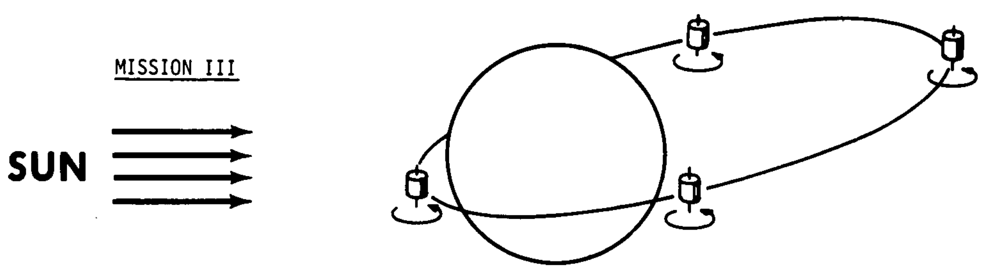
Circular Orbit: 555 km (300 n.mi.), 37.7° inclination
Lifetime: To 6 Months
Experiment Acceleration: 0g $\pm 10^{-4}$g
Launch Vehicle: Scout (Algol III, 42 in. Fairing)
Maneuvers: After Injection Despin, Sun and Earth Orient
Spacecraft Weight: 148 kg (327 lb)

MISSION II



Circular Orbit: 555 km (300 n.mi.), 37.7° inclination
Lifetime: To 6 Months
Experiment Acceleration: 0.1g to 1.5g (Variable Spin Rate)
Launch Vehicle: Scout (Algol III, 42 in. Fairing)
Maneuvers: After Injection Decrease Spin, Sun and Earth Orient
Spacecraft Weight: 156 kg (343 lb)

MISSION III



Elliptic Orbit: 555 x 241,000 km (300 x 150,000 n.mi.), 28.5° inclination
Lifetime: To 6 Months
Experiment Acceleration: 0.5g to 1.5g (Preflight Selected Spin Rate)
Launch Vehicle: Space Shuttle Vehicle
Maneuvers: After Injection Adjust Spin, Sun and Earth Orient
Spacecraft Weight: 152 kg (335 lb)

FIGURE I-1. - BIORESEARCH MODULE MISSIONS

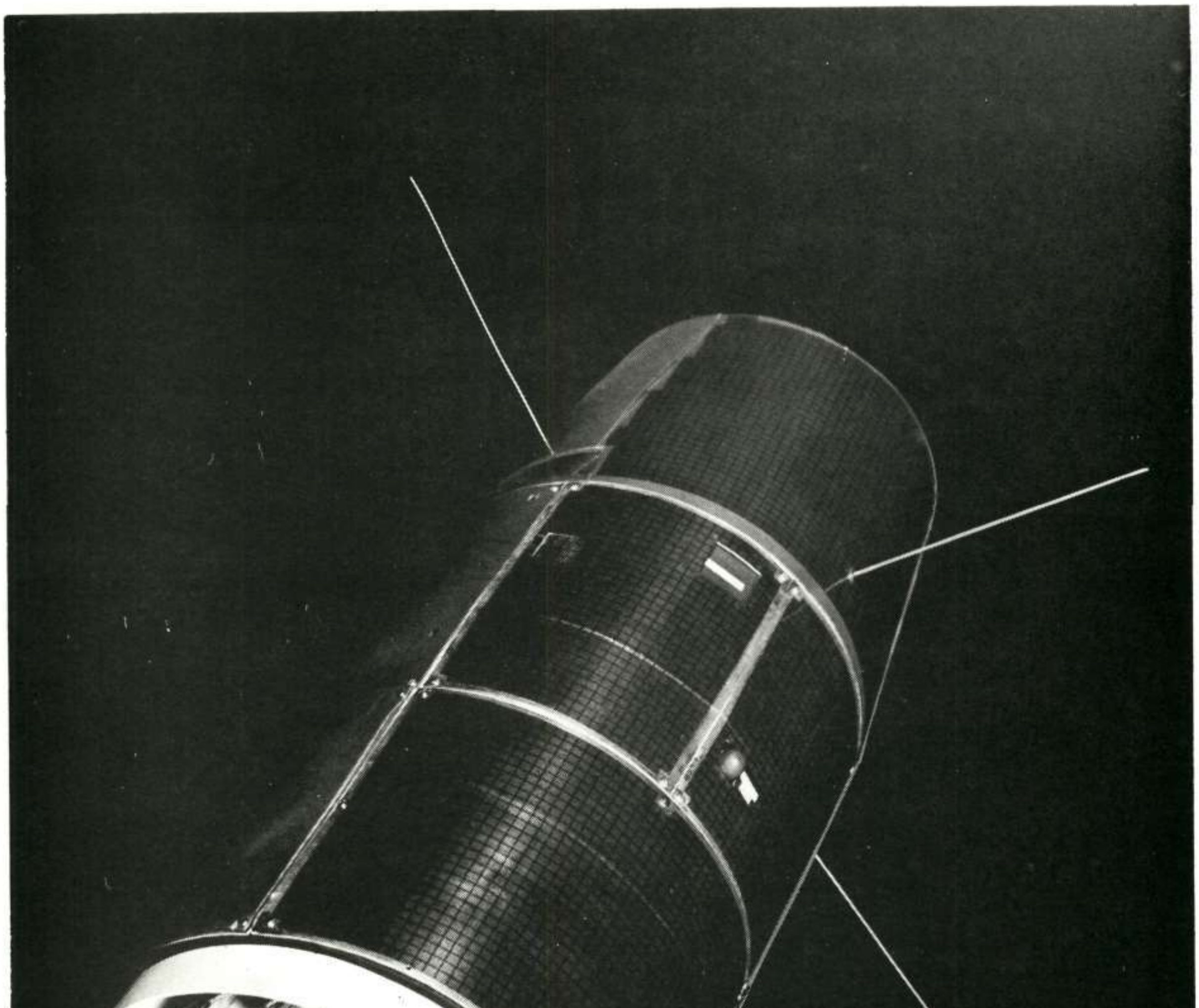


Figure I-2. — Mission I Bioresearch Module in Orbital Configuration

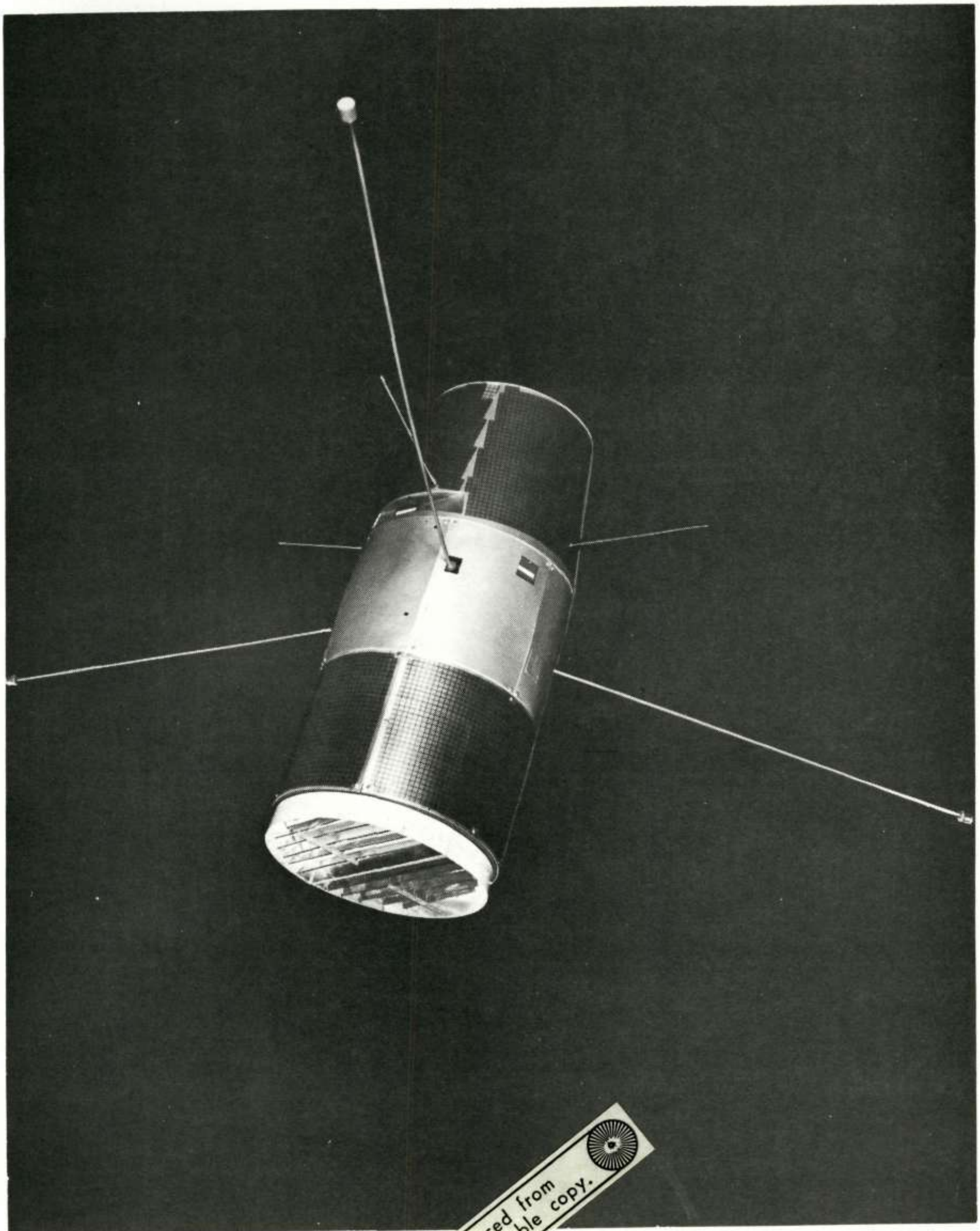


Figure I-3. — Mission II Bioresearch Module in Orbital Configuration

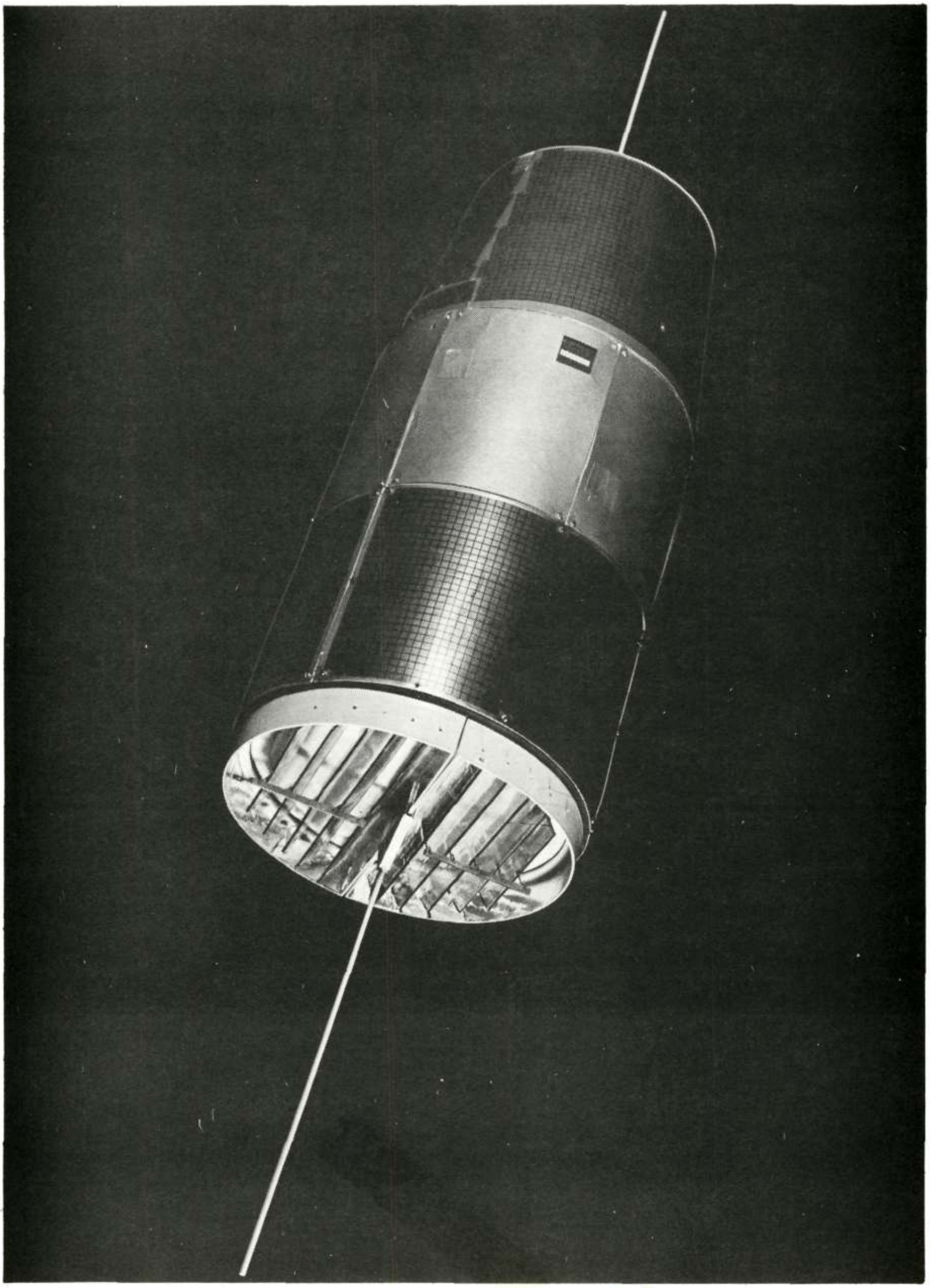


Figure I-4. — Mission III Bioresearch Module in Orbital Configuration

Study Approach

The results of the Bioexplorer studies, References 2, 3, and 4, were used as a "baseline" for the new study. The Bioexplorer designs were updated as necessary to conform to the new contract Specification, Reference 5. The resulting Bioresearch Module configurations, conforming to the Specification, were then established as the new baseline spacecraft. In this report, therefore, baseline refers to Bioresearch Module unless the context states otherwise.

In accordance with Reference 6, the baseline Bioresearch Module (Missions I and II Scout launched) was then analyzed to determine the design and cost impact of several change factors. These studies, accomplished under Task I-1 (see Table 1) included:

(1) Launch of Missions I, II and III, and recovery of Missions I and II by the SSV.

(2) Reduced experiment power

(3) Reduced experiment thermal load

(4) Addition of on-board television monitor for experiment

(5) Replacement of VHF with S-band communications

(6) Compatibility of Scout/SSV launch operations

The SSV studies were based on information furnished in the SSV Data Package, Reference 7, as part of the contract documentation.

During the study program two design reviews, References 9 and 10, were conducted to report progress and coordinate detail of the investigations.

Study Tasks

To indicate response to the contract statement of work, Table 1 has been prepared to show correlation between the statement of work and this final progress report document. The left column indicates the scope, task and deliverable items specified in Reference 5. The right column indicates the location of the study results in this document.

TABLE 1. - RELATIONSHIP BETWEEN CONTRACT STATEMENT OF WORK AND FINAL PROGRESS REPORT

*Contract Statement of Work Item	Location of Study Results in Final Progress Report
Scope	
1. Complete design definition of a Bioresearch Module as a Scout launched payload to accomplish Missions I and II.	Section 1 - Description, weights, drawings, interfaces Section 2 - Analyses Appendix A
2. Design impact of using SSV	Section 3
3. Preliminary definition of SSV/Bioresearch Module interfaces	Section 3.4, 3.5, 3.8
Contract Tasks	
Task I	
1. Modified requirements	Sections 1.3, 2.1, 4.7; Appendices B, C, D
2. Analysis of variable "g" spin rate control system.	Section 2.2, Appendix E
3. Power system performance and comparison with measured data from operational spacecraft.	Section 2.3
Task II	
1. Mission analysis using SSV for launch and retrieval	Section 3.1
2. On-orbit servicing and maintenance from SSV	Section 3.2
3. SSV operations in low circular earth orbits	Section 3.3
4. Increases in experiment support by use of SSV	Section 3.4
5. Requirements imposed by Bioresearch Module on SSV	Section 3.5
6. Impact of SSV operations on experiment operations.	Section 3.6
7. Potential cost savings and test program reductions by use of SSV.	Section 3.7
8. Impact on baseline of Scout/SSV compatibility	Section 3.8
9. Preliminary design for Scout/SSV compatible Bioresearch Module	Section 1 - Description, weights, drawings, interfaces Section 4.2 - flight hardware Section 4.3 - AGE Section 4.4 - Test program
Design Reviews	
1st	**LTV/VMSC Report No. T146-2 dated 26, 27 August 1971 ***LTV/VMSC Report No. T146-3 dated 5 November 1971
Deliverable Items	
Final Progress Report	This report

*Reference 5

**Reference 9

***Reference 10

SYMBOLS AND ABBREVIATIONS

AC	alternating-current
ACE	attitude control electronics
ACS	attitude control system
A-D	analog-to-digital
Ag	silver
AGE	aerospace ground equipment
AH	ampere-hour
Al	aluminum
Be	beryllium
B/M	Bioresearch Module
BOL	beginning of life
BPS	bits-per-second
Btu	British thermal unit
BW	bandwidth
Cd	cadmium
C_D	coefficient of drag
cm	centimeter
Cmd.	command
CONRAC	Giannini-Conrac Company
C_p	specific heat, Btu/lb °F
CRT	cathode ray tube
CW	continuous wave
db	decibel
DC	direct current

Dec	decoder
deg	degrees
DMS	Data management System
e	electrons
EFF	effective
EMI	electro-magnetic interference
EOL	end of life
ETR	Eastern Test Range
EVA	extra-vehicular activity
exp. pkg.	experiment package
F	force
°F	degrees Fahrenheit
ft	feet
FuSi	fused silica
g	unit of acceleration, 32.2 ft/sec^2; grams
GFE	government furnished equipment
G&H Tech.	G&H Technology, Inc.
GRARR	Goddard range and range-rate
GSFC	Goddard Space Flight Center
hr	hour
Hz	Hertz
I	moment of inertia, slug ft^2; total photon energy, Mev/electron
in.	inches
IVA	intra-vehicular activity
K	gain constant; one thousand

k	Bremsstrahlung photon energy, Mev
kg	kilogram
KHz	kilohertz
km	kilometer
lb	pound
LTV	LTV Aerospace Corporation
m	mass, meter
Mev	million electron volts
MHz	megahertz
mil	one thousandth of an inch
min.	minute
MSFN	Manned Space Flight Network
M.V.	millivolts
MW	milliwatts
N_2	nitrogen
NASA	National Aeronautics and Space Administration
Ni	nickel
n.mi.	nautical miles
p	empirical constant; protons
PCM	pulse code modulation
PMS	Power Management System
PWS	pulse width modulated
QA	quality assurance
QC	quality control
Q&RA	quality and reliability assurance
RANTEC	RANTEC, Inc.

RCS	reaction control system
RF	radio frequency
RFI	radio frequency interference
rms	root-mean-square
rpm	revolutions per minute
R&QA	reliability and quality assurance
S/C	spacecraft
SCI	Spacecraft, Inc.
sec	seconds
SPAR	SPAR Aerospace Products, Ltd.
SSV	Space Shuttle Vehicle
STADAN	Space Tracking and Data Acquisition Network
STEM	Antenna or control boom
T	launch time
T/M	telemetry
TV	television
UV	ultra violet
VHF	very high frequency
VMSC	Vought Missiles and Space Company
W	weight, pounds; watts
XMTR	transmitter
XPONDER	transponder
α	solar absorptivity
ϵ	thermal emissivity
Δ	incremental change
ϕ	proton or electron flux

ρ	density, lb/ft^3
σ	standard deviation
$^\circ$	degrees

1.0 BIORESEARCH MODULE SPACECRAFT

1.1 DESCRIPTION OF BASELINE CONFIGURATIONS

This section presents a description of the Bioresearch Module spacecraft which satisfies the requirements of Specification A-17193 of Reference 5. These "baseline" configurations are updated versions of the Bioexplorer spacecraft previously developed under Contract No. NAS2-6028 and reported in References 2, 3, and 4. The subsystem descriptions of Reference 4 are valid for the baseline Bioresearch Modules reported herein. Additional solar area has been provided to increase end-of-life power margin. Mission I and II spacecraft are capable of being launched by the Scout or Space Shuttle Vehicle (SSV), and the Mission III spacecraft is configured for SSV launch only to achieve the highly elliptical orbit with a six-day period.

The complete matrix of Bioresearch Module spacecraft configurations are shown in Table 2. All except the Mission I(S) spacecraft meet the requirements of the contract specification, Reference 5. The Mission I(S) spacecraft is 58.4 cm (23.0 in.) longer than the other spacecraft, projecting into the conical area of the Scout heatshield. The cold plate area in the forward end of the Mission I(S) spacecraft is thus limited to a 58.4 cm (23.0 in.) diameter compared to 86.4 cm (34.0 in.) diameter on the Mission I, II and III spacecraft. The Mission I(S) spacecraft is limited to a smaller heat load rejection capability, but this was accepted to retain the passive, radiation cooled cold plate on the forward end of the experiment package.

On all spacecraft configurations the cold plate has been assumed to form the forward closure of the experiment package to eliminate a bolted interface with attendant weight penalty and thermal conductivity uncertainty. The weight of the cold plate is charged to the spacecraft.

The various Bioresearch Module spacecraft configurations are shown in the drawings, Figures 1 through 6. All components used appear on the drawings in parts lists which show quantity, model number for off-the-shelf items, and weights.

1.1.1 Mission I. - Mission I, a zero gravity experiment conducted in near earth orbit, employs a non-spinning, attitude controlled spacecraft. The spacecraft is launched from Wallops Island, Virginia, on a Scout launch vehicle. Orbital injection is achieved by an FW-4S spin stabilized fourth stage motor. Following spacecraft separation from the fourth stage, the spacecraft is despun with a yo-yo system. As the yo-yo cables leave the spacecraft the deployable solar panels are unlatched and hinge-line torsion springs extend the panels outward so that three 120° segments of solar arrays around the equipment bay, plus a fourth 120° segment on the experiment bay all face the same direction as shown in Figure 1. A total of 4990 2x2 cm solar cells are used. A nitrogen cold gas reaction control system then captures, stabilizes, and orients the spacecraft. Two sun sensors

TABLE 2. - BIORESEARCH MODULE SPACECRAFT CONFIGURATIONS

	Mission I	Mission I(S)	Mission II	Mission III
Launch Vehicles	Scout	Scout	Scout	SSV
Orbit, km (n.mi.)	555 x 555 (300 x 300)	555 x 555 (300 x 300)	555 x 555 (300 x 300)	555 x 241,000 (300 x 150,000)
Inclination, deg.	37.7	37.7	37.7	28.5
Period	96 Min.	96 Min.	96 Min.	144 hrs.
Length, m (in.)	2.07 (81.3)	2.65 (104.3)	2.07 (81.3)	2.07 (81.3)
Diameter, m (in.)	.905 (35.6)	.905 (35.6)	.905 (35.6)	.905 (35.6)
Weight, kg (lb)	148 (327)	147 (324)	156 (343)	152 (335)
*Experiment Package	Standard Cylinder	Special Cone-Cylinder	Standard Cylinder	Standard Cylinder
No. solar cells, 2 x 2 cm	4990	4990	11,510	9,130
End-of-life power, watts	204	204	205	140
Communications: Uplink, MHz	148	148	148	148
Downlink, MHz	137	137	137	136
Description	Non-spinning, pitch and roll stabilized, slow yaw rate, experiment g < 10-4.	Similar to Mission I with longer experiment package for catapult test.	Spin stabilized, variable spin rate to achieve experiment g of 0.1 to 1.5.	Spin stabilized, preflight selected spin rate to achieve experiment g of 0.5 to 1.5.

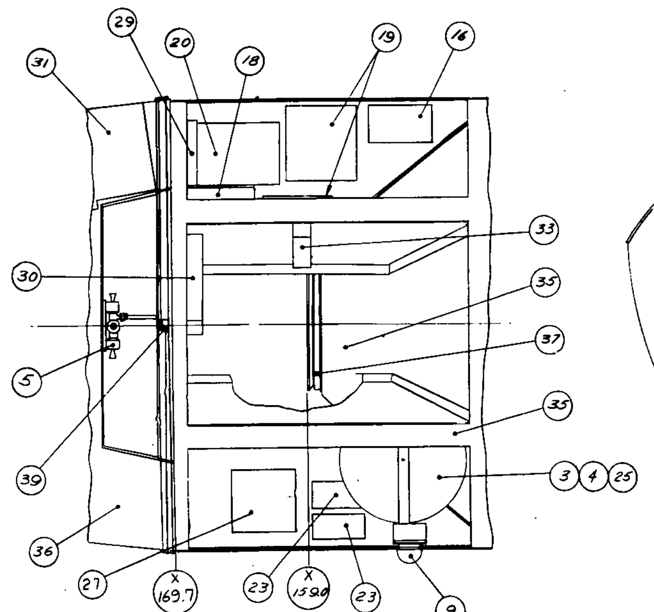
*Standard cylinder is 34 in. diameter x 24 in. length, 100 lb.

Special cone-cylinder adds 24 in. length truncated cone to top of standard cylinder, tapers to 23 in. diameter.

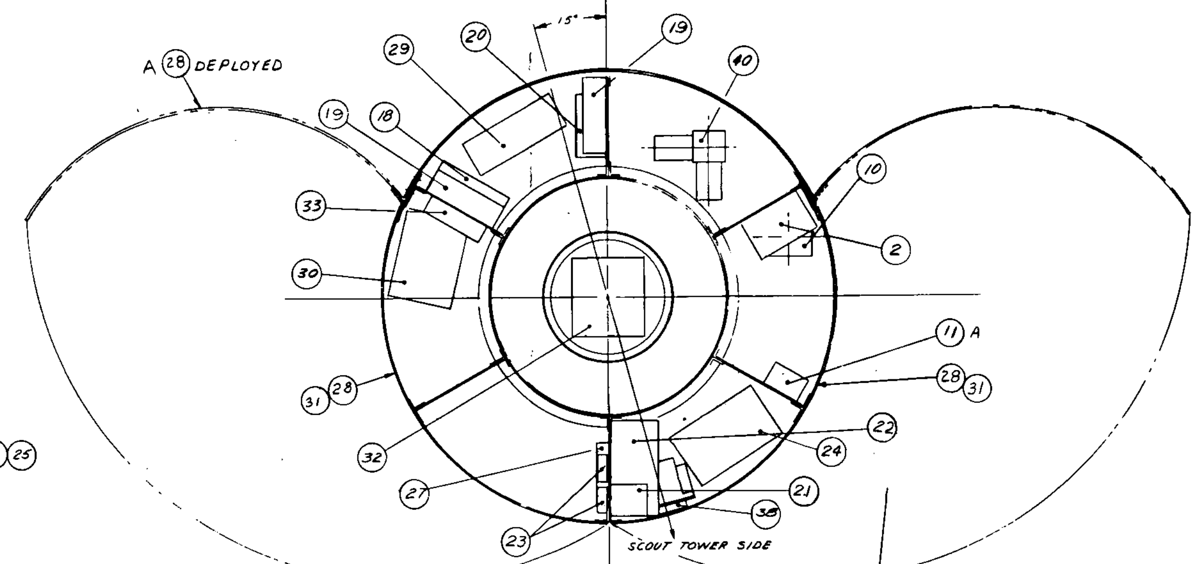
FOLDOUT FRAME 1

FOLDOUT FRAME 2

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
	A	UPDATED & REVISED UNDER CONTRACT NO. NAS2-6524	10-28-71	P.E.



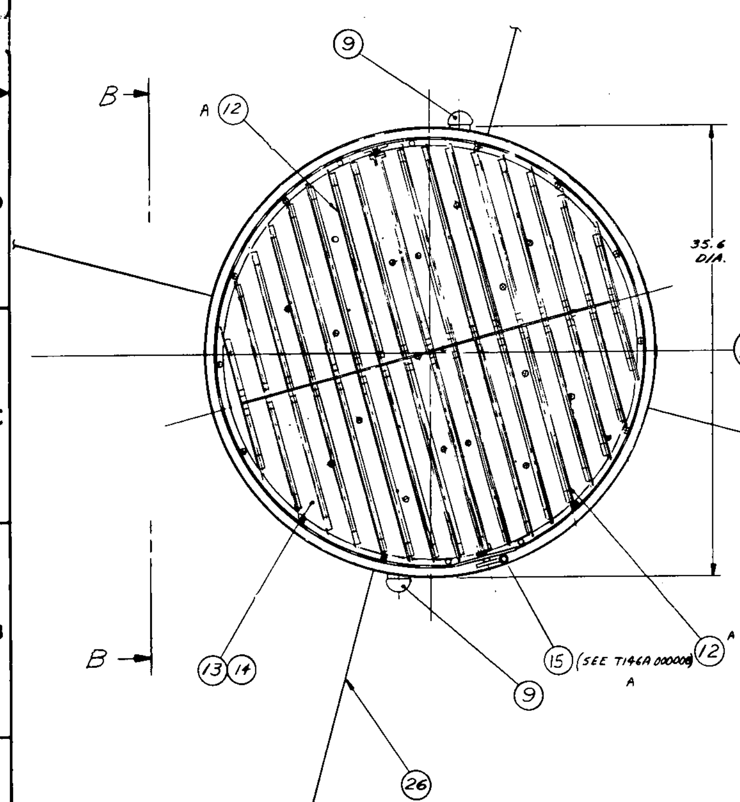
VIEW B-B

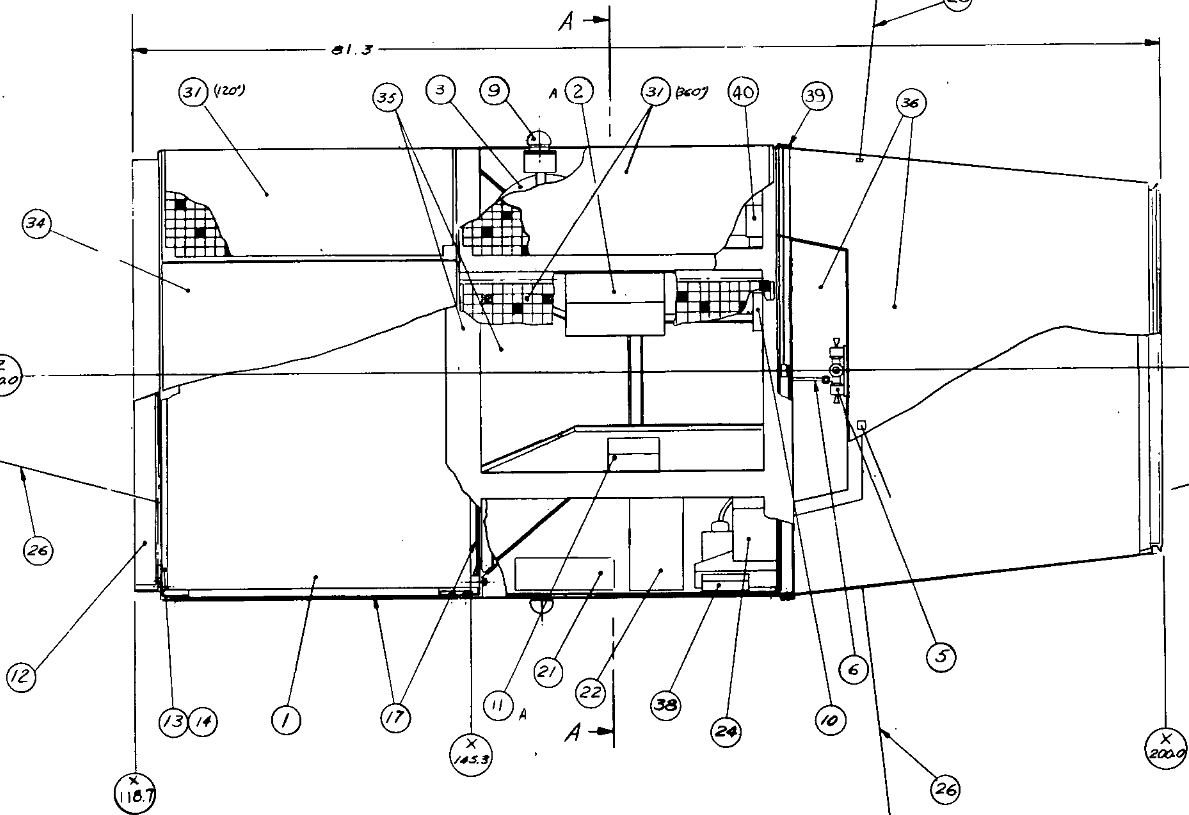


SECTION A-A

ITEM	NOMENCLATURE	MODEL OR PART NO.	W.T.	
1	EXPERIMENT PACKAGE	GFE	100.0	
	ATTITUDE CONTROL			
2	CONTROL ELECTRONICS	-	6.0	A
3	NITROGEN TANKS PLUS NITROGEN	FANSTEEL 4120006	27.5	
4	NITROGEN REGULATOR	STERER 30630		
5	THRUSTERS	STERER 29210-1	3.9	
6	VALVES & PLUMBING	-		
39	YO-YO ASSY	-	4.5	
9	SUN SENSORS	BENDIX 1771858	.4	
10	RATE GYRO ASSEMBLY	NORTHROP 79157-350	2.0	
40	INTEGRATING RATE GYROS	HONEYWELL 66110I	2.0	
	THERMAL CONTROL			
12	LOUVER ASSEMBLIES	-	5.0	A
13	RADIATING COLD PLATE ASSEMBLIES	-	23.0	
14	THERMISTOR ASSEMBLIES	-	.4	
15	LOUVER CONTROL ACTUATOR	CLIFTON MSL-8-A-1	.4	A
16	CONTROL ELECTRONICS	-	1.0	
17	INSULATION BLANKETS	ALUMINIZED MYLAR	1.6	
	COMMUNICATIONS & TELEMETRY			
18	COMMAND RECEIVERS ASSY (2)	SCI-DWG. NO. 42466	4.5	
19	COMMAND DECODERS (2)	AVCO MODEL 407	6.0	A
20	PROGRAMMER-CLOCK	-	3.5	
21	SIGNAL CONDITIONER	-	1.5	
22	PCM ENCODER	SCI MODEL 680	6.7	
23	TELEMETRY TRANSMITTERS (2)	SCI 1510100-1	1.0	
24	DATA STORAGE ASSY	SEMS-5L	6.5	
25	NITROGEN PRESSURE TRANSDUCER	CONRAC 4613198V	0.4	
26	TURNSTILE ANTENNA	-	0.3	
27	ANTENNA COUPLER	RANTEC FVV-431	1.5	
11	DATA PROCESSING UNIT	-	1.0	A
29	DATA PATCH UNIT	-	1.0	
	ELECTRICAL POWER			
30	POWER CONTROL ASSY	-	5.5	
31	SOLAR CELLS	N/P SILICON, 2X2 CM	15.2	A
32	BATTERY ASSY	GULTON 80432 CELLS	34.5	A
33	POWER PATCH UNIT	-	1.0	
	STRUCTURE			
34	EXPERIMENT PACKAGE COVER	-	7.5	
35	EQUIPMENT SECTION	-	15.5	A
36	AFT SECTION	-	10.3	A
37	SCOUT SUPPORT RING	LTV/VMSC 23-002689-5	0.7	A
28	DEPLOYABLE PANELS (2)	-	3.0	
38	UMBILICAL CONNECTOR-RECEPTACLE	G/H TECH. MOD 676	.73	A
	FLUID CONNECTOR (2)	SYMETRICS 46154-3	.77	
42 (NOT SHOWN)	COOLANT VALVES & PLUMBING	-	1.5	
	ELECTRICAL WIRING & CONNECTORS	-	18.8	
	TOTAL BASELINE WEIGHT		326.6	A

( ) - QUANTITY WHEN >1





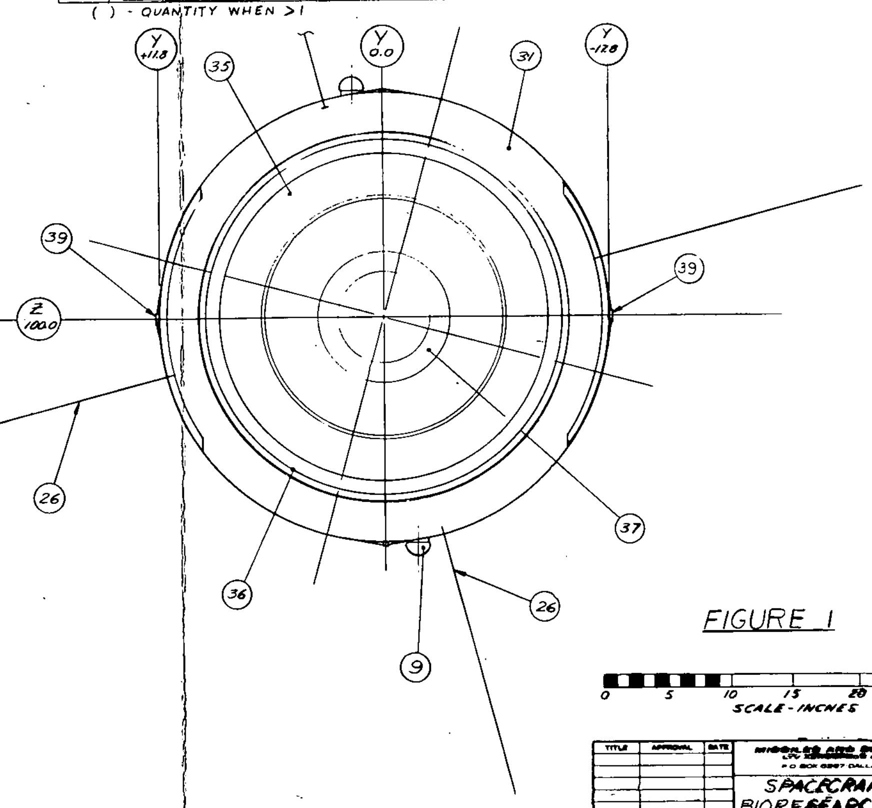


FIGURE 1

0 5 10 15 20 25 30
SCALE - INCHES

MISSILES AND SPACE DIVISION
LTV AEROSPACE CORPORATION
P.O. BOX 6267 DALLAS TEXAS 75222

SPACECRAFT ASSY.
BIORESEARCH MODULE
MISSION I

SIZE J | IDENT NO. 11613 | T146A000001

19

provide information for orienting the body-mounted solar cells toward the sun. The experiment package is contained forward in a thermally insulated compartment. A direct radiating cold plate with louvers forms the forward closure of the experiment package. Thermal control of the experiment package consists of cycling the louvers open and closed to maintain a specified cold plate temperature. A one degree-per-second yaw rate about the earth-sun line is maintained to protect the radiator from earth thermal radiation.

Spacecraft and experiment power are provided by solar cells and a battery sized to maintain power both in the earth's shadow and in sunlight. Spacecraft communications provide experiment and housekeeping data transmission to ground stations and command transmissions from ground stations to the spacecraft.

Figure 1 is an inboard profile drawing of the Mission I spacecraft showing general arrangement, and callout and weight of components. Attachment of the spacecraft to the Scout launch vehicle, and of the experiment package to the spacecraft are discussed in Section 1.4.

1.1.2 Mission I(S). - The Mission I(S) spacecraft is similar in most respects to the Mission I spacecraft. Differences are a result of the longer experiment package (1.22m/48 in. versus 0.61 m/24 in. for Mission I). A truncated conical section has been added to the experiment compartment to accommodate the longer I(S) experiment, as shown in Figure 2. A smaller cold plate and louver assembly forms the forward closure of the I(S) experiment package. This cold plate can dissipate the reduced heat loads discussed in Section 2.1. Although Reference 5 describes the I(S) experiment package as a right cylinder with 0.508 m (20 in.) diameter and 1.22 m (48 in.) length, a larger experiment package can be accommodated as noted in Figure 2. Total length is still 1.22 m (48 in.), but a lower cylinder plus upper truncated cone can be used if desired.

1.1.3 Mission II. - Mission II, a simulated gravity experiment conducted in near earth orbit, employs a spin stabilized spacecraft. The spacecraft is launched from Wallops Island, Virginia, on a Scout launch vehicle. Orbital injection is achieved by an FW-4S spin stabilized fourth stage motor. All spacecraft functions to this point are identical with the Mission I configuration.

The Mission II spacecraft employs only one sun sensor, has two earth horizon scanners, has larger attitude control thrust (1 lb. versus 0.05 lb. for Mission I) and has body-mounted solar cells (11,510 2x2 cm) around the entire periphery of the experiment bay and the aft skirt as noted in Figure 3. Following spacecraft separation from the fourth stage, the nitrogen cold gas reaction control system reduces the spin rate to a predetermined value to establish from 0.5 to 1.5 g on the experiments. The single sun sensor provides information for orienting the spin axis normal to the sun line for maximum illumination of the solar cells. Thermal control is provided by cycling louvers open and closed to maintain a specified temperature on the radiating cold plate which forms the forward closure of the experiment package.

The earth horizon scanners provide information for initially precessing the spin axis normal to the ecliptic plane to allow the radiator to view deep space.

Mission II is a variable g experiment, achieved by varying the spin rate. To minimize the quantity of nitrogen gas required for the six-month mission, this subsystem is not used to change spin rate. Rather, the spacecraft contains three masses on extendible booms which vary spin moment of inertia to preserve angular momentum while changing spin rate.

Spacecraft and experiment power are provided by solar cells and a battery sized to maintain power both in the earth's shadow and in sunlight. The battery is identical to that for Mission I, but the solar cell area differs to account for the spin mode.

