AEROSPACE REPORT NO.
ATR-74(7341)-3, ADD.

Operations Analysis (Study 2.1)

Payload Designs for Space Servicing
Addendum

DRA

Prepared by
ADVANCED MISSION ANALYSIS DIRECTORATE
Advanced Orbital Systems Division

30 September 1974

(NASA-CR-140897) OPERATIONS ANALYSIS (STUDY 2.1). PAYLOAD DESIGNS FOR SPACE SERVICING, ADDENDUM (Aerospace Corp., El Segundo, Calif.) 88 p HC $4.75 CSCL 22B
N75-14823
Unclas
G3/18 17550

Prepared for

OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546

Contract No. NASW-2575

Systems Engineering Operations

THE AEROSPACE CORPORATION

Aerospace Report No.
ATR-74(7341)-3, Add.

OPERATIONS ANALYSIS (STUDY 2.1)

Payload Designs for Space Servicing

Addendum

Prepared by

Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

30 September 1974

Systems Engineering Operations
THE AEROSPACE CORPORATION
El Segundo, Calif. 90245

Prepared for

OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C. 20546

Contract No. NASW-2575

Report No.
ATR-74(7341)-3, Add.

OPERATIONS ANALYSIS (STUDY 2.1)

Payload Designs for Space Servicing

Addendum

Prepared

R. R. Wolfe

R. R. Wolfe
NASA Study 2.1 Director
Advanced Mission Analysis
Directorate

Approved

R. H. Herndon

R. H. Herndon, Group Director
Advanced Mission Analysis
Directorate
Advanced Orbital Systems Division

FOREWORD

The Aerospace Corporation Technical Report, Payload Designs for Space Servicing, ATR-74(7341)-3 was issued 30 June 1974. That report provided a set of reference data for use in performing trade studies for space servicing of automated payloads. The candidate payloads were extracted from the October 1973 NASA Mission Model. Forty-two different payload programs out of 95 in the mission model were selected as candidates for space servicing. A set of standard space replaceable units (SRUs) were developed and used to recompose the payload designs, keeping in mind the overall subsystem performance requirements.

That report serves as the parent document for this addendum. Since issuing the original ATR, the SRU and payload configurations have been revised to reflect increased levels of redundancy to be more consistent with current design practices. In addition, a reassessment of expendable payload design reliabilities has been performed to provide a common basis for comparison with space serviceable configurations. This new data provides the foundation of trade studies to be performed under this contract which will be documented in the final report.

While developing this addendum, several typographical errors were observed in the parent report, ATR-74(7341)-3. An errata has been prepared and is enclosed in this addendum as an appendix. Copy holders of the parent report should incorporate these corrections.

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 BACKGROUND

The original volume, to which this addendum applies, was intended as the first step in an evaluation process of arriving at representative space serviceable payload designs. That volume served to categorize all subsystem performance requirements for a set of 42 different payload programs identified in the October 1973 NASA reference Mission Model. The subsystems and mission equipment components were modularized into space replaceable units (SRUs) and placed within a non-replaceable framework (NRU) to arrive at space serviceable configurations. Due to the vagueness of the reference mission model payload definitions, the first design efforts were restricted to a minimum of redundant components, as described in the parent report. This addendum provides the next iteration of those designs described in the parent document. Levels of redundancy, consistent with current design practices, have been incorporated; therefore, being more representative of actual payload designs. In addition, to provide a valid basis of comparison, it was necessary to estimate the reliability and levels of redundancy for expendable payload designs, since no information is provided in the reference mission model. The revised data can then be used as a basis of trade studies on space servicing. The results of this iteration, for both expendable and space serviceable payload designs, are provided in this addendum.

This is the only effort observed which provides space serviceable design data on such a broad scale. As improved information is developed, it is to be expected that further revisions will be required. However, the mission model is primarily a projection of the future levels of activity, rather than an attempt to dictate an absolute schedule for any given program. Within this context, the data contained in this addendum provides representative payload configurations suitable for trade studies which may be sensitive to specific payload programs in particular or the total mission model, in general.

The basic data provided in the parent report is still valid, and therefore, is not repeated in this addendum. In general, subsystem requirements and mission equipment definitions remain unchanged, along with subsystem component weights and reliabilities. The manner in which the components are assembled into SRUs is changed for a large number of items, and consequently, the SRU weights and reliability estimates have been revised. In addition, several typographical errors have been observed in the parent report. The necessary changes required to correct these errors are provided in the Appendix of this report.

A further aid for traceability from the parent report to the new data of this addendum is provided in Table 1-1. As shown, all the basic requirements, component characteristics, and mission model definitions remain unchanged. The composition of SRUs has changed substantially, as well as the manner in which the SRUs are combined to achieve a given payload configuration. If a third iteration is desired, it is necessary to refer to the parent report for payload requirements and suitable component data. New SRUs can be developed based upon new ground rules by following the approach presented in this addendum.

Table 1-1. Data Traceability

DATA TABLES PARENT REPORT			DATA TABLES ADDENDUM	
TABLE	ITEM	NO CHANGE	PARTIAL REV	COMPLETE REV
1-1	Subsystem Definitions	X		
2-1	1973 Mission Model	X		
2-2	Sortie Traffic	X		
3-1	Revised Mission Model	X		
4-1	Att. Control Design Par.	X		
4-2	G&N Design Parameters	X		
4-3	AVCS - SRUs		Table 3-1	
4-4	G&N - SRUs	X		
5-1	TT&C Design Assump.	X		
5-2	TT&C Requirements	X		
5-3	Transmitter Power Req.	X		
5-4	Link Calculations	X		
5-5	Trans. Power Req. - H. A. S.	X		
5-6	Trans. Power Req. - L. A. S.	X		
5-7	TT&C Equip. Req.	X		
5-8	Operational COM SATS	X		
5-9	High Alt. Sat.	X		
5-10	Low Alt. Sat.	X		
5-11	TT&C Configuration	X		
5-12	TT&C - SRUs			Table 3-2
6-1	Data Processing Par.	X		
6-2	Data Processing - SRU			Table 3-2
7-1	Power Requirements	X		
7-2	Power Storage Req.	X		
7-3	Power System Summary	X		
7-4	Elect. Power Syst. - SRUs		Table 3-3	
8-1	Mission Equip. - SRUs		Table 4-1	
8-2	Mission Equip. Reliability	X		
9-1	Non-Replaceable Modules	X		
10-1	Auto Service Techniques	X		
10-2	Satellite Module Assign.			Fig. 4-1
10-3	SRU Inventory Req.			Fig. 4-1
11-1	Service Unit Req.		Fig. 4-1	

1.2 OBJECTIVES

The data developed in this addendum is intended for use in future trade studies related to space servicing operational concepts. To provide a valid basis of comparison, it is necessary that a consistent set of data be provided for both space serviceable and expendable payload design concepts. For instance, objectivity would be lost if various levels of redundancy were afforded one concept and not the other. At the same time, there should be traceability to the reference mission model to demonstrate similar logistic traffic patterns such that realistic fleet sizing constraints can be represented. However, the NASA reference mission model fails to specify reliability data for expendable payload designs, although a deployment schedule is provided, which, in effect, alludes to the expected design life of each payload. It is, therefore, desirable that space serviceable design concepts be related to the original expendable designs which can then be related to the traffic projections of the reference mission model.

The objectives of this addendum are, therefore, as follows:

1. Provide a reference data base of expendable payload design reliabilities consistent with current design practices and correlated with the reference NASA Mission Model.
2. Provide a new data base for space serviceable payload concepts using the data of the parent report, but reconfigured to obtain a system reliability reasonably consistent with the expendable design concept. This reconfiguration will include the accountability of additional weights and volumes consistent with the increased redundancy of components.

2. STUDY APPROACH

Before meaningful tradeoffs can be performed, it is necessary to develop reliability estimates for both payload design concepts: expendable and space serviceable. These two efforts were performed in parallel and the results are presented in Section 5, which compares the relative reliability values for each payload of interest. Further iterations could be performed to improve the reliability of either design concept; however, until trade offs can be performed, there is no indication that improved reliability is warranted. Therefore, the following section provides the background employed in arriving at the reliability and weight values associated with each SRU and with the reconfigured payloads as a whole. This process can be repeated using the basic data of its parent report if further iterations are necessary.

2.1 EXPENDABLE PAYLOAD RELIABILITIES

Consistency is particularly important for future trade studies because the reliability of current payload designs spans a wide range of values. Commercial communication satellites have, in general, a high reliability on the order of 70% at a design life of five to seven years. Other satellites, with complex sensors may be as low as 20% reliable with a design life of three years. In some cases, the reliability of future payloads can be expected to improve over previous designs due to redundancy or improvement in the state-of-the-art. However, there will still be complex developmental sensors which will inherently have a relatively low, undefined reliability. Therefore, projecting future payload reliabilities becomes one of engineering judgment such that a baseline of comparison can be established for trade offs of space servicing concepts versus current expendable operations.

The approach selected for estimating the reliability of expendable payload designs is directed at obtaining realistic values consistent with the same level of technology employed for comparable space serviceable designs. At the same time, consistency with the reference mission model traffic is also desired to provide a realistic demand upon logistic fleet operations.

Those payloads identified as candidates for space servicing are addressed first. It is important that consistency between these two configurations be achieved; otherwise, no comparison would be valid. The space serviceable design concept was derived first as described in Section 4. This includes a "bottoms up" approach starting with components to achieve SRUs and arranging the SRUs within an NRU to arrive at a final configuration. This final configuration has specific characteristics in terms of SRU reliability, levels of redundancy and system weight. To be consistent, the expendable design counterpart to the serviceable configuration assumes the same reliability characteristics, including specified levels of redundancy. However, the overall weight estimate of the expendable design is taken from the referenced October 1973 NASA mission model. The philosophy being, whatever can be achieved in the space serviceable design, can certainly be accomplished with an expendable design approach at a lower weight. In fact, it may be possible to achieve a slight improvement in reliability of expendable designs because three axis stabilization is not necessarily required as with space servicing. However, there is no way to establish this effect with any degree of certainty, and, in addition, it is felt to be a second order effect. Consequently, it is neglected for the time being.

This approach, therefore, provides consistency between the two design concepts: expendable versus space serviceable. If a component failure occurs randomly with one, it should also occur with the other. If a redundant component is available for backup in one, it is available for the other. Consequently, the failure characteristics are identical; only the weight is changed. Therefore, a consistent basis for trade offs of space servicing operations is established; however, the traffic rate must also be considered as will be discussed later.

It is also necessary to consider those payloads which are not space serviceable candidates. The traffic required for deployment must be considered because it could impact upon the availability of the shuttle or upper stage for servicing operations. In this event, it was necessary to estimate the payload design life and reliability based upon experience from past programs. This becomes an exercise in judgment but fortunately the logistics traffic for expendable designs is not overly sensitive to the specified reliability value. On a statistical basis, such as will be employed for trade offs, any variation of a single payload tends to be averaged over the entire model with little effect on the final results.

The final step in this process is to compare the expected traffic developed with the reliability estimates as provided in Section 5, with the traffic of the reference mission model. The LOVES Computer Simulation Program was employed for this comparison. The reliability of the expendable payload designs is specified in terms of Weibull parameters, as explained in the parent document. The simulation program then provides a statistical average over a series of Monte Carlo operations of the Shuttle and Upper Stage traffic required to deploy the list of payloads. It is not possible to duplicate the reference mission model exactly because the specified deployment schedules are not directly relatable to payload reliability values.

However, the results shown in Table 2-1, show the estimated reliability characteristics to be valid for trade off purposes because of the close proximity of traffic generated by the simulation program to that of the reference mission model. The values shown are the number of payloads deployed over an eleven year period, 1980 through 1990, for various orbit categories. In general, the overall traffic pattern is close to the mission model although inconsistencies are seen for individual orbits. However, these results are considered to be sufficiently close for the purposes required here, verifying that a valid basis for subsequent trade offs has been established. A further comparison is provided in Section 5 where the characteristics of each payload are compared on an individual basis.