Spacecraft VHF communications provide experiment and housekeeping data to ground stations and command transmissions from ground stations to the spacecraft.

1.1.4 Mission III. - Mission III, a simulated gravity experiment conducted in highly elliptical earth orbit, employs a spin stabilized spacecraft shown in Figure 4. To achieve an orbit of 555 x 241,000 km (300 x 150,000 n.mi.) requires a large excess velocity at perigee. It is assumed this will be provided by a velocity package attached to the spacecraft and deployed at perigee by the SSV as discussed in Sections 3.1 and 3.3.

The Mission III spacecraft has one sun sensor, two earth horizon scanners, and the larger thrust (1 lb) attitude control system used for Mission II. Solar cells (9130 2x2 cm) are body-mounted around the entire periphery of the experiment compartment and the aft skirt of the spacecraft as for Mission II. Following spacecraft separation from the velocity package, the nitrogen cold gas reaction control system reduces the spin rate to a predetermined value which is then maintained throughout the six-month life of the mission. The remaining sequence is very similar to Mission II. The single sun sensor provides information for orienting the spin axis normal to the sun line for maximum illumination of the solar cells. Thermal control is provided by cycling the louvers open and closed to maintain a specified temperature on a radiating cold plate forming the forward closure of the experiment package. The earth horizon scanners provide information for initially precessing the spin axis normal to the ecliptic plane to allow the radiator to view deep space.

Spacecraft and experiment power are provided by the solar cells and a battery sized to maintain power both in the earth's shadow and in sunlight. The battery is identical to that for Missions I and II to preserve commonality. Since the Mission III elliptical orbit provides long periods of sunlight, the solar cell area is reduced over that required for Mission II.

The greater distances from earth during Mission III required changes in the Mission III spacecraft communications components, including

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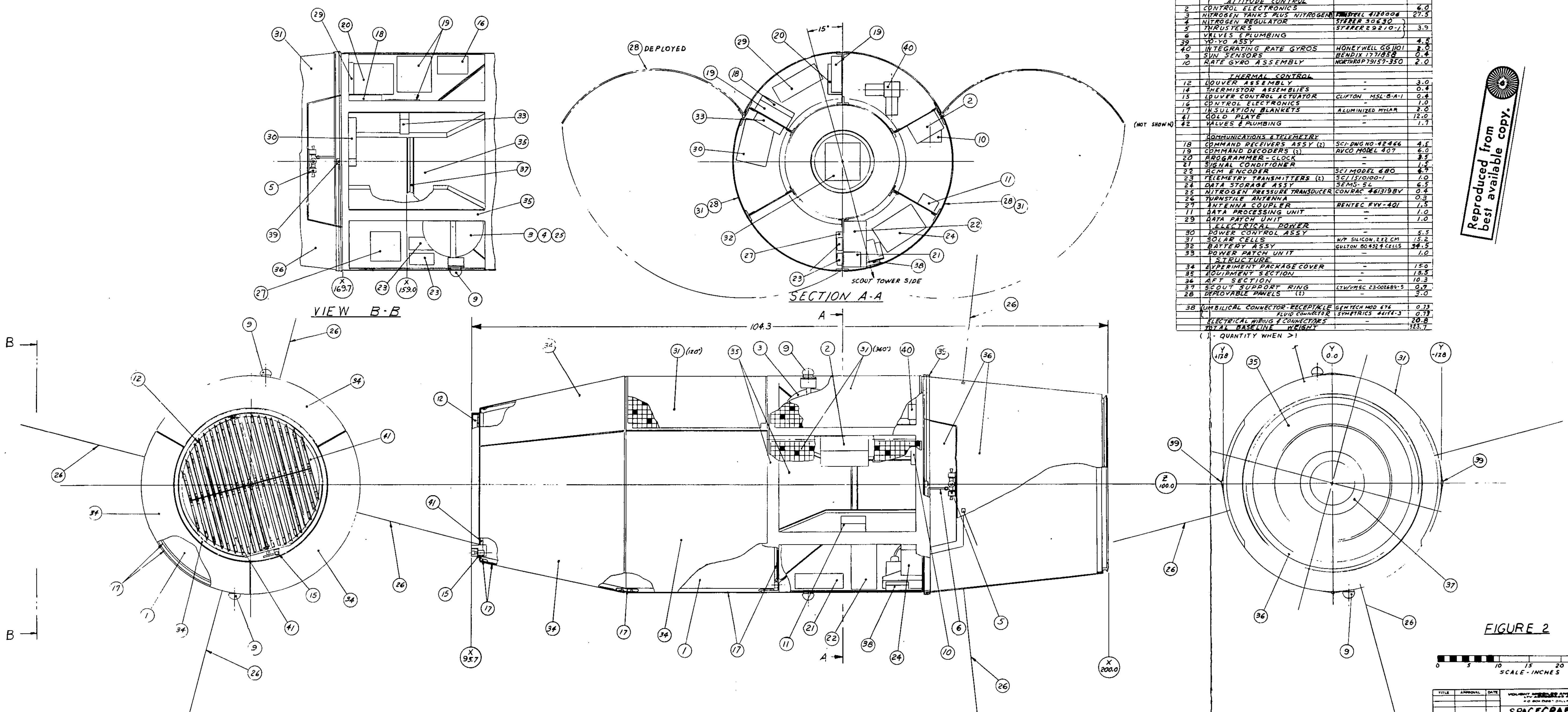

ITEM	NOMENCLATURE	MODEL OR PART NO.	WT.
1	EXPERIMENT PACKAGE	SPECIAL GFE	100.0
	ATTITUDE CONTROL		
2	CONTROL ELECTRONICS		6.0
3	NITROGEN TANKS PLUS NITROGEN	FANSTEEL 4120006	27.5
4	NITROGEN REGULATOR	STERER 30630	
5	THRUSTERS	STERER 29210-1	3.9
6	VALVES & PLUMBING		
39	YO-YO ASSY		4.5
40	INTEGRATING RATE GYROS	HONEYWELL GG1101	2.0
9	SUN SENSORS	BENDIX 1771858	0.4
10	RATE GYRO ASSEMBLY	NORTHROP 79157-350	2.0
	THERMAL CONTROL		
12	LOUVER ASSEMBLY	-	3.0
14	THERMISTOR ASSEMBLIES	-	0.4
15	LOUVER CONTROL ACTUATOR	CLIFTON MSL-8-A-1	0.4
16	CONTROL ELECTRONICS	-	1.0
17	INSULATION BLANKETS	ALUMINIZED MYLAR	2.0
41	COLD PLATE	-	12.0
(NOT SHOWN) 42	VALVES & PLUMBING	-	1.7
	COMMUNICATIONS & TELEMETRY		
18	COMMAND RECEIVERS ASSY (2)	SCI-DWG NO-42466	4.5
19	COMMAND DECODERS (2)	AVCO MODEL 407	6.0
20	PROGRAMMER-CLOCK	-	3.5
21	SIGNAL CONDITIONER	-	1.5
22	PCM ENCODER	SCI MODEL 680	6.7
23	TELEMETRY TRANSMITTERS (2)	SCI 1510100-1	1.0
24	DATA STORAGE ASSY	SEMS-5L	6.5
25	NITROGEN PRESSURE TRANSDUCER	CONRAC 461319BV	0.4
26	TURNSTILE ANTENNA	-	0.3
27	ANTENNA COUPLER	RENTEC FVV-401	1.5
11	DATA PROCESSING UNIT	-	1.0
29	DATA PATCH UNIT	-	1.0
	ELECTRICAL POWER		
30	POWER CONTROL ASSY	-	5.5
31	SOLAR CELLS	N/P SILICON, 2X2 CM	15.2
32	BATTERY ASSY	GULTON 80 4324 CELLS	34.5
33	POWER PATCH UNIT	-	1.0
	STRUCTURE		
34	EXPERIMENT PACKAGE COVER	-	15.0
35	EQUIPMENT SECTION	-	15.5
36	AFT SECTION	-	10.3
37	SCOUT SUPPORT RING	LTV/VMSC 23-002689-5	0.7
28	DEPLOYABLE PANELS (2)	-	3.0
38	UMBILICAL CONNECTOR-RECEPTACLE	G&H TECH MOD 676	0.73
	FLUID CONNECTOR	SYMETRICS 46156-3	0.73
	ELECTRICAL WIRING & CONNECTORS	-	20.8
	TOTAL BASELINE WEIGHT		323.7

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FIGURE 2

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SCALE - INCHES

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CUSTOMER		

SPACECRAFT ASSY
BIORESEARCH MODULE
MISSION I (S)

SIZE | CODE IDENT NO 11813 | T146A000006

SCALE 1/4 | REV LTR - | SHEET 1 OF 1

T146A000006

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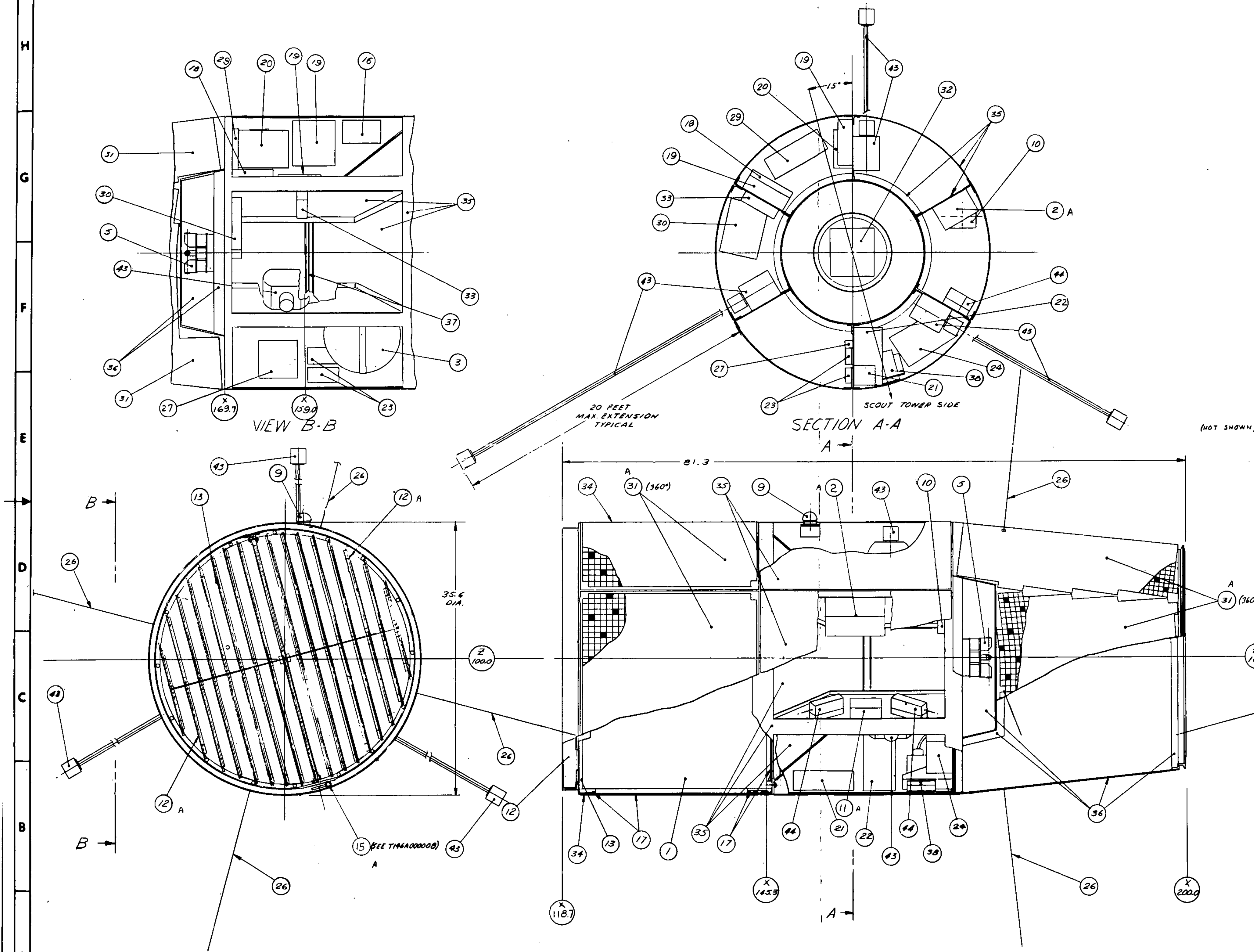

ITEM	NOMENCLATURE	MODEL OR PART NO.	WT.	
1	EXPERIMENT PACKAGE	GFE	100.0	
	ATTITUDE CONTROL			
2	CONTROL ELECTRONICS		7.0	A
3	NITROGEN TANKS PLUS NITROGEN	FANSTEEL 4120006	13.9	A
4	NITROGEN REGULATOR	STERER 15780		
5	THRUSTERS	STERER 24060-1	6.3	
6	VALVES & PLUMBING	-		
43	EXTENDIBLE BOOMS	SPAR A-18	12.6	
9	SUN SENSOR	BENDIX 1771858	0.2	
44	HORIZON CROSSING INDICATORS	BARNES 13-206	1.5	
10	RATE GYRO ASSEMBLY	NORTHROP 79187-350	2.0	
	THERMAL CONTROL			
12	LOUVER ASSEMBLIES	-	5.0	A
13	RADIATING COLD PLATE ASSY.	-	23.0	
14	THERMISTOR ASSEMBLIES	-	0.4	
15	LOUVER CONTROL ACTUATOR	CLIFTON MSL-8-A-1	0.4	A
16	CONTROL ELECTRONICS	-	1.0	
17	INSULATION BLANKETS	ALUMINIZED MYLAR	1.6	A
	COMMUNICATIONS & TELEMETRY			
18	COMMAND RECEIVERS ASSY (2)	SCI-DWG. NO. 42466	4.5	
19	COMMAND DECODERS (2)	AVCO MODEL 407	6.0	A
20	PROGRAMMER - CLOCK	-	3.6	
21	SIGNAL CONDITIONER	-	1.5	
22	PCM ENCODER	SCI MODEL 680	6.7	
23	TELEMETRY TRANSMITTERS (2)	SCI 1510100-1	1.0	
24	DATA STORAGE ASSY	SEMS-SL	6.6	
25	NITROGEN PRESSURE TRANSDUCER	CONRAC 4613198V	0.4	
26	TURNSTILE ANTENNA	-	.03	
27	ANTENNA COUPLER	RANTEC FVV-401	1.5	
11	DATA PROCESSING UNIT	-	1.0	A
29	DATA PATCH UNIT	-	1.0	
	ELECTRICAL POWER			
30	POWER CONTROL ASSY	-	5.5	
31	SOLAR CELLS	N/P SILICON, 2X2 CM	35.0	A
32	BATTERY ASSY	GULTON 804324CELLS	34.5	
33	POWER PATCH UNIT	-	1.0	
	STRUCTURE			
34	EXPERIMENT PACKAGE COVER	-	7.5	
35	EQUIPMENT SECTION	-	17.9	A
36	AFT SECTION	-	10.3	A
37	SCOUT SUPPORT RING	LTV/VMSC 23-002689-5	0.7	A
38	UMBILICAL CONNECTOR-RECEPTACLE	GM TECH. MOD 676	.73	A
	FLUID CONNECTORS (2)	SYMETRICS 46154-3	.77	
42	COOLANT VALVES & PLUMBING	-	1.5	
	ELECTRICAL WIRING & CONNECTORS	-	18.4	
	TOTAL BASELINE WEIGHT		342.6	A

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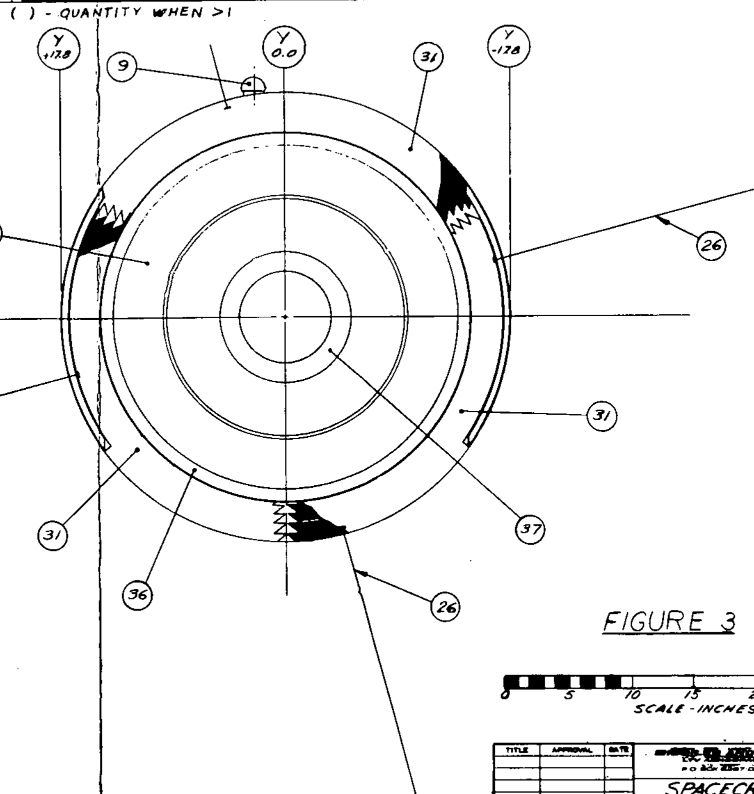

FIGURE 3

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SCALE - INCHES

SPACECRAFT ASSY
BIORESEARCH MODULE
MISSION II

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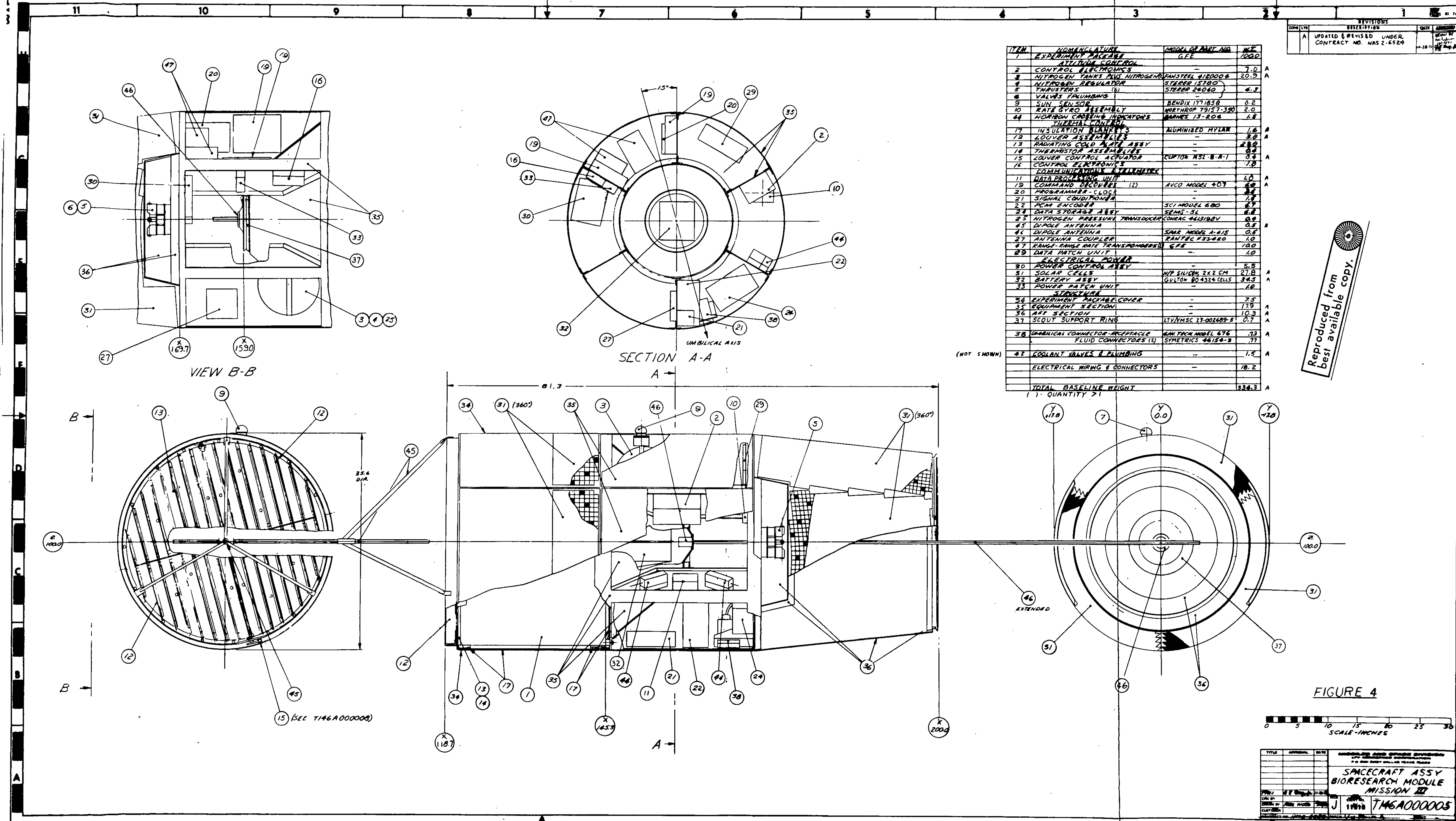

ITEM	NOMENCLATURE	MODEL OR PART NO.	WT.	
1	EXPERIMENT PACKAGE	GFE	100.0	
	ATTITUDE CONTROL			
2	CONTROL ELECTRONICS	—	7.0	A
3	NITROGEN TANKS PLUS NITROGEN (2)	FANSTEEL 4120006	20.9	A
4	NITROGEN REGULATOR	STERER 15780		
5	THRUSTERS (6)	STERER 24060	6.3	
6	VALVES & PLUMBING	—		
9	SUN SENSOR	BENDIX 1771858	0.2	
10	RATE GYRO ASSEMBLY	NORTHROP 79157-350	2.0	
44	HORIZON CROSSING INDICATORS	BARNES 13-206	1.8	
	THERMAL CONTROL			
17	INSULATION BLANKETS	ALUMINIZED MYLAR	1.6	A
12	LOUVER ASSEMBLIES	—	3.0	A
13	RADIATING COLD PLATE ASSY	—	[illegible]	
14	THERMISTOR ASSEMBLIES	—	[illegible]	
15	LOUVER CONTROL ACTUATOR	CLIFTON MSL-8-A-1	0.4	A
16	CONTROL ELECTRONICS	—	7.0	
	COMMUNICATIONS & TELEMETRY			
11	DATA PROCESSING UNIT		4.0	A
19	COMMAND DECODERS (2)	AVCO MODEL 407	[illegible]	A
20	PROGRAMMER-CLOCK	—	[illegible]	
21	SIGNAL CONDITIONER	—	[illegible]	
22	PCM ENCODER	SCI MODEL 680	[illegible]	
24	DATA STORAGE ASSY	SEMS-56	[illegible]	
25	NITROGEN PRESSURE TRANSDUCER	CONRAC 4613198V	[illegible]	
45	DIPOLE ANTENNA	—	0.5	A
46	DIPOLE ANTENNA	SPAR MODEL A-415	0.5	
27	ANTENNA COUPLER	RANTEC FS5420	1.0	
47	RANGE-RANGE RATE TRANSPONDERS (2)	GFE	10.0	
29	DATA PATCH UNIT	—	1.0	
	ELECTRICAL POWER			
30	POWER CONTROL ASSY	—	5.5	
31	SOLAR CELLS	N/P SILICON, 2x2 CM	27.8	A
32	BATTERY ASSY	GULTON 80 4324 CELLS	34.5	A
33	POWER PATCH UNIT	—	1.0	
	STRUCTURE			
34	EXPERIMENT PACKAGE COVER	—	7.5	
35	EQUIPMENT SECTION	—	17.9	A
36	AFT SECTION	—	10.3	A
37	SCOUT SUPPORT RING	LTV/VMSC 23-002689-5	0.7	A
38	UMBILICAL CONNECTOR-RECEPTACLE	G.W. TECH MODEL 676	.73	A
	FLUID CONNECTORS (2)	SYMETRICS 46154-3	.77	
42	COOLANT VALVES & PLUMBING	—	1.5	A
	ELECTRICAL WIRING & CONNECTORS	—	18.2	
	TOTAL BASELINE WEIGHT		334.3	A

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FIGURE 4

SPACECRAFT ASSY BIORESEARCH MODULE MISSION III

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the use of a dipole antenna instead of the turnstile antenna used for Mission I and II. Mission III spacecraft communications provide experiment and housekeeping data to ground stations and command transmissions from ground stations to the spacecraft. All missions use VHF communications with STADAN ground stations.

1.1.5 Description of Spacecraft Structure. - A drawing of the Bioresearch Module primary structure is shown in Figure 5. All material is magnesium except as noted. Since all skin gages and ring dimensions are the minimum practical rather than structural minimums, it was possible to choose lightweight magnesium for a saving of approximately 18 pounds compared to aluminum. The use of standard protection measures for dissimilar materials and the controlled atmosphere prior to launch should prevent any corrosion due to galvanic action.

The forward portion of the structure houses the experiment package. A fiberglass ring provides thermal isolation at the forward end of the experiment package. The walls of the experiment compartment are formed by .020 in. skin panels lined internally with aluminum coated mylar super insulation (15 layers) and externally with solar cells (120° for Mission I and I(S), 360° for Missions II and III). The base of the experiment compartment is an .020 in. shelf. This shelf is supported at its outer edge by a machined ring. Central stiffness of the shelf is provided by a cylinder formed of .020 in. skin. A cover permits access to the central cylinder which houses the spacecraft battery. As with the walls, the base of the experiment compartment is lined with super insulation. The experiment package itself is supported by a pattern of bolts through the large outer ring at the base of the experiment compartment. The bolts are thermally isolated from the spacecraft structure by means of fiberglass bushings.

The Mission I(S) spacecraft structure differs from that for the other missions only in the addition of a forward extension to the experiment compartment to accommodate the longer I(S) experiment package. This extension (not shown in Figure 5) consists of a splice ring and .020 in. magnesium walls with internal superinsulation. The forward end terminates in a fiberglass ring and smaller louver assembly as previously shown in Figure 2.

An .040 in. sheet metal cone forms the primary load path from the experiment compartment outer ring to the Scout payload attachment ring for Missions I and II. For Mission III this same structural arrangement interfaces with the velocity package motor as noted in Sections 3.1 and 3.3. As noted in Figure 5, Section B-B indicates lightening holes in the structural cone. The cold gas nitrogen tanks are mounted in these holes, as indicated. Number of tanks required depend on the mission: two on Mission I, I(S) and III; and one on Mission II. Additional tanks may be added up to a total of six as weight permits.

The equipment compartment is divided into six bays by .040 in. shear panels and edge members. An .020 in. annular shelf (Section A-A) forms the bottom of the equipment compartment. On Missions II and III the six equipment bays are closed by .020 in. removable covers. On Missions I and I(S) two 120° deployable panels replace four of these removable covers as noted in Figures 1 and 2. As previously described these deployable panels plus the two access panels are covered with solar cells on Missions I and I(S). On Missions II and III, all solar cells are excluded from the equipment compartment covers to avoid damage in handling.

The lower conical section of the spacecraft is formed of .031 in. magnesium sheet and terminates at the base in an aluminum ring which may be used for V-band attachment to the SSV. Thus, the Bioresearch module structure is compatible with both Scout and SSV launch geometry and environment.

The Bioresearch Module structure has been analyzed for the mechanical environments experienced on both Scout and the SSV. A factor of safety of 1.50 was used to define the ratio of design loads to flight environment loads. The stress analysis yielded positive margins of safety for all primary structure.

1.1.6 Experiment Package Structure. - The Bioresearch Module structure and equipment arrangement have been selected to achieve a simplified, low-cost spacecraft configuration favorable to installation and support of the experiment package. The cold plate is located at the forward end of the experiment package to permit passive radiation cooling. Integration of the cold plate into the experiment package achieves an overall systems weight advantage by avoiding a separate closure and bolted interface with attendant thermal conductivity uncertainty across the interface.

The large cold plate area, whether integral with or bolted to the experiment package, must have central support to avoid unfavorable "oil can" response to vibration environment. It has been assumed that structure within the experiment package would achieve this stiffening support of the cold plate. The aft closure of the experiment package must likewise be stiffened. This can be done internally, or additional central attachment of the experiment package to the spacecraft can be provided in addition to the peripheral bolted attachment shown in detail G of the interface drawing, Figure 8.

The many ways to achieve efficient load paths through and around the experiment package will be the subject of a separate trade study prior to selection of the final configuration.

1.1.7 Louver Actuation Mechanism. - Conceptual design for a typical louver actuation mechanism is shown in Figure 6. The louver blades are attached intermittently at one edge by means of a piano hinge directly to the cold plate. The louvers are ganged together by means of a draw bar so that each half hinges outward and down to cover the cold plate. The fiberglass louvers are gold coated by means of electroless plating to provide low absorbtivity and high reflectivity. An a-c stepping motor drives the

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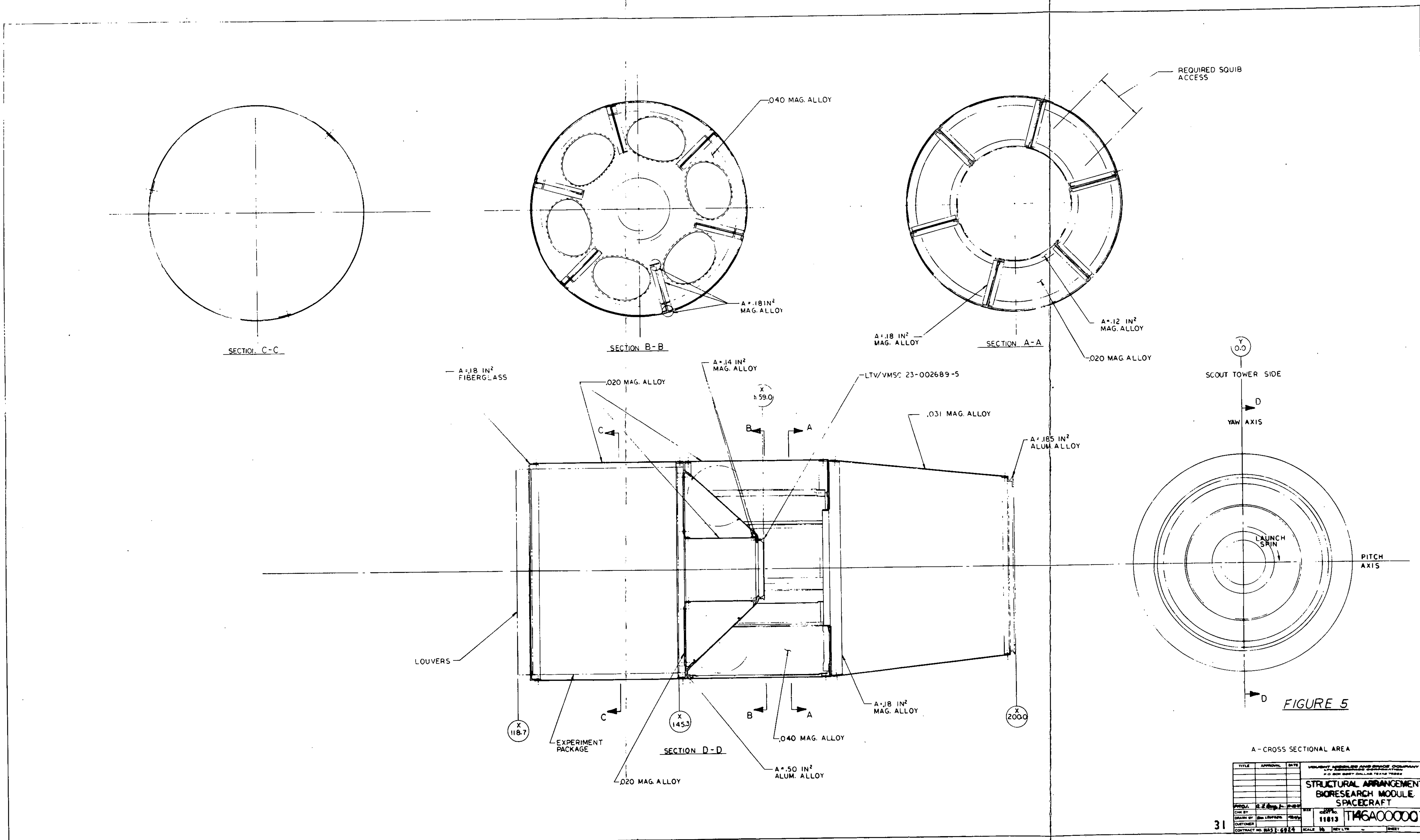

FIGURE 5

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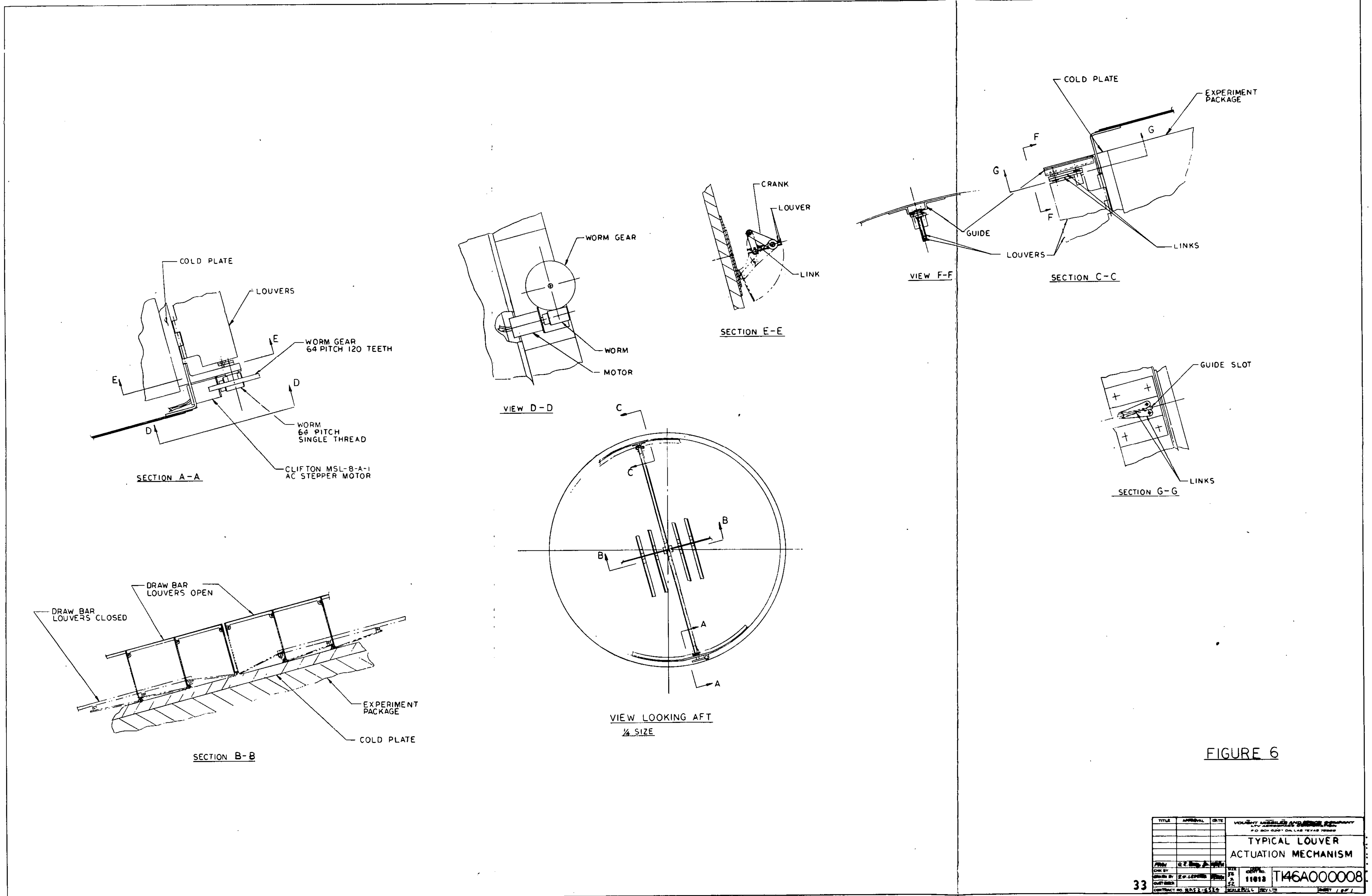

FIGURE 6

louvers open and shut thru a worm gear and mechanical linkage arrangement.

Additional arrangements are possible, for example, two motors which separately drive each half of the louver assembly. This would possibly offer increased reliability although the thermal response must be further investigated for the case where one-half of the louver system became inoperative.

1.2 WEIGHT STATEMENT

Candidate hardware for the Bioresearch Module baseline spacecraft are identified (by model number when known) on the inboard profile drawings of Figures 1 through 4. These drawings also present detailed component weights which are summed to obtain total spacecraft weight. Table 3 summarizes subsystem weights based on the data of Figures 1 through 4.

For Scout launches the payload-to-booster adapter, separation, and fourth stage telemetry hardware (total weight of 32 lb) are charged as payload weight. This has been added in Table 3 to the total spacecraft weights to arrive at a gross payload on the booster. The heaviest spacecraft, Mission II, is 10 pounds under the 385 pound payload which Scout (with 42 in. diameter heatshield) can place into a 300 x 300 n.mi. x 37.7° inclination orbit from Wallops Island, Virginia. There are several options to increase this 10 pound margin for Mission II, such as deletion of fourth stage telemetry, smaller battery, orbit at somewhat lower altitude. These will be explored during final design of the spacecraft.

1.3 DESCRIPTION OF OPTIONS

Changes to the baseline spacecraft designs studied and reported in Section 2.1 are summarized in this section. These changes result in equipment options which reduce cost and complexity of the spacecraft, increase capability to monitor experiment data, or increase reliability of the mission.

The options in Table 4 are provided for planning purposes. They cannot all be combined without regard to power or weight limitations. For example, when adding option 6, or 4 + 6, options 1 and 2 should be disregarded inasmuch as the total baseline power system is required to operate the S-band communications and TV monitor. Costs of options are presented in Section 4.7

1.4 INTERFACES

Interface descriptions were presented in specification format in Reference 4, Volume II, for the Bioexplorer spacecraft. With minor changes (to be accomplished during Phase C) these interface specifications are applicable to the Bioresearch Module. The following sections briefly describe the updated interface drawings, Figures 7 and 8.

TABLE 3. - BIORESEARCH MODULE WEIGHT SUMMARY

Mission	I	I(S)	II	III
Weights, lb				
Experiment Package	100	100	100	100
Attitude Control	46	46	43	38
Thermal Control	33	21	33	33
Communications and Telemetry	34	34	34	38
Electrical Power	56	56	76	69
Structure	37	44	37	37
Electrical Wiring, Connectors, Umbilical	21	23	20	20
Total Spacecraft, lb	327	324	343	335
Total Spacecraft, kg	148	147	156	152
(1) Payload-to-booster adapter, separation and T/M Package, lb.	32	32	32	-
Total Payload on booster, lb.	359	356	375	-
(2) Margin under 385 lb.	26	29	10	-

(1) For Scout launch vehicle. Not shown for Mission III launched by SSV.

(2) Scout with 42 in. diameter heatshield can place 385 lb. in 300 x 300 n.mi. x 37.7° orbit from Wallops Island, Virginia.

TABLE 4. - SUMMARY OF BIORESEARCH MODULE OPTIONS

OPTION NO.	OPTION	APPLICABLE TO MISSION NO.	EQUIPMENT REMOVED FROM BASELINE SPACECRAFT	EQUIPMENT ADDED TO BASELINE SPACECRAFT	WEIGHT CHANGE LB
1	Reduced experiment power	I I(S) II III	1154 solar cells, deployable panels 2344 solar cells, deployable panels 4140 solar cells 3027 solar cells		-3.5 -7.1 -12.6 - 9.2
2	Reduced battery size (made possible by Option 1)	I, I(S), II, III	Change from 12 AH to 9AH battery Change from 12 AH to 6 AH battery		- 9.2 -16.0
3	Reduced experiment thermal load	I, II, III I(S)	23 lb beryllium cold plate 12 lb beryllium cold plate	21 lb aluminum cold plate 12 lb aluminum cold plate	- 2.0 -
4	TV experiment monitor with S-band downlink	I, I(S), II	1 VHF transmitter	1 S-band transmitter 1 S-band antenna system 1 TV camera, lens and control unit	+14.9
5	S-band communications (Use of MSFN + STADAN)	I, I(S), II	1 VHF receiver 1 VHF transmitter	1 S-band receiver 1 S-band transmitter 1 S-band antenna system	+ 5.6
6	S-band communications (Use of MSFN in lieu of STADAN)	I, I(S), II	2 VHF receivers 2 VHF transmitters 1 VHF antenna system	2 S-band receivers 2 S-band transmitters 1 S-band antenna system	+ 6.3
7	Scout/SSV compatibility	I, I(S), II		1 nitrogen tank	+ 6.5
8	Redundant gyro package	I, I(S), II, III		Rate Gyro assembly	+ 2.0
9	Redundant integrating rate gyro package	I, I(S)		Two integrating rate gyros	+ 2.0
10	Redundant louver actuator package	I, I(S), II, III		Actuator motor, linkage	+ 1.0
4 & 6	TV experiment monitor with total S-band communications	I, I(S), II		Add TV camera (8.3 lb) to Option 6.	+14.6

1.4.1 Bioresearch Module/Scout Interface. - The Bioresearch Module/Scout interface is shown in Figure 7. Primary structural interface is at the Scout E Section separation plane (Scout Station 37.27). Spacecraft structure includes a Scout payload support ring for attachment at that plane. The separation system and boost telemetry are included on the Scout fourth stage. Squib access doors are provided in the spacecraft and Scout heatshield fairing. A heatshield bumper is assumed to prevent heatshield-spacecraft interference during boost; however, further analysis is required to determine if the bumper is actually necessary. Four spacecraft antenna wires bear against the Scout heatshield fairing prior to heatshield separation. Interface with launch facilities is through an umbilical receptacle (consisting of an electrical connector and two coolant fluid connectors) and the spacecraft communication system. A spring-loaded door in the heatshield fairing provides access to the umbilical receptacle.