Table 2-1. Number of Payloads Deployed

Orbits	Ref Model (Deterministic)	Statistical Sim. (Random Failures)
Geosynchronous Orbit	108	99
Polar Orbit	71	60
Low Earth Orbit	67	71
Planetary	33	34
Other	18	27
TOTAL	297	291

Although the approach used in establishing reliability values for expendable designs provides a reasonable comparison with the reference model, this does not necessarily imply accuracy in the reliability estimates. It provides a rational basis for subsequent trade offs only because it may be related to the reference mission model. In fact, the reliability values in certain cases appear low based upon experience within The Aerospace Corporation. Altering the estimated reliabilities would, however, create a disparity between the base line statistical case and the reference mission model, thereby making it difficult to relate future trade offs with previous study efforts. It is recognized that future payload programs should experience an improvement in reliability and also that traffic patterns may vary considerably from the reference model. Therefore, trade studies employing this data will also consider reliability improvements and traffic model variations before establishing any position relative to future operational concepts.

2.2 SPACE SERVICEABLE PAYLOAD RELIABILITIES

Several factors were considered when altering the basic SRU configurations of the parent report to obtain a reliability improvement. Perhaps the most important point was consideration of current practice in similar payload designs. This is the basic rule employed, rather than attempting an optimization to some arbitrary criteria. Further, it was also necessary to consider how the SRU would be employed in the reconfiguration of each space serviceable payload. For example, in general, four hydrozene reaction control SRUs (AVCS-7) are employed in each payload design. This provides an inherent redundancy in that any two of the four could provide attitude control for an extensive period of time. In addition, many of the payloads require a reaction wheel system for precise, continuous control. In this case, it is possible to provide redundancy with only one reaction jet control SRU, although four may be provided in the design. Although further improvements could obviously be employed, it should be remembered that the intent is to provide representative design concepts rather than optimized payload designs. At this point in time, it is not obvious what criteria should be employed for the optimization process. The only trade offs relate, in the broad application, to space servicing versus expendable ground refurbished payload design concepts.

Except where mentioned above, redundancy is achieved by adding components within a given SRU. For the most part, these are electronic components, it being somewhat impractical to add mechanical systems. For example, on the AVCS-1 (reaction wheel SRU), the resolver pickoff has been made redundant. This is common practice, and the weight penalty is trivial. However, since the resolver electronics represents the most likely item to fail, this simple addition has a significant influence on the overall SRU reliability.

One further comment is necessary before addressing the detail SRU designs. A further assessment of the potential failure paths of the telemetry and data processing SRUs has resulted in placing the data processing components in the TT&C SRUs. By this technique, it can be established that no single failure will prevent ground command signals to the receiver/decoder from being sent to a particular SRU. This capability is required to allow commands to reconfigure the payload for the space servicing maneuver. Signals would be issued from the TT&C SRU on redundant data buses. Therefore, although the weight of the TT&C SRUs is increased, the Data Processing SRU (DP-1) is eliminated altogether. Consequently, each payload will require one less SRU than shown in the parent document.

3. SPACE REPLACEABLE UNIT (SRU) REDUNDANCY

The revised subsystem SRUs are provided in this section. The basic component weight and reliability is unchanged from the parent report except as noted in the errata sheets of the Appendix.

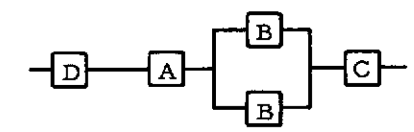
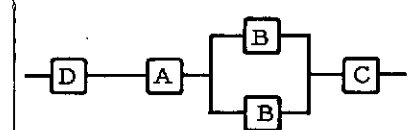
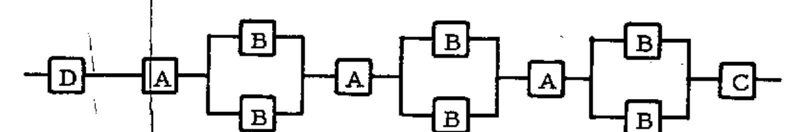
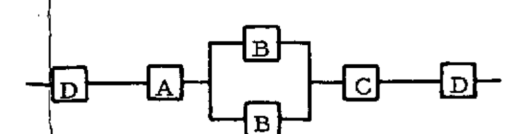
In general, wherever possible, standby (non-active) redundancy was employed as a means of improving SRU reliability. However, there are certain instances where active redundancy is required and the reliability estimates reflect this. Failure rates of standby elements have been assumed to be ten percent of the active element failure rate. The presentation format is similar to that employed in the parent document.

3.1 ATTITUDE AND VELOCITY CONTROL (AVCS)

The revised SRU definitions for the AVCS system are provided in Table 3-1. For those SRUs employing reaction wheels, it is possible to provide redundant wheel electronics. This includes resolver pick offs, torquers and tachometer pick offs operating in parallel. Therefore, active redundancy is assumed. Although redundant power supplies could also be employed, it does not appear to be significant. For AVCS-3, the three reaction wheels are considered to be in series, although alternate approaches using two reaction wheels could be employed to provide redundancy by resolving the momentum vectors. It should be recognized that the reliability at a design life of 10 years has typically been increased from 0.5 to 0.7. The SRU weight is increased by approximately 2 kg (5%).

The diagram for AVCS-5 through AVCS-6A indicates a different type of redundancy for the sun aspect sensor. In one axis, two of three sensors are required while in another axis, one of two is required. The added components were not selected on the basis of reliability but are required from a performance standpoint. Typical spacecraft designs result in at least one sun sensor in one axis being occluded for some portion of time. Therefore, an alternate location is required to provide continuous coverage. Since these are also lightweight items, many spacecraft have

Table 3-1. Standardized Subsystem Modules - Attitude and Velocity Control System (Revised)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
AVCS-1	Reaction Wheel (5 ft-lb-sec)	A	Reaction Wheel	1	4.5	4.5	700	10	0.718	26.16	1.224	
		B	Wheel Electronics	2	1.4	2.8	6000					
		C	Remote Terminal	1	2.0	2.0	500					
		D	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			40.3						
AVCS-2	Reaction Wheel (10 ft-lb-sec)	A	Reaction Wheel	1	8.2	8.2	700	10	0.718	26.16	1.224	
		B	Wheel Electronics	2	1.4	2.8	6000					
		C	Remote Terminal	1	2.0	2.0	500					
		D	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			44.0						
AVCS-3	Reaction Wheel (10 ft-lb-sec/ wheel)	A	Reaction Wheel	3	24.5	73.5	700	7	0.613	13.18	1.270	
		B	Wheel Electronics	6	2.7	16.2	6000					
		C	Remote Terminal	1	2.0	2.0	500					
		D	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			122.7						
AVCS-4	Control Moment Gyro (Double Gimbal) (500 ft-lb-sec)	A	CMG Wheel	1	68.0	68.0	700	2	0.944	30.24	1.063	
		B	Wheel Electronics	2	4.5	9.0	6000					
		C	Torquer, Damper and Resolver	2	4.5	4.0	1000					
		D	Remote Terminal	1	2.0	2.0	500					
		E	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			119.0						

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 3-1. Standardized Subsystem Modules - Attitude and Velocity Control System (Revised) (Continued)

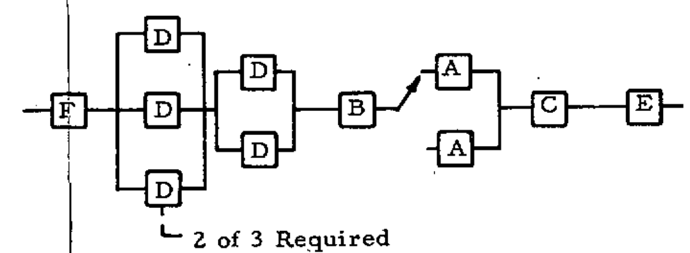
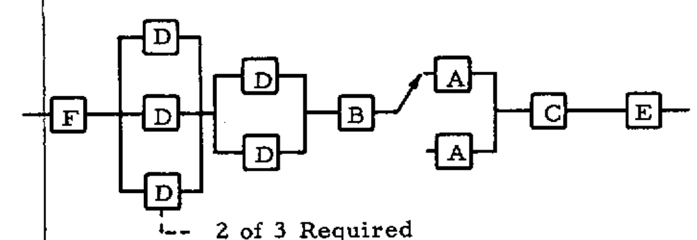
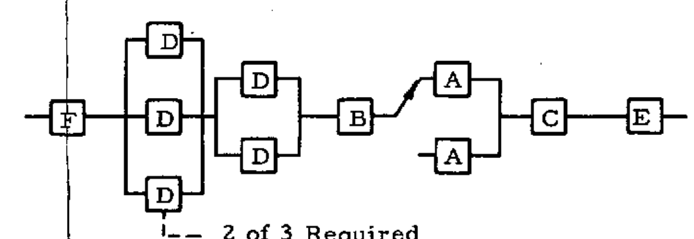
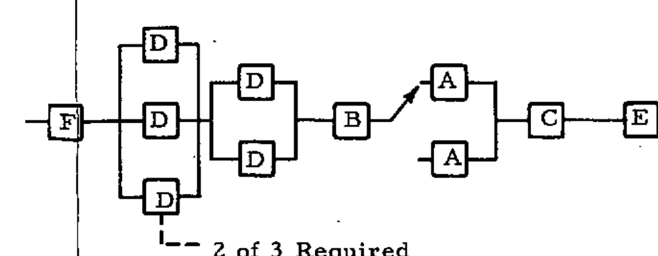
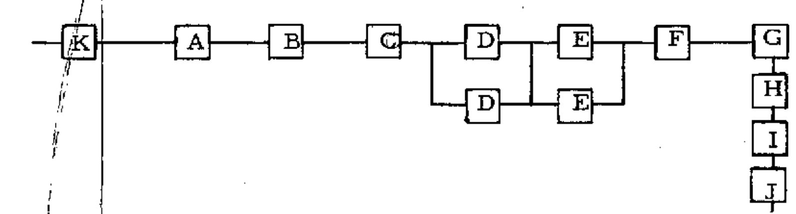
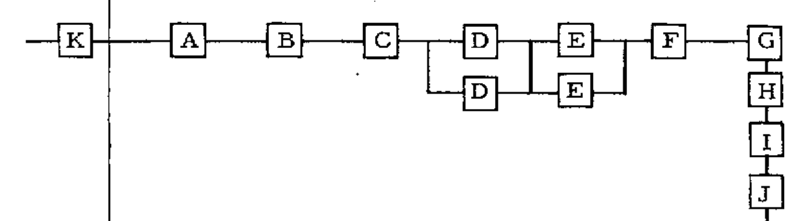
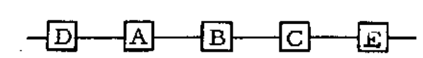
MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
AVCS-5	Sensing	A	Auxiliary Electronics Assembly (AEA)	2	4.5	9.0	6500	10	0.553	16.86	1.069	
		B	Rate Gyro Package	1	1.4	1.4	1000	(Based on	intermittent use)			
		C	High Altitude Horizon Sensor	1	5.5	5.5	3000					
		D	Sun Aspect Sensor	5	2.3	11.5	100					
		E	Remote Terminal	1	2.0	2.0	500					
		F	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			60.4						
AVCS-5A	Sensing	A	Auxiliary Electronics Assembly (AEA)	2	4.5	9.0	6500	7	0.675	17.43	1.056	
		B	Rate Gyro Package	1	1.4	1.4	1000	(Based on	intermitten use)			
		C	Low Altitude Horizon Sensor	1	5.5	5.5	3000					
		D	Sun Aspect Sensor	5	2.3	11.5	100					
		E	Remote Terminal	1	2.0		500					
		F	Power Conditioning	1	2.0		500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			60.4						
AVCS-6	Sensing	A	Auxiliary Electronics Assembly (AEA)	2	4.5	9.0	6500	7	0.528	10.00	1.033	
		B	Gimballed Star Tracker	1	18.1	18.1	5000					
		C	High Altitude Horizon Sensor	1	5.4	5.4	3000					
		D	Sun Sensor	5	2.3	11.5	100					
		E	Remote Terminal	1	2.0	2.0	500					
		F	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			77.0						
AVCS-6A	Sensing	A	Auxiliary Electronics Assembly (AEA)	2	4.5	9.0	6500	3	0.772	11.43	1.018	
		B	Gimballed Star Tracker	1	18.1	18.1	5000					
		C	Low Altitude Horizon Sensor	1	5.4	5.4	3000					
		D	Sun Sensor	5	2.3	11.5	100					
		E	Remote Terminal	1	2.0	2.0	500					
		F	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			77.0						

Table 3-1. Standardized Subsystem Modules - Attitude and Velocity Control System (Revised) (Continued)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
AVCS-7	Hot Gas Propulsion (N_2H_4) Small Tank	A	Nitrogen Tank (7.5-in OD)	1	2.3	2.3	1500	7	.618	14.35	1.021	
		B	Start Valve	1	0.5	0.5	100					
		C	Regulator Valve	1	1.8	1.8	100					
		D	Temperature Tranducer	2	0.05	0.1	2000					
		E	Pressure Transducer	2	0.05	0.1	2000					
		F	Hydrazine Tank (15-in OD)	1	4.0	4.0	1500					
		G	Latching Valves	2	0.5	1.0	200					
		H	Thruster (0.1 lb)	4	0.9	3.0	1000					
		I	Thruster (5.0 lb)	3	1.4	4.2	2000					
		J	Remote Terminal	1	2.0	2.0	500					
		K	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			50.6						
AVCS-8	Hot Gas Propulsion (N_2H_4) Large Tank	A	Nitrogen Tank (7.5-in OD)	1	2.3	2.3	1500	7	.618	14.35	1.021	
		B	Start Valve	1	0.5	0.5	100					
		C	Regulator Valve	1	1.8	1.8	100					
		D	Temperature Tranducer	2	0.05	0.1	2000					
		E	Pressure Transducer	2	0.05	0.1	2000					
		F	Hydrazine Tank (24-in OD)	1	11.0	11.0	1500					
		G	Latching Valves	2	0.5	1.0	200					
		H	Thruster (0.1 lb)	4	0.9	3.6	1000					
		I	Thruster (5.0 lb)	3	1.4	4.2	2000					
		J	Remote Terminal	1	2.0	2.0	500					
		K	Power Conditioning	1	2.0	2.0	500					
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			57.6						
AVCS-9	Magnetic Torquer	A	Magnetometer (3 Axis)	1	3.2	3.2	200	7	.832	38.05	1.0	
		B	Amplifier	1	1.4	1.4	1600					
		C	Coil	3	4.6	13.7	200					
		D	Power Conditioning	1	2.0	2.0	500					
		E	Remote Terminal	1	2.0	2.0						
			Cabling	AR	5.0	5.0						
			Connectors	AR	2.0	2.0						
			Environmental Protection	AR	5.0	5.0						
			Structure	AR	17.0	17.0						
			TOTAL			51.3						

FOLDOUT FRAME

FOLDOUT FRAME

multiple redundant sensors. All the sensor information is input to the auxiliary electronics assembly (AEA) which performs the autopilot and sequencing functions. Standby redundant AEAs have been employed. Redundant rate gyros and horizon scanners could also be employed but for this iteration were left as single string units. The estimated reliability has in general been increased from 0.3 to 0.5 at seven years.

The remaining AVCS modules were unchanged from that presented in the parent report and are included here for completeness only. The guidance and navigation (G&N) SRUs also remain unchanged as provided in Table 4-4 of the parent document. It is important to note, however, that these two SRUs (GN-1, GN-2) have relatively high failure rates and may require redundant elements at a later date.

3.2 TELEMETRY, TRACKING AND COMMAND (TTC)

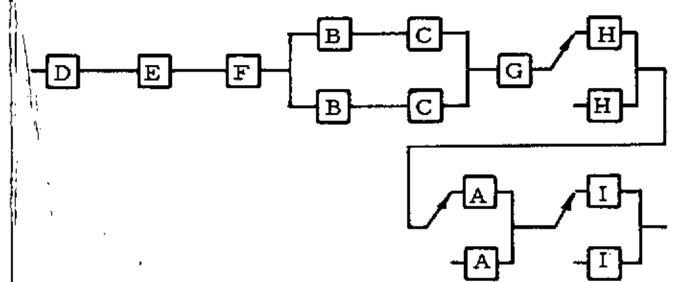
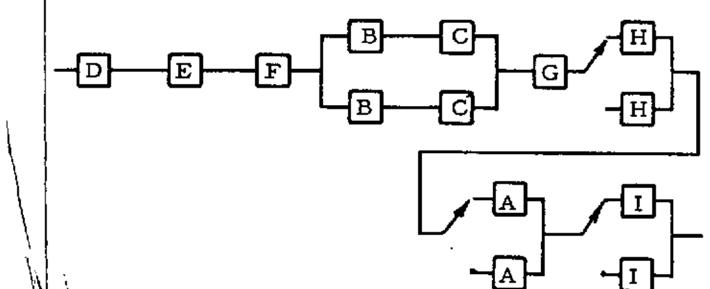
These SRUs received the major changes from those of the parent report. Standard practice dictates redundant receivers, transmitters, and other associated equipment. Both active and standby redundancy are employed. Active redundancy is required in the receiver/decoders to assure that a command capability into the payload systems always exists. Baseband assemblies and transmitters are also redundant, but in a standby mode only. These elements can be switched in by command through the receivers. The SRU descriptions are provided in Table 3-2.

In addition, the data processing SRU described previously in the parent document has been incorporated into the TTC modules. The basic elements are unchanged but redundant paths have been provided to assure that no single failure precludes a command link to other SRUs. Standby redundancy is assumed. The overall weight growth is approximately 30 kg per SRU configuration.

The first three TTC SRUs employ a single horn antenna, dual receivers, and redundant transmitters. The next three TTC SRUs require an omni and a dish antenna and two different transmitters are required, each redundant. There is the additional complication of a tape recorder for post

Table 3-2

Standardized Subsystem Modules - Telemetry, Tracking and Command (Revised)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY (3)	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
TTC-1	Telemetry, Tracking & Command	A	Transmitter (C-band, 0.1 W)	2	2	4	3000	10	0.663	19.21	1.485	
		B	Receiver (C-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Horn Antenna (C-band)	1	2	2	40					
		E	Diplexer	1	1	1	150					
		F	Hybrid	1	1	1	50					
		G	Power Conditioning	1	2	2	500					
		H	Baseband Assembly	2	1	2	1500					
		I	Data Processing Units(4)	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			80.2						
TTC-2	Telemetry, Tracking & Command	A	Transmitter (Ku-band 0.1 W)	2	2	4	3000	7	0.793	20.54	1.449	
		B	Receiver (Ku-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Horn Antenna (Ku-band)	1	2	2	40					
		E	Diplexer	1	1	1	150					
		F	Hybrid	1	1	1	50					
		G	Power Conditioning	1	2	2	500					
		H	Baseband Assembly	2	1	2	1500					
		I	Data Processing Units	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			80.2						

Notes: (1) Recorder #1 = Off-the-shelf (1 Mbit/sec)
(2) Recorder #2 = High technology (10 Mbit/sec)
(3) AR = As required
(4) Data Processing unit common to all TTC units consists of:

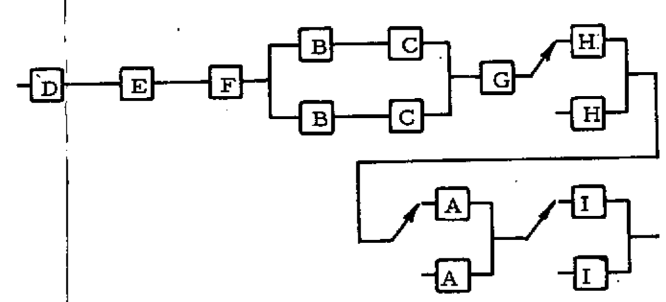
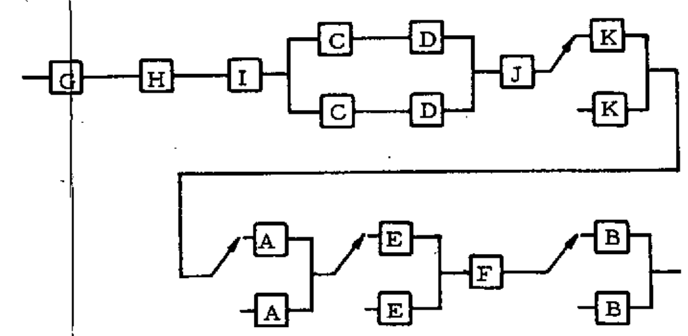
Program Storage Unit	2 Kg
Data Bus Processor	4 Kg
Data Storage Memory	3 Kg
Input/Output Processor	4.6 Kg

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 3-2

Standardized Subsystem Modules - Telemetry, Tracking and Command (Revised) (Continued)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
TTC-3	Telemetry, Tracking & Commmand	A	Transmitter (VHF, 0.2 W)	2	1	1	3000	7	0.790	20.56	1.433	
		B	Receiver (VHF)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Omni Antenna (VHF)	1	1	1	100					
		E	Diplexer	1	1	1	150					
		F	Hybrid	1	1	1	50					
		G	Power Conditioning	1	2	2	500					
		H	Baseband Assembly	2	1	2	1500					
		I	Data Processing Units	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Proctection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			77.2						
TTC-4	Telemetry, Tracking & Command	A	Transmitter (S-band 8 W)	2	2	4	8000	3	0.883	12.67	1.512	
		B	Transmitter (S-band 40 W)	2	8	16	12,000					
		C	Receiver (S-band)	2	4	8	4000					
		D	Signal Condition	2	2	4	2500					
		E	Basehand Assembly	2	1	2	1500					
		F	Dish Antenna (S-band, 1 1/2')	1	1	1	25					
		G	Omni Antenna (S-band)	1	1	1	100					
		H	Diplexer	1	1	1	150					
		I	Hybrid	1	1	1	50					
		J	Power Conditioing	1	1	2	500					
		K	Data Processing Units	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			96.2						

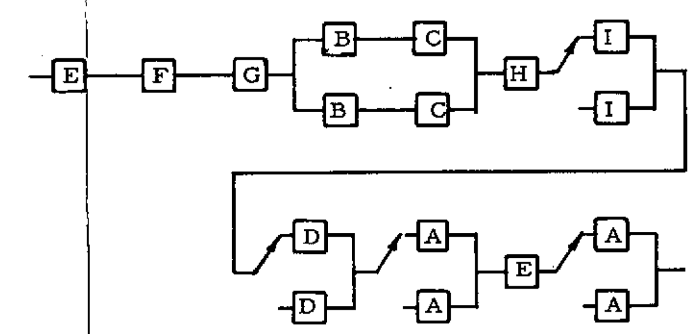
FOLDOUT FRAME 1

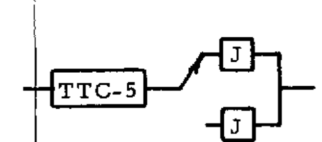
FOLDOUT FRAME 2

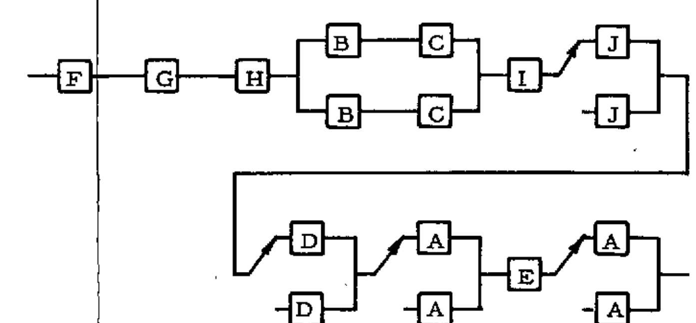
Table 3-2

Standardized Subsystem Modules - Telemetry, Tracking and Command (Revised) (Continued)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
TTC-5	Telemetry Tracking & Command	A	Transmitter (S-band), 8 W)	4	2	8	8000	5	0.833	17.05	1.466	
		B	Receiver (S-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Baseband Assembly	2	1	2	1500					
		E	Omni Antenna (S-band)	2	1	2	100					
		F	Diplexer	1	1	1	150					
		G	Hybrid	1	1	1	50					
		H	Power Conditioning	1	2	2	500					
		I	**Data Processing Units**	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connector	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			84.2						
TTC-5A	Telemetry, Tracking & Command		TTC-5	1	54	84.2		5	0.377	4.94	1.684	
		J	Recorder #1(1)	2	7	14.	40,000					
			TOTAL			98.2						
TTC-6	Telemetry, Tracking & Command	A	Transmitter (S-band 8W)	4	2	8	8000	7	0.565	10.19	1.631	
		B	Receiver (S-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Baseband Assembly	2	1	2	1500					
		E	Dish Antenna (S-band, 1 1/2')	1	1	1	25					
		F	Omni Antenna (S-band)	1	1	1	100					
		G	Diplexer	1	1	1	150					
		H	Hybrid	1	1	1	50					
		I	Power Conditioning	1	2	2	500					
		J	**Data Processing Unit**	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			84.2						