This summary of spacecraft to Scout launch vehicle interface is amplified in the interface specification, Appendix B of Volume II, Reference 4.

1.4.2 Bioresearch Module/Experiment Package Interface. - This interface is shown in Figure 8, consisting of structural, thermal, and electrical connections. Structural support is provided by insulated bolts at the base of the experiment package. The cold plate forms the forward closure of the experiment package. Insulation is provided to minimize other thermal paths. Electrical connections are provided for power and data lines.

The configuration arrangements permit experiment package and cold plate operation at a remote location from the spacecraft, during transport and assembly, and after installation. Structural support of the experiment package by the spacecraft does not require installation of experiment package cover panels.

Transition of thermal and electrical operations from ground to spacecraft control is performed without interruption of these functions by use of separate connectors for ground and flight operations. The ground cooling is not used after liftoff. Thermal lag in the cold plate is adequate to provide spacecraft cooling until the heatshield is ejected to expose the radiator system.

This summary of experiment package to spacecraft interface is amplified in the interface specification, Appendix B, Volume II of Reference 4.

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FOLDOUT FRAME 2

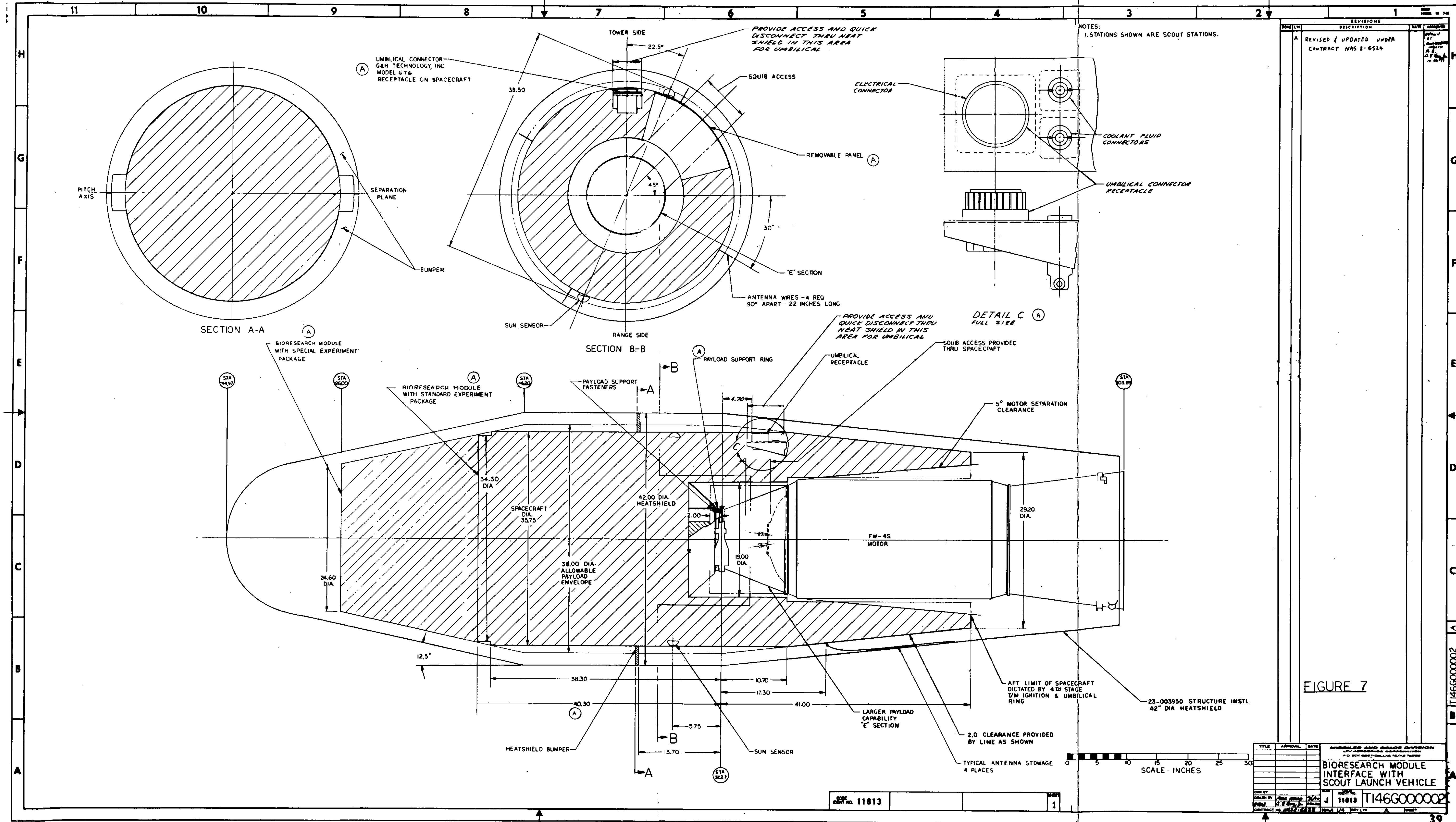

FIGURE 7

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FOLDOUT FRAME 1

FOLDOUT FRAME 2

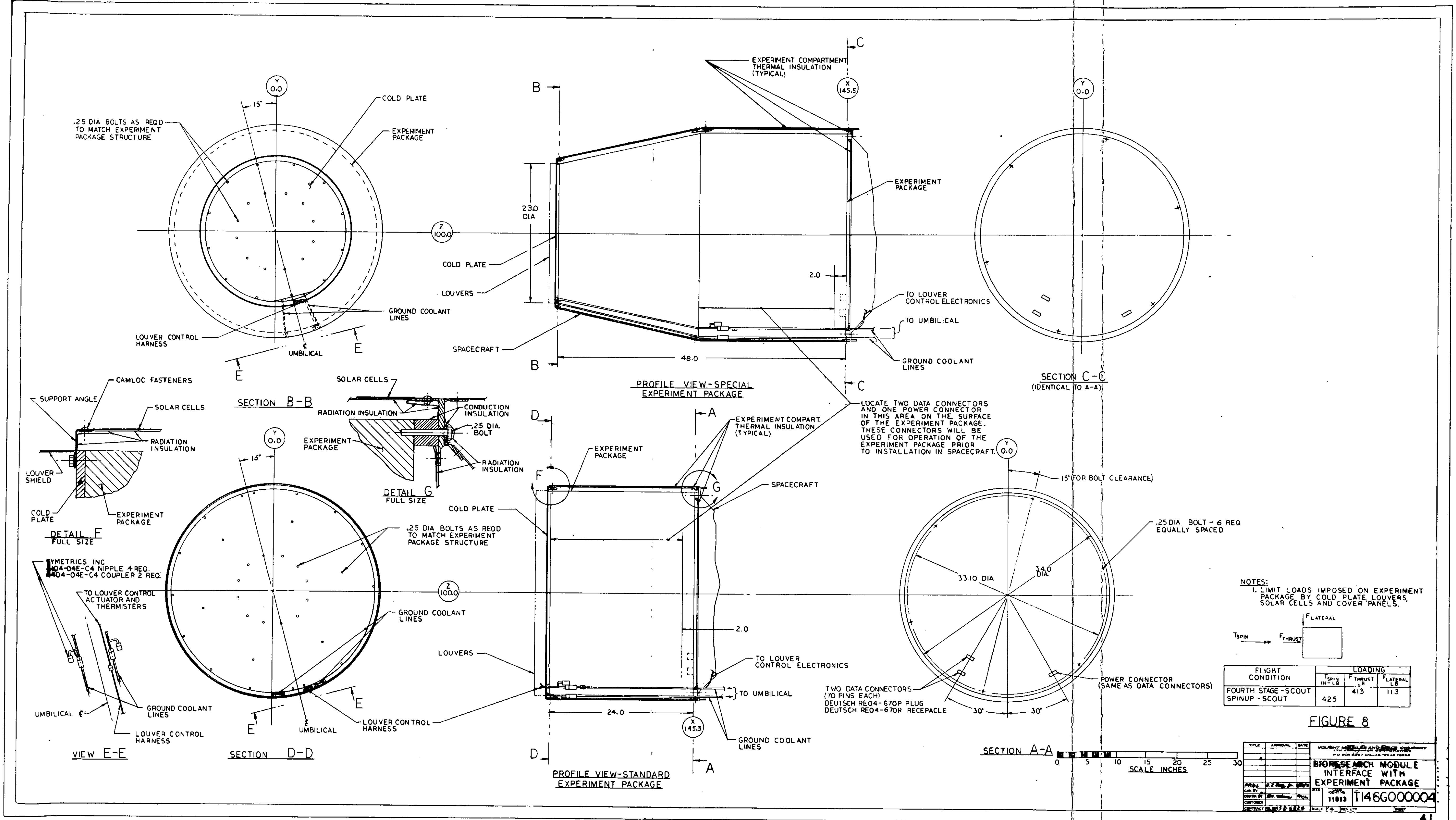

FIGURE 8

41

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2.0 ANALYSES OF SCOUT-LAUNCHED SPACECRAFT

Under the present contract the Bioexplorer spacecraft previously defined (References 1-4) has been revised to satisfy the requirements of the Contract Specification A-17193, Reference 5. The resulting spacecraft, now designated "Bioresearch Module," is configured as a Scout-launched payload to accomplish Missions I and II (low earth orbit) as defined in the Specification. The Mission III spacecraft, although not Scout launched, was also modified to delete the Delta launch and make it compatible with an SSV launch. These "baseline" spacecraft, conforming to the Specification, were then subjected to the analyses reported in the following sections.

2.1 MODIFIED EXPERIMENT SUPPORT

In accordance with Task I-1 of the Contract Statement of Work, Reference 5, the baseline designs have been evaluated against the Specification requirements to determine the relative cost change per spacecraft and the design impact of increasing or decreasing any of the experiment package support capabilities. The increment size and maximum range of capabilities to be evaluated were provided by Reference 6. The areas investigated include revised power and thermal profiles for the experiment, experiment monitoring by television, and command and data requirements.

2.1.1 Revised Power Profiles for All Missions. - Total spacecraft power is the sum of housekeeping plus experiment power requirements, including consideration of losses in distribution and use of power by the spacecraft subsystems. The baseline power systems which satisfy the Specification are summarized in Appendix A. This section defines modifications to the baseline power systems made possible by the revised (reduced) experiment power profiles.

Table 5 summarizes the baseline and revised experiment power requirements in terms of average and peak power demand. Average power is total energy consumed per orbit normalized to the orbital period, that is, watt-minutes consumed per orbit divided by orbital period in minutes.

Impact on Solar Array. - The reduced experiment power requirements permit a smaller solar array on the spacecraft. Table 6 shows for each mission the number of solar cells removed and the weight change from the baseline configuration. Cost savings are tabulated in Section 4.7.

Impact on Battery Size. - As noted in Appendix A a 12 amp-hour battery was selected for the baseline designs. This is a conservative design inasmuch as 8000 discharge/charge cycles are available at the 25% depth of discharge used in the Bioresearch Module application. The same battery is used on all missions to obtain the cost advantage

TABLE 5. - BASELINE AND REVISED EXPERIMENT POWER REQUIREMENTS

Baseline Experiment Power Requirements, All Missions (Reference 5)		
27.5 ±2.5 VDC	-	64 watts continuous
	-	89 watts peak for 6 min/hr
+15 ±2.5 VDC	-	3 watts continuous
-15 ±0.5 VDC	-	3 watts continuous
+5 ±0.02 VDC	-	7 watts continuous
TOTAL	-	87.1 watts average (including efficiency)
Revised Experiment Power Requirements, Missions I, II, III (Reference 6)		
27.5 ±2.5 VDC	-	31 watts continuous
	-	111 watts peak for 3 min/hr
+15 ±2.5 VDC	-	2 watts continuous
-15 ±0.5 VDC	-	2 watts continuous
+5 ±0.02 VDC	-	5 watts continuous
TOTAL	-	48.8 watts average (including efficiency)
Revised Experiment Power Requirements, Mission I(S) (Reference 6)		
27.5 ±2.5 VDC	-	20 watts continuous
	-	45 watts peak for 2 min/orbit
	-	150 watts peak for 15 sec/orbit
+15 ±2.5 VDC	-	2 watts continuous
-15 ±0.5 VDC	-	2 watts continuous
+5 ±0.02 VDC	-	5 watts continuous
TOTAL	-	33.8 watts average (including efficiency)

offered by commonality. If reduced experiment power as defined in Table 5 becomes the design criterion for this program it is worthwhile to consider a smaller battery. Table 7 summarizes battery options which may be used. Cost savings are tabulated in Section 4.7.

2.1.2 Revised Thermal Profiles for All Missions. - Thermal load is generated by both the spacecraft electrical equipment and the experiment. It is assumed that spacecraft equipment heat is distributed to structural heat sinks and radiated to space. This complex problem will be analyzed in detail during detail design. Experiment heat is transferred to a cold plate which forms the forward closure of the experiment package. This cold plate is of beryllium construction in the baseline design to

TABLE 6. - IMPACT ON SOLAR ARRAY OF REVISED EXPERIMENT POWER REQUIREMENTS

MISSION	I	I(S)	II	III
Spacecraft Avg. Power for Housekeeping, watts (Appendix A)	16.7	18.1	14.3	31.0
Reduced Experiment Power, watts (Table 5)	48.8	33.8	48.8	48.8
Total Power Required, watts	65.5	51.9	63.1	79.8
*Solar Array power required, watts	118	94	114	85
Number of Solar Cells Required, (Appendix A)	3836	2646	7370	6103
Number of Solar Cells on Baseline Spacecraft (Appendix A)	4990	4990	11,510	9130
Change from Baseline solar cells	-1154	-2344	-4140	-3027
Weight Change, lb.	-3.5	-7.1	-12.6	-9.2

*Considers 62% illumination of orbit (except Mission III which is almost 100%), 95% discharge efficiency, 80% charge efficiency for battery at 70°F.

TABLE 7. - BATTERY OPTIONS WITH REDUCED EXPERIMENT POWER

MISSION	I	I(S)	II	III
Baseline battery, amp-hr	12	12	12	12
Baseline battery weight, lb.	34.5	34.5	34.5	34.5
Battery permissible with reduced experiment power, amp-hr	9	9	9	6
Weight of new battery, lb.	25.3	25.3	25.3	18.5
Weight change over baseline, lb.	-9.2	-9.2	-9.2	-16.0

provide a high specific heat-to-weight ratio, thus permitting thermal lags which allow good temperature control despite heat spikes generated by the experiments. The thermal lag in the cold plate also minimizes cycling of the louver assembly to control temperature.

References 5 and 6 define, respectively, the baseline and revised thermal profiles for the experiments. These are summarized in Table 8. As noted the revised thermal profiles exhibit lower continuous heat loads. The peak is higher over a shorter period for Missions I, II, and III. The two revised peaks for Mission I(S) are both lower and of shorter duration than the baseline.

The cold plate thermal analysis for the revised thermal profiles is presented in Appendix B. It is noted that the smaller Mission I(S) cold plate cannot meet the Specification temperature requirements when subjected to the baseline thermal profile. Its thermal mass and radiating area are too small to maintain the desired tolerance of $^{+0}_{-5}$° F. However, the I(S) cold plate does perform to the Specification when subjected to the revised experiment thermal profile. This proviso on the I(S) cold plate permits deletion of the pumped fluid system defined in Reference 4 for the Bioexplorer version of Mission I(S).

Impact on Cold Plate. - The revised experiment thermal loads permit a change in cold plate material from beryllium to aluminum, and a slight weight reduction. Appendix B indicates some increase in louver cycling rate as a result of this change, but this is considered

TABLE 8. - BASELINE AND REVISED EXPERIMENT THERMAL PROFILES

Baseline Experiment Thermal Profile, All Missions (Reference 5)

Continuous - 180 to 270 Btu/hr
Peak - 350 Btu/hr for 10 min/hr

Revised Experiment Thermal Profile, Missions I, II, III (Reference 6)

Continuous - 136 Btu/hr
Peak - 408 Btu/hr for 3 min/hr

Revised Experiment Thermal Profile, Mission I(S) (Reference 6)

Continuous - 100 Btu/hr
Peaks - 185 Btu/hr for 2 min/orbit
- 340 Btu/hr for 15 sec/orbit

acceptable in view of the cost saving this change in materials would allow. Table 9 summarizes the changes. Cost savings are tabulated in Section 4.7.

TABLE 9. - IMPACT ON COLD PLATE DESIGN OF REVISED THERMAL PROFILES

	Missions I, II, III	Mission I(S)
Baseline Cold Plate		
Material	Beryllium	*Beryllium
Weight, lb.	23	12
Design to Revised Thermal Requirements		
Material	Aluminum	Aluminum
Weight, lb	21	12
Weight Change, lb.	-2	0

*Temperature tolerance exceeds Specification requirements

2.1.3 Experiment Monitoring for Mission I, I(S), II. - The baseline spacecraft are equipped with two-way VHF communications which interface with STADAN tracking stations. This system will handle the data rates stated in the Specification for Bioresearch Module. In accordance with Reference 6 a preliminary design has been defined for a television system to monitor biological activity in the experiment package. Appendix C summarizes the television monitor analysis.

The 137 MHz telemetry carrier frequency of the Bioresearch Module, which is that frequency assigned to the U.S. for space research telemetering by agreements reached by the Extraordinary Administrative Radio Conference of 1963, is allocated a monimal bandwidth of 30 KHz with a maximum bandwidth of 90 KHz. The requirement for real time or recorded television will require 1-3 MHz bandwidth for 100-300 line resolution, respectively. Thus, an S-band downlink is also needed to provide the necessary bandwidth for television transmission.

Appendix C compares real time with recorded playback transmission of television data. The greater weight and complexity of the recorded playback system favors choice of the real time system. This is compatible with the anticipated procedure of observing biological experiments which are initiated only during spacecraft passes over ground stations which can receive the televised data. Thus, real time transmission is selected for the television monitor option.

Table 10 summarizes the design impact of adding a television monitor to Missions I, I(S) and II. Costs are tabulated in Section 4.7.

TABLE 10. - IMPACT OF ADDING TELEVISION MONITOR

ITEM	Weight Change, lb.
Remove one VHF transmitter (SCI 1510100-1)	- 0.5
Add one S-band transmitter (SCI 2208100-1 Mod.)	+ 4.0
Add TV camera, lens, control unit (GEC ED6038A)	+ 8.3
Add S-band antenna (DMAK 522)	+ 2.0
Add power divider and cables	+ 0.5
Add diplexer (RANTEC FSS-420)	+ 0.6
TOTAL Weight Change	+14.9

NOTE: Camera and lens weight (14 oz) are charged to experiment. Baseline power system is adequate to handle short duty cycle (1 minute) of added components.

2.1.4 Use of Manned Space Flight Net. This item involved analysis of the design impact of using the Manned Space Flight Net (MSFN) either in addition to or in lieu of STADAN for ground station support. In addition, the MSFN was to be assumed available to support missions requiring television monitoring of the experiment. (MSFN stations have the equipment required to receive the S-band downlink transmission of televised data.) An analysis of MSFN and STADAN facilities in relation to Bioresearch Module operations is presented in Appendix D.

The analysis of Appendix D concludes that MSFN must be used for television transmission from the spacecraft since bandwidth requirements dictate use of S-band frequencies. This requirement was reflected in selection of equipment for the Television monitor (Section 2.1.3). Since MSFN and STADAN are now essentially a single network there is some merit in having capability aboard the spacecraft to communicate at VHF and S-band because this makes available many more ground stations with increased frequency of passage. Thus, spacecraft

TABLE 11. - IMPACT ON SPACECRAFT DESIGN OF USING MANNED SPACE FLIGHT NET

ITEM	STADAN ONLY (Baseline)		STADAN + MSFN		MSFN ONLY	
	No.	Tot. Wt. Lb.	No.	Tot. Wt. Lb.	No.	Tot. Wt. Lb.
VHF receiver (SCI 42466)	2	4.5	1	2.3		
VHF transmitter (SCI 1510100-1)	2	1.0	1	0.5		
Turnstile antenna	4	0.3	4	0.3		
VHF antenna coupler (RANTEC FVV-401)	1	1.5	1	1.5		
S-band transmitter (SCI 2208100-1 Mod.)			1	4.0	2	8.0
S-band receiver (AVCO AD-303)			1	1.2	2	2.4
S-band antenna (DMAK 522)			4	2.0	4	2.0
Power divider and cables			1	0.5	1	0.5
Diplexer (RANTEC FSS-420)		—	1	0.6	1	0.6
Total Weight, lb.		7.3		12.9		13.5
ΔWeight from baseline				+5.6		+6.2
End-of-life power margin, %						
Mission I	9		*1.5		1.5	
I(S)	9		*7		7	
II	12		*4		4	

*Worst case, with S-band operating into MSFN communication configurations have been defined for VHF (STADAN) only, VHF + S-band (STADAN + MSFN), and S-band (MSFN) only. The baseline power system is adequate for any of these combinations, although end-of-life power margin is very low for all S-band. Table 11 summarizes the design impact on the baseline spacecraft of the various approaches, and costs are tabulated in Section 4.7.

2.1.5 Command and Telemetry. - This item required command and data requirements to be maximized using available, off-the-shelf hardware within the Bioresearch Module weight and power requirements. No additional capability is recommended inasmuch as the baseline command and telemetry subsystems exceed substantially the requirements of the Specification. Table 12 summarizes the command and telemetry characteristics for the baseline spacecraft designs.

TABLE 12. - COMMAND AND TELEMETRY REQUIREMENTS COMPARED WITH BASELINE DESIGN

ITEM	SPECIFICATION REQUIREMENTS BY MISSION			BASELINE CAPABILITY FOR ALL MISSIONS
	I, I(S)	II	III	
(1) Commands	98	110	70	216
(2) Storage	4.9 K words at 7 bits/word = 34.3 K bits		9.8K words at 7 bits/word = 68.6 K bits	4.096 K words at 28 bits/word = 114.688 K bits
T/M Rate	1.68K bits/sec			10 K bits/sec

(1) Reference 4, Vol. II, page A-147
(2) Reference 4, Vol. II, page A-93

2.2 VARIABLE "G" SPIN RATE CONTROL

In accordance with Task I-2 of the Contract Statement of Work, Reference 5, a detailed analysis of the variable "g" spin rate control system concept for the Mission II spacecraft was conducted. The Bioresearch Module is configured to fit within the Scout heatshield envelope and to be placed in orbit with little or no deployment of mechansims such as solar array paddles or radiators. This approach allows a rugged, simple spacecraft configuration with high inherent reliability since all subsystems retain their fixed attachment to the structure. As a result the spacecraft moment of inertia is a minimum about its roll axis which coincides with the spin axis of the Mission II and III spacecraft.

2.2

Rotation about either the maximum or minimum moment of inertia axis of a completely rigid body is neutrally stable. However, for flexible bodies rotation about the minimum inertia axis is unstable, and dynamic coupling of precessional and bending motions, plus conservation of angular momentum, will cause the body to eventually spin at a slower rate about its axis of maximum inertia. This destabilizing effect caused by structural energy dissipation can be offset by an active pulse-jet nutation damper system (References 11 and 12). The cold gas attitude control system used to control the Bioresearch Module spacecraft will serve as a nutation damper to stabilize the spinning spacecraft configurations.

The Mission II spacecraft spin rate can be varied in flight to achieve an artificial gravity range of 0.1 to 1.5 g at the periphery of the experiment package. The variation in spin rate results from changing the length of three extendible booms containing tip masses, thus changing the spin moment of inertia and spin rate while conserving angular momentum. These booms are flexible and tend to aggravate the instability of the spacecraft spinning about its axis of minimum inertia. Several aspects of the variable "g" spin rate control system were studied to assure that the system is stable and a viable concept which offers essentially unlimited variation of experiment "g" for a small expenditure of on-board electrical power. These studies were:

(1) Spacecraft stability including effects of flexible booms,

(2) Reaction control propellant required to damp coning,

(3) Boom dynamics due to thermal bending,

(4) Thermal torsion-bending boom dynamics, and

(5) Interaction of attitude control system and booms.

Although the spacecraft is dynamically unstable, due both to spin about the minimum axis of inertia and boom flexibility, the rate of divergence is very slow. With booms retracted, days may be required to reach unacceptable coning while hours are required with booms extended. It is estimated that divergence can be kept within the required bounds (0.003 g) for 6 months with 1.5 pounds of nitrogen. This amount has been added to the Mission II and III spacecraft.

Thermal bending resonance was found to be non-existent due to spin rate and effective stiffening of the booms, also due to spin rate. A possibility of thermal torsion-bending instability exists, but it is dependent on the amount of overlap of the boom cross section and incidence angle of the sunline. A proper choice of these characteristics can be made which avoids regions of torsion-bending boom instability.

Excitation of boom bending by the attitude control motors

TABLE 13. - *SUMMARY OF ANALYSES OF VARIABLE "g" SPIN RATE CONTROL

ANALYSIS	DESCRIPTION AND APPROACH	RESULT
Overall spacecraft stability with booms in motion or at rest	Determine the dynamic stability of spinning Mission II spacecraft. Write differential equations of motion for rigid central mass and flexible booms. Assume boom extension/retraction rate slow enough to allow analysis at discrete lengths. Use linearized, small motion approach. Apply Routh-Hurwitz criterion to determine stability boundaries.	Stability boundaries indicate spacecraft is unstable for all boom lengths, coning motion will diverge if unchecked by cold gas control system.
Time history of coning divergence.	Determine time history of spacecraft coning angle for various lengths of extendible boom. Criteria for maximum coning angle is Specification limit of 3×10^{-3} g wobble-induced acceleration within experiment envelope.	Rate of cone angle growth (without pulse-jet damping from attitude control system) is a function of boom extended length and boom bending hysteresis. With booms retracted cone angle growth is slow, requires many days to exceed wobble limit. With booms extended wobble limit is exceeded in a few hours.
Boom thermal bending resonance.	For spacecraft spin axis normal to earth-sun line, investigate possibility of boom bending resonance as booms are heated on alternate sides during rotation toward and then away from sun. Assume no torsional deformation of booms.	No resonance occurs since at all spin rates forced thermal bending of booms occurs at frequency below boom natural bending frequency (spin forces increase boom natural frequency).
Boom thermal torsion-bending stability.	Since boom is not a closed structural tube bending and twist deformations are coupled. As boom is heated it bends away from sun, coupled twist alters heating to change bend direction. Data from operational spacecraft with open-section booms have indicated bending-torsion resonance phenomena of large magnitude. Write appropriate thermal-structural differential equations and apply Routh-Hurwitz criterion of stability.	Torsion-bending instability of booms is avoided by virtue of spacecraft spin and preferred orientation of sun angle to boom cross section.
Interaction of Cold gas attitude control system with deployed booms.	Determine response of spacecraft and booms to pulse-jet forces from attitude control system. Determine quantity of nitrogen gas required to stabilize coning motions during six-month mission.	Spacecraft response to pulse-jet forces is affected little by presence of booms, so that body rate information may be used to program damping forces. Worse boom length corresponds to spin rate producing 0.6 g on experiment, requires 2.25 lb. N_2 gas to damp coning for six months. If experiment g is variable with frequent change of boom length, 1.5 lb. of N_2 gas is required to damp coning motion for six months. Latter quantity has been added to baseline Mission II and III spacecraft.

*Details presented in Appendix E.

causes a disturbance at 1.8 times the spin frequency. Amplitude of this disturbance is about 15% of the transverse body rate sensed by the control system rate gyro. This is considered a secondary effect.

Results of these analyses are summarized in Table 13. The analyses are presented in Appendix E.

2.2.1 Synchronization of Boom Deployment. - It is essential that the three extendible booms be maintained at identical lengths to avoid introducing mass unbalance about the spin axis. Otherwise the experiments would experience modulated acceleration, and spacecraft stability would be uncertain. The extendible booms (Spar A-18) are off-the-shelf units with a long history of success on many operational spacecraft. Each unit contains a boom-length position potentiometer and a synchronous drive inverter. Thus each of the three booms have identical extension/retraction rates, and position potentiometer signals will be nulled in the spacecraft control electronics package to achieve symmetrical boom extension/retraction.

Although not considered necessary for Bioresearch Module, the following alternative approaches could also be used for boom synchronization.

(1) Single motor driving three booms from a single hub. This would require development of a new drive unit, and centerline mounting in the spacecraft may be difficult to achieve at the desired c.g. location.

(2) Flexible cable drive between boom units to achieve mechanical synchronization. This would require some modification of units and routing of the cables between units.

2.2.2 Variable Spin System Reliability. - The following statements provide a qualitative assessment of variable spin system reliability and assure its viability. During the spacecraft final design phase a detailed failure mode analysis will be conducted to define quantitative values of reliability for all spacecraft subsystems.

(1) Boom units are flight-proven, have been used on many spacecraft with no known failures.

(2) Equal length of booms is provided by position potentiometers and closed-loop control electronics.

(3) Through control interlock feature, failure of one unit will disable all units to assure equal, fixed-length booms. Spin rate can still be varied with N_2 gas for limited number of cycles.

(4) Low extension/retraction rate avoids excessive boom bending moments.

(5) Spacecraft turn-around maneuvers are conducted with booms retracted.

(6) Control gas damps wobble divergence and minimizes bending response of booms. Failure of attitude control system would result in precession of spacecraft axis independent of coning divergence. Occasional view of sun by cold plate would result in failure of environmental control of experiment. Thus, attitude control system primary reliability is not charged to variable spin system.

(7) Rate gyros are operated on a low duty cycle to assure adequate life.

2.3 POWER SUBSYSTEM

This section reports studies conducted in accordance with Task I-3 of the Contract Statement of Work, Reference 5.

2.3.1 Effect of Off-Nominal Orbits on Power Subsystem. - Nominal orbit for the Scout-launched Bioresearch Module will be a 555 x 555 km (300 x 300 n.mi.) x 37.7° inclination orbit. During each orbital period the spacecraft will experience alternate periods of solar illumination and eclipse with the percentages of each depending upon the orbital altitude, eccentricity and inclination to the ecliptic plane. The latter varies as the orbit precesses about the earth polar axis. The nominal Bioresearch Module orbit will be affected by these geometrical factors and by statistical variation of launch vehicle performance.

The variation in illumination/eclipse percentages has been accounted for in design of the solar array/chargeable battery power system. The shortest illumination period dictates sizing to provide ample power from the solar array to charge the battery, and the longest illumination period must be considered from the standpoint of dissipating excess power, as in the case of Mission III with almost 100% illumination in its highly elliptical orbit.

Table 14 shows time in sunlight for various orbits. The first is the nominal Scout orbit for Bioresearch Module with minimum sunlight per orbit of 60.2 minutes or 62.7% of the orbital period. Orbits 2 and 3 are 3σ deviations in inclination, but these do not affect minimum sunlight. Orbits 4 and 5 are arbitrary to show the effect on minimum sunlight of low and high orbits. Orbits 6 and 7 are at significantly different inclinations, representative of possible SSV launches.

Although maximum time in sunlight varies over a range of 79 to 100%, Table 14 shows that a large variation from the nominal orbit does not change significantly the minimum sunlight time of about 62%. The Bioresearch Module power system is designed to a sunlight/eclipse distribution of 60/40% and will also perform in 100% sunlight. Therefore, off-nominal orbits within the range defined in Table 14 can be handled satisfactorily by the spacecraft power system.

The thermal system likewise is satisfactory for these orbits.

TABLE 14. - EFFECT OF ORBIT VARIATION ON % SUNLIGHT

	ORBIT (Km)	ORBIT (N.Mi.)	Incl. (Deg.)	Period (Min.)	TIME IN SUNLIGHT (Min./%) Maximum	Minimum
1.	555 x 555 (Nominal)	300 x 300	37.7	96	77.2 (80.4)	60.2 (62.7)
2.	555 x 555 (+.8° Incl.)	300 x 300	38.5	96	78.4 (81.6)	60.2 (62.7)
3.	555 x 555 (-.8° Incl.)	300 x 300	36.9	96	76.1 (79.3)	60.2 (62.7)
4.	370 x 555	200 x 300	37.7	94.1	74.4 (79.0)	57.8 (61.4)
5.	647 x 647	350 x 350	37.7	98	82.2 (83.9)	62.5 (63.8)
6.	555 x 555	300 x 300	55	96	96 (100)	60.2 (62.7)
7.	555 x 555	300 x 300	90	96	96 (100)	60.2 (62.7)

TABLE 15. - SURVEY OF OPERATIONAL POWER SYSTEMS

CONTACTS:

TRW Systems Greenbelt, Md.	OGO-1, -2, -3, -4, -5, -6
GSFC Greenbelt, Md.	IMP-A, -B, -D, -I
APL Silver Spring, Md.	SAS-A
Space General El Monte, Calif.	OV3-1, -2, -3, -4
NRL Washington, D. C.	SOLRAD
NASA/Hdqrs. Washington, D. C.	GEOS-C
*COMSAT Labs. Clarksburg, Md.	INTELSAT I, II, III, IV

APPROACH:

Letter with questionnaire
Telephone advanced info., Document by mail
*Visit

TABLE 16. - POWER SYSTEM QUESTIONNAIRE

This questionnaire describes the Bioresearch Module power system design. Where applicable please furnish similar information for the ______________ spacecraft. Penciled answers on this form are satisfactory.

Item	Bioresearch Module				
	Mission I	Mission II	Mission III	Design	Measured
Description					
Orbit altitude, n.mi.	300 x 300	300 x 300	300 x 150,000		
Inclination, deg.	37.7	37.7	28		
Period	96 min.	96 min.	144 hr.		
Minimum sunlight per orbit	60 min.	60 min.	143.5 hr.		
Power system	Solar array/rechargeable battery				
Stabilization	Attitude Control, zero g	Spin Stab., variable g	Spin Stab., fixed g		
Orientation of longitudinal/ spin axis	Normal to earth-sun line				
Mission duration		6 months			
Solar Distance, AU	1	1	1		
Battery Data					
Type	12 AH, 23 cell nickel cadmium				
Discharge efficiency, %		95			
Charge efficiency, %		80 @ 70°F			
Max. depth of discharge, %		25			
Min. no. of reliable cycles		8,000			

TABLE 16. - POWER SYSTEM QUESTIONNAIRE (Continued)

Item	Bioresearch Module				
	Mission I	Mission II	Mission III	Design	Measured
Solar Cell Configuration					
Type	N/P Silicon				
Size	2 x 2 cm				
Base resistivity	2 ohm-cm				
Thickness	12 mil				
Cover	25 mil fused silica, blue filter, antireflection coating, UV reflective coating				
Substrate	Kapton, 3 mil (Dupont)				
Interconnector material	Silver mesh				
Interconnector Insulation	Parylene (Union Carbide) and PYRE M-L (Dupont)				
Coverslide Adhesive	RTV 602 (General Electric)				
Solar Cell Degradation Factors					
Cell mismatch	1%	1%	1%		
String mismatch	2%	2%	2%		
Cell covers	4%	4%	4%		
Array alignment to sun	1%	1%	1%		
Radiation	6%	6%	20%		
Ground handling damage	2%	2%	2%		

TABLE 16. - POWER SYSTEM QUESTIONNAIRE (Concluded)

Item	Bioresearch Module Mission I	Bioresearch Module Mission II	Bioresearch Module Mission III	Design	Measured
Power System Data					
No. of solar cells	4,990	11,510	9,130		
Cell mounting (Body, panel, paddle)	Body	Body	Body		
Orientation	Attitude Stabilized	Spin stabilized	Spin stabilized		
Array weight, lb.	15.2	35.0	27.8		
System Weight, lb.	70.7	90.0	79.3		
Nominal average temp. during illumination, °F)	108	54	51		
Avr. pwr. output, watts (BOL/EOL)	217/204	218/205	175/140		
Nominal operating voltage, volts	28	28	28		
BOL system power density, watts/lb	3.07	2.42	2.21		
Array area, ft^2	25.3	58.4	46.3		
BOL power rating, watts/ft^2	8.5	3.7	3.8		
[1] BOL array efficiency, %	6.6	2.9	2.9		
Power required, watts	187	183	125		
EOL margin, %	9	12	12		

[1] $\text{Array efficiency} = \dfrac{\text{Array Power}}{\text{Total array area} \times 0.14\ \text{watts/cm}^2}$

BOL = Beginning of life

EOL = End of life

TABLE 17. - OPERATIONAL SPACECRAFT POWER SYSTEM CHARACTERISTICS AND MEASURED DATA

	IMP A	IMP B	IMP C	IMP D	IMP E	IMP I
Orbit at Launch Alt. (N.Mi.)	105x105,600	104x51,600	112x140,800	2,744x270,000	1360x5100 Lunar	130x111,250
Inclination, Deg.	33.34	33.5	33.9	7-25	Ecliptic Plane	28.6
Battery Type	AgCd	AgCd	AgCd	AgCd	AgCd	AgCd
Solar Cell Type	P/N Silicon	P/N Silicon	N/P Silicon	N/P Silicon	N/P Silicon	N/P Silicon
Solar Cell Cover	12 Mil Corning 0211	12 Mil Corning 0211	6 Mil FuSi	6 Mil FuSi	6 Mil FuSi	6 Mil FuSi
No. Solar Cells	11,520	11,520	2,048	7,680	7,680	4,032
Cell Mounting	Paddle	Paddle	Paddle	Paddle	Paddle	Body
Orientation	Variable	Variable	Normal $\pm 65°$ to Sun	Variable	Spin Stab. & Att. Control	$\perp$ Sun $\pm 10°$
Solar Cell Size, cm	1 x 2	1 x 2	2 x 2	2 x 2	2 x 2	2 x 6
Solar Cell Radiation Degradation	25% at 1 Yr	25.8% at 6 Mo	16% at 2 yr.	13/8% at 2-1/2 yr.	14.8% at 1-1/2 yr	18% at 1 yr.
Array Weight, Lb.	26.5	26.5	25.6	22.0	24.5	58.7
System Weight, Lb.						
Nominal Avg. Temp, °F	41	32	-5	32	32	41
Avg. Pwr. Output, BOL/EOL, W	43-75/32-56	43-75/32-56	45-69/38-58	68-88/59-76	74/63	170/140
Nom. Op. Volts	19.6	19.6	18.2	18.3	19.6	28.2
BOL Sys. Pwr. Den, W/Lb			1.76-2.70	2.64-3.46	3.0	2.90
Array Area, Ft^2	29.1	29.1	30.9	38.7	38.7	63.1
BOL Pwr. Rating, W/ft^2	1.48-2.58	1.48-2.58	1.46-2.23	1.65-2.17	1.91	2.7
BOL Array Eff. %	1.14-1.98	1.14-1.98	1.12-1.72	1.27-1.67	1.47	2.07
Pwr. Required, W	38	37	36.6	40.3+10 Bat. Chg	35.7 Excl.Bat Chg.	110
EOL Mar in, %	-16 to +47	-13.5 to +51	-7 to +42	34 to 76 Excl. Bat. Chg.	76	21

TABLE 17. - OPERATIONAL SPACECRAFT POWER SYSTEM CHARACTERISTICS AND MEASURED DATA (Continued)

	OGO-1	OGO-2	OGO-3	OGO-4	OGO-5	OGO-6
Orbit at Launch Alt. (N.Mi.)	175x92,827	223x817	159x66,000	222x490	158x79,000	214x593
Inclination, Deg.	31	87.35	31	86.01	31.3	81.998
Battery Type	NiCd	AgCd	NiCd	NiCd	NiCd	NiCd
Solar Cell Type	P/N Silicon	N/P Silicon	P/N Silicon	N/P Silicon	N/P Silicon	N/P Silicon
Solar Cell Cover	6 Mil Corning 0211	6 Mil Corning 0211	6 Mil Corning 0211	6 Mil Corning 0211	6 Mil Corning 0211	6 Mil Corning 0211
No. Solar Cells	32,256	32,256	32,256	32,256	32,256	32,256
Cell Mounting	Paddle	Paddle	Paddle	Paddle	Paddle	Paddle
Orientation	⊥Sun		⊥Sun	⊥Sun	⊥Sun	⊥Sun
Solar Cell Size, cm	1 x 2	1 x 2	1 x 2	1 x 2	1 x 2	1 x 2
Solar Cell Radiation Degradation						5% in 2 Yr.
Array Weight, Lb	113	109	113	113	113	113
System Weight, Lb.	202	183	202	202	202	202
Nominal Avg. Temp, °F						
Avg. Pwr. Output, BOL/EOL,W	500/350	500/350	500/350	500/350	500/350	/574
Nom. Op. Volts	28.5±5V	28.5 ±5V	28.5 ±5V	28.5 ±5V	28.5 ±5V	28.5 ±5V
BOL Sys. Pwr. Den, W/Lb	4.8	4.8	4.8	4.8	4.8	4.8
Array Area, Ft^2	88	88	88	88	88	88
BOL Pwr. Rating, W/ft^2	7	7	7	7	7	7
BOL Array Eff, %	10.5	10.5	10.5	10.5	10.5	10.5
Pwr. Required, W	220-495	>OGO-1 or -2	220-495	220-495	220-495	278 Avg.
EOL Margin, %						

TABLE 17. - OPERATIONAL SPACECRAFT POWER SYSTEM CHARACTERISTICS AND MEASURED DATA (Concluded)

	SAS-A	OV3-1	OV3-2	OV3-3	OV3-4	SOLRAD 10
Orbit at Launch Alt. (N.Mi.)	300x300	192x3091	172x863	195x2419	347x2554	323x383
Inclination, Deg.	5	82.5	82.0	80.5	40.8	51°
Battery Type	NiCd	NiCd	NiCd	NiCd	NiCd	NiCd
Solar Cell Type	N/P Silicon	N/P Silicon	N/P Silicon	N/P Silicon	N/P Silicon	N/P Silicon
Solar Cell Cover	6 Mil Corning 0211	20 Mil Quartz	20 Mil Quartz	20 Mil Quartz	20 Mil Quartz	12 Mil FuSi
No. Solar Cells	6,712	2,560	3,308	2,980	2,880	2,432
Cell Mounting	Panels	Body	Body	Body	Body	Body, Paddle
Orientation	Spin	Spin	Spin	Spin	Spin	Spin, ⊥ Sun
Solar Cell Size, cm	2x2	1x2 and 2x2	1x2 and 2x2	1x2 and 2x2	1x2 and 2x2	1x2
Solar Cell Radiation Degradation						
Array Weight, Lb.	26.9	18.86	22.88	19.45	19.54	
System Weight, Lb	43.6	151.8	200.5	165.4	171.1	
Nominal Avg. Temp	70°F					72°F
Avg. Pwr. Output, BOL/EOL, W						/40 (Paddle)
Nom. Op. Volts	10.7V	26	26	26	26	12.5
BOL Sys. Pwr. Den, W/lb.						
Array Area, Ft^2	17					
BOL Pwr. Rating, W/ft^2						
BOL Array Eff, %						
Pwr. Required, W	30					
EOL Margin, %						

2.3.2 <u>Comparison with Operational Power Systems</u>. A comparison was made between the Bioresearch Module power system baseline design and measured performance of previously flown solar cell/rechargeable battery spacecraft power systems. Purpose of this comparison was to assure that the power system design was within the state-of-art of operational systems and to profit by lessons learned from space operational experience with solar cells and rechargeable batteries. The approach used was:

(1) Telephone contact with small spacecraft agencies. Table 15 lists the contacts made.

(2) Letter with questionnaire describing Bioresearch Module power system and requesting similar information on operational spacecraft. A copy of the questionnaire is shown in Table 16.

The power system data obtained is summarized in Table 17. Response to the questionnaire was very good considering that many of the flights were made several years ago and personnel associated with the operations have been reassigned or are otherwise not available. Some of the data requested were not measured or would require additional processing. Table 17 presents power system characteristics (such as battery and solar cell type) and measured performance (such as EOL power output, solar cell degradation).

The measured spacecraft data of Table 17 may be compared with the Bioresearch Module design data in Table 16. To assist in this comparison Table 18 has been prepared which shows a composite range of parameters for the Bioresearch Module and operational spacecraft power systems. The following conclusions are drawn from the comparison:

(1) Ni-Cd batteries are preferred over Ag-Cd and appear to have a longer, more reliable life expectancy.

(2) N/P silicon solar cells are preferred for their higher resistance to radiation.

(3) The 25 mil fused silica solar cell covers chosen for Bioresearch Module are somewhat thicker than ordinarily used.

(4) Bioresearch Module power system sizing falls within the spectrum of practice used by other spacecraft.

(5) Bioresearch Module end-of-life power margin appears to be satisfactory.

(6) Solar cell radiation degradation projected for Bioresearch Module appears to be conservative, considering use of thicker covers.

TABLE 18. - POWER SYSTEM COMPARISON

	BIORESEARCH MODULE (DESIGN)	OTHER SPACECRAFT (ACTUAL OR MEASURED)
Battery Type	NI-CD	NI-CD, AG-CD
Solar Cell Type	N/P Silicon	N/P, P/N Silicon
Solar Cell Cover	25 Mil Fu Si	6-20 Mil Fu Si, Corning 0211, Quartz
No. Cells	4990 to 11,510	2048 to 32,256
Cell Mounting	Body, Panel	Body, Panel, Paddle
EOL Avg. Pwr., Watts	140 to 204	32 to 574
BOL Pwr. Sys. Den., W/Lb.	2.21 to 3.07	1.76 to 4.8
BOL Pwr. Rating, W/Ft^2	3.7 to 8.5	1.46 to 7
BOL Array Eff., %	2.9 to 6.6	1.12 to 10.5
Pwr. Reqd., Watts	125 to 187	30 to 495
EOL Margin, %	9 to 12	-16 to +76
Solar Cell Radiation Degradation During Mission, %	6 to 20 (6 months)	5 to 25.8 (to 2-1/2 years)

3.0 ANALYSES OF SPACE SHUTTLE LAUNCHED SPACECRAFT

In conjunction with design definition of a Bioresearch Module as a Scout-launched payload to accomplish Missions I and II, parallel studies were conducted for preliminary definition of the design impact of using the Space Shuttle Vehicle to launch Missions I, II and III anc recover Missions I and II. The SSV studies were started early to determine whether a basis for common hardware existed which would permit launch operations by both the Scout and SSV without penalizing performance or cost of the baseline Scout-launched spacecraft. Studies showed the changes were so minor that the baseline spacecraft design was made compatible with both launch vehicles. The following sections present the results of Bioresearch Module/SSV studies. Basis for the shuttle configuration is the SSV Data Package, Reference 7.

3.1 MISSION ANALYSIS

This analysis, Task II-1 of Reference 5, evaluated the feasibility, and by mission analysis investigated the impact of using the SSV for launching Missions I, II and III and retrieving and returning either the experiment package or the entire spacecraft for Missions I and II.

3.1.1 Approach to Bioresearch Module/SSV Studies. - The SSV configuration and program is currently very fluid and subject to considerable change. Data available to payload users is preliminary, incomplete, and often conflicting. However, information on cargo bay configuration; payload storage, deployment and retrieval; availability of power, communications and thermal control; and environment is sufficiently well known to assess small payload missions and identify payload-peculiar problems.

Accordingly, this study investigates achievable missions and problems highlighted in adapting Bioresearch Module to deployment and retrieval by the SSV. Support requirements such as external power, external cooling, and checkout are identified in terms of function only. Payload requirements such as propulsion stages, adapters, spin tables and structural changes are investigated in sufficient detail to identify hardware configuration and impact on baseline design.

3.1.2 Guidelines for Bioresearch Module/SSV Studies. - Study of the SSV Data Package and preliminary analysis of launch operations and SSV performance generated the following set of guidelines which were used in the mission analyses:

- Bioresearch Module systems using a simulated experiment package will be checked out prior to installation in orbiter.
- The simulated experiment package will remain with Bioresearch Module in orbiter through erection on the pad.

- Orbiter will accommodate installation of experiment package and walkaway from eight hours before launch to one hour before crew exit to fuel.
- Orbiter will provide on-board checkout of Bioresearch Module.
- Orbiter will provide external power, command and data link, and heat exchanger for external thermal cooling equipment.
- Bioresearch Module will provide adapters (including spin table) for interface with the orbiter deployment mechanism and structural attachment points.
- Direct deployment of Mission I and II from SSV in 500 km (270 n.mi.) or higher circular orbit.
- Hohmann transfer of Missions I and II by velocity package from SSV in 185 km (100 n.mi.) circular orbit.
- Injection of Mission III by velocity package from SSV.
- No rendezvous with another vehicle for deployment.
- Active SSV achieves retrieval by rendezvous with stabilized, passive module.
- SSV capable of retrieving aborted mission including module with propulsion stage.
- Deployment and retrieval furnished by SSV standard mechanisms with module adapters.
- Minimum change to baseline module.
- Maximum compatibility of Module/SSV interface for Missions I, II and III.
- Maximum compatibility of module with both Scout and SSV.

3.1.3 SSV Missions. - Various studies have projected many possible missions for the SSV. It is useful to examine these to determine those which may provide opportunity for Bioresearch Module launch. Table 19 summarizes the missions defined in the SSV Data Package. Those involving placement and retrieval of payloads provide a generous range of orbital parameters ideal for Missions I and II, and for Mission III in conjunction with a velocity package. However, Table 20 indicates bioscience payload deployments will be restricted to two altitude bands, namely, 185 km (100 n.mi.) and 500 km (270 n.mi.). At the lower altitude

TABLE 19. - SUMMARY OF SSV PROJECTED MISSIONS

- Baseline (Logistical Support of Space Station):

  Insertion orbit of 92 x 185 km (50 x 100 n.mi.) x 55° inclination
  Final orbit of 500 x 500 km (270 x 270 n.mi.) x 55° inclination
  Orbiter stay time is up to 7 days
  (Reference SD71-103-1 Page 2-31, and SD71-103-2 Page 23 of SSV Data Package)

- Placement and Retrieval of Payload:

  Circular orbits 185 to 777 km (100 to 420 n.mi.)
  Inclinations 28.5° to sun synchronous
  Orbiter stay time is up to 7 days
  (Reference SD71-103-2, Page 48 of SSV Data Package)

- Delivery of Propellants:

  Parking orbits 185 x 185 km (100 x 100 n.mi.) at 28.5° or 55° inclination
  Circular orbit 500 km (270 n.mi.) at 31.5° inclination
  Predetermined orbit for emplacement of propellant module
  Orbiter Stay time 2-7 days
  (Reference SD71-103-2, Page 55 of SSV Data Package)

- Short Duration Orbital Missions:

  Orbital altitudes 185 km (100 n.mi.) to limit of capability of SSV
  Inclination 28.5° to sun synchronous
  Orbiter stay time up to 30 days
  Consumables beyond 7 days charged to payload.
  (Reference SD71-103-2, Page 62 of SSV Data Package)

- Rescue Mission:

  Not applicable to small payload operations.

TABLE 20. - SSV DELIVERY-OF-PAYLOAD MISSIONS

ALTITUDE, km (N.Mi.)	185 (100)	370-500 (200-270)	185 (100)	500 (270)	185 (100)
Inclination (Deg.)	28.5-33	28.5-33	55-63	55-63	90-100
No. of Missions	251	4	5	10	70
Mission Types	Planetary Space Applica-tion Astronomy Experi-ments DOD Bio-science Space Physics Non-NASA	Develop-ment	DOD Space Physics	Bioscience Development	Space Application DOD Non-NASA Space Physics Astronomy

Ref. SD 71-103-1, Page 2-32 (SSV Data Package) all Bioresearch Modules would require velocity packages for transfer to higher altitudes. At 500 km (270 n.mi.) only 10 missions are indicated. This orbit is suitable for direct deployment of Missions I and II, with Mission III again requiring a velocity package for injection into its highly elliptical orbit. Table 21 shows the projected mission quantities for each of the mission types defined in Tables 19 and 20.

The only valid conclusion to be drawn from these data is that SSV orbits can be used for Bioresearch Module deployment. As previously noted, in some cases velocity packages will be required. Definition of launch opportunity must be deferred until a firm SSV program is authorized.

3.1.4 Orbital Mechanics. - At the lower SSV orbital altitudes it will be necessary to use velocity packages on all Bioresearch Module missions for transfer to higher circular orbits. This is necessary to assure a six-month lifetime for Missions I and II, and to achieve the highly elliptical orbit for Mission III. Figure 9 shows the total Δ velocity requirements for Hohmann transfer (two burns, the first at injection, and the second to circularize). It is noted that 201 m/sec (660 ft/sec) Δ velocity is required for transfer from 185 km (100 n.mi.) circular orbit to 555 km (300 n.mi.) circular orbit. This is a modest velocity requirement, easily achieved by adding two small motors to the Mission I or II spacecraft. This is discussed further in Section 3.3.

Figure 10 indicates the large velocity requirement for injection of Mission III into a highly elliptical orbit. For an apogee of 277,000 km (150,000 n.mi.) Δ velocities of 3040 m/sec (9970 ft/sec) and 3110 m/sec (10,200 ft/sec) are required for injection, respectively from perigees of 185 km (100 n.mi.) and 555 km (300 n.mi.). This would require a very large velocity package, discussed in Section 3.3.

If an orbital plane change is desired, this also can be accomplished with a velocity package on the Mission I or II spacecraft. However, Figure 11 shows this to be very costly for even modest changes in the orbital plane. The example shows that an FW-4S motor (Scout fourth stage) is required by a 150 kg (350 lb) payload to provide the 2500 m/sec (8200 ft/sec) velocity to achieve a 19 degree plane change in a 555 km (300 n.mi.) circular orbit. This velocity must be added as the spacecraft crosses the equator if all the plane change is to result in a change in orbital inclination.

The desired six-month duration for Bioresearch Module missions requires orbits of sufficient altitude to avoid orbital decay due to atmospheric drag. Figure 12, based on data from Reference 13, presents orbital lifetime versus perigee altitude for circular ($\epsilon = 0$) and elliptic orbits. This lifetime data is quite conservative and is applicable for any level of activity during the solar cycle. The resulting orbit altitudes will generally be higher than actually required to produce the desired lifetime, however, when the spacecraft characteristics, mission and launch time have been finalized the required orbit altitude can be determined considering effects of solar activity. The ballistic coefficient,

W/C_DA, is estimated to be 7 for Bioresearch Module spacecraft. The data of Figure 12 indicates that Missions I and II should operate in circular orbits above 500 km (270 n.mi.). The highly elliptical Mission III with ϵ = .955 will have adequate life with a perigee as low as 185 km (100 n.mi.) with proper selection of orientation of the orbit plane and injection time. Perturbations from the sun and moon are the predominate factors affecting lifetime of highly elliptical orbits and are sensitive to the location of perigee and the launch time. Again these factors can be determined when the launch date has been selected.

TABLE 21. - SSV MISSION TYPES

MISSION TYPES	NUMBER
Space Station Support	70
Placement of NASA Payloads	184
Placement of DOD Payloads	156
Tug Delivery/Support	33
Other Missions	2
	445

Reference SD 71-103-1, Page 2-37 (SSV Data Package)

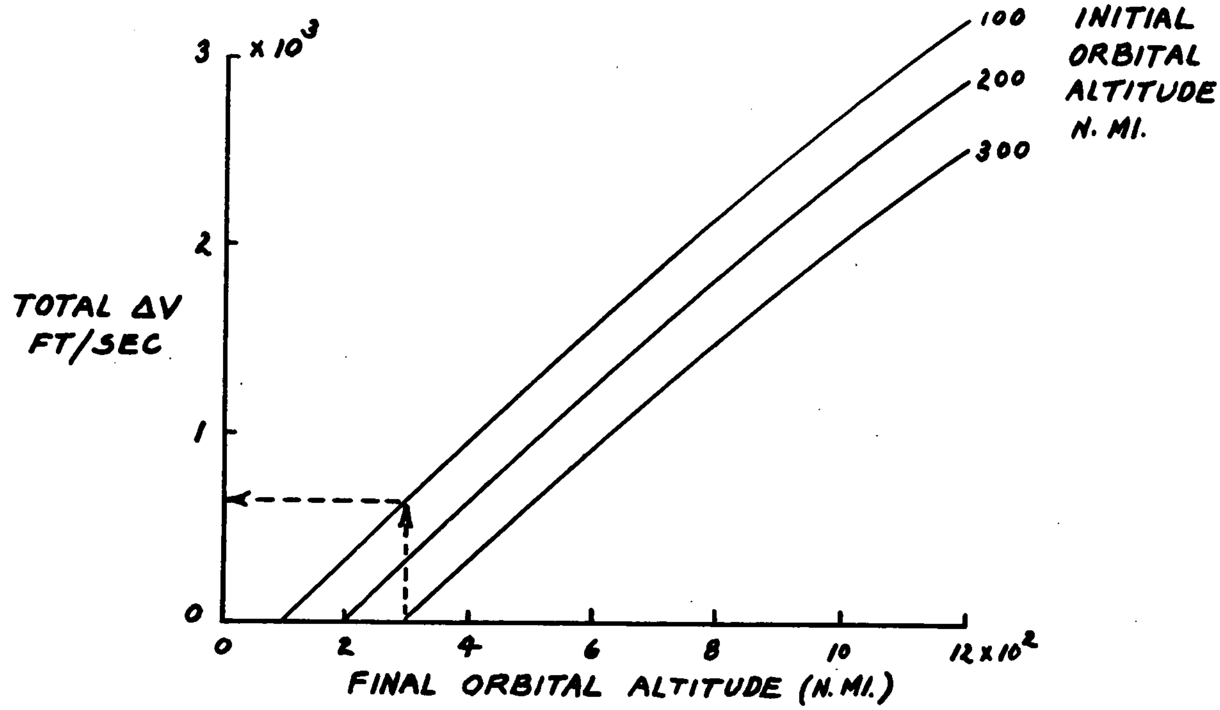


FIGURE 9. - TOTAL HOHMANN TRANSFER ΔV REQUIRED

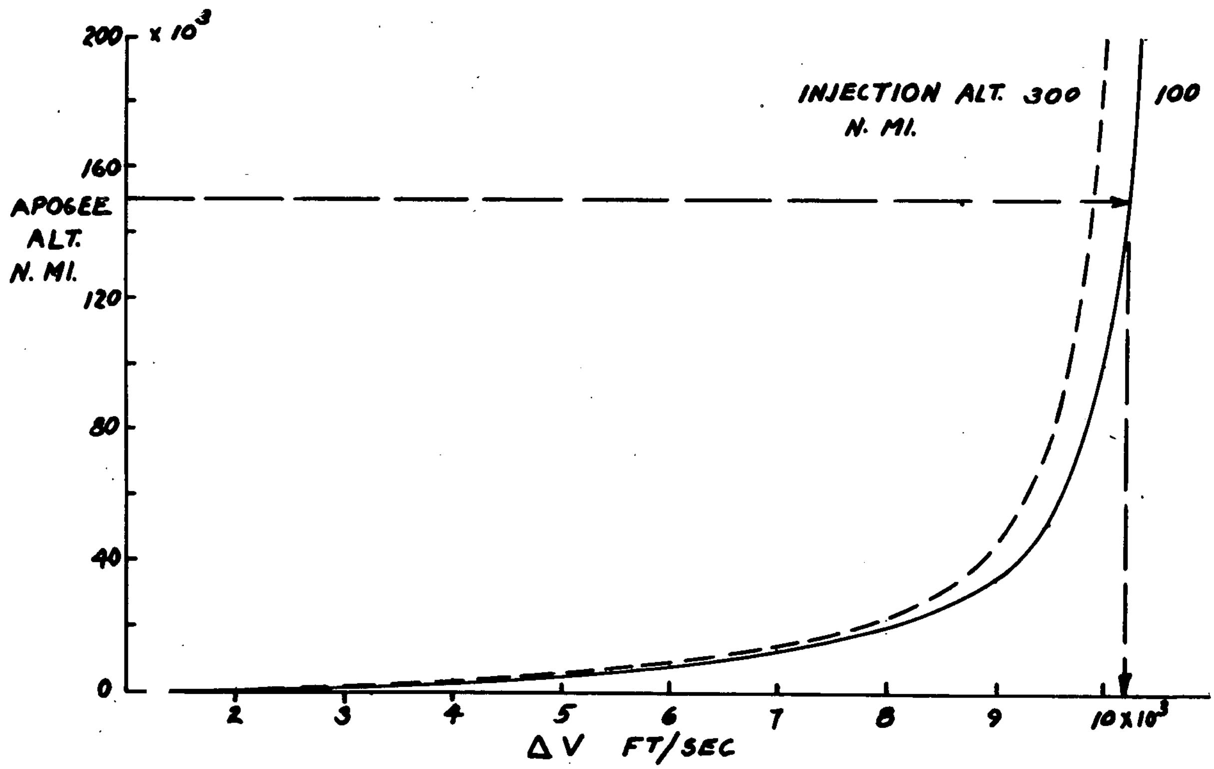


FIGURE 10. - ΔV FOR INJECTION INTO ELLIPTIC ORBIT

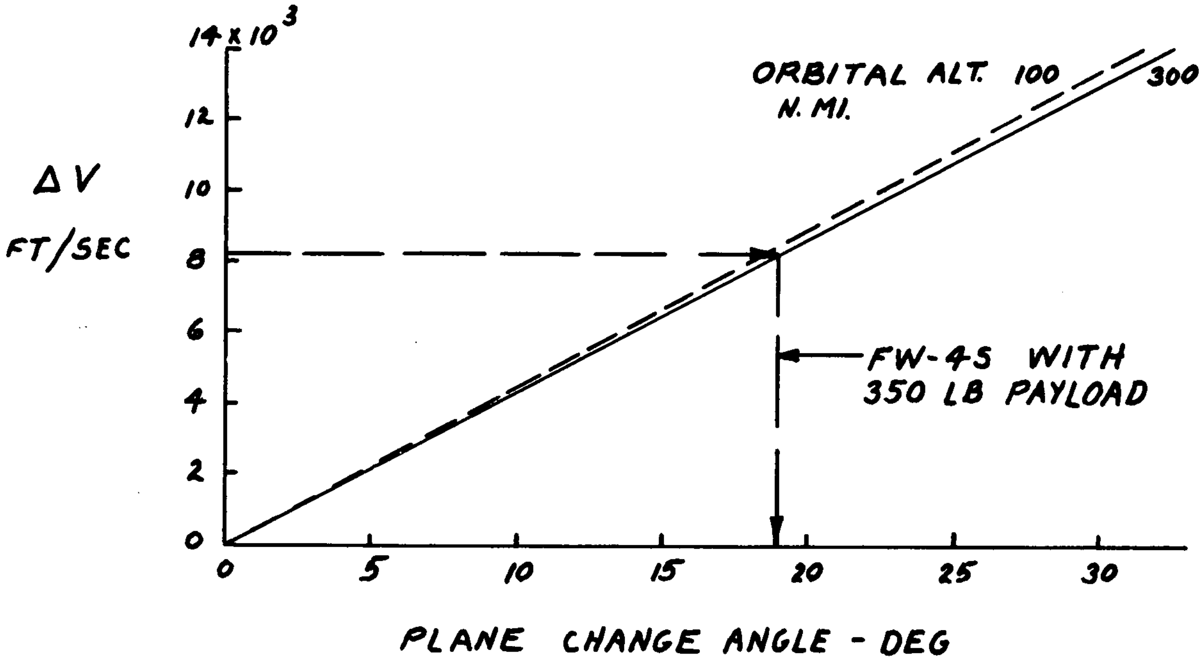


FIGURE 11. - ΔV FOR PLANE CHANGE OF CIRCULAR ORBIT

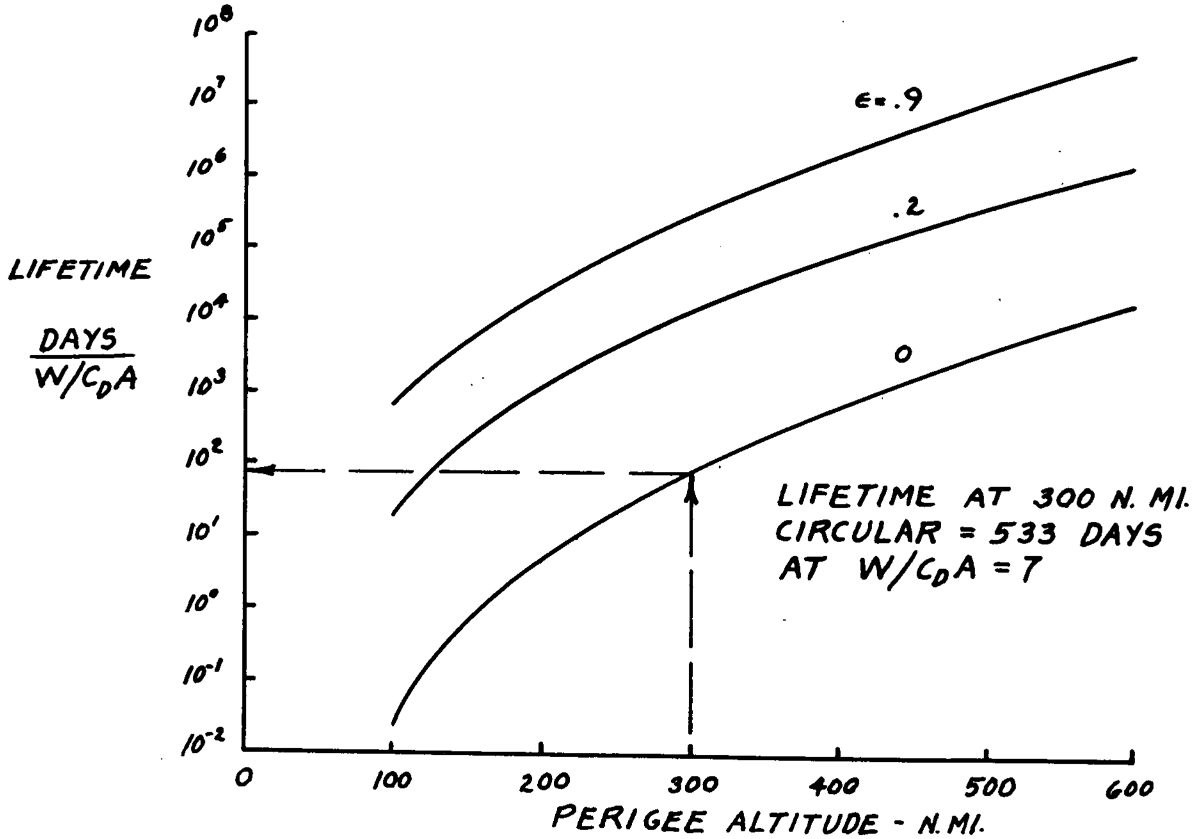


FIGURE 12. - ORBITAL LIFETIME

3.1.5 SSV Operational Procedures. - The following discussion of SSV operational procedures centers on deployment and retrieval of the Bioresearch Module spacecraft in orbit. The SSV Data Package, Reference 7, includes a trade study of Oribter payload deployment mechanisms. That study identified the boom manipulator as the preferred mechanism concept, and this approach was selected for use in the present study. It will be assumed that the boom manipulator removes the spacecraft from the Orbiter cargo bay for deployment, and similarly, that during retrieval the boom manipulator places the spacecraft back into the cargo bay. As an alternate procedure, Sections 3.4 and 3.5 assume spacecraft deployment directly from the cargo bay, and retrieval by use of a manipulator boom.

Tables 22 and 23, and Figures 13 and 14 summarize SSV deployment and retrieval of payloads as described in Reference 7. The starred items in the tables indicate procedures requiring modification for the Bioresearch Module spacecraft. Note, for example, item 5 of Table 22, where power and subsystems are activated outside the cargo bay. Bioresearch Module power and data systems will be continuously operated until the umbilical is pulled at deployment, at which point spacecraft on-board systems take over. Figures 13 and 14 illustrate the steps called out in Tables 22 and 23, respectively.

Tables 24 through 28 itemize the operational procedures which have been specifically adapted to Bioresearch Module launch and retrieval by the SSV. The structural adapters and support equipment required by these operations are further discussed in following Sections.

3.1.6 Bioresearch Module Hardware for SSV Operations. - Figure 15 notes the changes to the baseline spacecraft necessary for SSV operations. These were incorporated as part of the Scout launched spacecraft. Since the changes were so minor they were included to extend hardware commonality to the SSV operations. The aft skirt skin gage was increased from 0.020 in. to 0.031 in. magnesium, and the aft ring was changed to the upper half of a split ring for attachment by V-band to an adapter or docking mechanism. Total weight increase is 2.5 pounds. The spacecraft can be supported at the Scout payload ring (Figure 7) for launch, and reattachment during retrieval may be done at the aft ring. These interfaces are shown in Section 3.8. The Mission III spacecraft requiring a velocity package is discussed in Section 3.3.

Figure 16 is a sketch of the Mission I or II velocity package in a possible SSV installation. Details of the supporting hardware are covered in later sections of this report. The spacecraft is restrained by the SSV attachment mechanism and by a tie-down cradle and louver cover. The electrical umbilical provides power and data monitoring from the SSV. The liquid umbilical attaches to the payload-supplied liquid-to-liquid heat exchanger which is cooled by the SSV payload-dedicated heat exchanger. For deployment the umbilical is pulled and the SSV boom manipulator attaches to the deployment and retrieval mechanism to move the spacecraft outside the cargo bay. The spacecraft is then separated from the spin table and docking cone.

TABLE 22. - SSV DEPLOYMENT OF PAYLOAD

1.	Orbiter Achieves Desired Orbit
2.	Attach Cargo Manipulator Arm to Payload
3.	Release Payload from Tie-down structure
4.	Position Payload Outside Cargo Bay
*5.	Activate Payload Power and Subsystems via Radio Command
6.	Final Checkout of Activated Payload Subsystems
*7.	Release Payload from Manipulator Arm
8.	Orbiter Station Keeps near Payload
9.	Activate Remaining Payload Susbystems, ACS, Propulsion
10.	Monitor Payload Operation
11.	Retract Manipulator Arm into Cargo Bay
12.	Orbiter Conducts Other Missions or Retrieves Malfunctioning Payload.

* Alternate procedures required for Bioresearch Module (Reference SD-71-103-2, page 50 of SSV Data Package).

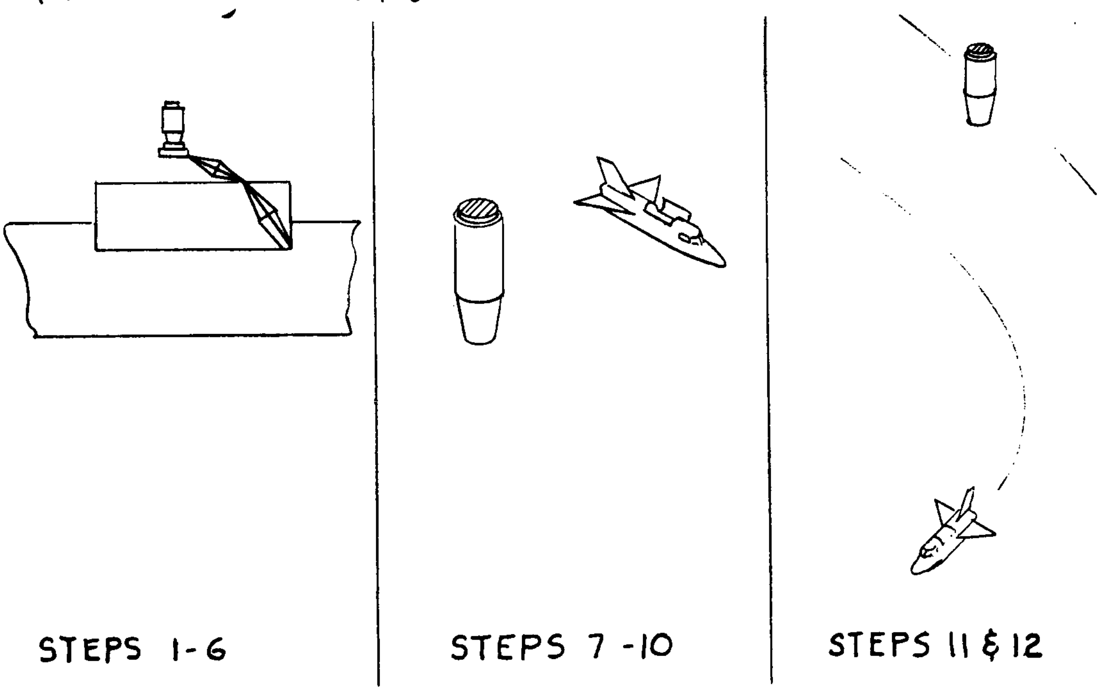


FIGURE 13. - SSV DEPLOYMENT OF PAYLOADS

TABLE 23. - SSV RETRIEVAL OF PAYLOAD

1.	Orbiter achieves rendezvous with payload.
2.	Orbiter establishes position near payload (≅ 100 yards).
*3.	Despin payload and deactivate subsystems via Radio command.
4.	Orbiter performs closing and docking maneuver
5.	Payload secured to manipulator arm.
*6.	Remaining payload subsystems shut down, deployed antennas and mechanisms retracted or removed.
7.	Payload retracted to cargo bay.
8.	Payload stowed for service or repair, or for return to earth.

*Alternate Procedures required for Bioresearch Module.

(Ref. Page 53 of Vol. II, Item 5 of SSV Data Package)

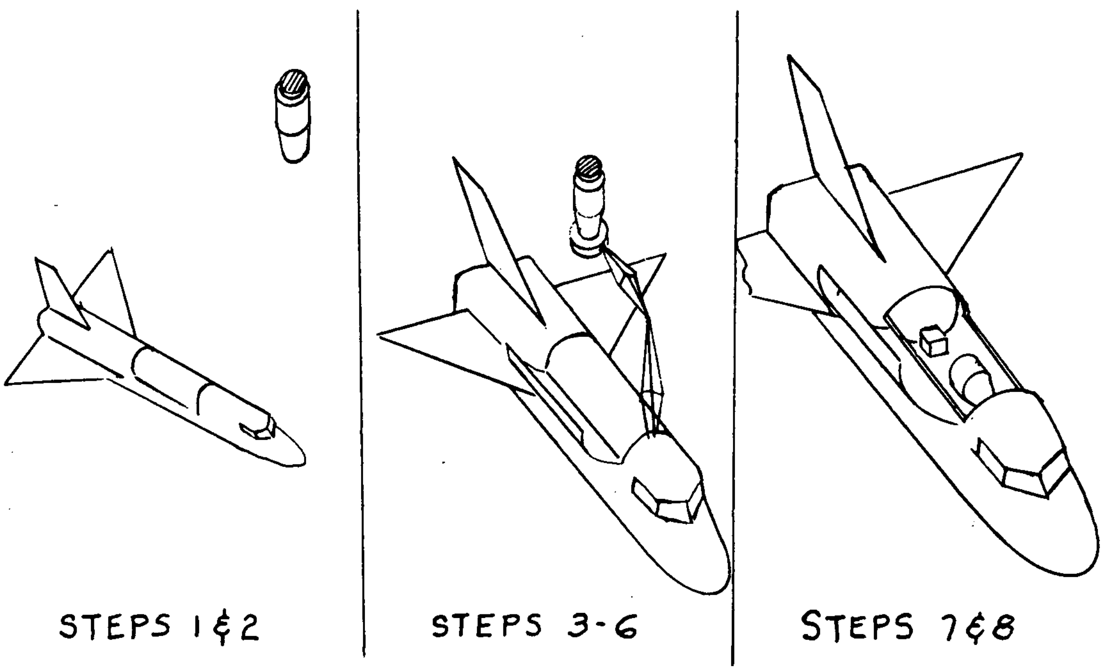


FIGURE 14. - SSV RETRIEVAL OF PAYLOADS

TABLE 24. - DEPLOYMENT OF MISSION I MODULE FROM SSV

1. Install module with simulated Exp. Pkg. in Orbiter at flight preparation area.
2. Transport Orbiter to launch pad, mate with booster, and erect.
3. Install Flight Exp. Pkg. in Module in Orbiter w/o interruption of power, data or cooling.
4. Checkout Module systems and place in launch status.
5. Launch and achieve desired orbit with SSV.
6. Checkout Module systems and power down experiments and systems.
7. Condition cold plate to lowest acceptable temperature.
8. Disconnect umbilical from module, transfer to internal power, thermal control and data handling.
9. Transfer Module outside cargo bay.
10. Make final check of module systems and power up experiments and systems to operational status.
11. Release module from manipulator arm.
12. Activate module ACS by radio command.
13. Monitor Module via communications link and verify operational status.
14. Orbiter retrieves malfunctioning Module, or proceeds to other operations or reentry.

TABLE 25. - RETRIEVAL OF MISSION I MODULE BY SSV

1. Orbiter achieves rendezvous with Module.
2. Deactivate Module ACS by radio command.
3. Attach manipulator arm to Module.
4. By radio command condition cold plate to lowest acceptable temperature and power down systems and experiments.
5. Transfer Module to cargo bay, attach to tie-down points
6. Attach umbilical, transfer to external power, thermal control, data handling.
7. Orbiter monitors Module systems.
8. Orbiter services or repairs module for redeployment, or proceeds to other operations or reentry.

TABLE 26. - DEPLOYMENT OF MISSION II MODULE FROM SSV

1\. ..... 10. Same as Mission I (Table 24).

11. Orbiter establishes release attitude.
12. Via Hardline on manipulator arm:

    Command spin rocket ignition

    Command separation clamp bolt ignition
13. Expansion springs separate module from orbiter at small relative velocity.
14. Orbiter establishes chase mode.
15. Activate Module ACS by radio command.
16. Monitor Module via communications link and verify operational status.
17. Orbiter retrieves malfunctioning Module, or proceeds to other operations or reentry.

TABLE 27. - RETRIEVAL OF MISSION II MODULE BY SSV

1.	Orbiter achieves rendezvous with Module.
*2.	By radio command despin and stabilize module with ACS
3.	By radio command deactivate module ACS
-----	Remaining items same as 3 thru 8 of Mission I (Table 25)

*Alternate procedure required for malfunctioning module.

TABLE 28. - DEPLOYMENT OF MISSION III MODULE FROM SSV

1.	Install Module/Propulsion Stage W/O ordnance in Orbiter at flight preparation area.
2.	Steps 2 - 7 for Mission I.
3.	Install ordnance on launch adapter (spin rocket igniter squibs and explosive bolt igniters) and on Propulsion motor (igniter squibs and explosive bolt igniters).
4.	Steps 8 - 10 for Mission I.
5.	Orbiter establishes firing attitude
6.	Via hardline on manipulator arm: Command spin rocket ignition Command separation clamp bolt ignition
7.	Expansion springs separate Module/propulsion stage from Orbiter at small relative velocity.
8.	Orbiter establishes chase mode 100 yards distance measure normal to Module/Propulsion stage spin axis.
9.	By radio command Orbiter ignites propulsion stage. **
10.	On-board programmer stages and deploys Module into elliptical orbit.
11.	Orbiter proceeds to other operations or reentry.

* Retrieval sequence required if separation tipoff excessive or ignition fails.

** Timing is critical to establish proper injection into elliptic orbit

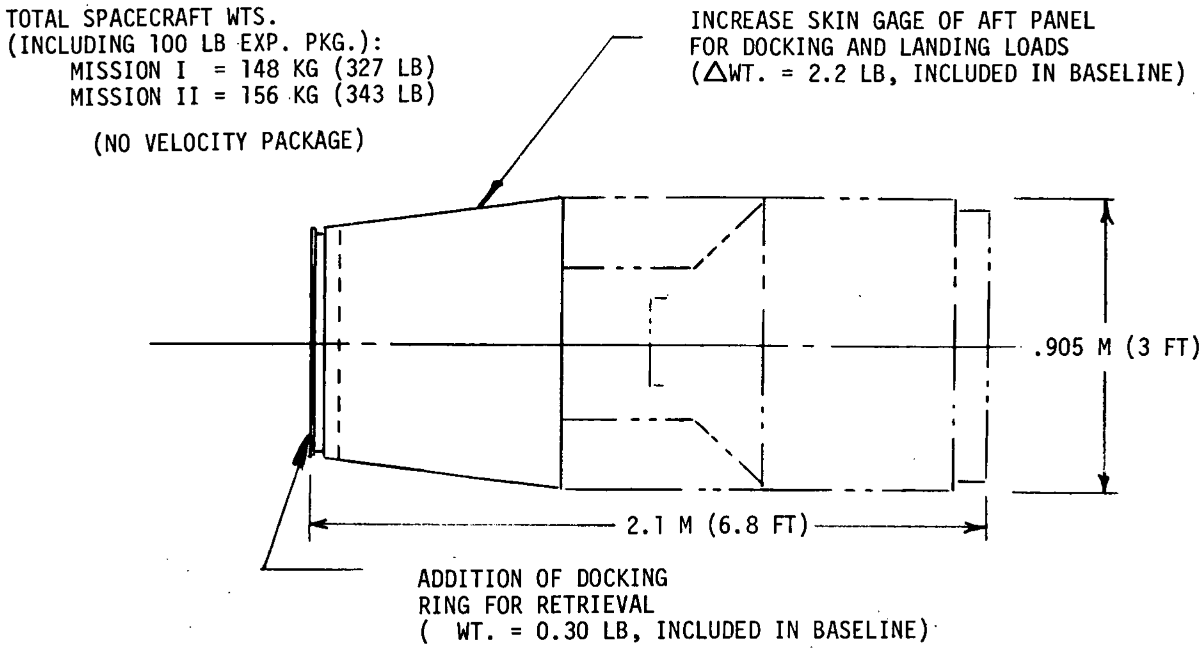


FIGURE 15. - MISSION I & II CONFIGURATIONS

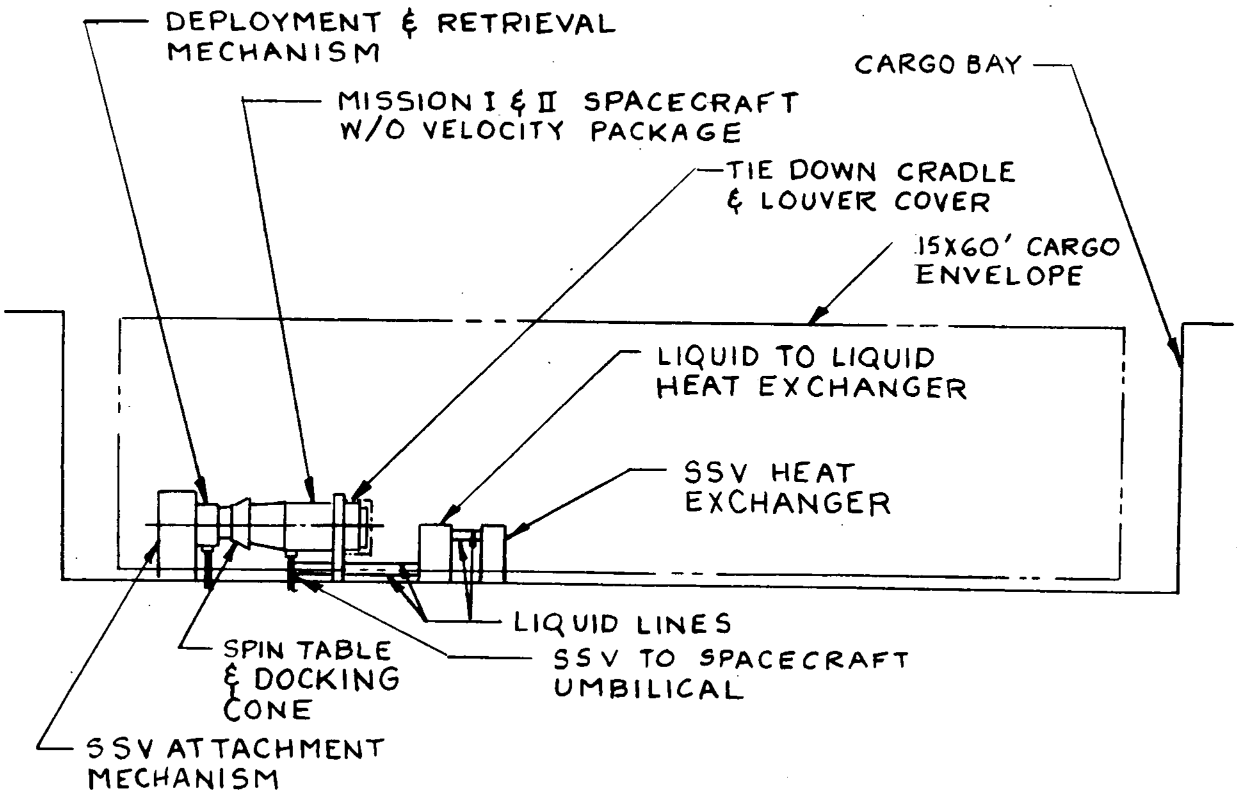


FIGURE 16. - SSV INSTALLATION

3.1.7 Summary of Findings from Mission Analysis. The following conclusions are drawn from the analysis of Bioresearch Module operations from the SSV:

(1) The spectrum of SSV orbits is adequate for direct deployment of Mission I and II modules.