FOLDOUT FRAME

FOLDOUT FRAME

Table 3-.2

Standardized Subsystem Modules - Telemetry, Tracking and Command (Revised) (Continued)

4

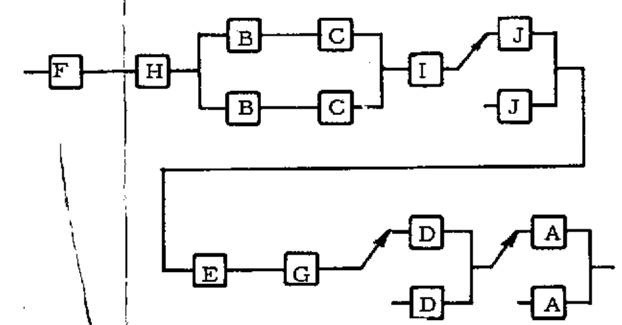
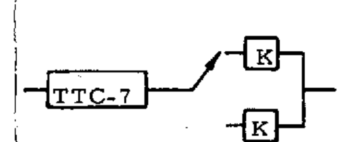
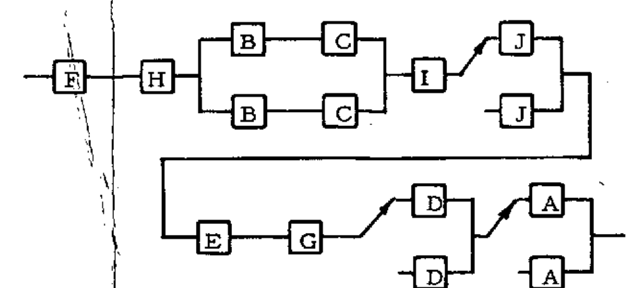
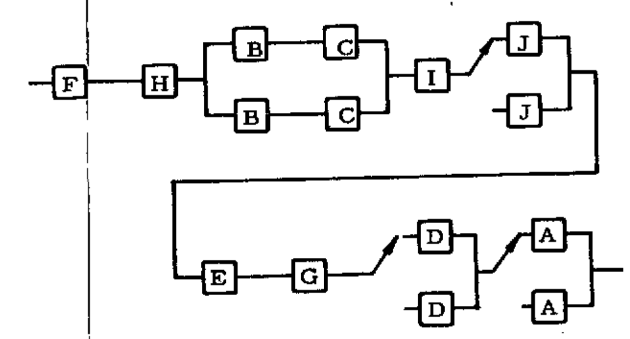
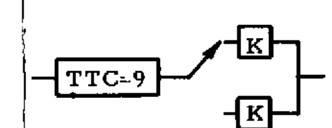
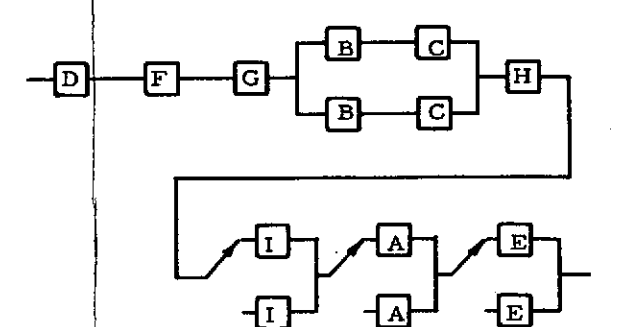
MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
TTC-7	Telemetry, Tracking & Command	A	Transmitter (S-band, 7 W)	2	3	6	8000	3	0.885	17.56	1.238	
		B	Receiver (S-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Track Circuitry	2	2	4	5000					
		E	Tracking Antenna (S-band, 1 1/2')	1	3	3	25					
		F	Omni Antenna (S-band)	1	1	1	100					
		G	Antenna Drive	1	2	2	1500					
		H	Hybrid	1	1	1	50					
		I	Power Conditioning	1	2	2	500					
		J	Data Processing Unit	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Control	AR	5	5						
			Structure	AR	17	17						
			TOTAL			87.2						
TTC-7A	Telemetry, Tracking & Command		TTC-7	1	57	87.2		3	0.618	4.56	1.567	
		K	Recorder #1(1)	2	7	14.	40,000					
			TOTAL			101.2						
TTC-8	Telemetry, Tracking & Command	A	Transmitter (S-band, 40 W)	2	8	16	12,000	3	0.864	14.28	1.291	
		B	Receiver (S-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Tracking Circuitry	2	2	4	5000					
		E	Tracking Antenna (S-band, 1 1/2')	1	3	3	25					
		F	Omni Antenna (S-band)	1	1	1	100					
		G	Antenna Drive	1	2	2	1500					
		H	Hybrid	1	1	1	50					
		I	Power Conditioning	1	2	2	500					
		J	Data Processing Unit	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connector	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			97.2						

Table 3-2

Standardized Subsystem Modules - Telemetry, Tracking and Command (Revised) (Continued)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
TTC-9	Telemetry, Tracking & Command	A	Transmitter (Ku-band, 12 W)	2	2	4	8000	3	0.882	17.42	1.230	
		B	Receiver (S-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Track Circuitry	2	2	4	5000					
		E	Tracking Antenna (Ku/S band 1 1/2')	1	3	3	25					
		F	Omni Antenna (S-band)	1	1	1	100					
		G	Antenna Drive	1	2	2	1500					
		H	Hybrid	1	2	1	50					
		I	Power Conditioning	1	2	2	500					
		J	Data Processing Unit	2	13.6	27.2	5500					
			Cabling	AR	5	5						
			Connectors	AR	2	2						
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			85.2						
TTC-9A	Telemetry, Tracking & Command		TTC-9	1	56	85.2		7	0.616	4.83	1.563	
		K	Recorder #2(2)	2	11	22.0	40,000					
			TOTAL			107.2						
TTC-10	Telemetry, Tracking & Command	A	Transmitter (S-band, 40 W)	2	8	16	8000	3	0.646	4.84	1.703	
		B	Receiver (S-band)	2	4	8	4000					
		C	Signal Condition	2	2	4	2500					
		D	Omni Antenna (S-band)	1	1	1	100					
		E	Recorder #1	2	7	14	40,000					
		F	Diplexer	1	1	1	150					
		G	Hybrid	1	1	1	50					
		H	Power Conditioning	1	2	2	500					
		I	Data Processing Unit	2	13.6	27.2	5500					
			Cabling	AR	5	5		Note: Without Recorder,				
			Connectors	AR	2	2		3	0.925	20.10	1.397	
			Environmental Protection	AR	5	5						
			Structure	AR	17	17						
			TOTAL			103.2						

pass playback of data at 20 times real time. The recorder is also considered to be redundant when required. Because of its high failure rate, it may be that three recorders should be employed, which is often done in current practice.

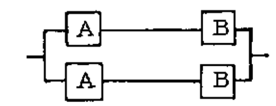
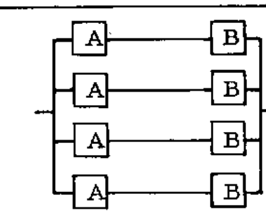
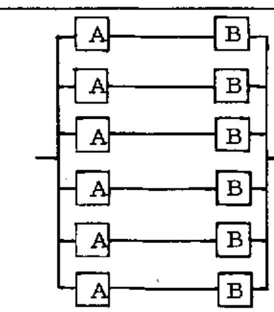
The remaining SRUs are also shown in Table 3-2. In general, the reliability at design life was increased from approximately 0.5 to 0.8. These SRUs cover the full spectrum of TTC and data processing requirements for the reference mission model.

3.3 ELECTRICAL POWER SYSTEM (EPS)

The electrical power modules have not been changed significantly from the parent report. Each SRU has at least two batteries, each with its separate charge controller. All batteries and all EPS SRUs are tied to a single power bus in parallel. All battery modules have been sized for cyclic duty and depth of discharge to meet operational requirements at the end of their design life (estimated to be five years). Consequently, at all times prior to this, excess capacity exists. Also, in no case is the payload totally dependent upon the battery modules because solar panels also exist. Consequently, a ground rule has been adopted, which considers the fact that multiple batteries exist within a given EPS SRU. The EPS SRU will be assumed to be operating satisfactorily if 50% or more of the batteries are functioning as planned. Consequently, if a particular SRU has 10 6-amp-hr batteries, that SRU would not be replaced on orbit until five of the 10 batteries had experienced a failure. This ground rule can easily be varied if necessary but this should be sufficient to represent EPS servicing requirements. The revised EPS reliability information is shown in Table 3-3. The revised values changed considerably from those of the parent document because of an error in the original model.

For the purpose of performing tradeoffs, it will also be assumed that battery life is truncated at five years. Hence, if a failure has not forced a replacement prior to this time, the battery SRU would be replaced anyway. Experience has indicated that this is also conservative and that with proper design the nickle cadmium batteries can survive for

Table 3-3. Standardized Subsystem Modules - Electrical Power System (Revised)

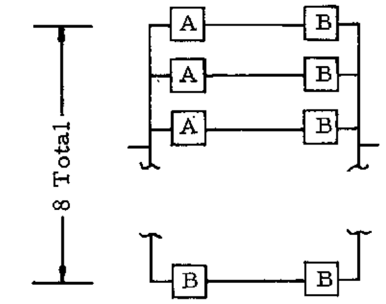
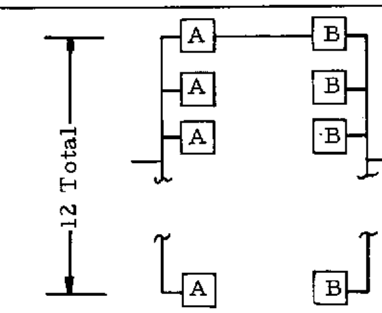
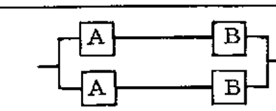
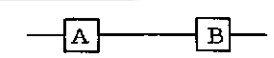
MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY (1)	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
EPS-1A	Battery	A	6 AH Battery	2	7.2	14	2700	5.0	0.987	18.67	1.9666	
		B	Charge Controller	2	4.5	9	100					
			Cables	AR		3						
			Connectors	AR		2						
			Structure	AR		17						
			Environmental Protection System	AR		5						
			TOTAL			50						
EPS-1B	Battery	A	6 AH Battery	4	7.2	29	2700	5.0	0.994	21.10	2.921	
		B	Charge Controller	4	4.5	18	100					
			Cables	AR		5						
			Connectors	AR		4						
			Structure	AR		17						
			Environmental Protection System	AR		5						
			TOTAL			78						
EPS-1C	Battery	A	6 AH Battery	6	7.2	43	2700	5.0	0.998	23.72	3.873	
		B	Charge Controller	6	4.5	27	100					
			Cables	AR		8						
			Connectors	AR		5						
			Structure	AR		17						
			Environmental Protection System	AR		5						
			TOTAL			105						