(2) A velocity package is necessary to deploy the Mission III module. Timing of ignition is a critical factor.

(3) Most SSV operations will be conducted in 185 km (100 n.mi.) circular orbit. A velocity package is required for transfer to higher orbit.

(4) Significant Plane change ($> 5°$) of module orbit requires a large velocity package.

(5) Module orbital altitude must exceed 500 km (270 n.mi.) to assure six month life.

(6) SSV manipulator arm should provide damage-free deployment and retrieval of module.

(7) Module solar array and thermal control can function immediately after transfer from SSV cargo bay. Umbilical can be disconnected in cargo bay.

(8) Module requires only minor changes for SSV operations. Remains compatible with Scout.

3.2 ON-ORBIT SERVICING FROM SSV

Task II-2 of the Contract Statement of Work, Reference 5, involved investigating feasibility of on-orbit servicing and maintenance of the Bioresearch Module from the SSV. Direct deployment and recovery of spacecraft by the SSV at altitudes ranging from 462 to 555 km (250 to 300 n.mi.) altitude was assumed. Servicing was considered from the standpoint of refurbishment at the completion of a six-month mission so that another six-month mission could be conducted without returning the spacecraft to earth. Maintenance was considered to be emergency repair of a spacecraft malfunction so that a mission could be continued. Only Missions I and II were considered for on-orbit servicing.

3.2.1 Requirements. - The following requirements serve as guidelines for defining orbital service operations:

(1) Resupply or replace experiment package every six months.

(2) Replace expendables used by spacecraft.

(3) Inspect all spacecraft subsystems.

(4) Replace faulty subsystem components.

(5) Replace subsystem components with short operating life not sufficient for the next six month operating period.

(6) Perform subsystem functional tests.

(7) Perform spacecraft system checkout after servicing.

(8) Redeploy Spacecraft.

3.2.2 Results. - On-orbit servicing and maintenance of the Bioresearch Module from the SSV is technically feasible but probably not desirable. Normally the spacecraft will be built up and checked out on the ground prior to SSV launch to minimize the inflight operations and the supporting equipment carried by the Orbiter. A review of the Bioresearch Module subsystems shows that the useful life time of several major components is sufficient for only a single six-month mission. Replacement of the experiment package, thermal control actuators, and flight control gyros imposes a new and significant time and checkout requirement on the SSV. The removal and replacement of a major component requires a complete subsystem checkout and revalidation of the spacecraft before committing range and tracking facilities to another mission. The airborne servicing and checkout equipment that must be added to the Orbiter appear to occupy more volume and weigh more than a complete Bioresearch Module. In addition the Astronaut-Repairman must use approximately 10 to 22 hours of expensive orbital time to prepare the spacecraft for another mission. Therefore, the component useful life, the astronaut time requirements, additional weight, volume, and complexity make it more desirable to replace a small spacecraft such as the Bioresearch Module than to service, repair, and redeploy an orbiting unit.

3.2.3 Assessment of Servicability. - The experiment package is assumed to have complexity and biological requirements of a nature that will preclude servicing in orbit anything more than life support expendables (food, water, and atmosphere). The removal of biological specimens or the repair of experimental equipment can be accomplished best and most economically on the earth in a suitably equipped laboratory. Therefore, the only on-orbit servicing foreseen would be the "plug in" and refilling of life support supply tanks or the replacement of the entire experiment package.

The spacecraft structure will not generally require any servicing or repair. Structural damage to the spacecraft will most likely be of a catastrophic nature and will require the replacement of the entire vehicle. Exceptions may be the replacement of a removable panel or the aft skirt.

The electrical power system as currently designed may require the replacement and repair of the solar cells, batteries, and perhaps the power regulation components.

Solar cells currently available will degrade approximately 6% during a six-month mission, as noted in Table 16. For this study it was assumed that radiation degradation continued at a rate of 6% loss each six months. The following data for Mission I were compiled to determine the probable replacement frequency of solar cells on extended missions. Data are from Table 16 and Appendix A.

Time	Power Avail. Watts	Power Required Watts	Margin %
Beginning of Life	217	187	16
End of 6 months (1st mission)	204	187	9
End of 12 months (2nd Mission)	192	187	2.7
End of 18 months (3rd mission)	181	187	-3.2

These margins assume no additional losses due to cell breakage during retrieval and launch operations. While a positive margin is shown for the first and second missions, the margin may be too low on the second mission to commit a biological payload, unless power requirements are reduced.

The 12 AH batteries will reliably provide 8000 to 12,000 charge-discharge cycles. Each six-month mission requires approximately 2700 cycles. Therefore, the batteries will be good for two to four missions.

The attitude control system will require refilling of the gaseous N_2 supply after each mission. The useful life time of the gyros indicates they must be replaced after each six-month mission. The thrusters may require replacing due to wear in the control valves. Quantitative data to establish lifetime and reliability of the thrusters and pressure regulators is not readily available at this time.

The thermal control system does not utilize any expendables which require resupply. While some "ground cooling" fluid is lost with each release of the umbilical the loss will be replaced with each umbilical connection. The thermal control louver actuators appear to be the most vulnerable components which may require replacement after each mission. Quantitative data on the lifetime and reliability is not available without lengthy material and reliability analyses.

The data management (T/M) system does not use any expendable materials. The sensor instruments appear to be the only items requiring possible replacement due to handling and environmental stresses.

The above servicing considerations are summarized in Table 29 which shows servicing priorities (A, B, C) and short life replacement after N missions. Priorities were established primarily by judgment. This is straightforward for expendables. Although priorities are shown for replacement of faulty components, it is unlikely that any of these could be realistically replaced in orbit.

This top level analysis shows that the performance of a second mission will require refilling the cold gas supply with nitrogen replacing the experiment package life support supplies. An alternate to replenishing the life support supplies would be the replacement of the entire experiment package. Spacecraft components requiring replacement after the first mission include the flight control system gyros, the louver control actuator and the insulation blankets around the experiment package. After the second mission the expendables, experiment package, flight control gyros, louver control actuator, solar cells, insulation blankets, and batteries will be replaced.

3.2.4 Orbit Servicing Procedure. - Repair and refurbishment begin after spacecraft recovery from orbit and transfer into a laboratory module in the SSV payload bay. This laboratory provides a shirt sleeve environment for the Astronaut-Repairman as well as a repair facility. The spacecraft is secured to a cradle providing zero g restraint, electrical power, and environmental control. The experiment package is removed and attached to an umbilical to sustain the experiments if the experiment package is replaced instead of resupplied. The new experiment package is removed from its supporting rack and umbilical for installation in the spacecraft. After installing the new experiment package or resupplying the existing experiment package the refurbishment proceeds with the attitude control system. The nitrogen gas tanks are replenished. The rate and integrating gyros are replaced after removing two access panels covered with solar cells. An attitude control system continuity and functional test is made after installing the gyros. The electronics are recalibrated to accommodate the new gyros. The access panels are replaced and the solar cell array reconnected. The electrical power system is checked for continuity and the solar cells checked for damage. The louver actuator for the thermal control system is replaced next. This unit is accessible at the forward end of the spacecraft. A thermal control system continuity and functional test is made. An abbreviated Bioresearch Module system check is made, a simulated mission is flown to ensure spacecraft integrity and high probability of mission success. The spacecraft refurbishment time is estimated to require between 10 and 22.5 man-hours based on the average ground repair times of 2 hours minimum and 4.5 hours maximum per subsystem as listed in the maintenance design handbooks, Reference 14. Zero "g" on-orbit repair is likely to require additional time.

The SSV supporting equipment includes the expendables, an experiment package, new gyros (3), new louver control actuator, new insulation blankets, miscellaneous fasteners, and test equipment. Subsystem test equipment must be provided to check performance and function

TABLE 29. - ON-ORBIT SERVICING APPROACH

SUBSYSTEM/COMPONENT	SERVICING PRIORITIES			
	RESUPPLY EXPEND-ABLES	REPLACE AFTER (N) MISSIONS	REPLACE FAULTY UNITS	RETURN MODULE TO EARTH
-1 EXPERIMENT PACKAGE	A			
ATTITUDE CONTROL				
-2 CONTROL ELECTRONICS			A	B
-3 N_2 TANKS	A		B	C
-4 N_2 REGULATOR			A	B
-5 THRUSTERS			A	B
-6 VALVES AND PLUMBING			A	B
-9 SUN SENSORS			A	
-10 RATE GYROS		A(1)		
-40 INTEGRATING RATE GYROS		A(1)		
-43 EXTENDIBLE BOOMS			A	
-44 HORIZON CROSSING INDICATORS			A	
THERMAL CONTROL				
-12 LOUVER ASSEMBLY } INTEGRAL				
-13 OR -41 COLD PLATE } PART OF			A	
-14 THERMISTOR ASSEM. } EXP. PKG.				
-15 LOUVER CONTROL ACTUATOR		A(1)		
-16 LOUVER CONTROL ELECTRONICS			A	B
-17 INSULATION BLANKETS		A(1)		
-42 LINES, VALVES, FITTINGS			A	B
COMMUNICATIONS AND TELEMETRY				
-18 COMMAND RECEIVERS			A	B
-19 COMMAND DECODERS			A	B
-20 PROGRAMMER/CLOCK			A	B
-21 SIGNAL CONDITIONER			A	B
-22 PCM ENCODER			A	B
-23 T/M TRANSMITTERS			A	B
-24 DATA STORAGE ASSEMBLY			A	B
-25 N_2 PRESSURE TRANSDUCER			A	B
-26, -45, -46 ANTENNAS			A	B
-27 ANTENNA COUPLER			A	B
-29 DATA PATCH UNIT			A	B
-47 RARR TRANSPONDERS			A	B
-11 DATA PROCESSOR			A	B
ELECTRICAL POWER				
-30 POWER CONTROL ASSEMBLY			A	B
-31 SOLAR CELLS		A(2)	B	C
-28 EXTENDIBLE SOLAR PANELS		A(2)	B	C
-32 BATTERY		A(2)	B	
-33 POWER PATCH UNIT			A	B
-38 UMBILICAL CONNECTOR			A(FLUID)	A(ELEC.)
STRUCTURE				
-34 EXP. PKG. COVER		*A(2)	**A	
-35 EQUIP. SECTION		*A(2)	**A	***A
-36 AFT SECTION		*A(2)	**A	
-37 SUPPORT RING			A	

* PORTION WITH SOLAR CELLS
** W/O SOLAR CELLS
*** FIXED STRUCTURE

of the flight control, electrical power, thermal control and experiment package subsystems. The verification of spacecraft integrity requires test equipment capable of exercising the spacecraft sensors and subsystems and then measuring the subsystem responses. Key elements of the Bioresearch Module mission would be used to establish an abbreviated mission simulation.

Table 30 summarizes on-board equipment requirements for servicing, test and checkout. New equipment chargeable to Bioresearch Module is indicated along with estimates of weight and volume. The indication of equipment available on-board the SSV is based on generous interpretation of information in the SSV Data Package, Reference 7.

In summary, the supporting repair and test equipment to refurbish the Bioresearch Module will probably occupy more volume and weigh more than the spacecraft. The Astronaut-Repairman time to refurbish will be much more expensive than that performed on the ground. Therefore, it is concluded that on-orbit servicing and maintenance is not feasible for the Bioresearch Module as it is presently designed. The state of the art for gyros and electro-mechanical actuators is not likely to produce in the foreseeable future new low cost components that can survive longer missions and thereby eliminate the required replacements and retesting of the flight control and thermal control systems. Based on current practices, launch operations are not expected to eliminate spacecraft checkout and combined systems tests after servicing and maintenance. The practice of thoroughly testing the experiment and its spacecraft before committing range facilities and the spacecraft to a mission is expected to continue.

A functional flow diagram of the recovery, refurbishment, and release of the Bioresearch Module is shown in Figure 17. Table 31 summarizes some factors which must be considered in a choice between ground and orbital servicing of spacecraft.

3.3 OPERATION IN LOW CIRCULAR EARTH ORBITS

As was noted previously in Table 20, a majority of the SSV orbits involving deployment of bioscience payloads are planned for 185 km (100 n.mi.) orbital altitude. Therefore, in accordance with Task II-3 of Reference 5 a mission feasibility analysis was conducted to determine impact on the baseline design of operation and recovery with the SSV operating only in these low circular orbits. The mission profiles are assumed to be coplaner with SSV orbits to avoid the complexity of orbital plane changes as previously noted in Figure 11. The study thus investigated operation of Bioresearch Module at 185 km (100 n.mi.),transfer to 555 km (300 n.mi.), injection of Mission III into highly elliptical orbit, and candidate hardware necessary to achieve these operations.

3.3.1 Mission Approaches. - A number of approaches were considered for accomplishing the Bioresearch Module missions from a 185 km (100

TABLE 30. - EQUIPMENT REQUIRED FOR ON-BOARD SERVICING, TEST, CHECKOUT

ITEM	SPECIAL FOR B/M	AVAILABLE ON SSV	WT. LB	VOL. FT^3
Solar Panel Covers	X		50	27
N_2 Service		X		
N_2 Pressure Control Panel		X		
N_2 Hose and Leak Test Adapter Kit	X		20	1
△*Electronic Flight Control		X		
△*T/M and Instrumentation Console		X		
△*Mission Control Console		X		
Exp. Pkg. Work Stand	X		100	43
Hoist Sling (Module)	X		50	5
△*Environmental Control Console		X		
△ Thermal Exchange Unit	X		50	12
△ Power Control Console		X		
Simulated Exp. Pkg.	X		100	28
Hoist Sling (Exp. Pkg.)	X		40	4
Exp. Pkg. Servicing Unit	X		150	27
Servicing Umbilical	X		10	2
△ Buffering (For * Items)	X		100	2
Pressurized Payload Lab (13' Dia. x 15' Length)			1250	2000
TOTAL (All items assumed inside payload lab)			1920	2000
△ Required for deployment only (No on-orbit service)			150	14

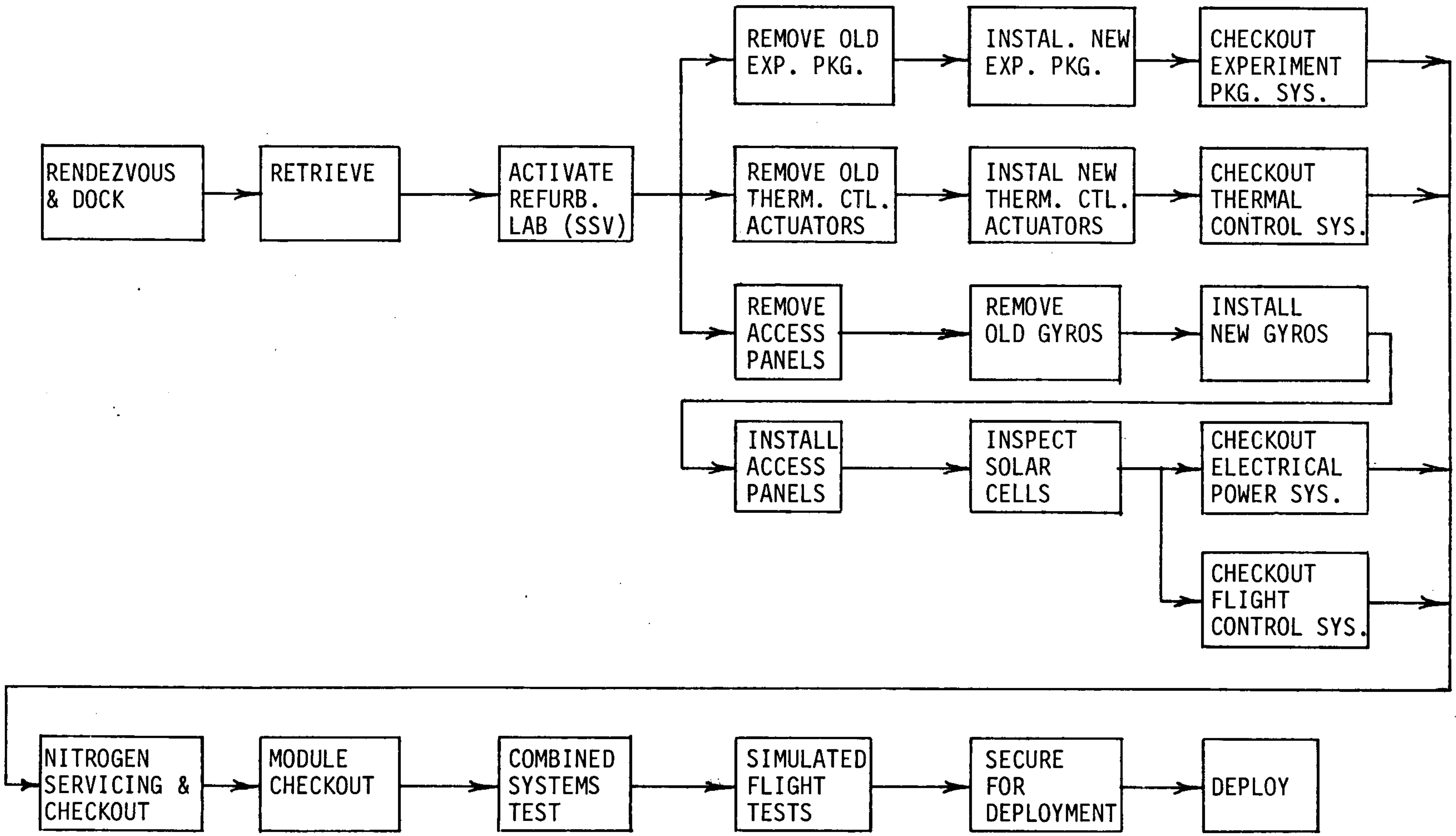


FIGURE 17. - TYPICAL BIORESEARCH MODULE REFURBISHMENT FLOW (ON-ORBIT FROM SSV)

TABLE 31. - ON-BOARD SERVICING CONSIDERATIONS

Diagnosis of Module problem (what parts to bring)
Isolation of problem area
Level of replacement
Shirtsleeve vs. IVA
Time to service
Compact space, small fasteners, connectors
Weight and volume of support equipment
Interchangeability of predrilled parts
Calibration of replaced component
Alignment of gyros and sensors
Spin balance after servicing
Checkout and revalidation
Operation with other payloads (time sharing on-board facilities)
Cost

n.mi.) SSV orbit. These are listed in Table 32. Approach (1) involves direct deployment and thrusting by the spacecraft to maintain this low orbit in the presence of atmospheric drag. Table 33 lists several fuel systems which might accomplish this. Even the most efficient fuel, liquid O_2 and H_2, would require weights almost double that of the spacecraft.

Approach (2), a two-burn Hohmann transfer to higher orbital altitude, is shown in nomograph form in Figure 18, which also includes orbital lifetime data from Reference 13. The example shows that transfer from 185 km (100 n.mi.) to 500 km (270 n.mi.) requires a total ΔV of 172 m/sec (565 ft/sec), and expected orbital lifetime is 228 days for spacecraft W/C_DA of 7. Hohmann transfer is considered the best approach for Missions I and II. Associated hardware is discussed in the following section.

Approach (3) of Table 32, as an alternate to the Hohmann transfer, is a single-burn velocity package for injection of Mission I or II into an elliptic orbit. Figure 19 shows the parametric data in nomograph form. The elliptic orbit must have enough eccentricity to achieve sufficient lifetime for the six-month mission. The example shows that to achieve the same 228 day life as noted for the circular orbit in Figure 18, the elliptical orbit must have an apogee of 4380 km (2370 n.mi.), and the ΔV requirement is 906 m/sec (2970 ft/sec) for injection. Approach (3) has the advantage of a single burn requirement, but the outweighing disadvantages are high velocity requirements, non-recoverability of the spacecraft, and more complex tracking from ground stations.

Approach (4) of Table 32 considered the SSV would never operate above 185 km (100 n.mi.). Four burns would therefore be required to transfer the spacecraft to a higher circular altitude, then return it back to the SSV altitude for recovery. This approach is completely unacceptable because of the great complexity added to the spacecraft. Approach (2) is preferred with SSV retrieval at the higher orbital altitude. In summary, if SSV operations are limited to 185 km (100 n.mi.) circular obits, Missions I and II must be transferred to higher altitudes and they will not be recoverable.

Table 32 presents two approaches for conducting Mission III from low SSV orbits. Approach (5) is the preferred one, using a single-burn velocity package to achieve the 185 x 270,000 km (100 x 150,000 n.mi.) elliptical orbit. Approach (6) uses a two-burn velocity package to both inject and retrieve Mission III. Studies showed that the enormous motor stages required to achieve this approach were completely out of proportion with the basic simplicity desired to reliably accomplish Mission III. A preferred approach to retrieve Mission III is by means of atmospheric re-entry, requiring, of course, repackaging of the spacecraft within a re-entry heatshield.

3.3.2 Orbital Transfer Hardware. - The hardware arrangements presented in this section are typical of what might be used in transfer

TABLE 32. - MISSION APPROACHES FROM 100 N.MI. SSV ORBIT

MISSIONS I AND II

(1) Direct deployment of Module, maintain 100 N. Mi. orbit with thrust, retrieval by SSV.

(2) With 2-burn velocity package, Hohmann transfer of Module to higher circular orbit (270-300 N.Mi.), retrieval by SSV in higher orbit.

(3) With single-burn velocity package inject Module into elliptic orbit with 100 N.Mi. perigee, no retrieval.

(4) With 4-burn velocity package transfer Module to higher circular orbit, conduct mission, return Module to 100 N.Mi. circular orbit for retrieval by SSV.

MISSION III

(5) With single-burn velocity package inject Module into 100 x 150,000 N.Mi. orbit, no retrieval.

(6) With 2-burn velocity package inject Module into 100 x 150,000 N.Mi. orbit, conduct mission, return to 100 N.Mi. circular orbit, retrieval by SSV.

TABLE 33. - FUEL REQUIREMENTS TO MAINTAIN 100 N.MI. CIRCULAR ORBIT

BY THRUSTING

$W/C_DA=7$, MEET ACCELERATION LIMITS

FUEL TYPE	FUEL QUANTITY LB/DAY	LB/MONTH	LB/180 DAYS
Cold Gas (N_2) I_{SP} = 60	20	600	3600
N_2H_4 Pulsing, I_{SP} = 180	7	210	1260
Steady, I_{SP} = 225	5.5	167	1000
N_2O_4-Aerozine 50			
Pulsing, I_{SP} = 210	6	179	1070
Steady, I_{SP} = 265	4.7	141	850
LO_2 - LH_2			
Pulsing, I_{SP} = 320	3.9	117	700
Steady, I_{SP} = 380	3.3	100	600

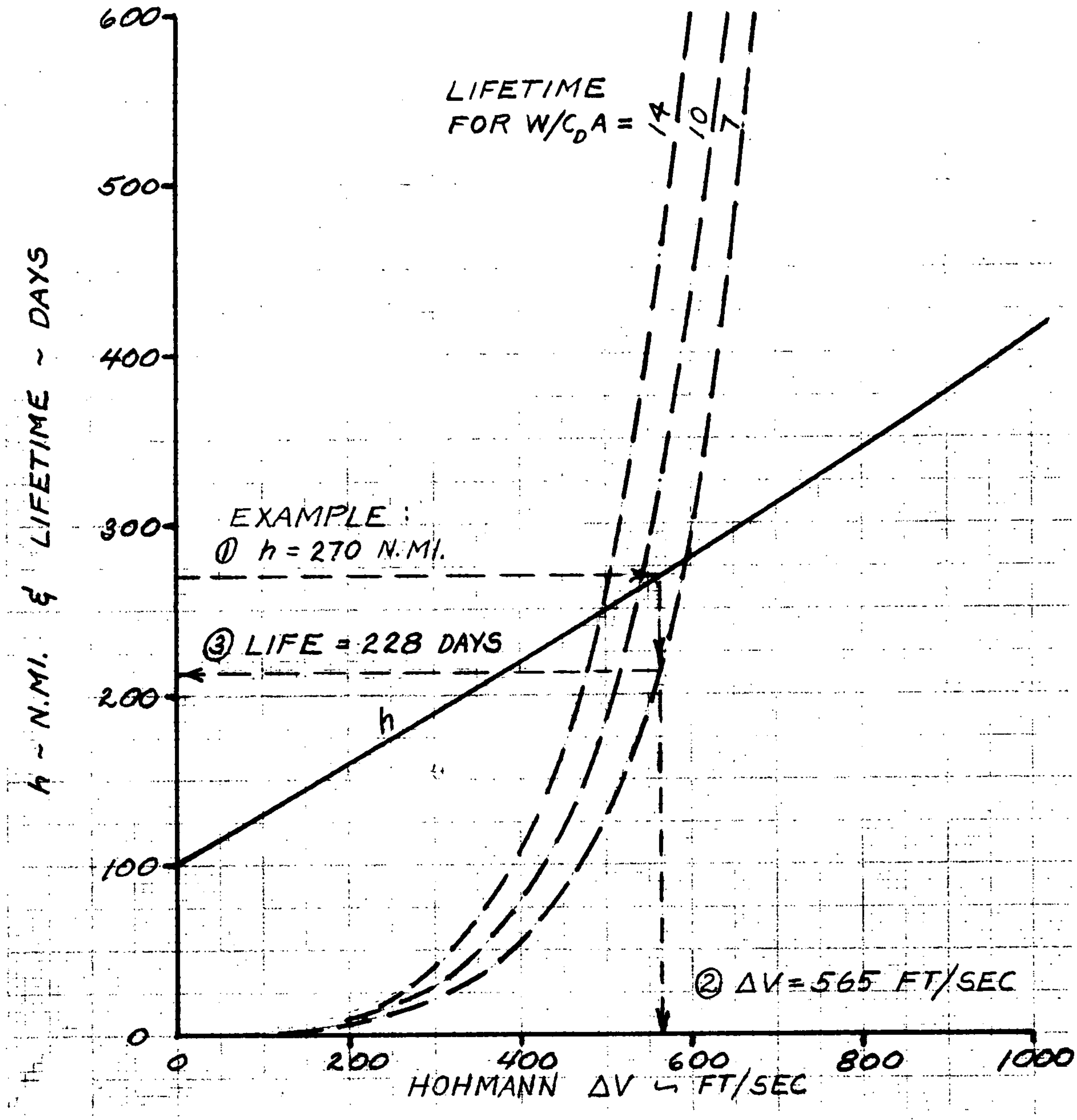


FIGURE 18. - LIFETIME FOR CIRCULAR ORBITS AND

ΔV FOR HOHMANN TRANSFER FROM 100 N.MI. PARKING ORBIT

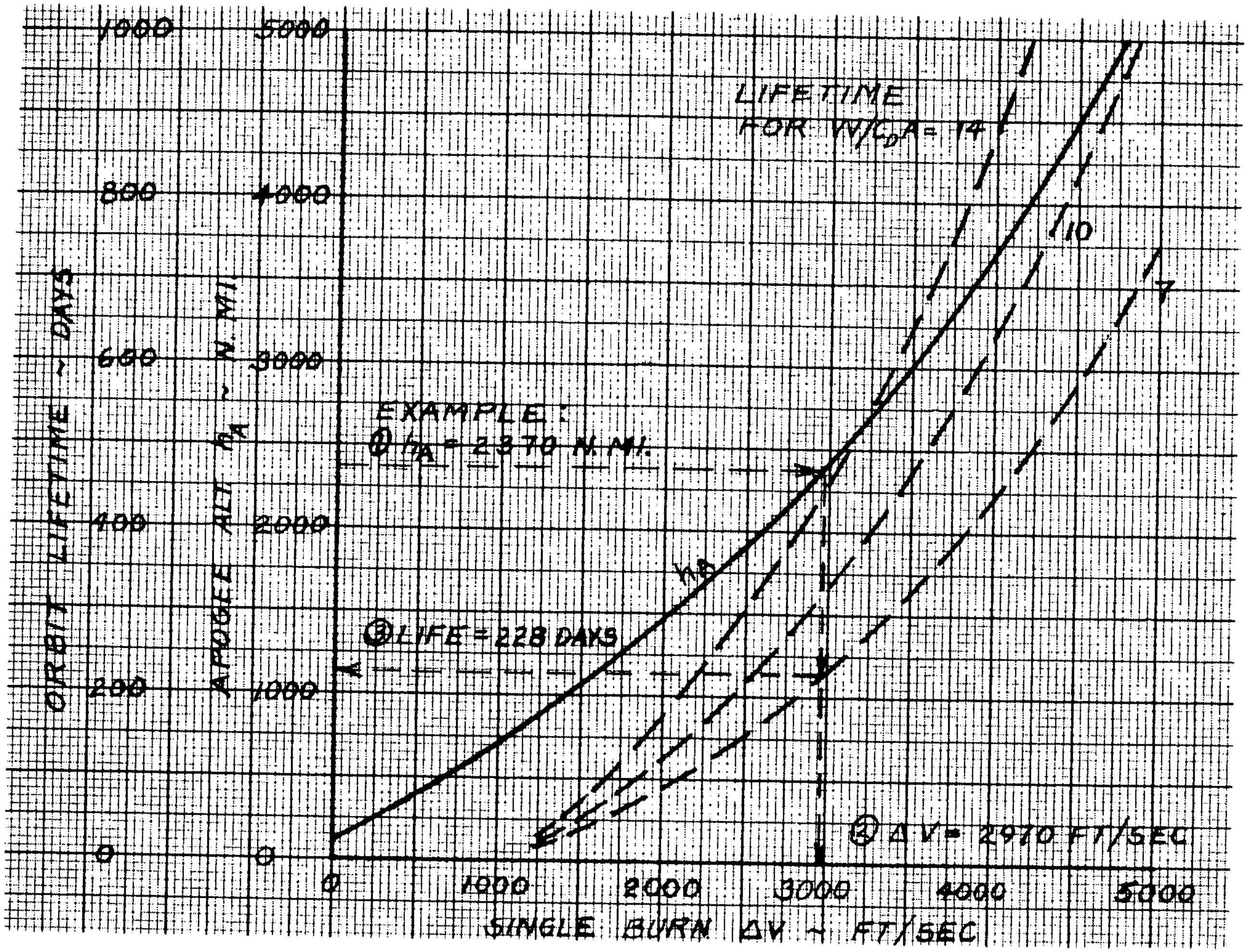


FIGURE 19. - LIFETIME FOR ELLIPTIC ORBITS AND ΔV FOR INJECTION FROM 100 N.MI. PARKING ORBIT

from SSV low circular orbits (185 km/100 n.mi.) to the higher orbits required by Bioresearch Module. Preliminary studies only have been conducted to provide indications of the hardware needed.

Figure 20 illustrates a two-motor arrangement to accomplish Hohmann transfer from 185 km (100 n.mi.) to approximately 555 km (300 n.mi.) for Missions I and II. A long, cylindrical adapter is attached to the spacecraft payload ring by means of a V-band clamp. Two Lockheed 12.8 KS 330 Col 1 motors are attached to the end of this adapter aft of the rear end of the spacecraft. Following spinning spacecraft deployment from the SSV the first motor is fired and then ejected to establish the elliptical transfer orbit. At apogee a turnaround maneuver is performed by precessing the spinning spacecraft 180 degrees. The second motor is then fired and the entire cylindrical adapter ejected to circularize the orbit at the higher altitude. Mission I is then despun and stabilized by the attitude control system. The Mission II spin rate would be reduced by the attitude control system to the levels specified for the experiment. Table 34 summarizes the sequence for deployment of Missions I and II from the SSV at 185 km (100 n.mi.). Table 35 summarizes the analysis for a typical Hohmann transfer. Weights are estimates for the hardware shown in Figure 20. The spacecraft weight of 330 pounds is nominal for purposes of illustration. By coincidence the weights and motor selection achieved the exact apogee desired (555 km/300 n.mi.) for the transfer orbit, but the second burn at apogee produced a slight over-velocity resulting in the 555 x 647 km (300 x 350 n.mi.) orbit, still acceptable, however. The example of Table 35 serves to illustrate that a relatively simple spacecraft could achieve the Hohmann transfer maneuver. The spacecraft attitude control system and programmer-clock are capable of performing the motor ignitions and turn-around maneuver automatically.

Several candidate motors were investigated for Mission III injection from the 185 km (100 n.mi.) SSV orbit. Figure 21 shows parametric performance data for four motors. The data were prepared to show the relationship of orbital period achievable by the motor candidates with various payload weights. The desired period is 144 hours so that the biological experiments are removed from earth influence for prolonged time. From Table 3 it is noted that the Mission III spacecraft weighs 152 kg (335 lb). If we add to this 32 lb. for payload-to-booster adapter, separation and T/M package (Table 3), total weight charged to the velocity package motor is 367 lb. From Figure 21 it is noted that for a 367 lb. payload the Scout FW-4S achieves a 12-hour orbit and the Aerojet Alcol IB achieves a 62-hour orbit. The X-259 overperforms, but could possibly be ballasted to produce the 144 hour period. However, the X-259 would require a large adapter to fit behind the spacecraft.

The Aerojet Alcor IB motor has enjoyed a long success on Athena and on the Astrobee 1500 launch vehicles. Its diameter and structural attachment details are very similar to the Scout FW-4S, but the Alcor IB is longer and has 50% more impulse than the FW-4S. Therefore, the Alcol IB would be a candidate for Mission III injection from 184 km (100 n.mi.) if a shorter 62-hour orbital period is acceptable. Figure 22

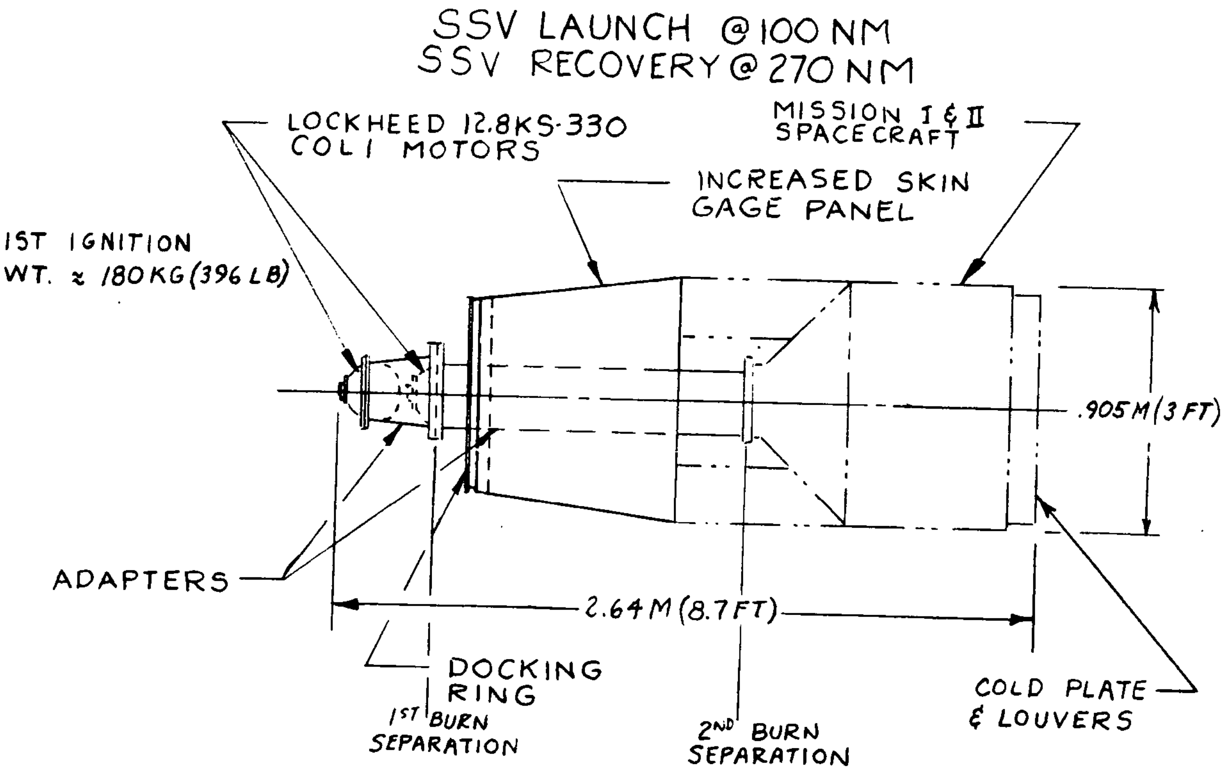


FIGURE 20. - MISSION I & II CONFIGURATION FOR HOHMANN TRANSFER

TABLE 34. - DEPLOYMENT OF MISSIONS I AND II MODULE FROM SSV AT 100 N.MI.

1. Install Module/propulsion stage w/o ordnance in Orbiter.
2. Achieve desired orbit with SSV.
3. Checkout Module systems and power down experiments and systems.
4. Install ordnance.
5. Condition Cold Plate.
6. Disconnect umbilical.
7. Transfer Module outside cargo bay.
8. Make final check of Module systems and power up experiments and systems to operational status.
9. Orbiter establishes firing attitude.
10. Command spin rocket ignition and separation clamp bolt ignition.
11. Expansion springs separate Module/propulsion stage from orbiter.
12. Orbiter establishes chase mode.

*13. By radio command Orbiter ignites propulsion stage.

14. On-board programmer fires motors for Hohmann transfer to 300 N.Mi. circular orbit.
15. Orbiter proceeds to other operations or re-entry.

* Retrieval sequence required if separation tipoff excessive or ignition fails.