Notes: (1) AR = As required

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 3-3. Standardized Subsystem Modules - Electrical Power System (Revised) (Continued)

MODULE CODE	MODULE NAME	ITEM	COMPONENT	QTY	WEIGHT (kg) ITEM	WEIGHT (kg) TOTAL	FAILURE RATE (10^{-9}/hr)	MODULE DESIGN LIFE (yrs)	MODULE RELIABILITY AT DESIGN LIFE	WEIBULL PARAMETERS α (yrs)	WEIBULL PARAMETERS β	BLOCK DIAGRAM
EPS-1D	Battery	A	6 AH Battery	8	7.2	58	2700	5.0	0.999	28.89	4.823	
		B	Charge Controller	8	4.5	36	100					
			Cables	AR		11						
			Connectors	AR		7						
			Structure	AR		17						
			Environmental Protection System	AR		5						
			TOTAL			134						
EPS-1E	Battery	A	6 AH Battery	12	7.2	86	2700	5.0	0.999	44.28	6.678	
		B	Charge Controller	12	4.5	54	100					
			Cables	AR		16						
			Connectors	AR		11						
			Structure	AR		17						
			Environmental Protection System	AR		5						
			TOTAL			189						
EPS-2	Battery	A	50 AH Battery	2	47.6	95	2700	5.00	0.987	18.67	1.966	
		B	Charge Controller	2	4.5	9	100					
			Cables	AR		3						
			Connectors	AR		2						
			Structure	AR		17						
			Environmental Protection System	AR		5						
			TOTAL			131						
EPS-3	Solar Array Dr.	A	Motor	1	9.0	9	500	5.0	.978	263.78	0.966	
		B	Engage Mechanism	1	14.5	15	1 per 10,000					
			Cables			3						
			Connectors			2						
			Structure			17						
			Environmental Protection System			5						
			TOTAL			51						

FOLDOUT FRAME 1

FOLDOUT FRAME 2

extended periods of time, being recharged by the solar panels. However, other extenuating parameters, such as heat dissipation, excessive discharge, etc., can foreshorten the battery life. Consequently, five years has been selected as a rational value to represent future payload design practices.

The solar array drive mechanisms (EPS-3) have also been revised, however the effect is negligible. The engage mechanism, although mechanical and highly reliable in nature, has a definable failure rate. The value selected as being representative of this type of design is one failure in 10,000 engagements.

4. CANDIDATE PAYLOAD RECONFIGURATION

The reconfiguration of space serviceable payloads has changed considerably from that employed in the first iteration. At the outset of the first iteration, it was ground ruled to maintain a simplified design approach such that visibility could be retained at all levels of the space servicing analysis. Therefore, once the SRUs had been selected to meet the performance requirements of a given payload program, there was no consideration given to the manner in which these SRUs would be linked together; that is, the SRUs were in effect placed end to end functionally, to form a single string reliability model. In certain instances, this was satisfactory because only a few SRUs were required and it would not be easy to form any redundant paths anyway. However, in a majority of cases, the large number of SRUs treated in a single string fashion resulted in a total payload reliability which was unrealistic. Consequently, a thorough review of each space serviceable payload has been conducted with the view of reconfiguring the SRU arrangements to represent the actual payload design requirements. This obviously requires judgment, because few of the payloads in the NASA mission model have sufficient information to interpret their true design objectives. However, as will be shown in the next section, a comparison of reliabilities at the payload level (rather than SRU) can be made with estimated expendable design concepts to provide a rational comparison of what should be expected from a space serviceable design concept. Although increased redundancy could be provided through the addition of more SRUs, the comparison with expendable designs could lose its validity since redundant elements could also be incorporated to increase that reliability. Therefore, the following configurations have been developed with a view toward performing tradeoffs of space serviceable design concepts versus expendable or ground refurbishable designs.

In general, it should also be recognized that the total spacecraft weight for space serviceable designs will increase above an expendable concept. This is particularly true for payloads whose current design weights are less than 1000 kg. The total payload weight may double in these cases. As the initial weight (expendable design) increases, the penalty drops sharply as indicated in Section 13 of the parent document. For large payloads (3000 kg), the overall weight penalty may be as low as 10%. The weight increase may pose a problem for the shuttle upper stage performance; however, it is possible for space serviceable designs to deploy only part of the total payload on the initial flight. Remaining SRUs can be supplied at a later date when servicing is performed. For example, EO-7, Advanced Synchronous Meteorological Satellite, as described below, has five different mission equipment SRUs ranging from 60 to 100 kg in weight. The EO-7 satellite could be deployed initially with only one or two of the five if necessary to stay within the performance requirements of the shuttle upper stage. This operational flexibility could prove to be a key factor in favor of space servicing even though the total weight may be greater.

It should also be recognized that immediate servicing of a payload is not necessarily required if one mission equipment SRU fails. Although degraded performance results, the payload is still operational and can continue until the level of performance falls below some arbitrary value. It could be when the last mission equipment SRU fails, if perhaps that SRU was primary to the mission. In establishing reliability values for the reconfigured payloads, it is not possible in most instances to establish which mission equipment is primary. Therefore, for the purpose of comparing reliabilities with expendable designs, it is assumed that the payload be considered operational if at least 50% of the mission equipment is functioning as planned. Again this is arbitrary, but should provide a rational basis for comparison of design concepts.

In a few cases, it is apparent which SRU is primary and, therefore, it is treated separately from the remaining mission equipment which would be subject to the 50% ground rule. Also, there is required, on certain highly complex payloads, a special data collection system over and above the TT&C subsystem (i.e., EO-7). This data collection system is required to meet the demands for high data rates of 30 to 50 Mbps, and as such, is generally associated with a specific sensor. In these cases, the data system is placed in series with the specific mission equipment SRU, since a failure of either represents a loss of the mission data.

One other change, relative to mission equipment, has been made from the parent document. The Environmental Monitoring Satellite (NND-8) has been shown to have six different mission equipment sensors (Table 8-1 of the basic report) each being redundant. This results in 12 SRUs to make up the complement of mission equipment for this payload. This set of SRUs has now been modified to incorporate both sensors into a single SRU, thereby providing the same level of redundancy but having only six SRUs. Size constraints do not preclude this arrangement based upon current information; but if the sensor sizes increase in the future, this position should be reexamined. The revised data is provided in Table 4-1.

In addition to the considerations given above, it is also necessary to alter the subsystem SRU relationships. Several basic changes have been made to account for the inherent redundancy existing within the SRUs required for each payload. In nearly all cases, four monopropellant reaction control SRUs are required for attitude stabilization. In all cases, these SRUs have been sized such that any two SRUs will provide adequate control over a five year period. Consequently, from a reliability standpoint any two of the four SRUs is sufficient to maintain a stable configuration (assuming each SRU can be isolated in the event of a thruster-on failure mode).

In general, the reaction control systems (AVCS-7 and AVCS-8) are in parallel with a reaction wheel SRU. The reaction wheel provides long term, highly accurate attitude control. If the reaction wheel SRU fails, the reaction control SRUs provide a backup mode until servicing can be performed. For low altitude operations, a magnatometer is also provided to aid fuel consumption by counteracting magnetic torques. For the purposes here, it is treated in parallel with the reaction wheel. It is doubtful that a servicing mission would be performed just to replace this item; however, its reliability is such that treating it this way should not create any problems.

Table 4-1. NND-8 Space Replaceable Mission Equipment (Revised)

Module Code	Component	Qty.	Weight (kg)	Design Life (Yrs)	Reliability at Design Life
NND-8-1	Ozone-Sun Polarimeter	4	60.8	3	0.898
	Baseplate	1	10.5		
	Mechanism	1	4.5		
	Environ. Control	AR	26.5		
	Elect. Connectors	AR	2.3		
	Elect. Dist. & Power Cond.	AR	11.0		
	Total		115.6		
NND-8-2	Limb Atmosphere Composition Radiometer	4	126.0	1	0.824
	Cryogen Cooler	4			
	Baseplate	1	10.5		
	Mechanism	1	4.5		
	Environ. Control	AR	26.5		
	Elect. Connectors	AR	2.3		
	Elect. Dist. & Power Cond.	AR	11.0		
	Total		180.8		
NND-8-3	Air Pollution Sensor Optical Head	4	60.0	1	0.885
	Electronics	4			
	Baseplate	1	10.5		
	Mechanism	1	4.5		
	Environ. Control	AR	26.5		
	Elect. Connectors	AR	2.3		
	Elect. Dist. & Power Cond.	AR	11.0		
	Total		114.8		
NND-8-4	High Speed Interferometer	4	50.0	1	0.897
	Baseplate	1	10.5		
	Mechanism	1	4.5		
	Environ. Control	AR	26.5		
	Elect. Connectors	AR	2.3		
	Elect. Dist. & Power Cond.	AR	11.0		
	Total		104.8		

AR = As Required

Table 4-1. NND-8 Space Replaceable Mission Equipment (Revised) (Continued)

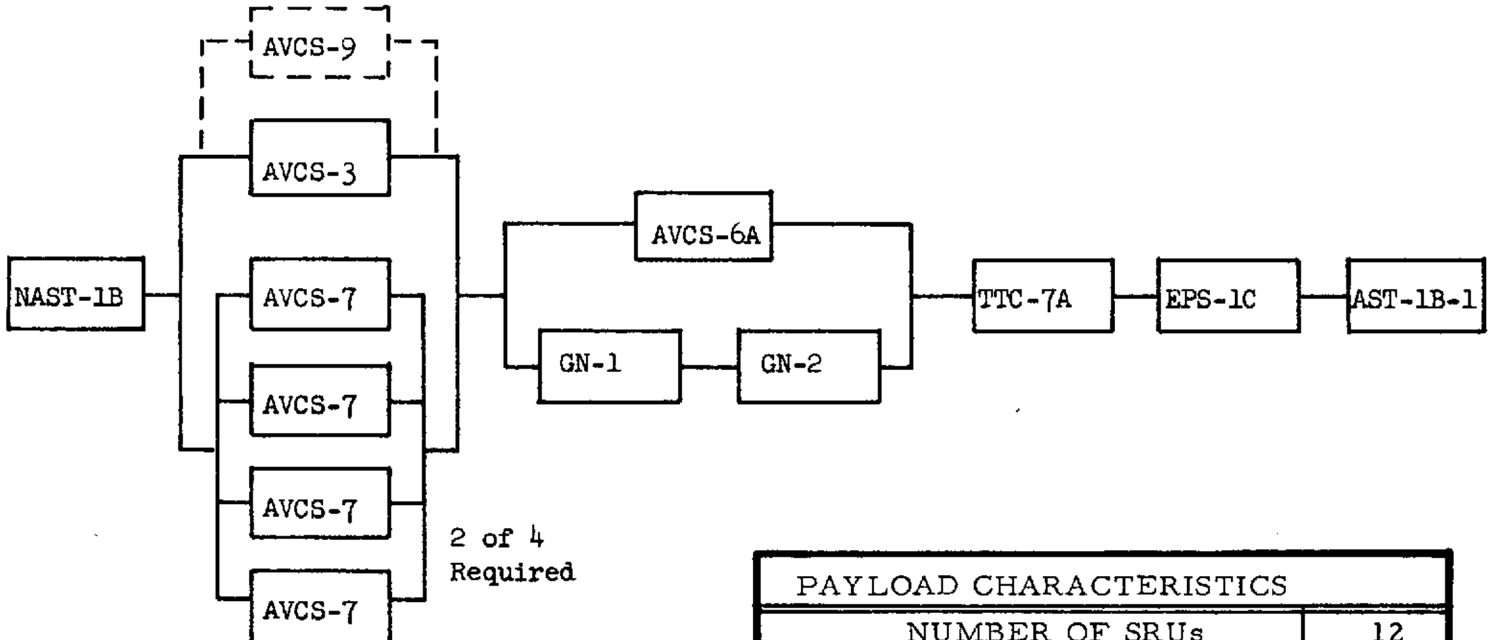
Module Code	Component	Qty	Weight (kg)	Design Life (Yrs)	Reliability at Design Life
NND-8-5	Ocean Scanning Spectrophotometer	4	50.0	3	0.910
	Baseplate	1	10.5		
	Mechanism	1	4.5		
	Environ. Control	AR	26.5		
	Elect. Connectors	AR	2.3		
	Elect. Dist. & Power Cond.	AR	11.0		
	Total		104.8		
NND-8-6	Coastal Zone Color Scanner	4	54.0	3	0.824
	Baseplate	1	10.5		
	Mechanism	1	4.5		
	Environ. Control	AR	26.5		
	Elect. Connectors	AR	2.3		
	Elect. Dist. & Power Cond.	AR	11.0		
	Total		108.8		

A similar condition exists with the AVCS sensing modules when employed with the guidance and navigation SRUs (GN-1 and GN-2). The inertial measuring unit (IMU) (GN-1) has the capability to provide three-axis attitude sensing to backup the rate gyros and horizon scanners in the AVCS modules. The computer (GN-2) has the capability to backup the autopilot (Auxiliary Electronics Assembly) in the AVCS sensing module. However, the IMU requires the computer for resolving the coordinate system; hence, GN-1 and GN-2 are treated in series when required. This series is then treated in parallel with the AVCS sensing module. These arrangements are shown for each of the 29 payloads in Figure 4-1.