TABLE 35. - ANALYSIS OF TYPICAL HOHMANN TRANSFER

Spacecraft Wts., lb.			
Spacecraft (nominal Mission I or II)	330		
Cylindrical Adapter	5		
Separation clamp and springs	2.5		
Aft Motor adapter	5		
Separation clamp and springs	2.5		
Motor ignition system	6		
12.8 KS-330 Lockheed Col.-1 Motor Data			
Isp = 260 sec			
Ignition wt., lb.	22.34		
Consumed wt., lb.	16.34		
Inert weight, lb.	6		

Staging Weight Sequence and Orbit

			Weight lb.	Orbit km	Orbit N.Mi.
Separate from SSV and ignite			395.68	185x185	100x100
Burnout 1st motor (ΔV=353 ft/sec)			379.34	185x555	100x300
Separate 1st motor:	Case	6			
	Adapter	5			
	Sep. Sys.	2.5			
Ignite 2nd motor			365.84	185x555	100x300
Burnout 2nd motor (ΔV=382 ft/sec)			349.50	555x647	300x350
Separate 2nd motor:	Case	6			
	Adapter	5			
	Sep. Sys.	2.5			
	Ign. Sys.	6			
Spacecraft in orbit			330	555x647	300x350

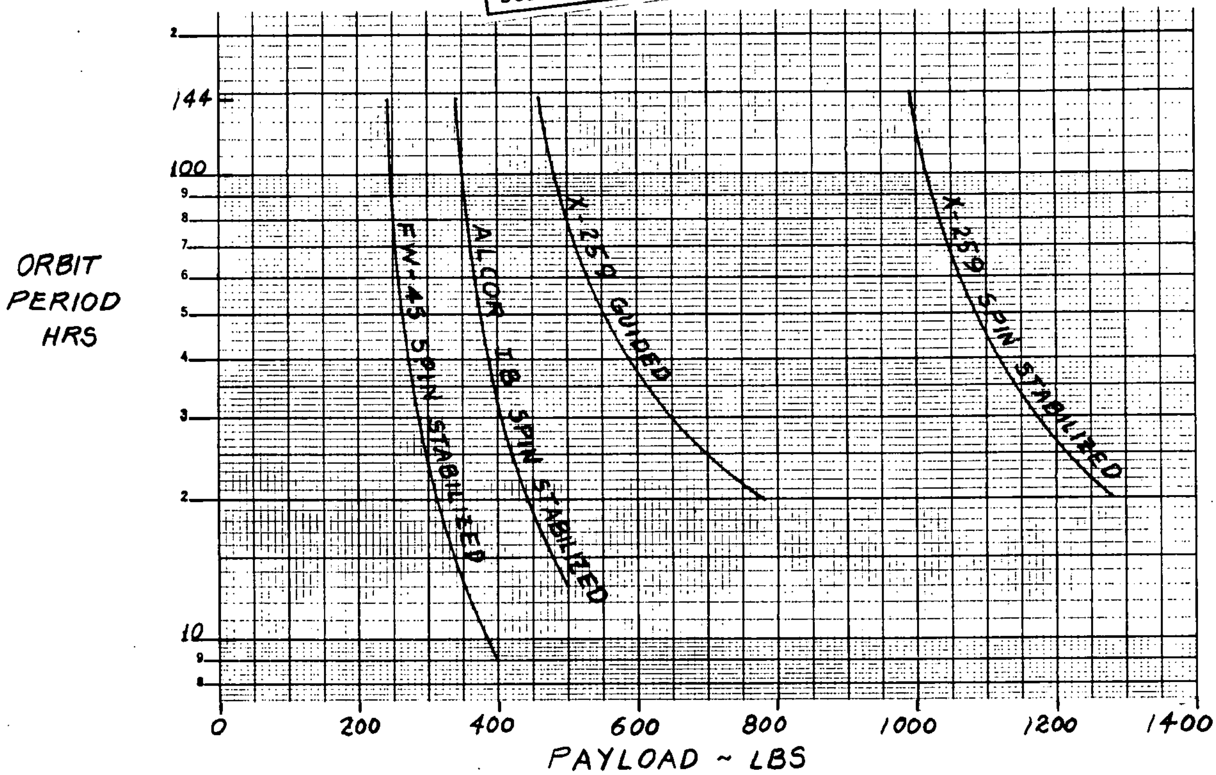


FIGURE 21. - CANDIDATE MOTORS FOR MISSION III INJECTION

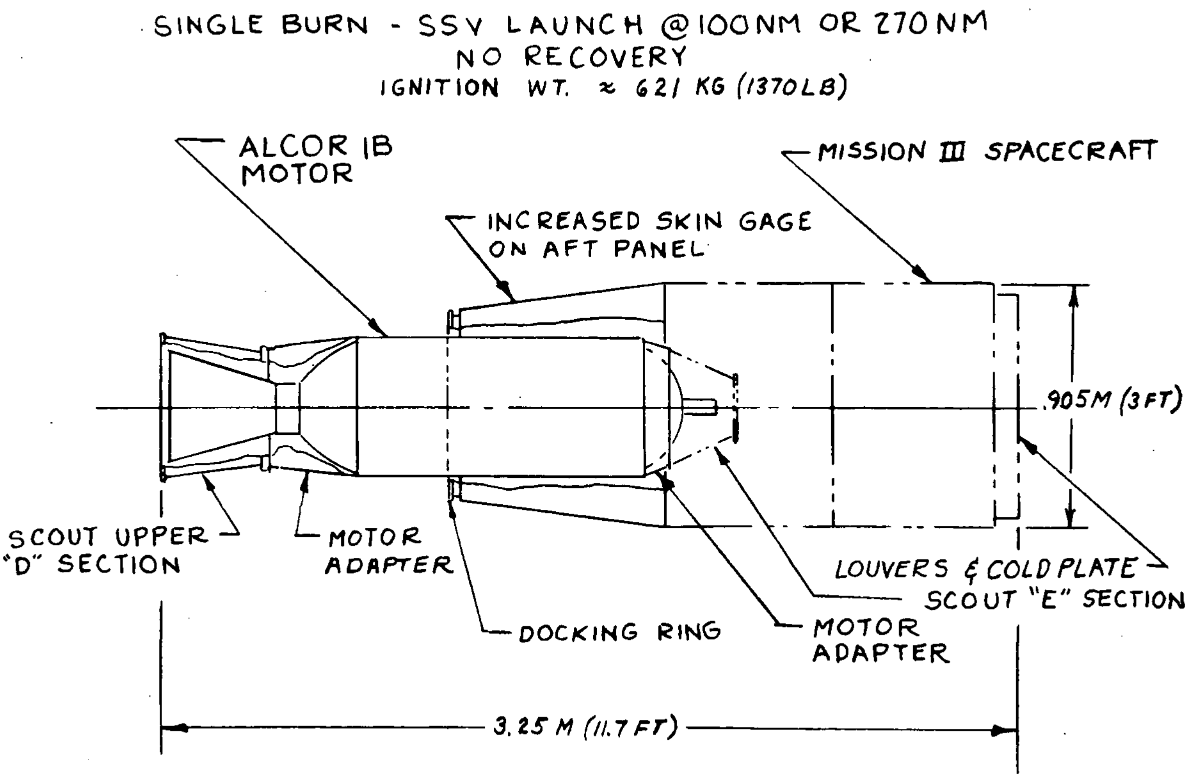


FIGURE 22. - MISSION III CONFIGURATION WITH VELOCITY PACKAGE

illustrates the Mission III configuration with an Alcor IB velocity package. Total weight with the 1003 lb motor is 621 kg (1370 lb).

3.3.3 Assessment of Operation in Low Circular Earth Orbits. - The following conclusions are drawn from the preceding studies:

(1) Direct deployment of module and maintenance of orbit at 185 km (100 n.mi.) requires excessive fuel.

(2) Hohmann transfer of missions I and II from 185 km (100 n.mi.) to 500 - 555 km (270-300 n.mi.) requires relatively small ΔV of 172-201 m/sec (565-660 ft/sec.).

(3) Elliptic orbits with 185 km (100 n.mi.) perigee for missions I and II require large ΔV of 905 m/sec (2970 ft/sec) to achieve apogee with adequate life.

(4) Alcor IB is suitable motor for Mission III module velocity package for a 62 hour orbital period.

(5) The X-259 Scout motor, with ballast and special adapter, will provide a 144 hour orbital period for Mission III.

(6) Deployment and retrieval of Missions I and II at 185 km (100 n.mi.) requires two Hohmann transfers (4 burns). Better procedure is to retrieve directly by SSV rendezvous at higher module orbit.

(7) Retrieval of Mission III is not practical - requires large, complex, two-stage velocity package.

(8) All mission I and II modules compatible with SSV at 185 or 500 km (100 or 270 n.mi.), and Scout launch.

(9) Mission III module suitable for SSV at 185 or 500 km (100 or 270 n.mi.) deployment.

3.4 INCREASES IN EXPERIMENT SUPPORT

This task (II-4 of Reference 5) evaluated and determined possible increases in experiment support capability made possible by use of the SSV as a launch vehicle. Experiment package servicing procedures during launch preparation, boost, deployment and recovery were examined to identify basic support requirements and possible increases.

3.4.1 Approach. - Bioresearch Module and SSV operating procedures were reviewed and an Orbiter mission was postulated in which a Bioresearch Module was deployed and recovered. The study was coordinated with cognizant NASA/MSC offices responsible for the Orbiter vehicle design and payload integration. A ground operations timeline, a conceptual design for installation of the Bioresearch Module in the Orbiter, and a typical operating sequence were established.

The operational sequence analyzed here differs from the procedures presented in Sections 3.1 and 3.3 in that the spacecraft is deployed directly from the Orbiter cargo bay rather than from a manipulator boom. The boom is used, however, for spacecraft recovery. Although this approach recommended by NASA/MSC, differs somewhat from recommendations in the SSV Data Package, it was considered worthwhile to pursue the direct deployment as another facet of the many possibilities which must be eventually investigated in the study of SSV launching procedures for small payloads.

3.4.2 Installation in Orbiter Cargo Bay. - A postulated installation of Bioresearch Module in the Orbiter cargo bay is shown in Figure 23. The representation is Mission I or II without a velocity package. As noted, a total of four payloads are stored, each to be deployed from the Orbiter on a given flight. The manipulator arm is used for retrieval of payloads and for positioning of items within the cargo bay. Each payload and its associated support equipment are mounted on a pallet. The pallets attach to a payload structure installed in the cargo bay to accummodate small payload installations.

The Bioresearch Module will undergo preparation and checkout remotely from the pressurized crew quarters. Spacecraft condition will be observed through windows which facilitate operation of the manipulator boom. Data monitoring will be provided by displays at the Orbiter payload console. These facilities will be used by each payload on a time-shared basis.

3.4.3 Launch and Recovery Operations. - The SSV launch and recovery operations, previously discussed in the mission analyses of Sections 3.1 and 3.3, are shown pictorially in Figure 24 to emphasize the payload support operations, and to illustrate direct deployment from the Orbiter cargo bay. The various steps presented in the figure indicate the payload support functions performed.

The SSV ground operations timeline, obtained from Reference 15, is shown in Figure 25. To this timeline has been added the Bioresearch Module operations within the dashed boxes. As noted the Module with simulated experiment package is complete and calibrated 8 days before SSV launch. Installation and checkout in the Orbiter are complete at approximately 3-1/2 days before launch. The flight experiment package is available one day before launch. It replaces the simulated experiment package with installation complete typically from T-480 to T-120 minutes. At T-120 minutes the crew exits for booster and Orbiter fueling.

3.4.4 Increases in Experiment Support. - Analysis of SSV launch and recovery of payloads indicates the possibility of some increase in experiment support as a result of using this launch mode. The extent of

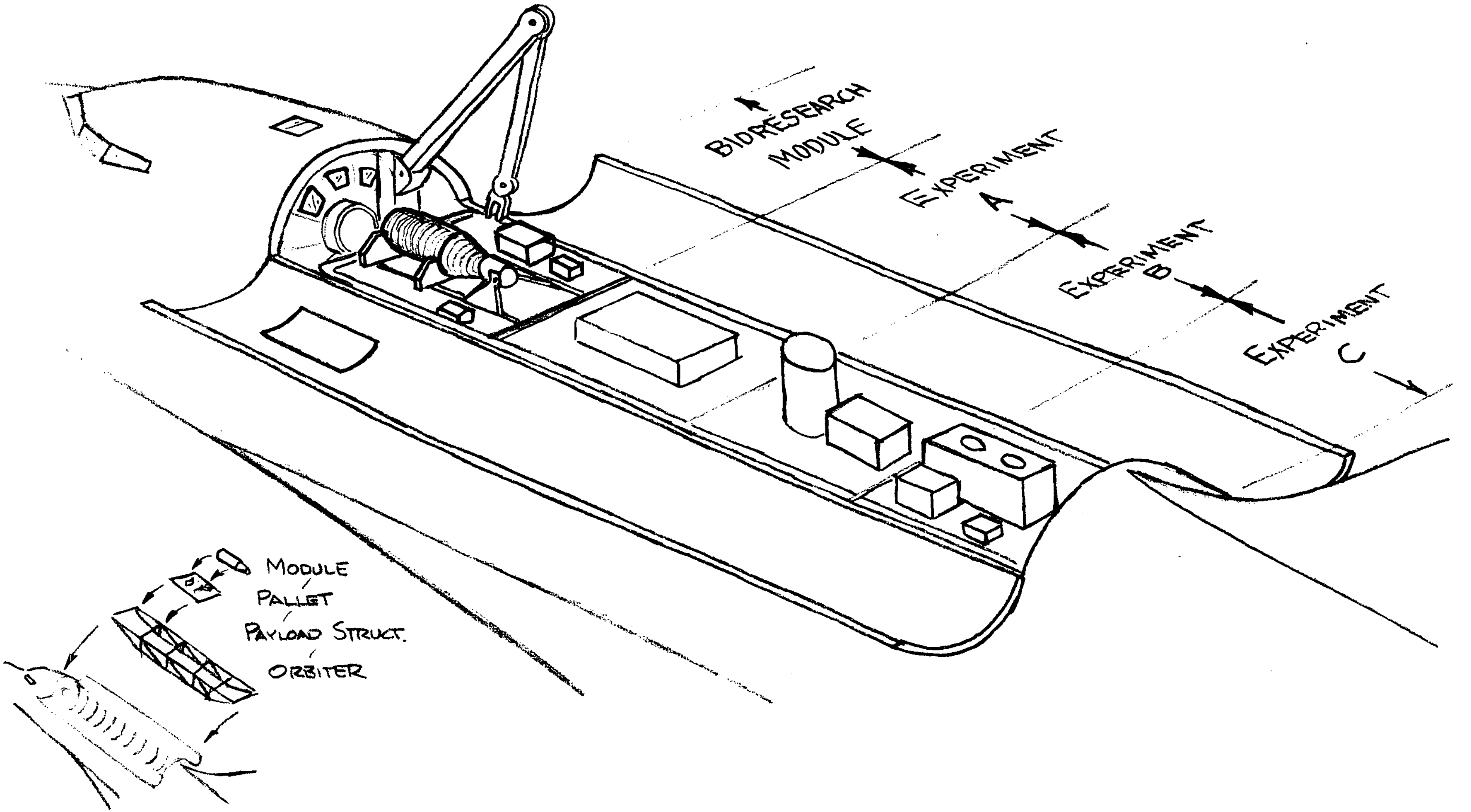
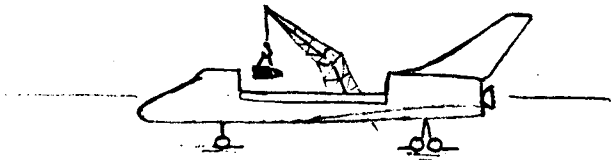
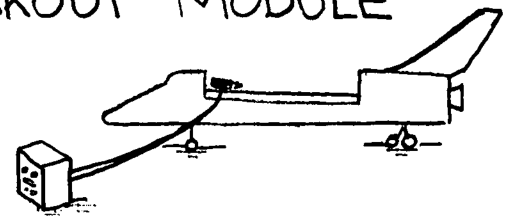


FIGURE 23. - BIORESEARCH MODULE IN ORBITER CARGO BAY

1. INSTALL BIORES. MODULE

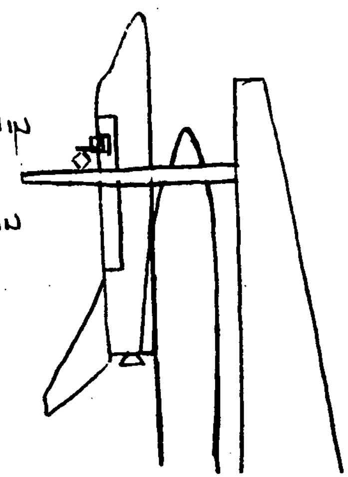


2. CHECKOUT MODULE



C/O WITH EXPERIMENT SIMULATOR
INITIAL SERVICING

3. TOWER SERVICING



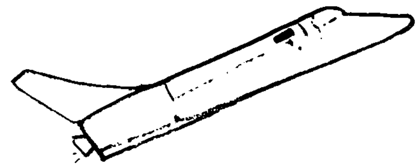
- FINAL SERVICING T-600 MIN
- INSTALL EXP. PKG T-480
- VALIDATE MODULE T-460 MIN
- REMOVE MODULE GSE

EXP PKG ≈ 100 LB
3.5' DIA × 3'

	MODULE REQMTS	ORBITER PROVISIONS
EPS	150 W (MAX) 28V DC	50 KW (MAX) AC & DC
ECS	350 BTU/HR	5122 BTU/HR (PEAK)
DMS	1.68 KBPS	25 KBPS
TV	TBD	

FIGURE 24. - SSV LAUNCH AND RECOVERY OPERATIONS

4. LAUNCH



MONITOR
SAFETY
HOUSEKEEPING

PROVIDE
ENVIRON. CONTROL
ELECT POWER

5. ORBIT

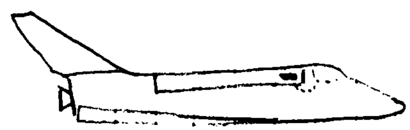


FIGURE 24. - SSV LAUNCH AND RECOVERY OPERATIONS (CONTINUED)

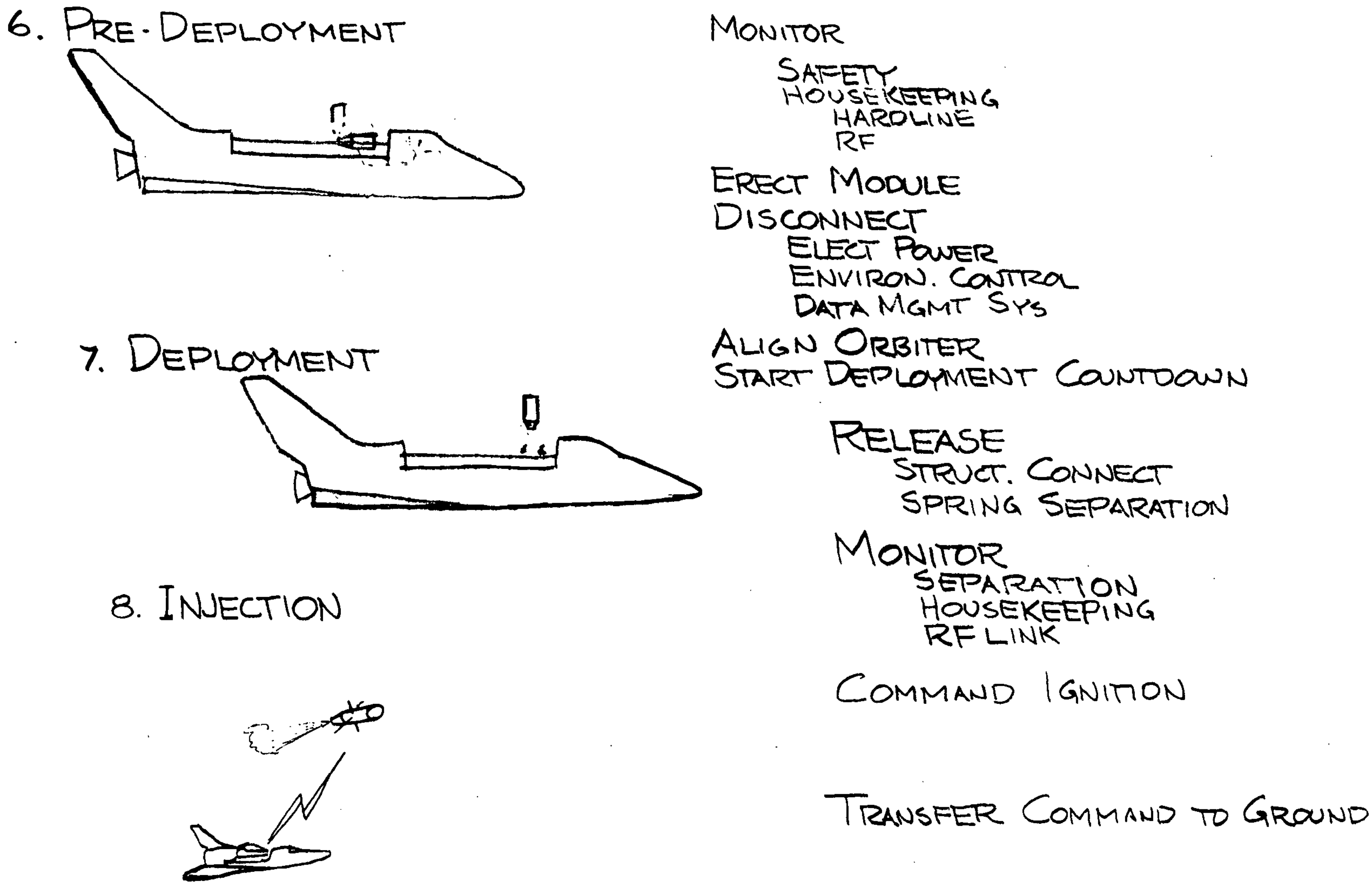
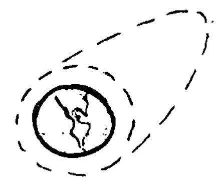


FIGURE 24. - SSV LAUNCH AND RECOVERY OPERATIONS (CONTINUED)

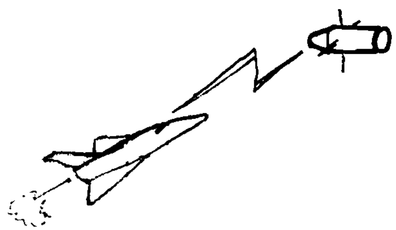
RECOVERY

9. ESTABLISH RENDEZVOUS ORBIT



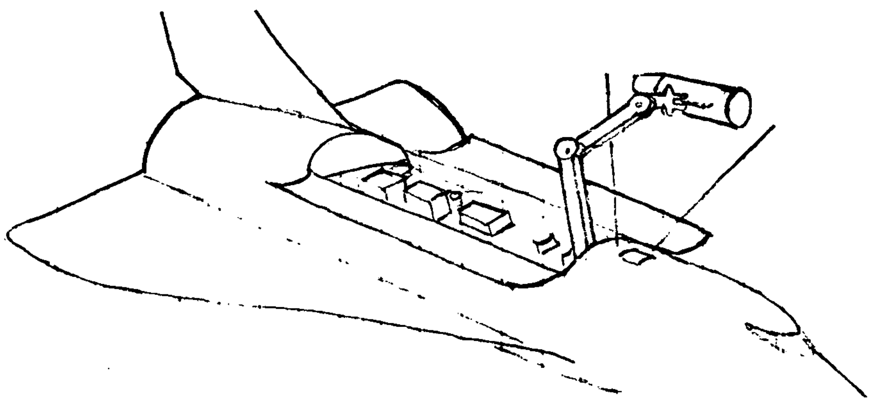
GROUND COMMAND
ORBIT TRANSFER
PARKING ORBIT

10. RENDEZVOUS



ORBITER
ACQUIRE BIORES MODULE
TERMINAL RENDEZVOUS MANEUVERS
COMMAND BIORES MODULE
DESPIN
DEACTIVATION

11. ACQUISITION

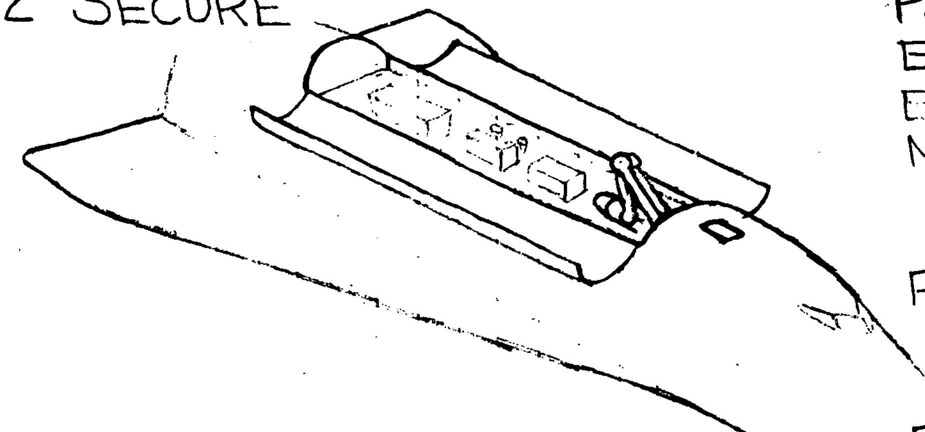


ORBITER
OPEN P/L DOORS
EXTEND MANIPULATOR
CAPTURE BIORES MODULE
RETRACT MANIPULATOR
& MODULE

FIGURE 24. - SSV LAUNCH AND RECOVERY OPERATIONS (CONTINUED)

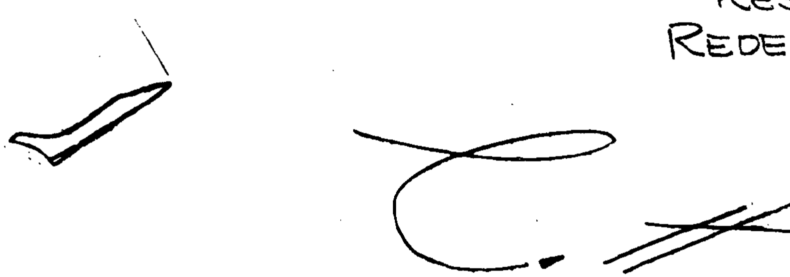
RECOVERY

12 SECURE



POSITION BIORES MODULE ON PALLET
ENGAGE TIEDOWN STRUCTURE
ENGAGE UMBILICAL
MONITOR
SAFETY
HOUSEKEEPING
PROVIDE
ELECTRICAL POWER
ENVIRONMENTAL CONTROL
RETURN TO EARTH
OR
RECYCLE
IVA
REPLACE EXPERIMENT
RESUPPLY EXPENDABLES
REDEPLOY

13 REENTRY & LANDING



MONITOR
SAFETY
HOUSEKEEPING
PROVIDE
ELECTRICAL POWER
ENVIRONMENTAL CONTROL

FIGURE 24. - SSV LAUNCH AND RECOVERY OPERATIONS (CONCLUDED)

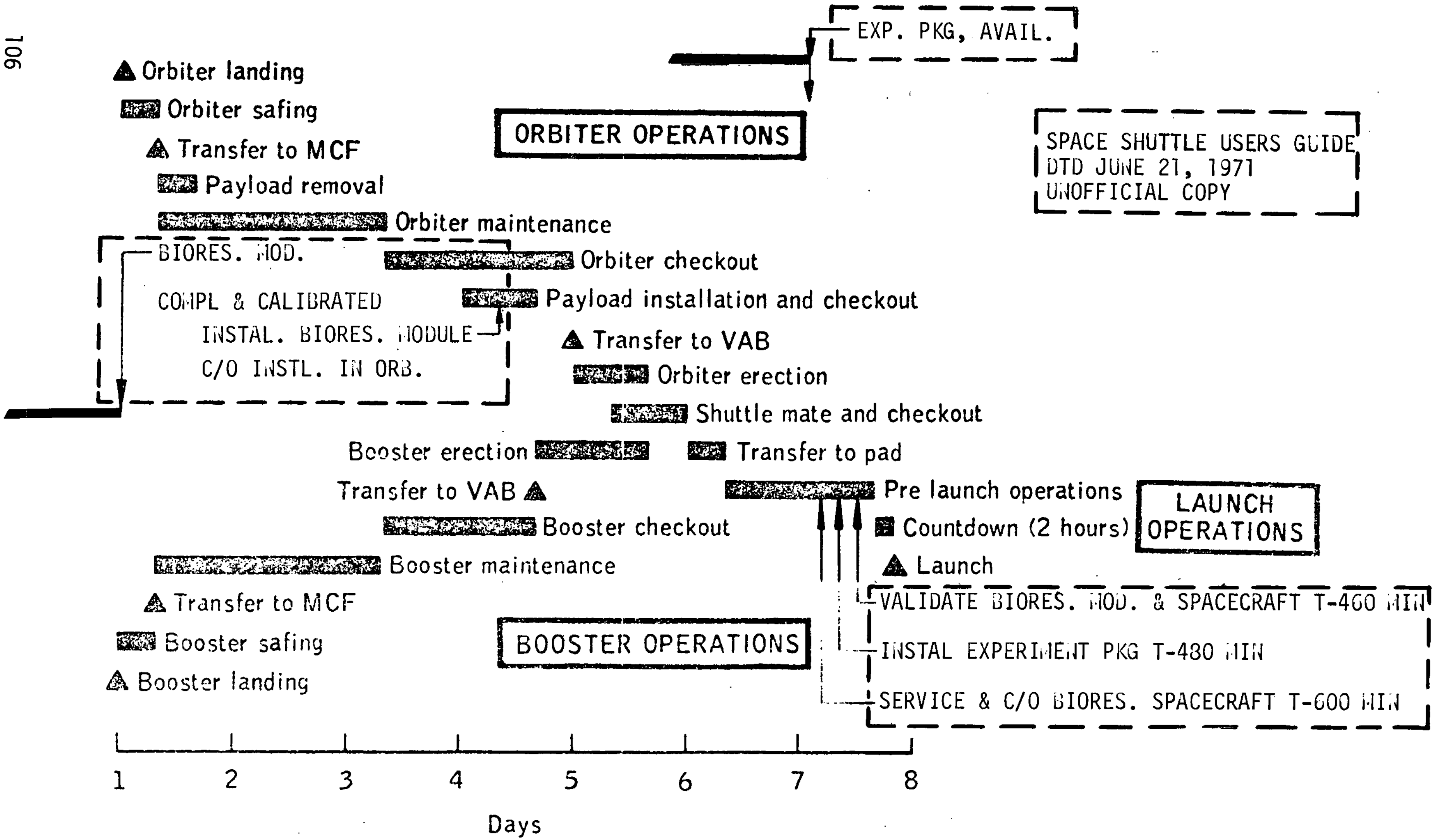


FIGURE 25. - SSV GROUND OPERATIONS TIMELINE

the increase depends upon whether the Bioresearch Module configuration is compatible with both Scout and SSV, or SSV only.

Compatible with Scout and SSV.- The following increased support items are possible when using the SSV:

(1) Additional N_2 tanks for more spacecraft maneuvering, greater attitude control gas reserve.

(2) Larger battery and added solar cell area for higher peak and continuous power demand by experiments.

(3) Post-launch checkout of spacecraft and experiment subsystems before deployment into orbit.

(4) Soft ride during launch, requiring less restraint of experiments.

(5) Return of experiment to earth in the event of a malfunction.

Compatible with SSV Only. - This actually opens the door to a completely new approach to spacecraft design. With modest change the following increases in experiment support are visualized:

(1) Larger experiment volume and weight.

(2) Larger power supply, thermal control, data handling capability.

(3) Better access to experiments through less compact packaging of spacecraft. Therefore, more amenable to on-board servicing.

3.4.5 Conclusions from Experiment Support Studies. - The following conclusions are derived from the studies of SSV experiment support:

(1) Bioresearch module is compatible with the SSV operations. Timelines of ground operations can be integrated without significant changes to either. Inflight crew operations estimated to be low. Two periods approximately 8 Hrs. each.

(2) Bioresearch Module can be installed with other payloads and launched from the SSV payload bay with minor hardware changes.

(3) Interface restraints and requirements imposed on the SSV and Bioresearch Modules can be identified from the preliminary installation and operating concepts established.

(4) Scout Bioresearch Module is compatible with SSV. Bioresearch Module designed to exploit SSV payload capabilities may not be compatible with Scout due to size, weight and lower qualification environment.

3.5 INTERFACE RESTRAINTS AND REQUIREMENTS IMPOSED ON SSV

The interface requirements between the SSV and the Bioresearch Module have been investigated (under Task II-5 of Reference 5) to a degree commensurate with the data available. Because the SSV design has not been selected and firm payload provisions established the data presented on interfaces will be of a top level, gross nature. Several interface problems have been investigated to the limits of available data. The data presented below are based on SSV - payload integration currently in work at NASA-MSC.

3.5.1 Manipulators. - The payload deployment devices that appear most promising at this time include spring loaded tie down structures and a manipulator. Power and crew time considerations limit the use of the manipulator to recovery operations only. The release of a payload and the subsequent separation from the Orbiter is by means of springs incorporated into the payload support structure. After the payload bay doors are opened the crew commands the structural latches to release. Electric or hydraulic actuators open the latches and the springs provide a separation impulse. This approach involves less risk and requires less power and crew time than IVA, EVA, or manipulators. The use of pyrotechnic devices is to be avoided. Explosive bolts, clamps and actuators will not be used unless these provide the only alternative accomplishing a particular function. If pyrotechnic devices are used they will be subjected to stringent safety, environmental, and contamination test requirements. The manipulator design has not been firmly established at this time, however, the trend is toward a simple articulated loading boom with limited lateral motions. Preliminary studies to integrate a manipulator into the orbiter indicate the 'reach' will be between 20 and 100 feet with a slow moving and very flexible arm. The manipulators with weights approaching the weight limits allocated will be "relatively simple" and "not very stiff." Quantitative data are not available.

3.5.2 Data Displays. - The Orbiter will display payload data to the vehicle commander and the payload operator's station. CRT and advisory lights are available. The vehicle commander will have payload condition information supplied at all times. This data will be limited to that which affects overall safety and mission management. In the case of the Bioresearch Module, lights indicating an "unsafe" and "go-no-go" condition will be provided the commander while the payload operator will be provided more information. The CRT and the payload operator's station may be used for TV viewing of the Bioresearch Module, or the Orbiter payload bay during release/recovery operations, or reference information from the microfilm data storage. Payload checkout will be accomplished on the ground, and the inflight checkout prior to deployment will be of a continuity and

C.3

go-no-go type. In the case of the Bioresearch Module minimum IVA or inflight servicing are desired. Currently, the payload engineering studies indicate that recovery of an old satellite and deployment of a new satellite is preferred to inflight refurbishment and redeployment.

3.5.3 Other Payloads. - Other payloads are expected to be carried with the Bioresearch Module on SSV flights. The missions of the other experiments have not been postulated nor have the effects of bioresearch on astronomy or radiation modules been assessed. Bioresearch Modules using rocket powered spin tables and upper stages will require analysis of exhaust plume contamination of the other payloads. At this time no quantitative data is available on plume effects, contamination levels, and protective schemes.

3.5.4 Requirements Imposed on SSV by Bioresearch Module. - The SSV should provide the following:

(1) Access to Module in cargo bay on launch pad (in vertical position), 10 to 6 hours before launch to service, install experiment package and validate spacecraft. A 1-1/3 x 2 m (4 x 6 ft) access door into the cargo bay is needed, plus AGE on the tower.

(2) Access to Module in cargo bay in orbit by Inter-Vehicular Activity (IVA) with provisions to refurbish expendables, experiment package, limited spares.

(3) Provide environmental control on ground, 77 $\pm 5°F$ and less than 55% relative humidity, peak cold plate cooling of 350 Btu/hr.

(4) Provide electrical power, 28 VDC at an average of 150 watts.

(5) Attachments for the payload pallet-structural, electrical and electronic, fluid.

(6) Retrieval manipulator and visual access to payload operations.

(7) RF links for data, commands to spacecraft for subsystem control and rendezvous. SSV provides attitude orientation, firing sequence and countdown functions.

(8) Orbital tracking and rendezvous.

(9) Monitor safety and housekeeping.

3.5.5 Requirements Imposed on Bioresearch Module by SSV. - The Module should provide the following:

(1) Pallet attachments (adapters, spin tables)

(2) Recovery manipulator grappling points

(3) SSV umbilical - cooling fluid loop, 28 VDC, data system.

(4) Buffer units for flight, data, mission, and environmental control consoles.

(5) Liquid-to-liquid thermal exchange unit (see Section 3.8).

3.5.6 Pallet Design Requirements. - The pallet, interfacing with the SSV payload structure (Figure 23) and charged to the payload, should provide the following:

(1) Structural attachment to the SSV multiple payload frame.

(2) Bioresearch Module support structure (adapters, spin table, cradle restraints, protective covers).

(3) Bioresearch Module umbilical.

(4) Structural support of buffer units.

(5) Structural support of liquid-to-liquid heat exchanger.

3.6 IMPACT OF SSV OPERATION REQUIREMENTS ON BIOLOGY EXPERIMENT OPERATIONS

Under Task II-6 of Reference 5 the impact of SSV operation requirements on biological experiment peculiar operational requirements was evaluated. Operations considered are those leading to SSV launch. Orbital operations were considered earlier in Sections 3.1, 3.2, and 3.3.

3.6.1 Requirements. - The following requirements serve as guidelines for analysis of the prelaunch operations:

(1) Bioresearch Module baseline design based on Scout launch vehicle.

(2) Launch site operations to be similar for SSV and Scout when feasible.

(3) Exceptions to Scout launch operations to be identified when Bioresearch Module is launched by SSV.

(4) Identify alternate launch operations for SSV/ Bioresearch Module combination.

(5) Identify launch support equipment required on board SSV to launch Bioresearch Module.

3.6.2 Analysis of Prelaunch Operations. - Table 36 compares prelaunch preparations for a Bioresearch Module mission for a Scout and an SSV launch vehicle. The operations shown are at a fairly gross level, but detail is sufficient to point up similarities and differences. An X on Table 36 indicates the operation is conducted. Absence of an X, therefore, is the area of interest, where a difference in operations exists. These differences are summarized by mission:

Mission I.

(1) Since Mission I is attitude controlled, when launched by the SSV spin balance is not required for an injection motor nor the Module itself.

(2) No ordnance is used on an SSV launch.

(3) A predeployment checkout can be conducted in orbit by the SSV.

Mission II.

(1) No injection motor is used by the SSV, so balance of a motor is not involved. However, the Module must be spin balanced in either case.

(2) No ordnance is used on an SSV launch. The Module will be spun up on a table by means of an electric motor.

(3) Again, a predeployment checkout can be conducted in orbit by the SSV.

Mission III.

This mission cannot be launched by a Scout, so that only SSV operations are shown.

To expedite SSV operations it is desirable to install the Bioresearch Module and experiment package in the Orbiter's horizontal maintenance facility prior to mating with the booster and erecting on the pad as was shown in the timeline, Figure 25. Electrical power, cooling and instrumentation will be supplied to the payload bay by the Orbiter during these 4-5 days on the ground to ensure survival of the Bioresearch Module and experiment package as well as other payloads. In orbit, the Orbiter may release a number of high priority payloads before maneuvering

TABLE 36. - COMPARISON OF SCOUT AND SSV LAUNCH OPERATIONS

	MISSION I		MISSION II		MISSION III
	SCOUT	SSV	SCOUT	SSV	SSV
B/M WITH SIM. EXP. PKG. CHECKED OUT	X	X	X	X	X
SPIN BALANCE INJECTION MOTOR	X		X		X
SPIN BALANCE B/M	X		X	X	X
SPIN BALANCE INJ. MTR. WITH B/M	X		X		X
MATE B/M TO LAUNCH VEH.	X	X	X	X	X
RFI CHECK	X	X	X	X	X
TRANSPORT LAUNCH VEH. TO PAD	X	X	X	X	X
ORDNANCE INSTALLATION	X		X		X
DRESS REHEARSAL	X	X	X	X	X
REMOVE SIM. EXP. PKG.	X	X	X	X	X
INSTALL FLIGHT BATTERY	X	X	X	X	X
INSTALL FLIGHT EXP. PKG.	X	X	X	X	X
FINAL CHECKOUT	X	X	X	X	X
LAUNCH COUNTDOWN	X	X	X	X	X
BOOSTED FLIGHT	X	X	X	X	X
PREDEPLOYMENT CHECKOUT		X		X	X
ON-ORBIT DEPLOYMENT	X	X	X	X	X
VELOCITY PACKAGE BURN					X
FINAL ORBIT					X

to the Bioresearch Module on-orbit release point. The combination of ground and on-orbit SSV operations can result in the Bioresearch experiment package remaining in the Orbiter's payload bay as little as 8 hours or as many as 7 days. While this delay is short compared to the Bioresearch Module's six-month mission, an on-orbit check of the experiment, T/M system and power supply would probably be desirable before deployment.

3.6.3 Analysis of Post-Launch Operations. - The on-orbit checkout of the Bioresearch Module will use the Orbiter equipment and displays dedicated to payload operations. These displays will be multiplexed to support several payloads. The Orbiter will have an alphanumeric diode matrix display, a multiform color CRT display, a reference microfilm display, monitor/alarm lights, controls, and space for a payload peculiar display in the payload monitoring console. These payload displays are compatible with the shared useage concept in which several payloads can be monitored in sequence and specific subsystems monitored, exercised, and readouts assessed against stored standards. The Bioresearch Module can store data for three orbits while another payload uses the payload displays. On-orbit checkout of the Bioresearch Module will be through the umbilical. The experiment package will be checked through the 88 pin umbilical. In the event the experiment package contains a TV camera, a real time display can be made on the CRT at the Orbiter Payload Monitoring Console. The Module and experiment package will be monitored through the housekeeping data system and displayed on the Orbiter's alphanumeric matrix display. The post-boost checkout performed immediately before deployment consists of the following:

(1) Communication check

(2) Payload deployment/release system activation

(3) Reaction Control system checkout

(4) Experiment Package validation

(5) Electrical Power System checkout

(6) N_2 Pressure check

(7) Sun Sensor operation

(8) Command-control circuits

(9) Extendible booms

(10) Thermal Control/Louver operation

(11) T/M/Data management system operation.

Readouts of operations will be made on either the alphanumeric matrix or CRT or observed directly through the view port between the crew compartment and payload bay. At this time no payload peculiar displays are anticipated at the payload monitoring crew station. In the Orbiter payload bay it will be necessary to install in addition to the power, cooling, T/M umbilical, the equipment necessary to interface the Bioresearch Module and Orbiter command control and data management systems. Since the Bioresearch Module is designed to operate independently of other spacecraft in orbit it is necessary to provide interfacing units between Orbiter command control and T/M systems to maintain communications until the Module has been fully deployed and command responsibility transferred to the Goddard Space Center ground stations.

The SSV must provide thermal control of the Bioresearch Module cold plate. This is done by circulating a fluid from a payload-supplied heat exchanger to the cold plate. The payload-supplied heat exchanger is cooled by an SSV payload-dedicated heat exchanger, described more fully in Section 3.8. The Bioresearch Module must be deployed shortly after its umbilical is pulled so that cold plate/louver system can operate for thermal control. In addition, quick deployment allows the solar array to supply power, although on a fully charged battery the Bioresearch Module can be deployed on the dark side of the earth.