Other modules are similarly treated. If more than one electrical power module is required, they are treated as being in parallel. The same is true for the solar array drives. In general, if one solar array drive fails, there remains enough residual power to continue operations until servicing can be performed. Additional reaction control propellant may be required but the margins are such that this effect can be neglected. If the payload is in low earth orbit, there could be an impact on recharging of batteries due to reduced power from the solar array but this can be compensated for by taking certain mission equipment off line to reduce power requirements. Consequently, these SRU arrangements appear to be rational and provide a basis for estimating the total payload reliability over its design life.

A close examination of Figure 4-1 will show that the reliability diagrams are only approximately correct. Numerous different failure modes exist which impart a high stress on other parts, thereby influencing the overall reliability of the system. However, for the purposes intended here, these diagrams are felt to be reasonably descriptive, allowing interpretation of the reconfigured payloads as developed by this first iteration of the parent document. A more definitive representation would require an in depth knowledge of each payload in the mission model. This is obviously impractical since the mission model is a projection only of the type of payloads to be deployed in the future and the frequency with which this will take place. Everything else is speculation.

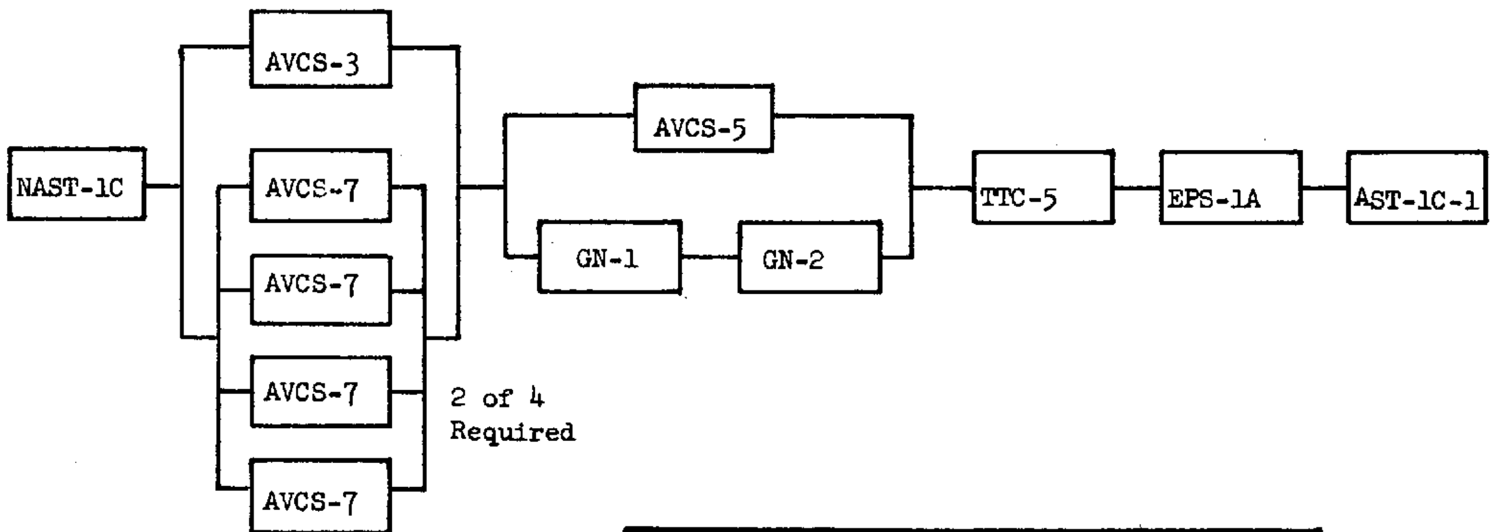
AST-1B Cosmic Background Explorer



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	12
DESIGN LIFE (YRS)	3
RELIABILITY @ D. L.	0.024
WEIGHT - DRY (Kg)	1235.9
PROP (Kg)	76.0
TOTAL (Kg)	1311.9

Figure 4-1. Space Serviceable Payload Descriptions

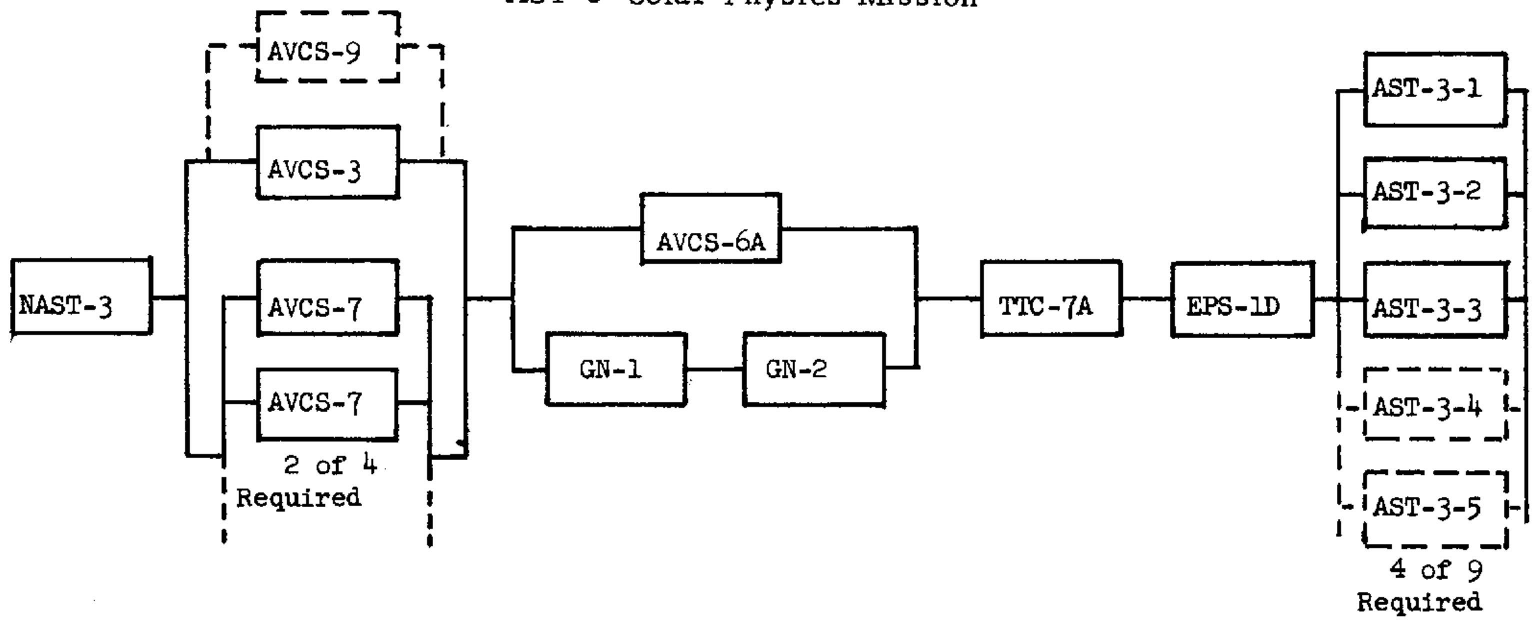
AST-1C Advanced Radio Astronomy Explorer



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	11
DESIGN LIFE (YRS)	10
RELIABILITY @D. L.	0.113
WEIGHT - DRY (Kg)	1107.4
PROP (Kg)	68
TOTAL (Kg)	1175.4

Figure 4-1. Space Serviceable Payload Descriptions

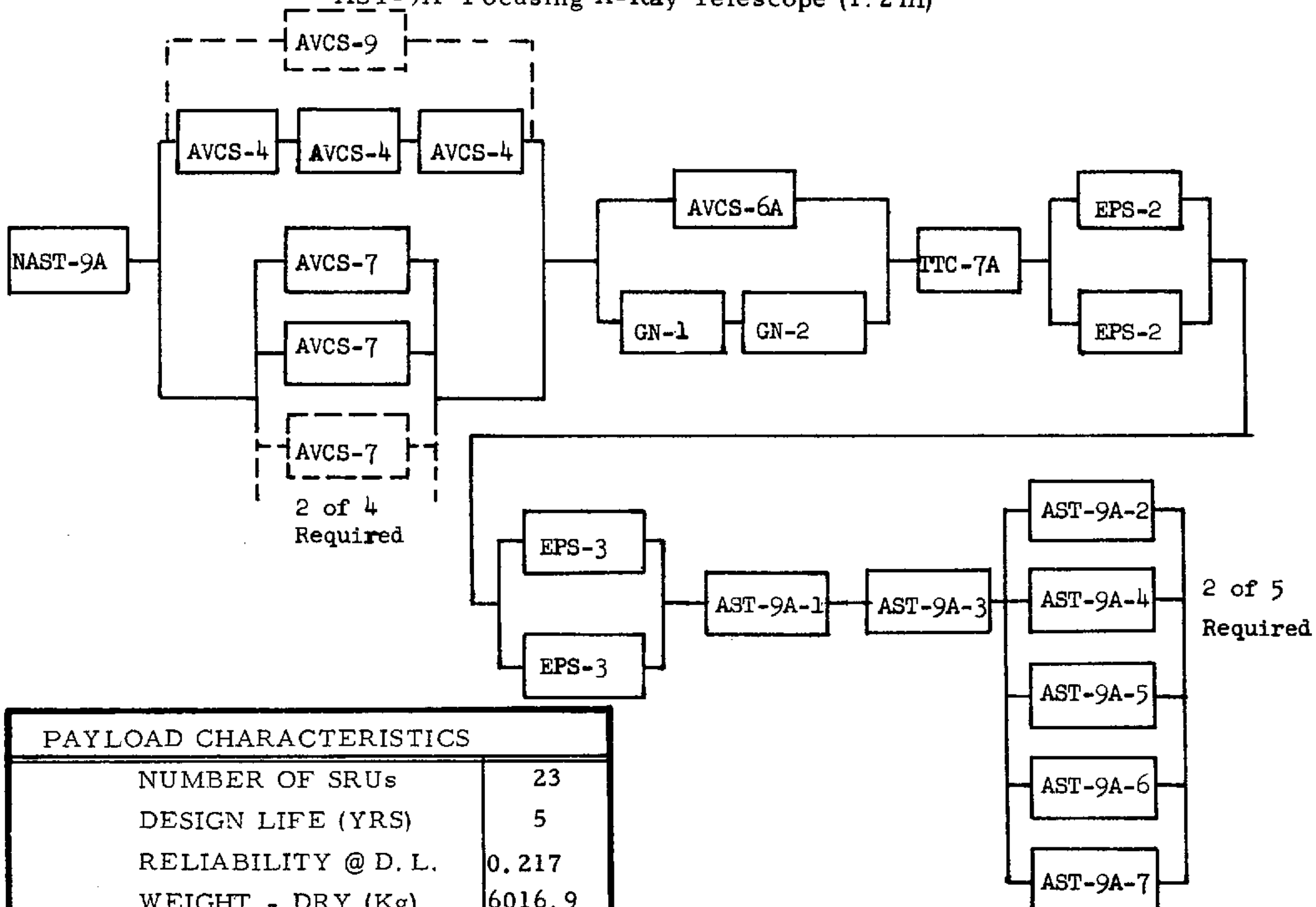
AST-3 Solar Physics Mission



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	20
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.122
WEIGHT - DRY (Kg)	2101.7
PROP (Kg)	80
TOTAL (Kg)	2181.7