3.6.4 Summary of SSV Operation Impact. - The SSV launch does not impact the Bioresearch Module operations to a significant degree. The only change of consequence from those experienced in a Scout launch is the extended time between the Bioresearch Module combined systems test and final deployment. Since the Orbiter is capable of supplying electrical power, environmental control, and payload monitoring on a continuous basis the delay in deployment should not present a problem. A second change of note is the in-orbit checkout of the Bioresearch Module before release from the Orbiter. This will enhance the Module operation since the experiment and spacecraft status can be determined before release and commitment to a six month mission. In the unlikely event of failure, the Module can be returned to earth by the Orbiter for refurbishment/repair and the mission rescheduled. The SSV must also provide the important functions of attitude orientation to establish proper firing angle for the Mission III velocity package and launch control functions for proper timing of the velocity package motor ignition. Table 37 summarizes the results of this analysis.

3.7 POTENTIAL COST SAVINGS AND TEST PROGRAM REDUCTIONS

The large cargo bay and predicted softer ride provided by the SSV for small payloads offers potential cost savings and test program reductions. These possibilities were investigated under Task II-7 of Reference 5 to assess impact on the Bioresearch Module. Three approaches in using the SSV are considered: 1) Scout/SSV compatible payload, 2) SSV-dedicated payload, 3) use of SSV for sortie missions. These are discussed briefly on a qualitative basis only in the following sections inasmuch as the development plan, Section 4, is concerned primarily with the baseline Scout-launched Bioresearch Module.

3.7.1 Scout/SSV Compatible Spacecraft. - As noted in Section 1 the baseline Bioresearch Module is compatible with both Scout and SSV launch

TABLE 37. - IMPACT OF SSV OPERATION ON B/M OPERATION REQUIREMENTS

Timeline on Ground:	Scout	SSV
B/M Installed ___ days before launch	6-9	4-5
Exp. Pkg. installed ___ hrs before launch	2-8	2-8
Timeline after launch:	**Scout**	**SSV**
B/M deployed after launch	10-12 Min	8 Hrs -7 Days

Extended predeployment time no problem since SSV provides continuous power, environmental control, data monitoring.

Additional checkout of B/M in SSV orbit before deployment is new, favorable procedure.

SSV deployment of payload similar to sequence for Scout launch.

B/M can store data for 3 orbits while another payload uses SSV data monitor.

B/M requires buffering units (data and commands) to interface with SSV payload console.

B/M requires heat exchanger to interface with SSV payload-dedicated thermal control system.

vehicles. All qualification testing is based on the more severe Scout environment. For the baseline spacecraft, therefore, use of the SSV involves an increase in cost and testing to develop and qualify the specialized adapters used on-board the SSV. Although Scout hardware can be used for this purpose, it must be modified to replace, for example, the spin table rockets with an electric motor, and the explosive bolts in the V-band clamp (see Section 3.8) must be replaced with a mechanical unlatching mechanism for spacecraft separation. Buffering units, as noted in Section 3.2, are also needed for matched interface with the SSV power, data, communications and thermal control systems.

3.7.2 SSV-Dedicated Spacecraft. - Full benefit of the SSV advantages can be realized only by an SSV-dedicated payload which need not meet the requirements of another launch vehicle with more severe environment and restricted volume. This would involve a completely new approach to Bioresearch Module design. It could be heavier and of a larger volume to accommodate less-than-optimum packaged components. However, spacecraft power requirements would very likely increase, with attendant growth of the solar array and its large expense. Also, a larger volume payload may be assessed an increased charge for launch if SSV cargo rates are assigned on a volumetric, as well as weight basis.

For comparative purposes in the present study it is more useful to consider the baseline Bioresearch Module for SSV launch only and determine the savings over a Scout launch, exclusive of launch vehicle cost. Table 38 presents this comparison. Estimated cost savings are presented in Section 4.7.

3.7.3 Sortie Missions on SSV. This approach uses the SSV as a space station which stays on orbit, say, for 30 days. The experiments remain on board the SSV instead of being deployed. Two approaches were considered for operating Bioresearch Module in the sortie mode. The first assumes the baseline spacecraft, fully capable of deployment, is simply left on board the SSV with the umbilical attached. External cooling and power are supplied by the SSV, and spacecraft data are routed by hardline to the SSV data displays, or relayed to the ground. The experiments can function normally in this mode, although only the non-spinning Missions I and I(S) could be considered, the six-month mission will be shortened to 30 days, and the SSV in performing its various maneuvers may exceed the desired 10^{-4}g environment for Bioresearch Module. This approach would result in no cost saving over a deployment of the spacecraft outside the SSV.

The second approach to a sortie mode is to modify the Bioresearch Module by deleting all subsystems unnecessary to the mission. These include attitude control, RF communications, louver assembly, solar array and battery. The power distribution and data systems would be retained. Power and cooling would be supplied through the umbilical. Operation would be identical to the baseline spacecraft before it is deployed. Again, only the non-spinning Missions I and I(S) can be considered, the six-month mission would be shortened, and the desired 10^{-4} g environment would be exceeded. Cost, however, would be well below that for the baseline.

Table 39 summarizes the sortie mission approaches. A cost analysis of sortie missions was not conducted.

3.8 IMPACT OF COMPATIBILITY WITH SCOUT AND SSV

Purpose of this task (II-8 of Reference 5) was to identify the cost and design impact on the baseline design of making the Bioresearch Module compatible with both the Scout and SSV for the various missions. As previously noted in Section 1, the baseline design has already been configured for compatibility with both the Scout and the SSV. This is in reference to the spacecraft itself, which can ride unaltered on either launch vehicle. Cost and design impact occur in the spacecraft/launch vehicle interfaces and support equipment, which are analyzed in the following sections.

3.8.1 Environment. - Scout and SSV launch environments are compared in Table 40. It is noted that the SSV provides a relatively "soft" ride

TABLE 38. - PROGRAM COMPARISON OF SCOUT/SSV VERSUS SSV-DEDICATED BIORESEARCH MODULE

ITEM	SCOUT/SSV Spacecraft	SSV-DEDICATED SPACECRAFT
Engineering	*X	X
R and QA		Reduced
Tooling	X	X
Hardware		Reduced due to lower cost of components through less stringent specifications.
Fabrication	X	X
Development Testing		Reduced due to adaptation of more off-the-shelf components which are larger, heavier.
Qualification Testing		Reduced due to acceptance by similarity and/or by analysis.
Acceptance Testing		Slight reduction
Launch Support	X	X
Mission Support	X	X

*X indicates approximately similar program and cost.

for the baseline spacecraft qualified for Scout. The Bioresearch Module thermal control system is adequate for the indicated thermal environments on either launch vehicle. Thermal cooling during a Scout launch is handled by precooling the cold plate to 35°F and then using it as a heat sink during the two minutes of boost until heatshield ejection. Thermal control in the SSV cargo bay is provided by circulating a cooling fluid through the cold plate. In summary, the SSV provides a more favorable launch environment with no design or cost impact on the spacecraft in providing Scout/SSV compatibility.

TABLE 39. SORTIE MISSIONS ON SSV

USE SSV AS EXPERIMENT SPACE STATION, PAYLOADS REMAIN ON BOARD. ADAPT BIORESEARCH MODULE TO THIS PROCEDURE. TWO APPROACHES:

1) <u>USE BIORESEARCH MODULE AS IS</u>.
   - LEAVE UMBILICAL CONNECTED
   - USE EXTERNAL POWER AND COOLING SUPPLIED BY SSV
   - ATTITUDE CONTROL AND LOUVER CONTROL NOT ACTIVATED
   - DATA HANDLING AND COMMANDS PROVIDED BY SSV OR BY RELAY TO GROUND
   - SUITABLE ONLY FOR MISSIONS I AND I(S)

2) <u>MODIFY BIORESEARCH MODULE</u> BY REMOVING ALL FUNCTIONS PROVIDED BY SSV:
      - ALL ATTITUDE CONTROL AND COMMUNICATIONS COMPONENTS
      - LOUVER ASSEMBLY
      - SOLAR ARRAY AND BATTERY
   - RETAIN POWER DISTRIBUTION AND DATA SYSTEMS
   - USE EXTERNAL POWER AND COOLING SUPPLIED BY SSV THROUGH UMBILICAL
   - DATA HANDLING AND COMMANDS PROVIDED BY SSV OR BY RELAY TO GROUND
   - SUITABLE ONLY FOR MISSIONS I AND I(S)

TABLE 40. - SCOUT AND SSV LAUNCH ENVIRONMENT

		*Scout	**SSV
Acceleration			
Boost:	Axial	11g or 350 lb payload	3g
	Lateral or Vertical	±3g	±1g
Spinup		1g tangential	1g tangential
Despin		1g tangential	1g tangential
Landing:	Axial	Not applicable	+0.8g to -1.0g
	Lateral	Not applicable	±0.5g
	Vertical	Not applicable	-2.5g
Vibration			To be determined. Lower than conventional boosters.
Sinusoidal:	Axial	4g	
	Lateral	1g	
Random		5g rms	
Shock		Along thrust axis, 30g peak for 7 to 13 millisecond.	To be determined Lower than conventional boosters.
Acoustic		142 db overall outside heatshield	To be determined. Lower than conventional boosters.
Thermal		Maximum temperature +150°F on inside wall of heatshield	-100°F to +150°F in cargo bay.
Pressure		Vented	Vented.

*Data from Reference 16
**Data from Reference 7.

3.8.2 Impact of Interfaces. - The required interfaces for Scout/SSV compatibility do not affect the spacecraft, but additional hardware is required for the SSV launches.

Mechanical Interfaces. - These are listed in Table 41 to indicate the more complex interface with the SSV. The differences are attributed to the fact that the Scout fourth stage provides the necessary adapters, spin table, and separation hardware, all of which must be added to the SSV to provide spacecraft support and separation. In addition, the SSV may be called upon to provide a docking capability for retrieval.

TABLE 41. - MECHANICAL INTERFACES

SCOUT	SSV
• Module to 4th stage • Payload to Cooling Unit. • Heatshield to Module • Cooling Unit to Launcher	• Module to Docking Cone • Docking Cone to Spin Table • Spin Table to Adapter • Adapter to Manipulator Boom • Adapter to Orbiter Support Struct. • Liquid-to-Liquid Heat Exchanger to Experiment • Velocity Pack. to Module • Velocity Pack. to Docking Cone • Cooling Unit to Orbiter • SSV Heat Exchanger to Liquid-to-Liquid Heat Exchanger
Mechanical interfaces are interchangeable between Scout and SSV. Docking ring added to the Bioresearch Module for SSV operations may remain for Scout launch without interference.	

Figure 26 compares the Scout and SSV mechanical launch arrangements. For illustrative purposes a manipulator boom is shown for the SSV, but the spacecraft deployment can be accomplished by a similar arrangement in the cargo bay, discussed in the following section.

Payload Contamination. - Figure 27 illustrates direct deployment of the Bioresearch Module from the Orbiter cargo bay. The Scout fourth stage spin table and separation system is shown attached to the payload pallet structure, with a Bioresearch Module attached to the spin table. The separation sequence begins with rocket ignition for spin up, followed by ignition of explosive bolts which segment a V-band clamp attaching the spacecraft to the spin table. Compressed springs then push the spacecraft away at a small relative velocity (see following Section 3.8.2 for further description and discussion of docking).

The V-band clamp segments can be captured by appropriate restraints (springs or lanyards), but the spin rockets spray contaminants into the cargo bay. Figure 27 defines the environment and gas constituents produced by a 1KS75 rocket plume at distances of 20 and 30 inches from the nozzle exit. This environment is probably unacceptable for SSV operations and certainly detrimental to nearby payloads. The solution is to modify the spin table for electric motor spin up and mechanical unlatching of the V-band clamp.

Electrical Interfaces. - Scout and SSV electrical interfaces are listed in Table 42. The baseline design is not affected by requirements imposed on the SSV for power, data and command links. Interface with the spacecraft is through the launch umbilical which is identical for

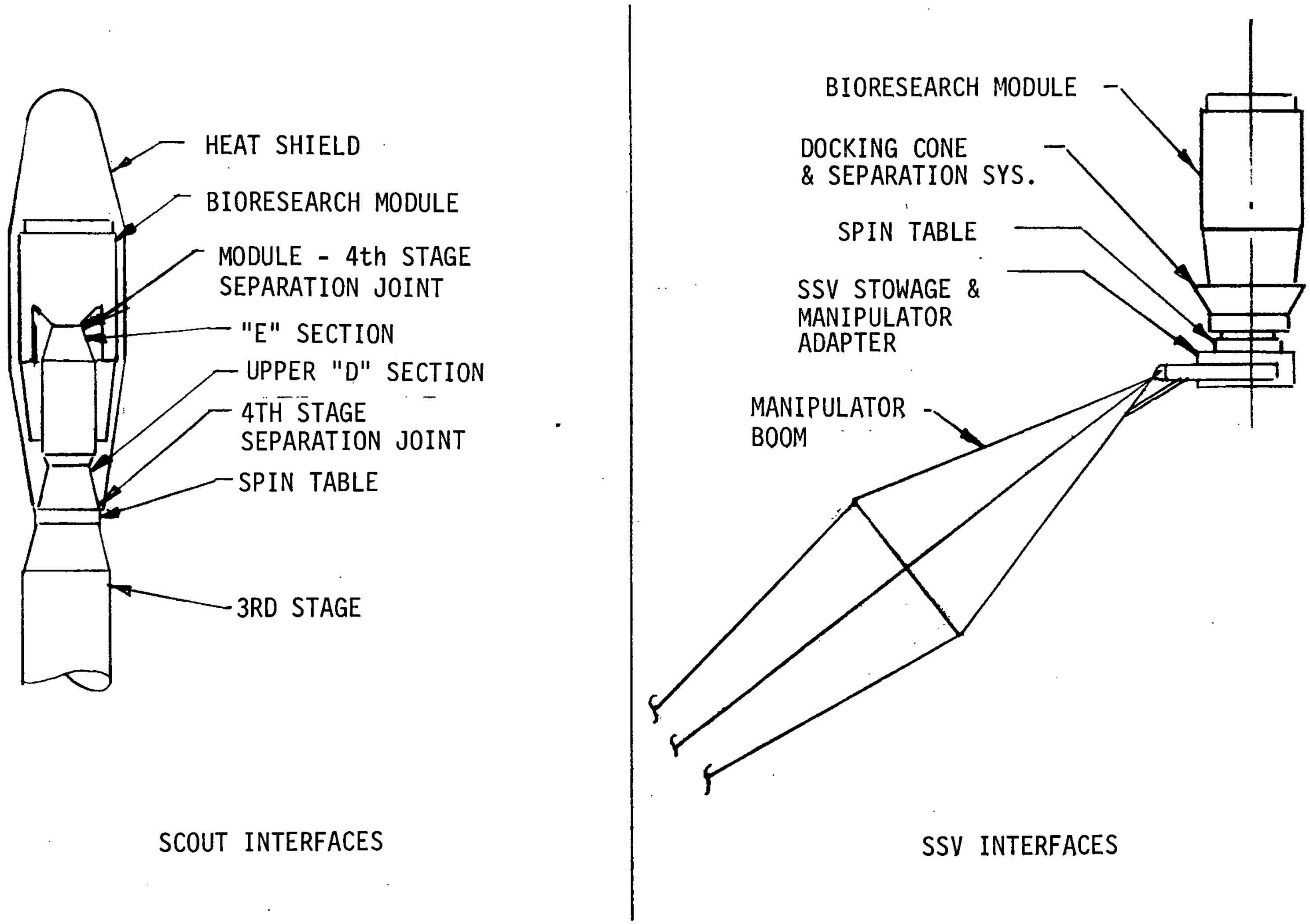
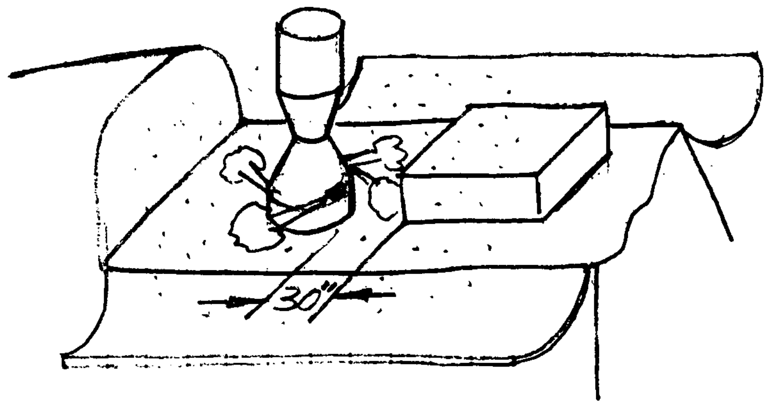
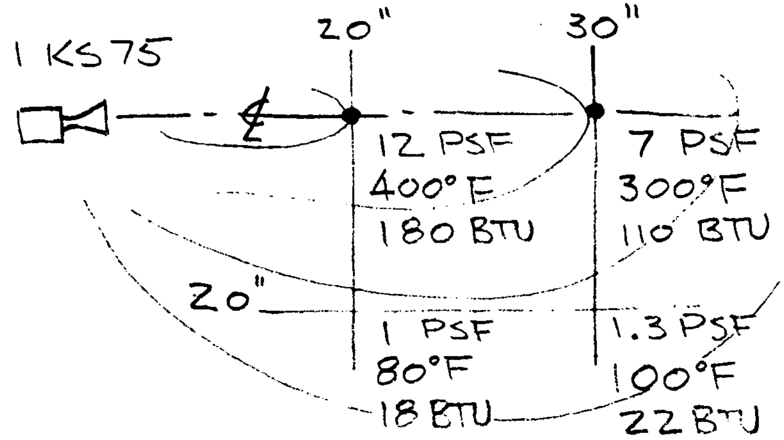


FIGURE 26. - MECHANICAL INTERFACES





- PAYLOAD PROTECTION
- CONTAMINATION CONTROL

EXHAUST PLUME CONTENT

Al_2O_3	40%
CO	25%
HCl	23%
N_2	7%
H_2	2.8%
H_2O	1.3%

FIGURE 27. PAYLOAD CONTAMINATION

TABLE 42. - ELECTRICAL INTERFACES

SCOUT
1. AGE to experiment package (power data, checkout). Through umbilical before experiment package is installed on spacecraft.
2. AGE to spacecraft (power, data, checkout). Through umbilical before spacecraft installed on launch vehicle.
3. Launch complex to spacecraft-plus-experiment installed on launch vehicle (power, data, checkout). Through spacecraft launch umbilical.
4. Launch complex to cooling unit. Power to refrigerant unit on launcher.
SSV
1. Power, data and checkout to spacecraft through umbilical.
2. Power to spin table.
3. Power to actuate mechanical unlatch of V-band for spacecraft separation.
4. Power to spacecraft-supplied heat exchanger.
5. RF command and data link to deployed spacecraft.
6. RF command link to velocity package (when used).

Scout and SSV launches.

Prelaunch Cooling. - Figure 28 illustrates the proposed concept for prelaunch temperature control of the cold plate. A single phase liquid circulates through integral passages in the cold plate to transfer experiment heat to the payload-supplied liquid-to-liquid heat exchanger. This heat exchanger is common to both Scout and SSV launches. Single phase liquid cooling was selected for its simplicity and capability of functioning on the ground or in gravity-free environment. During Scout launches the liquid-to-liquid heat exchanger interfaces with a two phase refrigeration unit for heat removal. On SSV launches the liquid-to-liquid heat exchanger interfaces with a payload-dedicated heat exchanger supplied for the SSV. This interface can be mechanical for conductive heat transfer, or another single phase liquid system can be used as suggested in Figure 28.

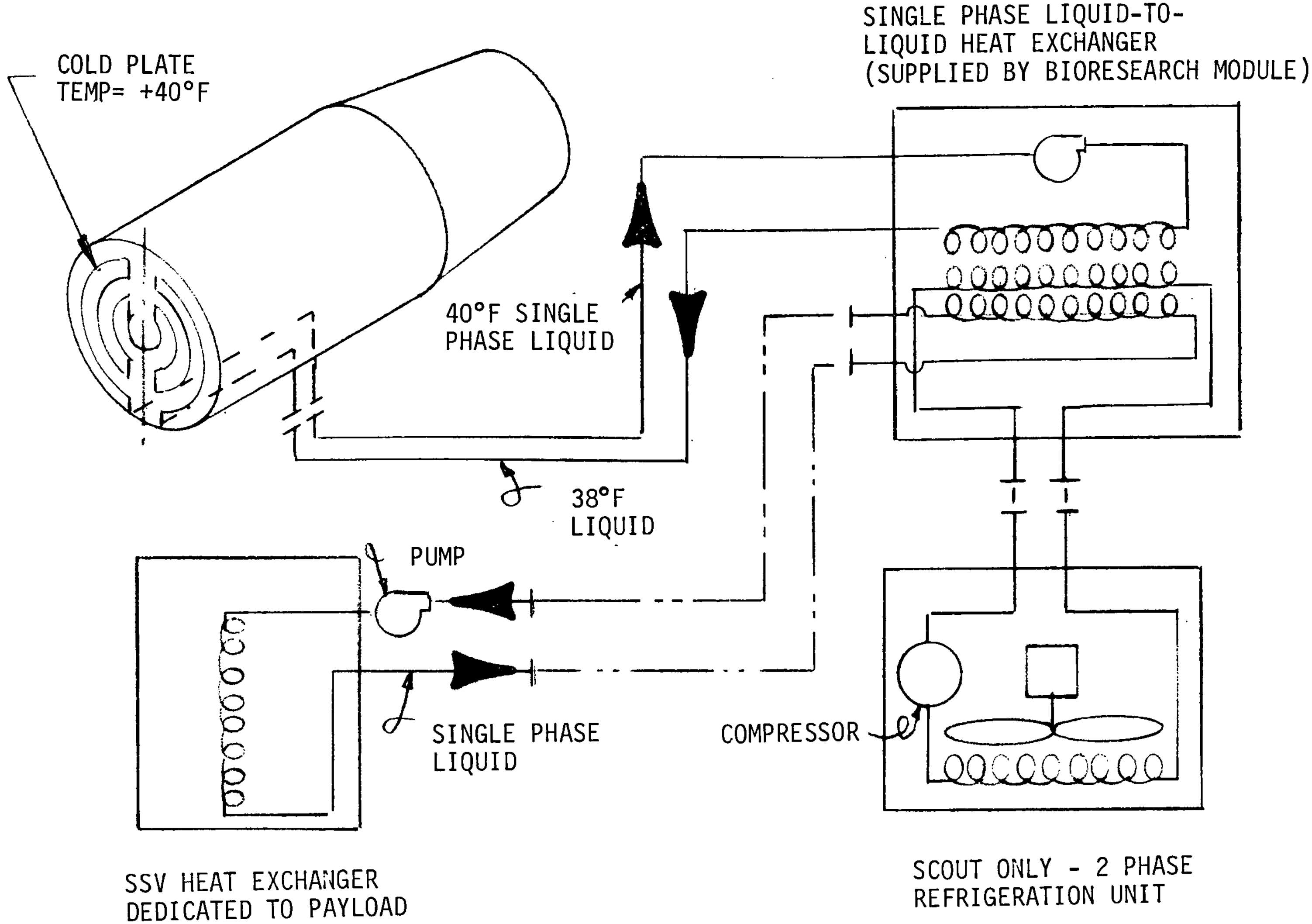


FIGURE 28. - EXTERNAL COOLING ARRANGEMENT

The prelaunch cooling arrangement is shown in Figure 29 as it would be installed on the Scout launcher or in the Orbiter cargo bay. The spacecraft supplied heat exchanger plus refrigeration unit will be mated to the cold plate when the experiment package is assembled in the biological laboratory. The cooling system will remain attached to the experiment package and provide environmental control throughout all prelaunch operations. For Scout launches the cooling system is attached intact to the launcher. For SSV launches the refrigeration unit is replaced by the SSV payload-dedicated heat exchanger and this cooling system accompanies the SSV into orbit, providing environmental control until spacecraft deployment.

The spacecraft supplied liquid-to-liquid heat exchanger minimizes cost and design impact of environmental control for both Scout and SSV launches of Bioresearch Module.

3.8.2 Spacecraft Deployment and Retrieval. - The Bioresearch Module will be deployed from the SSV with or without a velocity package. Scout launch vehicle hardware can be adapted for this purpose, as described below.

Velocity Package Deployment. - Figure 30 is a cross section of the Scout spin table with fourth stage attached. The outer race of the spin bearing can interface with a new adapter for structural attachment to the payload pallet in the SSV cargo bay. The four spin motors would be be replaced with an electric motor drive for spin-up torque. V-band clamp separation can be accomplished by a mechanical draw bar mechanism. Following release of the V-band clamp by breaking it into four segments, 32 compressed springs and plungers thrust forward against the motor adapter to separate the velocity package at a small velocity relative to the SSV. Due to tight tolerances held in manufacture of the springs and plungers, this spinning separation system has demonstrated very small tipoff on many Scout flights. The Scout spin table can be adapted to other motors which may serve as velocity packages for the Mission III Bioresearch Module.

Universal Deployment and Docking. - Without a velocity package the Bioresearch Module can be supported on its aft structural ring, shown in Figures 5 and 15. An arrangement for deployment from this support condition is shown in Figure 31, which illustrates a spin table capable of universal deployment and retrieval of Bioresearch Module.

Mission I and II, without velocity package, are attached at A. Separation is achieved (without or with spin) by rotating the release latches away from the upper half of the split ring (on spacecraft). The spring-plungers at A thrust the spacecraft away. For retrieval, the spring plungers are re-compressed and the SSV maneuvers the docking cone guide, C, around and toward the spacecraft so that the latches can be rotated to secure the spacecraft ring.

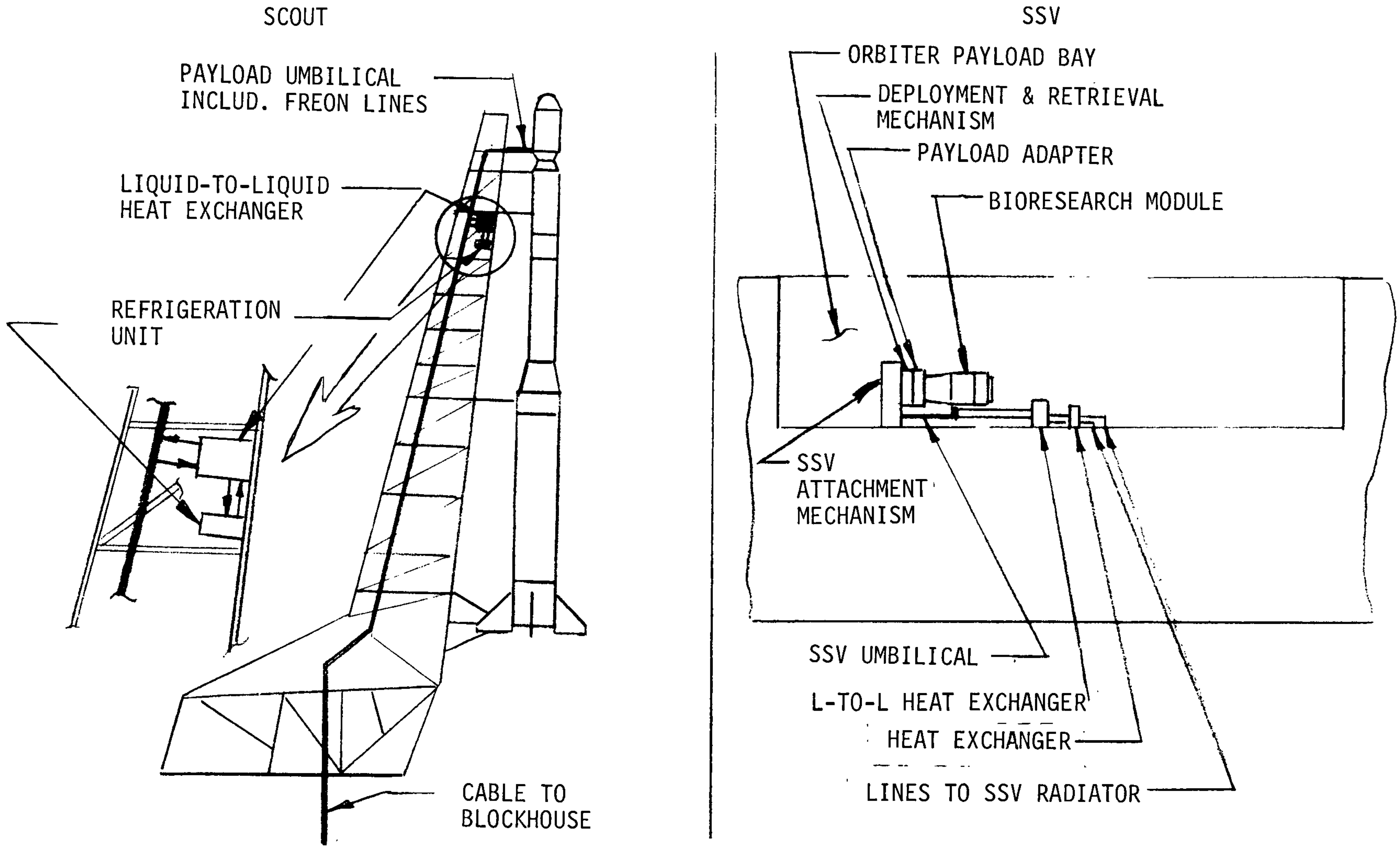


FIGURE 29. - PRELAUNCH COOLING

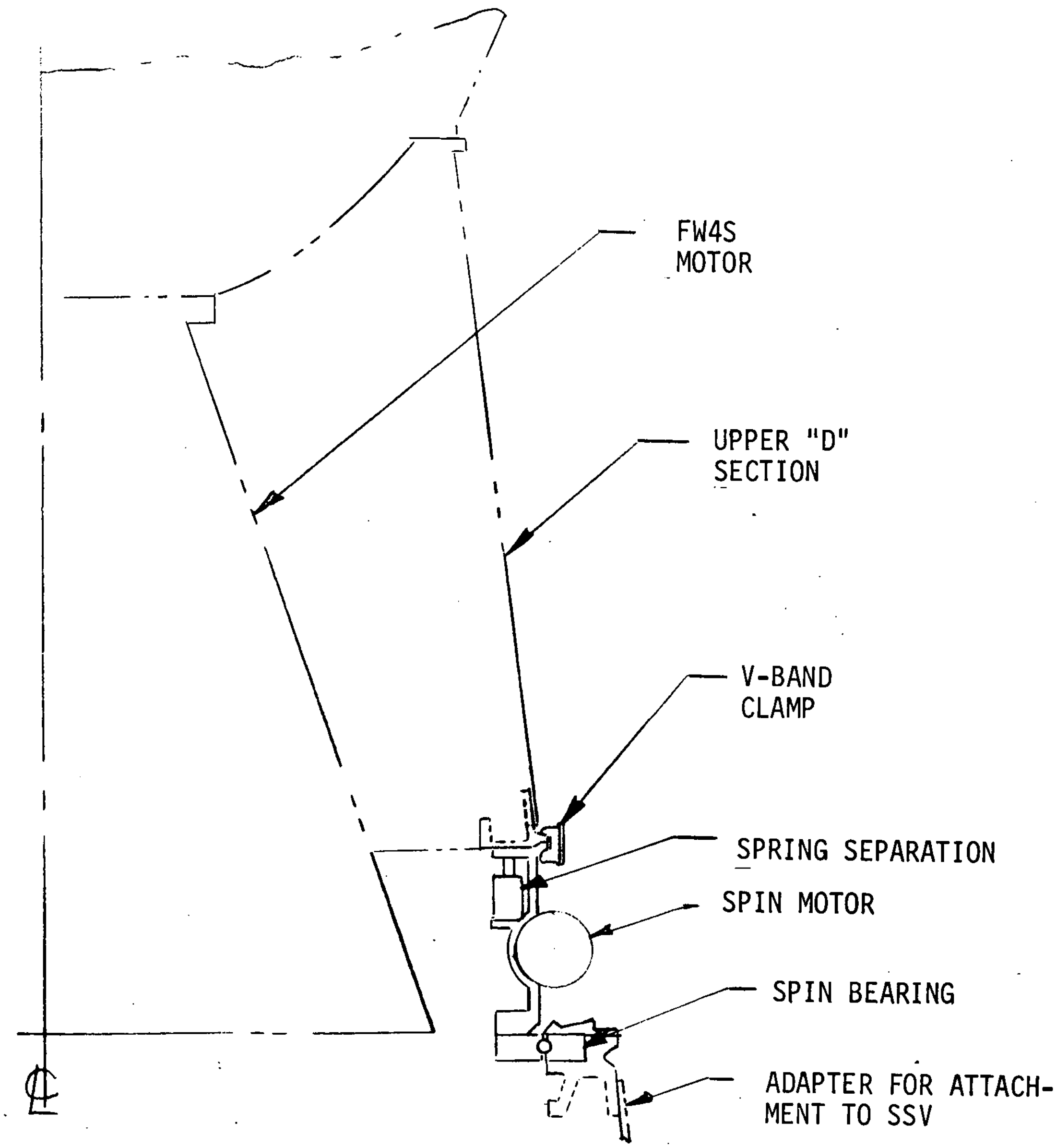


FIGURE 30. - SCOUT SEPARATION SYSTEM

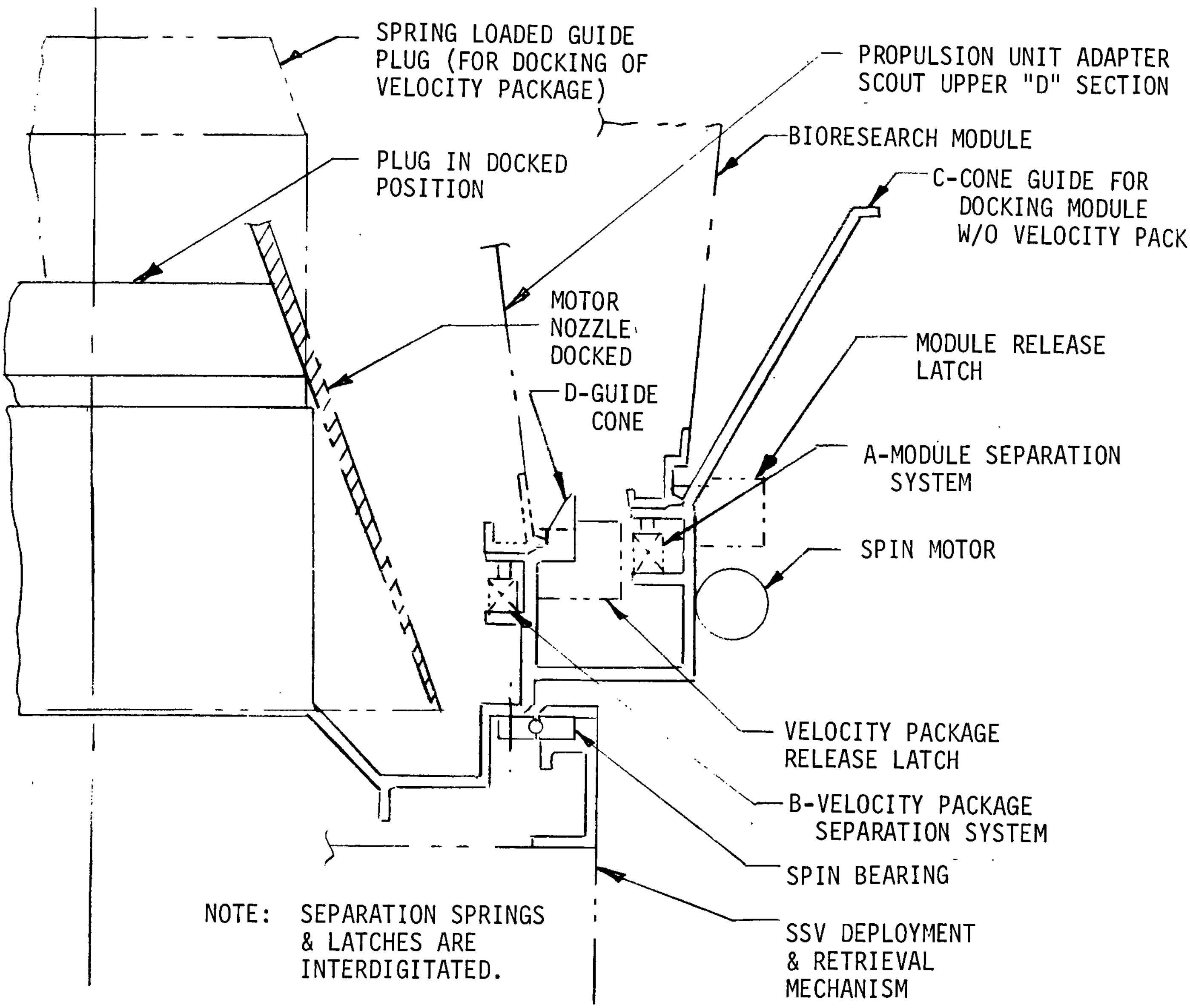


FIGURE 31. SSV SEPARATION & DOCKING

Mission III, with velocity package, is attached at B. Separation is achieved (following spin up) by rotating the release latches away from the upper half of the split ring (aft end of Scout upper "D" section). The spring plungers at B thrust the velocity package away. In the event of a velocity package malfunction, the motor and spacecraft can be retrieved. The spring plungers at B are recompressed, and the SSV maneuvers the spring loaded guide plug (now extended) into the velocity motor nozzle. This aligns the Velocity package so that it can re-seat on the ring at B, aided by a small guide cone, D. After seating the latches are rotated to secure the velocity package aft ring.

The separation mechanisms shown in Figures 30 and 31 are reliable, flight-proven concepts. The docking mechanisms are preliminary design concepts only. The SSV Data Package, Reference 7, does not contain information on payload docking mechanisms. However, the Bioresearch Module may be adapted to the Neuter docking mechanism (Reference 17), recently selected for detailed investigation by NASA/MSC.

3.8.3 Summary of Impact of Scout/SSV Compatibility. - The design impact and cost items associated with making Bioresearch Module compatible with both Scout and SSV are:

(1) Slight weight increase to module by addition of docking ring and structural beef-up of aft skirt (already included in baseline design).

(2) Design and development of docking and retrieval mechanism including relatching release system.

(3) Design and development of launch and stowage adapter compatible with spin table and boom manipulator.

(4) Design of displays and controls for SSV.

(5) Design of propulsion adapters for attachment of velocity packages to Bioresearch Module.

The following functions normally supplied by the launch complex will be added to the SSV.

(1) Cooling (liquid-to-liquid heat exchanger).

(2) Umbilical for electrical power checkout, data retrieval and cooling fluids.

(3) Data and checkout display.

(4) Telemetry data relay to ground prior to spacecraft separation from SSV.

(5) Command link for:

    (a) Spacecraft spinup
    (b) Separation

(6) Radio Command for spacecraft motor ignition.

(7) Radio Command for retrieval functions

    (a) Module despin
    (b) Module attitude stabilization
    (c) Module ACS deactivation

(8) Stowage and louver cover.

4.0 DEVELOPMENT PLAN FOR BASELINE SPACECRAFT

4.1 APPROACH

A development plan is presented for Design and Development, and for Fabrication and Operations for the Baseline Bioresearch Module. The plan assumes a single contractor will be awarded both phases of the program. Therefore, the work flow does not show a typical demarcation between phases. Instead, a single integrated program is structured. Significant milestones are identified as points of review and approval to permit efficient utilization of resources downstream of demonstrated prerequisite effort.

4.2 FLIGHT HARDWARE

Flight hardware requirements for each of the baseline spacecraft configurations are tabulated in Table 43. Breadboards are experimental models of circuits to be used in development tests where new components are required by Bioresearch Module. A packaged prototype is then required for qualification tests which are assumed to be destructive. Spares are indicated on the basis that one extra set of electronic and electro-mechanical devices will be in inventory to support the launch schedule. Commonality of hardware will minimize the spares requirements. The structural "breadboard" will consist of a structural prototype for fit checks, qualification tests of the structure, and spacecraft vibration tests to determine amplification factors at component mounting locations. Table 43 also indicates the procurement basis for each item of flight hardware. Table 44 contains notes of explanation primarily for new hardware items which must be fabricated and qualified.

4.3 AEROSPACE GROUND EQUIPMENT

A list of the required Aerospace Ground Equipment (AGE) is tabulated in Table 45. This list represents the minimum requirements, compiled on the basis that much of the AGE used by the Scout launch vehicle can be shared with the Bioresearch Module spacecraft. Both in-plant and launch-site AGE are involved with some items used at both locations during the course of fabrication, checkout, shipment, and preflight launch operations. Careful planning will be necessary to coordinate this shared utilization at two locations and with other payloads using Scout. Section 4.6 shows a separate tabulation of "shared use" AGE cost in the event that additional sets are dictated by scheduling conflicts.

4.4 TEST PROGRAM

Test philosophy for the Bioresearch Module is similar to that defined under the Bioexplorer study program and reported in Section VI, Volume I of Reference 4. The test program is designed to achieve a high probability of mission success at minimum cost.