Figure 4-1. Space Serviceable Payload Descriptions

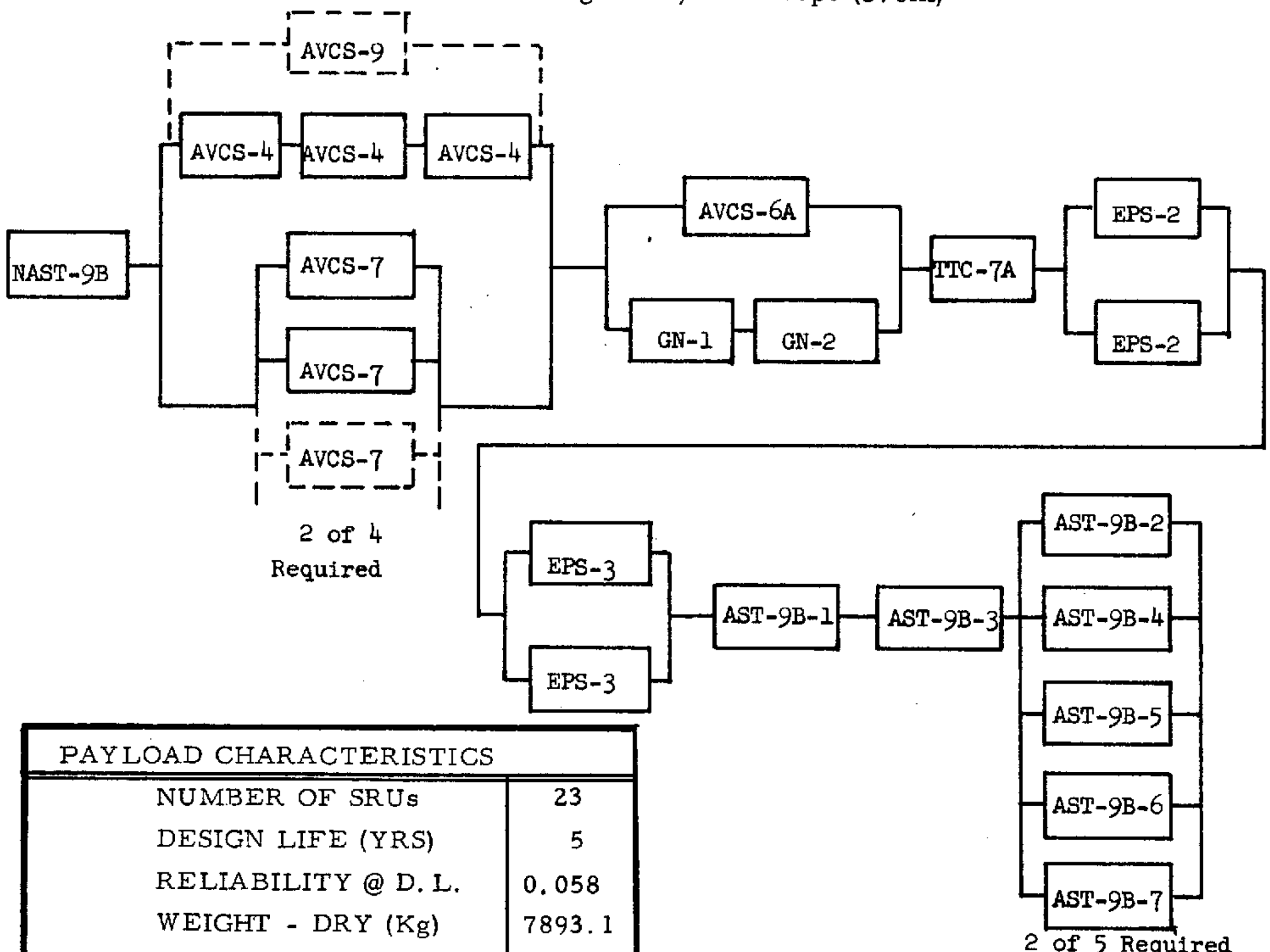
AST-9A Focusing X-Ray Telescope (1.2 m)



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	23
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.217
WEIGHT - DRY (Kg)	6016.9
PROP (Kg)	80
TOTAL (Kg)	6096.9

Figure 4-1. Space Serviceable Payload Descriptions

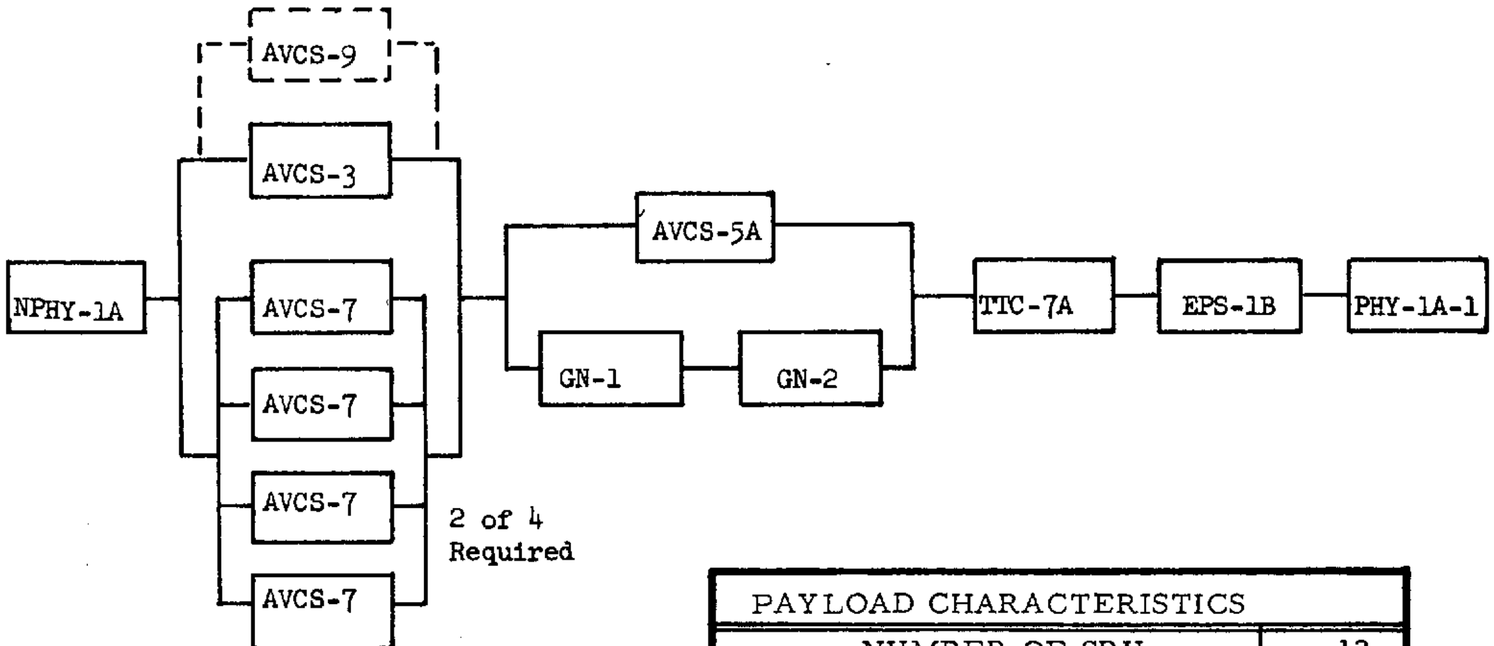
AST-9B Focusing X-Ray Telescope (3.0m)



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	23
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.058
WEIGHT - DRY (Kg)	7893.1
PROP (Kg)	80
TOTAL (Kg)	7973.1

Figure 4-1. Space Serviceable Payload Descriptions

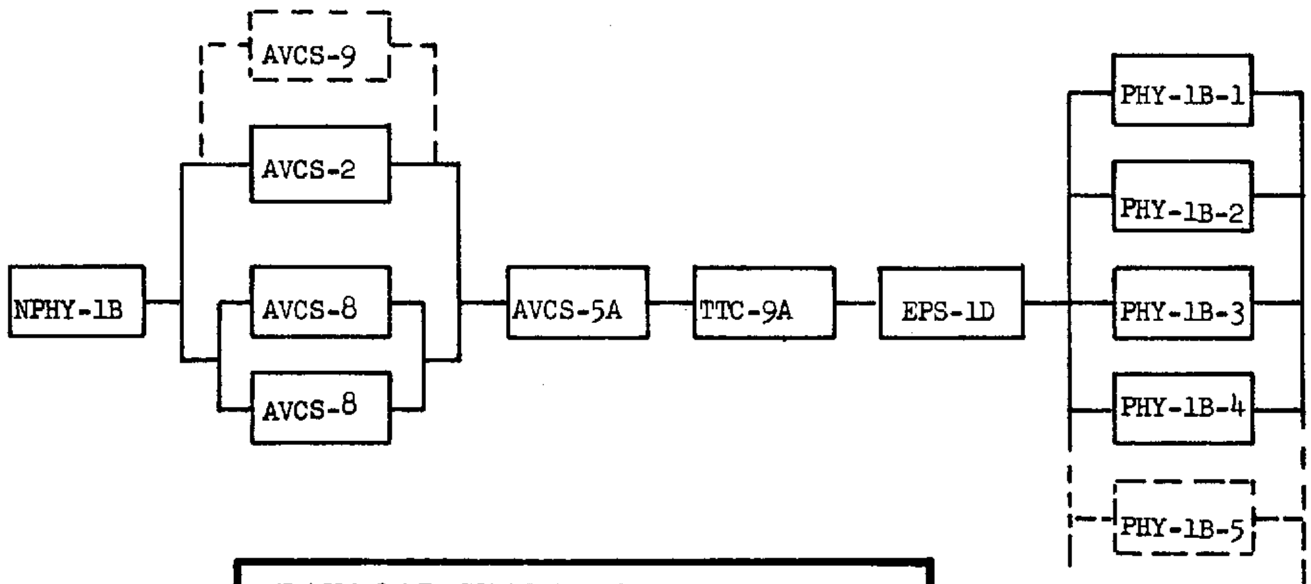
PHY-1A Small High Energy Observatory



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	12
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.037
WEIGHT - DRY (Kg)	1192.0
PROP (Kg)	60
TOTAL (Kg)	1252.0