TABLE 43. - BIORESEARCH MODULE FLIGHT HARDWARE LIST

ITEM NO.	ITEM	NO. REQUIRED: BREAD-BOARD	QUAL. TEST	SPARES	I	I(S)	II	III	PROCUREMENT BASIS	NOTES TABLE 44
1	Experiment Package				1	1	1	1	GFE	X
	ATTITUDE CONTROL									
2	Control Electronics	1	1	1	1	1	1	1	Make	X
3	Nitrogen Tanks			1	2	2	1	2	Buy. Fansteel 4120006	
4	Nitrogen Regulator			1	1	1			Buy. Sterer 30630 (Modified)	X
	Nitrogen Regulator			1			1	1	Buy. Sterer 15780 (Modified)	X
5	Thrusters			1	2	2			Buy. Sterer 29210-1	
	Thrusters			2			6	6	Buy. Sterer 24060-1 (Modified)	
6	Valves and Plumbing			1	1	1	1	1	Make	X
9	Sun Sensors			1	2	2	1	1	Buy. Bendix 1771858	X
10	Rate Gyro Assembly			1	1	1	1	1	Buy. Northrop 79157-350	
39	Yo-Yo Assembly		1	1	1	1			Make	
40	Integrating Rate Gyros			1	2	2			Buy. Honeywell GG 1101	
43	Extendible Booms			1			3		Buy. Spar A-18	
44	Horizon Crossing Indicators			1			2	2	Buy. Barnes 13-206	X
	THERMAL CONTROL									
12	Louver Assembly	1		1	1		1	1	Make	X
	Louver Assembly	1		1		1			Make	X
13	Cold Plate	1			1		1	1	Make. Beryllium, 23 pounds	X
41	Cold Plate	1				1			Make. Beryllium, 12 pounds	X
14	Thermistor Assemblies	1		1	1	1	1	1	Make	X
15	Louver Control Actuator			1	1	1	1	1	Buy. Clifton MSL-8-A-1	
16	Louver Control Electronics	1	1	1	1	1	1	1	Make	X
17	Insulation Blankets			1	1	1	1	1	Make	X
42	Coolant Valves and Plumbing			1	1	1	1	1	Make	X
	COMMUNICATIONS & TELEMETRY									
18	Command Receiver/Demodulator			1	2	2	2		Buy. SCI Dwg. No. 42466	
19	Command Decoder			1	2	2	2	2	Buy. AVCO Model 407(PCM, two decoders in package).	
20	Programmer-Clock	1	1	1	1	1	1	1	Make	X
21	Signal Conditioner	1	1	1	1	1	1	1	Make	X
22	PCM Encoder			1	1	1	1	1	Buy. SCI Model 680	
23	Telemetry Transmitter			1	2	2	2		Buy. SCI 1510100-1	
24	Data Storage Assembly			1	1	1	1	1	Buy. Electronic Memories SEMS-5L	
25	Nitrogen Pressure Transducer			1	1	1	1	1	Buy. CONRAC 461319 BV	
26	Turnstile Antenna			1	4	4	4		Make	X
27	Antenna Coupler			1	1	1	1		Buy. RANTEC FVV-401	
	Antenna Coupler			1				1	Buy. RANTEC FSS-420	
11	Data Processing Unit	1	1	1	1	1	1	1	Make	X
29	Data Patch Unit		1	1	1	1	1	1	Make	X
45	Dipole Antenna			1					Make	
46	Dipole Antenna			1				1	Buy. Spar Model A-415	
47	Range-Range Rate Transponder			1				2	GFE	
	ELECTRICAL POWER									
30	Power Control Assembly	1	1	1	1	1	1	1	Make	X
31	Solar Cells, Set	1			1	1	1	1	Buy. N/P Silicon, 2x2 cm, 2 ohm-cm	X
32	Battery Assembly		1	1	1	1	1	1	Make. 23 Gulton 80432 Cells/Battery	X
33	Power Patch Unit		1	1	1	1	1	1	Make	X
	STRUCTURE									
34	Experiment Package Cover	1		1	1	1	1	1	Make	
35	Equipment Section	1		1	1	1	1	1	Make	
36	Aft Section	1		1	1	1	1	1	Make	
37	Payload Support Ring		1	1	1	1	1	1	Furnished with Scout Launch Vehicle	
28	Deployable Panels	1	1	1	2	2			Make	X
38	Umbilical-Electrical			1	1	1	1	1	Buy. G&C Technology Model 676	
	-Fluid			1	2	2	2	2	Buy. Symetrics, Inc. 46154-3	
48	Electrical Wiring & Connectors			1	1	1	1	1	Make	

Table 44. - Notes on Bioresearch Module Flight Hardware

Item No.	Note
1	Simulated Experiment Package (GFE) needed during in-plant testing and launch operations.
2	Attitude Control Electronics package is similar to unit used on Scout launch vehicle. Adaptable to all missions.
4	Nitrogen Regulators require some modification to change value of regulated N_2 pressure. Should not require re-qualification.
6	Attitude Control Valves and Plumbing made from standard stainless steel 1/4 in. fittings and tubing.
9	On Missions I and I(S) Sun Sensor facing away from sun must be wired with reverse logic. Should not require requalification.
44	Horizon Crossing Indicator requires some modification of electronics to adapt to higher than normal spin rate. Should not require requalification.
12	Louvers are fiberglass with integral aluminum piano hinge, gold coated by electroless plating.
13/41	Cold plate contains integral fluid cooling passage made by machining channel in one surface and closing with diffusion bonded cover plate.
14	Thermistor Assembly is four thermistors attached to cold plate and connected to Louver Control Electronics by wire harness.
16	Louver Control Electronics uses thermistor data to drive louvers open/shut to control cold plate temperature. Sixteen commandable set-point temperatures from 50°F to 35°F.
17	Insulation Blankets. Fifteen layers of aluminized mylar with alternate layers of woven quartz fiber. Used in experiment compartment to cover inside of access panels and upper side of aft closure shelf.
42	Coolant Valves and Plumbing: 100 in. 1/4 in. stainless tubing (160 in. for I(S)) 4 each Symetrics, Inc. 4104-04E-C4 Nipple 2 each Symetrics, Inc. 4404-04E-C4 Coupler 2 elbow fittings for attachment to beryllium cold plate

Table 44. - Notes on Bioresearch Module Flight Hardware (Contd)

Item No.	Note
20	Programmer-Clock consists of a 107.52 KHz oscillator and digital countdown circuitry. Performs four functions: 1) Data encoder sequence signals 2) Time signals to experiment 3) Spacecraft control pulses 4) Time Tag for stored and real-time data
21	Signal Conditioner standardizes data voltages for compatibility with encoder, isolates data signals from primary subsystem operation, provides sensor excitation.
26	Turnstile Antenna made from purchased components.
11	Data Processing Unit organizes data into words and frames for storage in memory so that recovered data can be identified.
29	Data Patch Unit is essentially insertable circuit board in junction box which permits circuit rearrangement for experiment without changes to wire harness and spacecraft components.
30	Power Control Assembly contains protective devices and components associated with control and distribution of power.
31	Solar Cells are body mounted in numbers which depend on mission power requirements and stabilization (spinning or non-spinning). Solar array areas for baseline spacecraft are indicated on drawings, with following quantities:

Mission	Solar Array Area ft^2 (m^2)	No. 2x2 cm cells
I	25.3 (2.35)	4990
I(S)	25.3 (2.35)	4990
II	58.4 (5.43)	11,510
III	46.3 (4.31)	9130

Item No.	Note
32	Battery Assembly is cast magnesium box containing 23 cells in series.
33	Power Patch Unit is essentially insertable circuit board in junction box which permits circuit rearrangement for experiment without changes to wire harness and spacecraft components.

Table 44. - Notes on Bioresearch Module Flight Hardware (Concluded)

Item No.	Note
28	Deployable Panels are used on Missions I and I(S) to increase area of solar array. The two panels are each 120° doors on equipment bay. Yo-yo cable restrains doors in closed position. Following despin and release of yo-yo cables doors swing open by action of torsion spring on hinge line.

4.4.1 Flight Hardware. - Where possible, off-the-shelf, flight-qualified components have been selected to avoid qualification testing. Nine electronics units (items 2, 11, 16, 20, 21, 29, 30, 32, 33, Table 43) and two mechanical units (items 28, 39, Table 43) are new and must be qualified. The qualification units for each of these eleven items will not be flown. A structural prototype (items 34, 35, 36, 37 of Table 43) will serve as a hard mockup and will undergo spin, vibration and static load tests to destruction. The cold plates (items 13 and 41 of Table 43) and louver assemblies (items 12 and 15 of Table 43) should be flightworthy following all tests.

Development tests are outlined in Table 46. Most of these are breadboard assemblies of components to assist in design of circuit logic and to demonstrate function of the final arrangement. Test D-3, a full-scale model, will develop the mechanical louver system for controlling cold plate temperature. Test D-8 is a full-scale mechanical mockup to size the yo-yo cables and weights and to develop the deployable solar panel concept. Test D-9 is an element test to verify cold plate material and fabrication processes prior to full-scale fabrication. Test D-10 will verify that the integral fluid passages in the prototype cold plates are leakproof.

Qualification tests are outlined in Table 47, and Acceptance tests in Table 48. These tests are to be conducted in general accordance with the Test Specification of Reference 4, Appendix C.

It should be noted that Tables 46, 47, and 48 present only brief descriptions of tests proposed for the Bioresearch Module. A complete Test Plan defining tests in detail will be prepared during Phase C.

4.4.2 Aerospace Ground Equipment. - AGE tests will be limited to those required to verify workmanship, performance of function and safety of personnel. The following tests will be performed as applicable:

G-1) Make Items - Calibrate, verify functional performance, proof test hoist slings.

TABLE 45. - AEROSPACE GROUND EQUIPMENT LIST

ITEM NO.	DESCRIPTION & MAJOR COMPONENTS	FEDERAL STOCK NO. OR IDENTITY	REQUIREMENT	USE & QUANTITY			PROCUREMENT BASIS		
				CHECKOUT & ASSY.	LAUNCH SITE	MISSION CONTROL	MAKE	BUY	SHARED USE
SPACECRAFT: MECHANICAL									
101	Shipping Container	*	Transport and Protection of Spacecraft		1		X		
102	Hoist Crane	Facilities Item 1 Ton	Lifting and Positioning Spacecraft	1	1				X
103	Spacecraft Hoist Sling		Hoisting S/C For Assembly	1			X		
104	Work Stand		Spacecraft Assembly & Checkout	1			X		
105	Roll Over Stand		Roll Spacecraft for Assembly & Checkout	1			X		
106	Scales	Facilities Item	Spacecraft Weight	1					X
107	Solar Panel Covers		Protect Panels During Ground Operations	1			X		
108	Experiment Pkg. Simulator		Systems Validation	1			GFE		
SPACECRAFT: FLUIDS AND PNEUMATICS									
109	GN_2 Service Cart	Gaseous Nitrogen K Bottles (1190-773-1758 CM)	Nitrogen Source for Flight Control System	1					X
110	Nitrogen Pressure Control Panel		Control Tests and Nitrogen Servicing	1			X		
111	Nitrogen Hose & Adapter Kit		Interconnections	1				X	
112	GN_2 System Leak Test Adapters		Spacecraft GN_2 System Leak Check	1			X		
SPACECRAFT: ELECTRONIC: FLIGHT CONTROL									
113	Flight Control Console		Hold Checkout Units	1				X	
114	Inner Colsole Cabling		Interconnect Equipment	1			X		
115	FCE Test Panel		System Checkout & Simulated Flt. Control	1			X		
116	Power Supply	Christie	System Power	2					X
117	Blowers	Bud B-25	Console Cooling	2					X
118	D. C. Digital Voltmeter	Hewlett Packard 3440A	Systems Checkout	1					X
119	Signal Generator	Hewlett Packard 614A (6625-351-5958)	Systems Checkout	1					X
120	E Put Counter	Beckman 7360	Systems Checkout	1					X
121	Oscilloscope	Tektronix RM 503	Systems Checkout	1					X
122	Servo Analyzer	Ling Model 401 AR	Systems Checkout	1					X
123	Rate Table	Genisco C181	Systems Checkout	1					X
124	Megohmeter	General Radio 1862-C (6625-880-9446)	Systems Checkout	1					X
125	Power Control Panel		Power Distribution	1			X		

* "Make" items will be assigned numbers during design.

TABLE 45. - AEROSPACE GROUND EQUIPMENT LIST (Continued)

SPACECRAFT: ELECTRONIC; TELEMETRY

ITEM NO.	DESCRIPTION & MAJOR COMPONENTS	FEDERAL STOCK NO. OR IDENTITY	REQUIREMENT	USE & QUANTITY			PROCUREMENT BASIS		
				CHECKOUT & ASSY.	LAUNCH SITE	MISSION CONTROL	MAKE	BUY	SHARED USE
126	Telemetry/Instrumentation Console		Hold Checkout Units	1				X	
127	Inner Console Cabling		Interconnect Equipment	1			X		
128	Telemetry Control Panel		System Checkout & Simulated Flight Control	1			X		
129	Power Supply	Christie	System Checkout	2					X
130	Blowers	Bud B-25	Console Cooling	2					X
131	Power Control Panel		System Checkout	1			X		
132	Distortion Analyzer		System Checkout	1					X
133	Audio Oscillator	Hewlett Packard 200AB (6625-519-2384)	System Checkout	1					X
134	PCM Formatter	Stellametrics MOD 753	System Checkout	1					X
135	PCM Synchronizer	Stellametrics MOD 1023	System Checkout	1					X
136	Digital Voltmeter	Hewlett Packard 3440A (6625-055-5348)	System Checkout	1					X
137	Oscilloscope	Tektronix RM503 (6625-827-6225)	System Checkout	1					X
138	Time Code Generator		System Checkout	1					X
139	Time Code Converter		System Checkout	1					X
140	Patch Panel		System Checkout	1			X		
141	Signal Conditioner Test Panel		System Checkout	1			X		
142	Receiver	NEMS Clark 10376	System Checkout	1					X
143	Antenna	APN 101B	System Checkout	1					X
144	Strip Chart Recorders	Brush RD-2682-00 (6625-683-9788)	System Checkout	2					X
145	Events Recorder	Brush RE-3610-55 (6625-720-3037)	System Checkout	2					X
146	Tape Recorder	Sangmo Model 3562	System Validation	2					X

SPACECRAFT: ELECTRONIC; MISSION CONTROL

147	Mission Control Console		Hold Checkout and Monitor Units	1	1	1		X	
148	Inner Console Cabling		Interconnect Equipment	1	1	1	X		
149	Command Control Panel		Systems Checkout	1	1	1	X		
150	Power Supply	Christie	Systems External Power	2	2	2			X
151	Blowers	Bud B-25	Console Cooling	2	2	2			X
152	Signal Generators 100-1700 MHz	Singer SG 1000	Systems Checkout	1					X
153	Frequency Meter	Beckman 92841 (6625-783-5012)	Systems Checkout	1					X
154	Power Meter	Beckman T360	Systems Checkout	1					X
155	RF Load Meter	Bird Model 43	Systems Checkout	1					X
156	Electronic Counter	Hewlett Packard HP 52546	Systems Checkout	1	1	1			X
157	Function Generator	Hewlett Packard HP 3310A	Systems Checkout	1					X
158	Battery Charger		Systems Checkout	1					X
159	Battery Load Tester		Systems Checkout	1					X

TABLE 45. - AEROSPACE GROUND EQUIPMENT LIST (Concluded)

EXPERIMENT PACKAGE: FLUIDS AND PNEUMATICS

ITEM NO.	DESCRIPTION & MAJOR COMPONENTS	FEDERAL STOCK NO. OR IDENTITY	REQUIREMENT	USE & QUANTITY			PROCUREMENT BASIS		
				CHECKOUT & ASSY.	LAUNCH SITE	MISSION CONTROL	MAKE	BUY	SHARED USE
160	Environmental Control Console		Experiment Environmental Control	1			X		
161	Thermal Exchange Unit		Environmental Control	2			X		

EXPERIMENT PACKAGE: MECHANICAL

ITEM NO.	DESCRIPTION & MAJOR COMPONENTS	FEDERAL STOCK NO. OR IDENTITY	REQUIREMENT	CHECKOUT & ASSY.	LAUNCH SITE	MISSION CONTROL	MAKE	BUY	SHARED USE
162	Trailer Van		Validation & Transport of Exp. Pkg	1					X
163	Experiment Pkg. Work Stand		Hold/Position Experiment Module	1			X		
164	Platform Scales	Facilities Item	Weight and Balance of Experiment Package	2	2				X
165	Roll Over Stand		Weight and Balance of Experiment Package	1			X		
166	Hoist Sling		Hoist & Position Experiment Package	1			X		
167	Spacecraft Simulator		Systems Validation	1			X		

EXPERIMENT PACKAGE: ELECTRONIC, MISSION CONTROL

ITEM NO.	DESCRIPTION & MAJOR COMPONENTS	FEDERAL STOCK NO. OR IDENTITY	REQUIREMENT	CHECKOUT & ASSY.	LAUNCH SITE	MISSION CONTROL	MAKE	BUY	SHARED USE
168	Power Control Console		Hold Control Units	1			X		
169	Harness		Interconnect Equip.	1			X		
170	Power Supply	Christie	External Power	2					X
171	Blowers	Bud B-25	Console Cooling	2					X
172	Power Panel		Power Distribution	1			X		
173	Experiment Control Console		Hold Control Units	1		1	X		
174	Event Control Panel		Experiment Validation & Control	1		1	X		
175	Event Monitor Panel		Experiment Monitor	1		1	X		

TABLE 46. - DEVELOPMENT TEST OF BIORESEARCH MODULE FLIGHT HARDWARE

TEST NO.	*ITEM	TEST	NOTES
D-1	(2) Attitude Control Electronics	Electrical Performance	Breadboard. Demonstrate output response to sensor and command inputs.
D-2	(11) Data Processing Unit	Electrical Performance	Breadboard. Demonstrate output response to simulated data input.
D-3	(12) Louver Assembly, (15) Louver Control Actuator, (13) Dummy Cold Plate, Mechanical Linkage	Electrical and Mechanical Performance	Fabricate simplified version of Louver assembly, linkage and actuator attached to a flat plate. Demonstrate cycling of louvers in response to commands to a.c. stepping motor (actuator).
D-4	(16) Louver Control Electronics	Electrical Performance	Breadboard. Demonstrate output response to simulated thermistor inputs and to commanded set-point temperature inputs.
D-5	(14) Thermistor Assembly, (16) Louver Control Electronics	Thermal Vacuum and Electrical Performance.	Breadboard. Complements Test D-4. Demonstrate response of Louver Control Electronics to Thermistor inputs from plate alternately heated and cooled in thermal vacuum.
D-6	(20) Programmer-Clock	Electrical Performance	Breadboard. Demonstrate timing sequence and control pulses.
D-7	(30) Power Control Assembly	Electrical Performance	Breadboard. Simulate solar array, battery and power load. Demonstrate power distribution, voltage regulation, protection, and battery charging.
D-8	(28) Deployable Panels, (39) Yo-Yo Assembly	Structural and Mechanical	Mount (28) Deployable Panels and (39) Yo-Yo Assembly prototypes on simulated (35) Equipment Sections. Simulate mass of solar array on panels and roll moment of inertia of spacecraft. Using spin test fixture demonstrate despin by Yo-Yo, release and deployment of panels.
D-9	(13/41) Cold Plate	Materials and Processes	In surface of 12 in. x 12. in. x 0.35 in. beryllium plate machine 0.1 in. x 0.1 in. groove across center. Add 0.030 in. beryllium cover plate by diffusion bonding to form closed passage. Pump water through passage at 100 lb/hr to demonstrate no leak of bond. Apply coatings to surface to develop desired ϵ/α .

*Numbers in parentheses refer to items on drawings and in Table 43.

TABLE 47. - QUALIFICATION TESTS OF BIORESEARCH MODULE FLIGHT HARDWARE

TEST NO.	*ITEM	TEST	NOTES
Q-1	(13) Cold Plate with Louver Hinges	Leak Detection	Prototype assembly. Non-destructive test. Demonstrate no leak as CCl_4 is pumped through fluid passage and observed by X ray.
Q-2	(41) Cold Plate with Louver Hinges	Leak Detection	Prototype assembly. Non-destructive test. Same procedure as Test Q-1.
Q-3	(2) Attitude Control Electronics (11) Data Processing Unit (12) (13) (14) (15) (16) Thermal Control (20) Programmer Clock (29) Data Patch Unit (30) Power Control Assembly (32) Battery Assembly (33) Power Patch Unit	Electrical Performance	Prototype units or assemblies. Non-destructive tests. Demonstrate electrical performance in accordance with Section 4.3.7 of Test Specification (Appendix C of Reference 4).
Q-4	(28) (34) (35) (36) (37) plus dummy components to simulate total spacecraft mass and c.g.	Balance and Spin	Prototype assembly. Non-destructive test. Demonstrate balanced placement of components and determine balance weight requirements. Test in accordance with Sections 4.1.5 and 4.1.6 of Test Specification.
Q-5	(28) (34) (35) (36) (37) Prototype structure plus dummy components to simulate total spacecraft mass and c.g.	Physical Measurements	Non-destructive test in accordance with Section 4.1.7 of Test Specification.
Q-6	(2) Attitude Control Electronics (11) Data Processing Unit (16) Louver Control Electronics (20) Programmer-Clock (30) Power Control Assembly (32) Battery Assembly	Temperature and Humidity	Prototype unit. Test in accordance with Section 4.1.8 of Test Specification, but at component level.

*Numbers in parentheses refer to items on drawings and in Table 43.

TABLE 47. - QUALIFICATION TESTS OF BIORESEARCH MODULE FLIGHT HARDWARE (Continued)

TEST NO.	*ITEM	TEST	NOTES
Q-7	(28)(34)(35)(36)(37) Prototype Structure plus dummy components, some (31) Solar Cells and rest simulated, (12) Louver Assembly, (13) Cold Plate, Dummy Experiment Package	Vibration and Shock	In accordance with Sections 4.1.9 and 4.1.10 of Test Specification.
Q-8	Same as Q-7 but substitute (41) Cold Plate and (34) Structure and Dummy Experiment Package for Mission I(S) spacecraft.		
Q-9	(2) Attitude Control Electronics (11) Data Processing Unit (16) Louver Control Electronics (20) Programmer-Clock (24) Data Patch Unit (30) Power Control Assembly (32) Battery Assembly (33) Power Patch Unit	Vibration, Shock, Acceleration	Prototype components. Test in accordance with Sections 4.3.9 and 4.3.10 of Test Specification. Shock accounted for in vibration test. Components not suitable for flight following these tests.
Q-10	(28)(34)(35)(36)(37) Prototype Structure	Structural Verification	Prototype or "breadboard" structure. Include both versions of (34) Experiment Package Cover to account for standard and I(S) missions. Apply static loads to simulate 125% of critical design conditions. Apply load to failure for most critical condition.
Q-11	Prototype Spacecraft with (13) and (41) Cold Plates, Standard and Special Experiment Package Simulators	Thermal Vacuum	Test in accordance with Section 4.1.12 of Test Specification.
Q-12	(26) Turnstile Antenna (45)(46) Dipole Antenna	Antenna Pattern	Test antenna in accordance with Section 4.1.13 of Test Specification.

*Numbers in parentheses refer to items on drawings and in Table 43.

TABLE 48. - ACCEPTANCE TESTS OF BIORESEARCH MODULE FLIGHT HARDWARE

TEST NO.	*ITEM	TEST	NOTES
A-1	(3) N_2 Tanks (4) N_2 Regulator (5) Thrusters (6) Valves and Plumbing (13) Cold Plate (38) Fluid Umbilical (41) Cold Plate (42) Coolant Valves and Plumbing	Leak Detection	Test all flight components in accordance with Section 4.4.4 of Test Specification (Appendix C of Reference 4)
A-2	(2) Attitude Control Electronics (5) Thrusters (9) Sun Sensor (10) Rate Gyros (11) Data Processing Unit (14) Thermistor Assem. (15) Louver Control Actuator (16) Louver Control Electronics (18) Command Receiver (19) Command Decoder (20) Programmer-Clock (21) Signal Conditioner (22) PCM Encoder (23) Telemetry Transmitter (24) Data Storage Assembly (25) N_2 Pressure Transducer (27) Antenna Coupler (29) Data Patch Unit (30) Power Control Assembly (28, 31) Solar Panels (32) Battery Assembly (33) Power Patch Unit (38) Electrical Umbilical	Electrical Performance	Test all flight components in accordance with Section 4.4.5 of Test Specification
A-3	All Flight Components	Physical Measurements	Verify dimensions, connector configuration and orientation, surface condition, weight.
A-4	All Flight Subsystems Attitude Control Thermal Control Communications & Telemetry Electrical Power Structure	Subsystem Function	Verify functional performance of subsystem as installed in flight spacecraft .
A-5	Spacecraft Verification with Simulated Experiment Package	 Leak Detection Electrical Performance Initial Balance Physical Measurements Vibration Temperature Sensor Calibration Space Environment Radio Frequency Interference	Tests in accordance with following paragraphs of Test Specification: 4.2.2 4.2.3 4.2.4 4.2.5 4.2.7 4.2.8 4.2.9 4.2.13

*Numbers in parentheses refer to items on drawings and in Table 43.

G-2) Buy Items - Certify model and calibration, verify functional performance.

G-3) Shared Use - Verify modification status, calibration, functional performance.

Although verification of functional performance is the primary mode for qualifying and accepting AGE, further study and detail design may indicate some need for development and qualification of a particular AGE item, such as the items (160-175, Table 45) which support the experiment package. These items will be designed to criteria which tend to avoid testing beyond that cited in G-1 through G-3 above. Should further testing be desirable, especially in view of launches using the SSV in addition to Scout, the tests will be identified prior to the Preliminary Design Review (see Schedule, Figure 32).

4.5 SCHEDULE AND PROGRAM PLAN

Four Bioresearch Modules, each with differing experiment packages, are to be launched at one year intervals after approximately two and one-half years of design and fabrication of the first spacecraft, as noted in Figure 32. Planning of the development was approached to identify steps and philosophies that would insure:

(1) Maximum flexibility for the experimenter agencies.

(2) Complete integration with booster (Scout) operations.

(3) Minimum costs for airborne and ground hardware modification to accommodate each mission.

(4) Early and meaningful reviews of airborne and ground design requirements, criteria, and finally the data/results from system acceptance testing.

(5) Easy transitions from plant to launch site and back again for successive operations.

(6) Optimum spares and logistical support to ensure launch within reasonable funding goals.

(7) Reasonable and realistic funding requirements and early visibility of these requirements.

Program characteristics and intrinsic technical as well as managerial details were investigated and probed from several viewpoints as illustrated in Figure 33. On one hand, the program was assessed to determine its products (Contract Line Items), that is, those things that could be grouped to form the program's deliverable items. On another hand, the program content was assessed and structured into areas

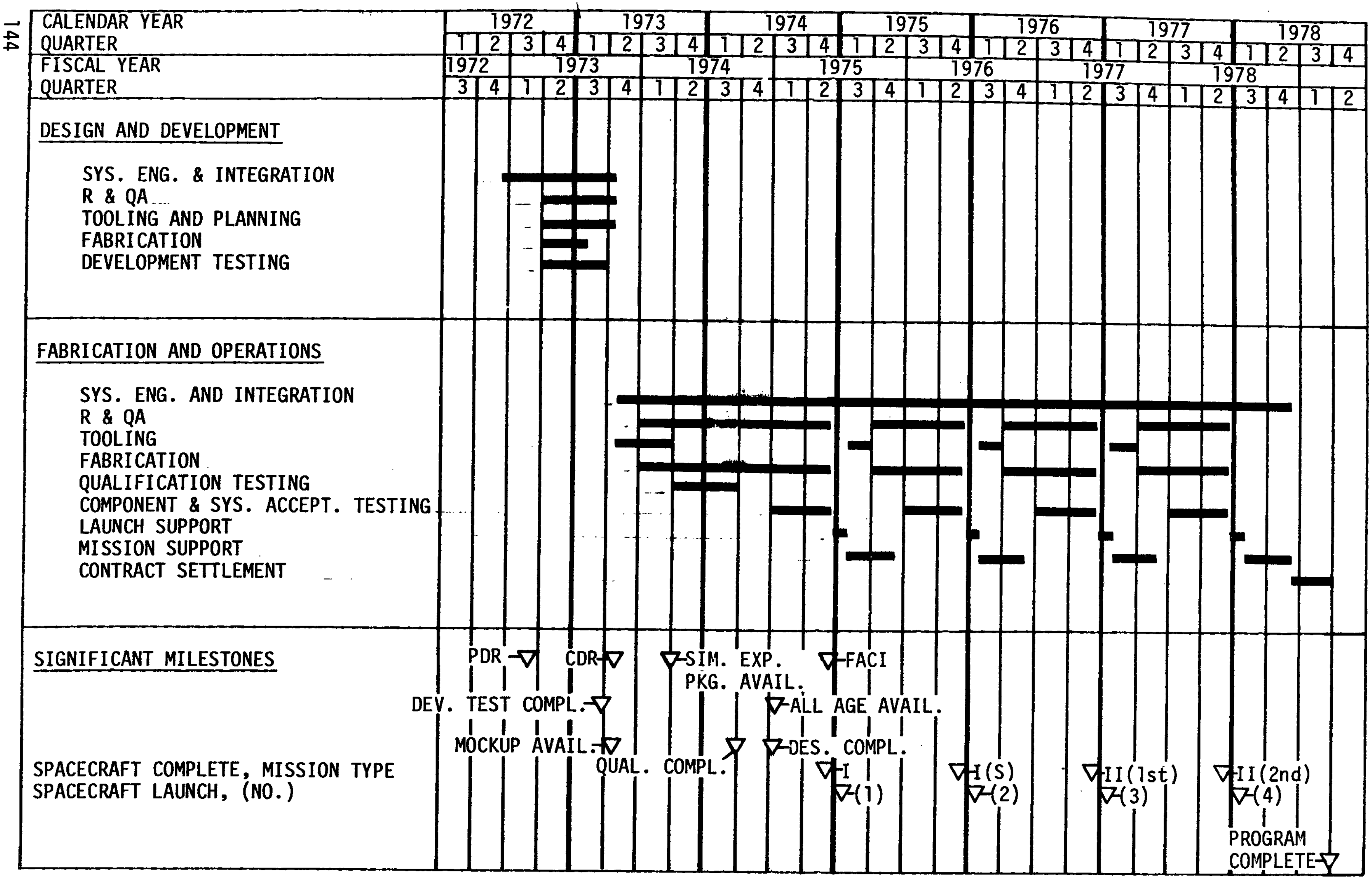


FIGURE 32. - BIORESEARCH MODULE PROGRAM SCHEDULE

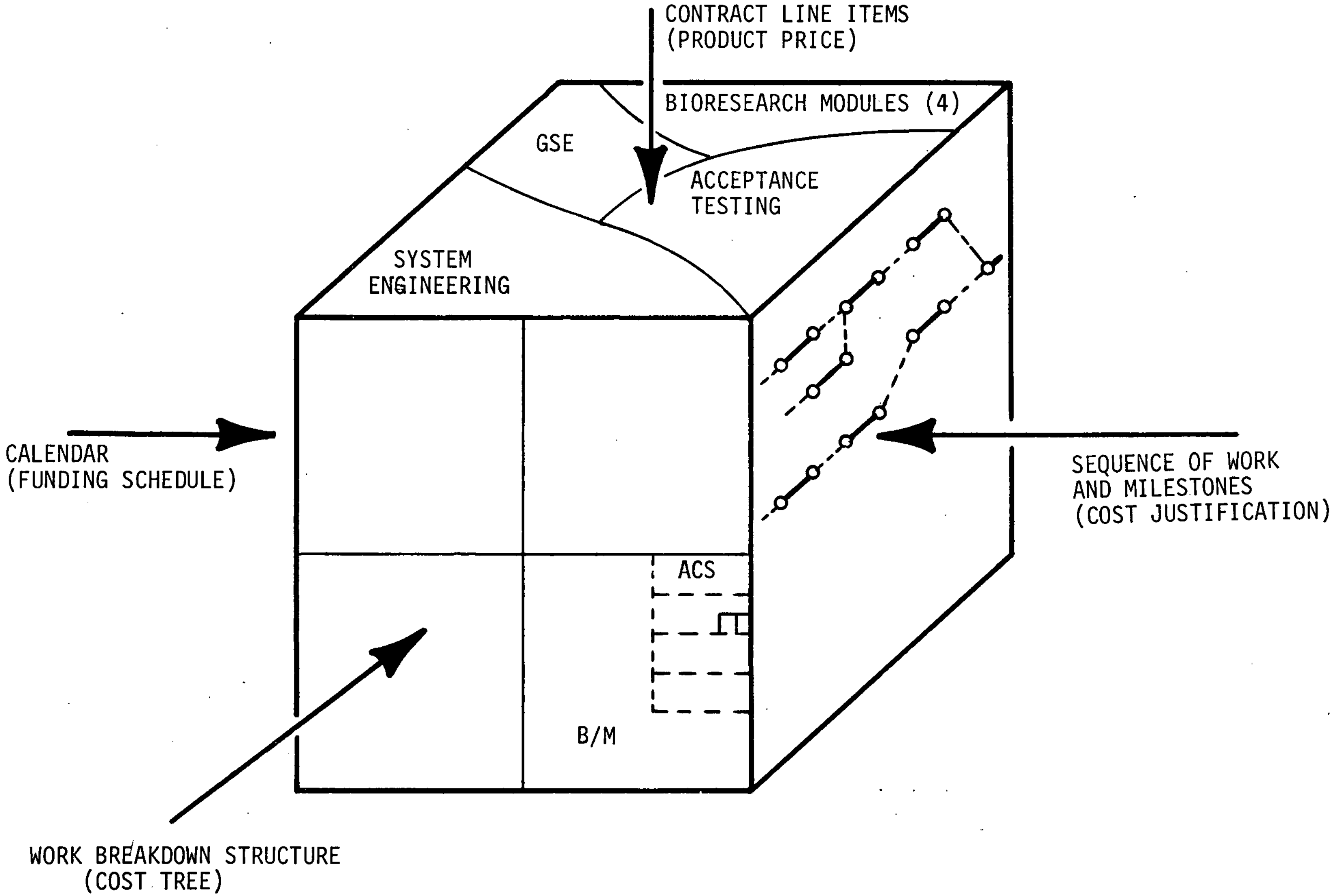


FIGURE 33. - PROGRAM PLANNING VIEWPOINTS

representative of hard/software, services, and integration (Work Breakdown Structure) necessary within the program. These areas were further penetrated along with the evolution of the detail design to uncover the work necessary to provide the design and thus perform the program and provide the deliverables.

Milestones/events vital to program success (Sequence of Work and Milestones) were also identified and placed in their general order of ocurrence. An overall Program Plan was then established to provide perspective of the flow of work, and the steps and philosophies to meet technical design requirements and furnish the program deliverables. Funding requirements were then derived (Calendar) by assessing the costs of work planned between/among milestones and depicting the total program in bar chart form (See Figure 32) to present the planned costs in relation to prescribed cost categories and also calendar time.

Appendix F contains the listing of potential deliverable Contract Line Items and brief descriptions of their content, the Work Breakdown Structure, the Program Plan depicting the flow of work, and a detailed calendar schedule for the accomplishment of program milestones depicted within the flow of work and vital to the program's success.

4.5.1 Significant Milestones. - The significant milestones shown on Figure 32 are summarized chronologically, as follows:

1 June 1972	Program Start
1 September 1972	Preliminary Design Review Complete
23 March 1973	Development Testing Complete
6 April 1973	Critical Design Review Complete
30 March 1973	Mockup Available
1 October 1973	Simulated Experiment Package Available
1 April 1974	Qualification Complete
18 July 1974	Design Complete
29 July 1974	All AGE Available
6 December 1974	First Article Configuration Inspection Complete
1 February 1975	First Launch (Mission I)
1 February 1976	Second Launch [Mission I(S)]
1 February 1977	Third Launch (First Mission II)
1 February 1978	Fourth Launch (Second Mission II)
29 September 1978	Program Complete

4.6 COSTS

Bioresearch Module program costs are provided under separate cover.

4.7 OPTIONS

Costs of Bioresearch Module options are provided under separate cover.

5.0 CONCLUSIONS

Conclusions are drawn in reference to the contractor tasks of Reference 5.

Task I-1

1. The Bioresearch Module spacecraft configurations for all missions have a high percentage of common hardware without compromise of specific experiment requirements.

2. The baseline spacecraft designs meet all requirements of the contract specification for standard experiments. In particular, the spacecraft/experiment interfaces are simple so that the experiment hardware can be developed independently of the spacecraft. The louvers and cold plate, proposed as the integral forward enclosure of the experiment package, will save system weight and facilitate continuous environmental control of the experiments from first assembly of the experiment package throughout the life of the mission.

3. The baseline VHF communications can be converted to S-band by substitution of appropriate components. Baseline power can handle either system.

4. The special mission I(S) spacecraft configuration, with smaller frontal area and reduced cold plate size, can provide adequate thermal control of the modified experiment heat loads.

5. Reduced experiment power and thermal requirements result in simplified spacecraft features. All solar cells can be body mounted, and aluminum can be substituted for beryllium in the cold plate.

6. An experiment television monitor can be added to the baseline spacecraft if one S-band downlink is substituted for a VHF downlink. Real time operation is preferred to on-board storage for delayed transmission to simplify on-board equipment. Television transmission must utilize MSFN ground stations due to broadband requirements.

Task I-2

7. The Mission II variable spin rate control system is stable when operated in conjunction with the nitrogen pulse-jet attitude control system.

Task I-3

8. Adequate end-of-life power margins are provided for all missions. The projected performance of the Bioresearch Module power system compares favorably with measured data from operational spacecraft.

Tasks II-1 and II-3

9. The higher SSV orbits (500 km/270 n.mi.) are adequate for direct deployment of Bioresearch Module Missions I and II. A velocity package is necessary to inject Mission III into its elliptic orbit. Mission I and II spacecraft deployed from 185 km (100 n.mi.) SSV orbits require Hohmann transfer to at least 500 km (270 n.mi.) circular orbits to assure six month life.

Task II-2

10. On-orbit servicing from the SSV is technically feasible but probably not desirable except for replacement of the total spacecraft.

Task II-4

11. Bioresearch Module designed to exploit SSV payload capabilities can offer more experiment support (size, weight, power, thermal control) but loses commonality with Scout-launched spacecraft.

Task II-5

12. The Bioresearch Module will not impose undue restraints and requirements on an SSV which is equipped to handle small payloads.

Task II-6

13. Chief impact of the biological payload on SSV operations is late installation of the experiment package at the launch pad.

Task II-7

14. Cost savings and test program reductions offered by use of the SSV can be realized only by a spacecraft which is SSV-dedicated.

Task II-8

15. The baseline spacecraft are compatible with both the Scout and the Space Shuttle Vehicles. Additional hardware is required for SSV launches.

REFERENCES

1. "Study for Development of a Preliminary Design for a Bioexplorer Spacecraft", NASA Contract No. NAS2-6028 dated 29 June 1970, and Amendment/Modification No. 1 dated 28 August 1970.

2. LTV/VMSC Report No. 00.1348, "Bioexplorer First Design Review," 13, 14 August 1970.

3. LTV/VMSC Report No. 00.1362, "Bioexplorer Second Design Review," 13, 14 October 1970.

4. LTV/VMSC Report No. T146-1 "Bioexplorer Spacecraft Preliminary Design Study," Vol. I - Basic Report, Vol. II - Appendices, 29 November 1970.

5. "Bioresearch Module Design Definition and Space Shuttle Vehicle Integration Study," NASA Contract No. NAS2-6524 dated 4 June 1971.

6. "Modified Experiment Support Requirements to be Evaluated Under Task I-1," Enclosure (1) to NASA/Ames letter PEF: 204-5 (80L) dated 11 June 1971.

7. "Space Shuttle Vehicle Data Package," provided by NASA/Ames during May 1971 meeting at LTV/VMSC, Dallas, Texas. Data listed in Enclosure (2) to NASA/Ames letter PEF: 204-5 (80L) dated 11 June 1971.

8. "Contract NAS2-6524, Guidelines for Preparing Cost Analyses required under Tasks I-2, II-7 and II-8," NASA/Ames letter PEF: 204-5 (170L) dated 3 September 1971.

9. LTV/VMSC Report No. T146-2, "Bioresearch Module First Design Review," 26, 27 August 1971.

10. LTV/VMSC Report No. T146-3, "Bioresearch Module Second Design Review," 5 November 1971.

11. NASA SP-8016, "Effects of Structural Flexibility on Spacecraft Control Systems," April 1969.

12. Grasshoff, L. H., "An Onboard, Closed-Loop, Nutation Control System for a Spin-Stabilized Spacecraft," J. Spacecraft Rockets, Vol. 5, No. 5, May 1968, pp 530-535.

13. Billik, B., "The Lifetime of an Earth Satellite," Aerospace Corporation Report No. TN-594-1105-1, 14 December 1960.

14. "Maintainability Engineering Handbook," NAVORD OD39223, 15 June 1969.

15. "Space Shuttle Users Guide," Unofficial copy, 21 June 1971.

16. LTV/VMSC Report, "Scout User's Manual," 1 July 1970.

17. Jones, James C., "Neuter Docking - Mechanism Study," NASA Manned Spacecraft Center, Houston, Texas, paper presented at the Sixth Aerospace Mechanisms Symposium held at NASA Ames Research Center 9, 10 September 1971.

SUMMARY

(To be used in preparation of Library-Card Abstract)

Preliminary designs of the Bioexplorer spacecraft, developed in an earlier study program, are analyzed and updated to conform to a new specification which includes use of both the Scout and the Space Shuttle Vehicle for launch. The new spacecraft design, referred to as Bioresearch Module, is capable of supporting a variety of small biological experiments in near-earth and highly elliptical earth orbits. Inboard profile drawings, weight statements, interface drawings, and equipment lists are provided to document the design. Considerable study is devoted to use of the Space Shuttle Vehicle for launch and retrieval. It is shown that the Bioresearch Module spacecraft is compatible with both Scout and the Space Shuttle Vehicle, but that the latter requires additional on-board hardware for launch support. A development plan is included to provide data for planning subsequent phases of the Bioresearch Module program.