Figure 4-1. Space Serviceable Payload Descriptions

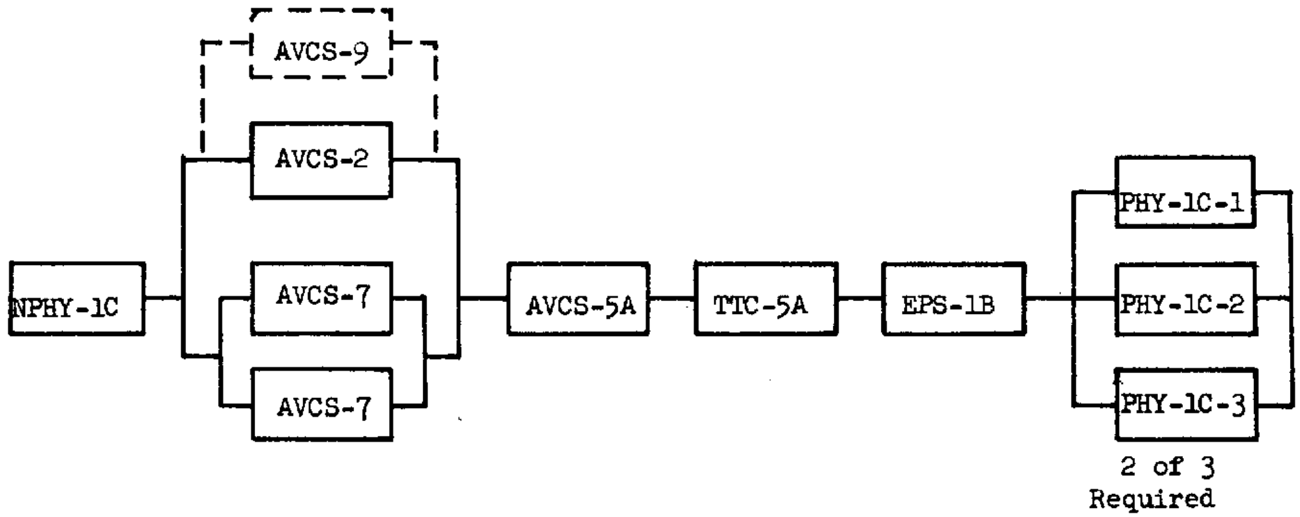
PHY-1B Upper Atmosphere Explorer



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	15
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.204
WEIGHT - DRY (Kg)	1407.5
PROP (Kg)	293
TOTAL (Kg)	1700.5

Figure 4-1. Space Serviceable Payload Descriptions

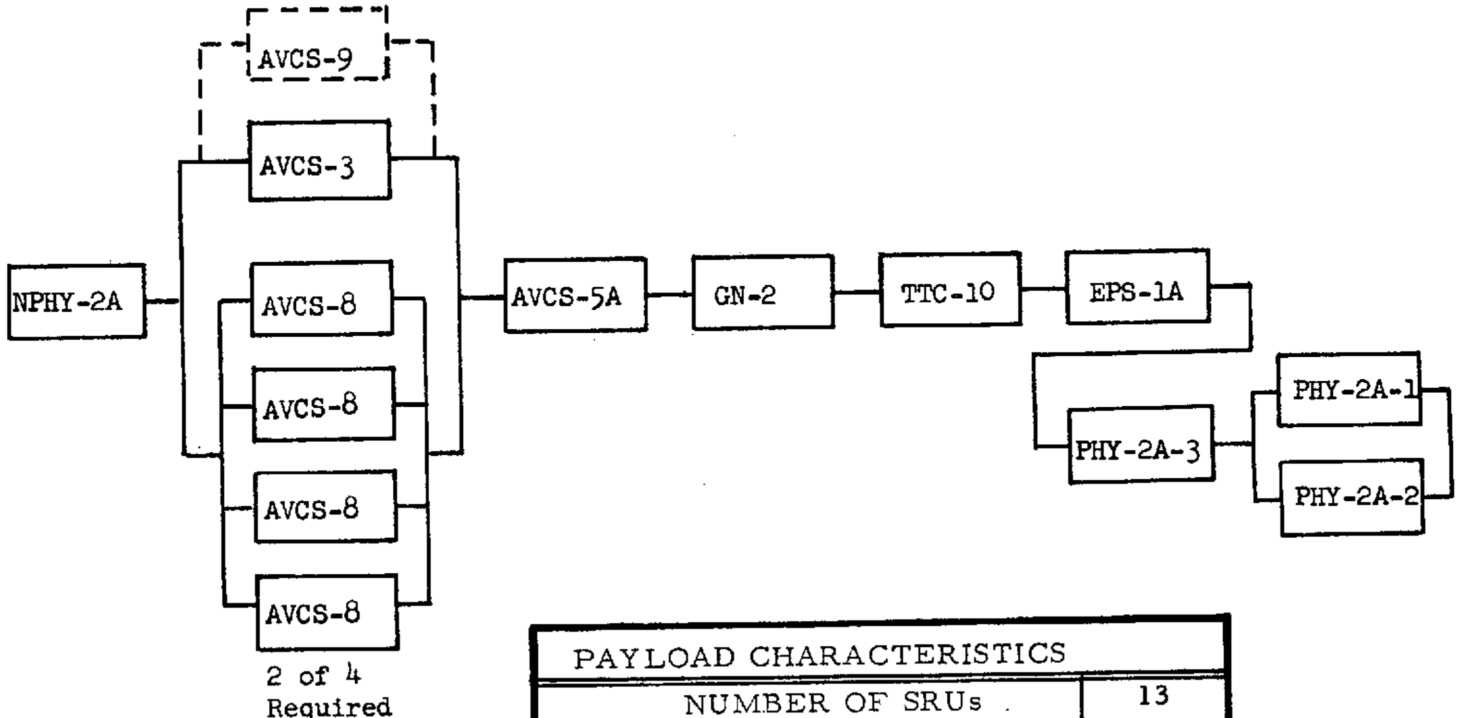
PHY-1C Medium Altitude Explorer



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	10
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.218
WEIGHT - DRY (Kg)	963.1
PROP (Kg)	30
TOTAL (Kg)	993.1

Figure 4-1. Space Serviceable Payload Descriptions

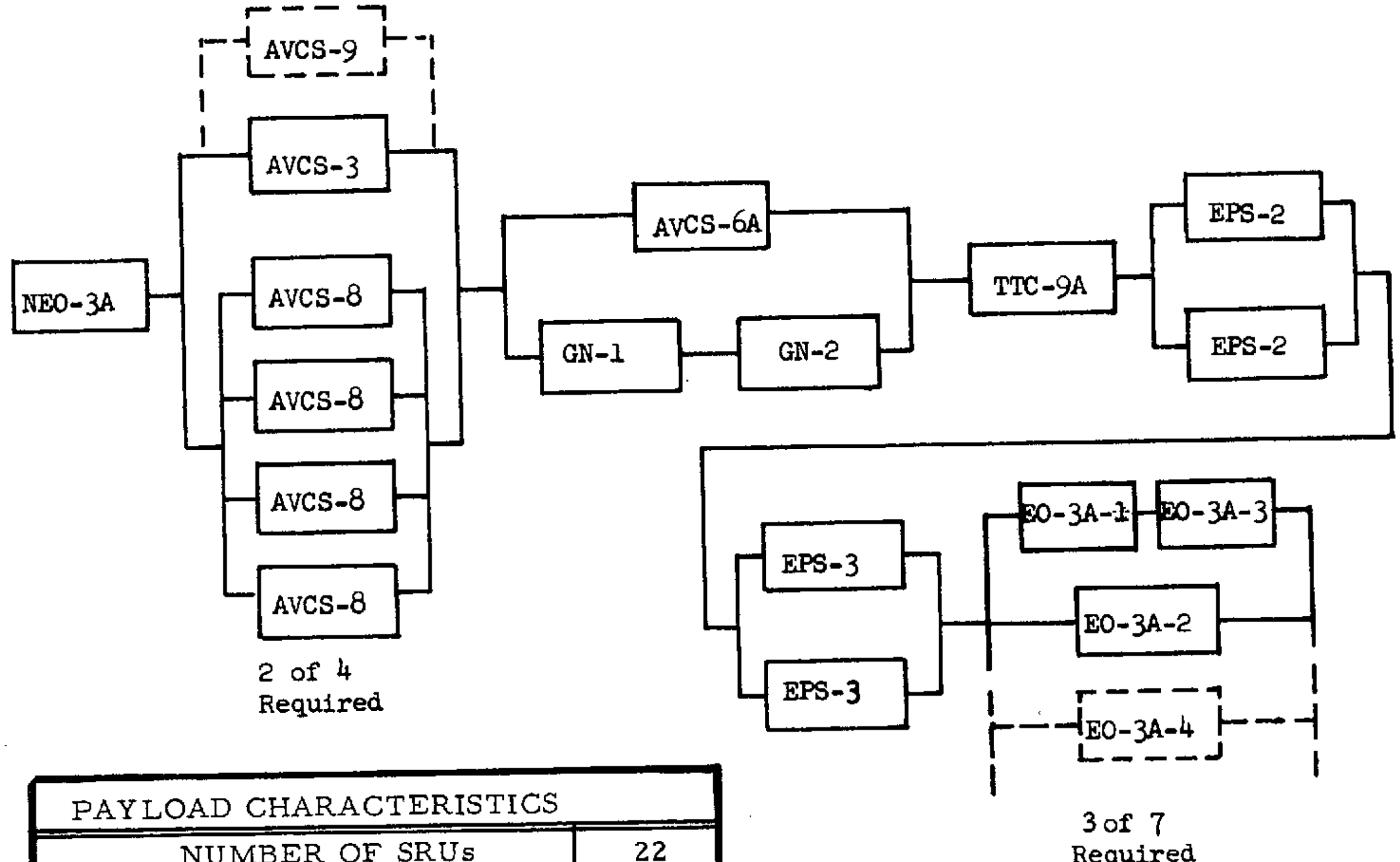
PHY-2A Gravity and Relativity Satellite - LEO



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	13
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.111
WEIGHT - DRY (Kg)	1258.1
PROP (Kg)	415
TOTAL (Kg)	1673.1

Figure 4-1. Space Serviceable Payload Descriptions

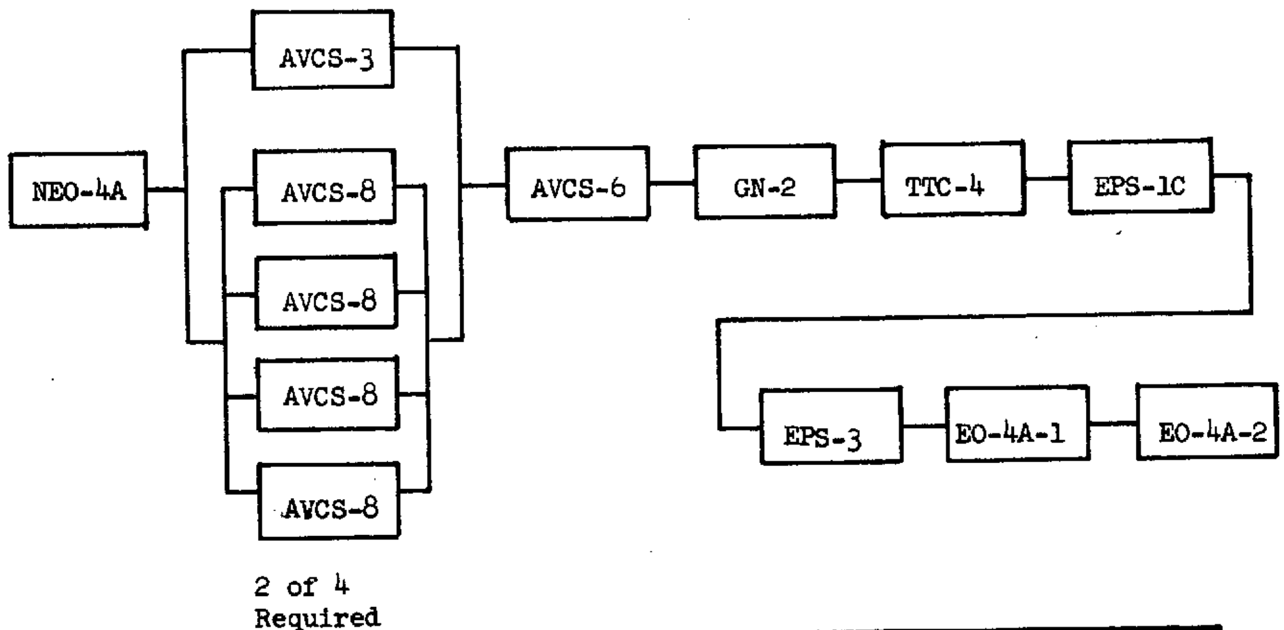
EO-3A Earth Observatory Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	22
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.10
WEIGHT - DRY (Kg)	2828
PROP (Kg)	227
TOTAL (Kg)	3155

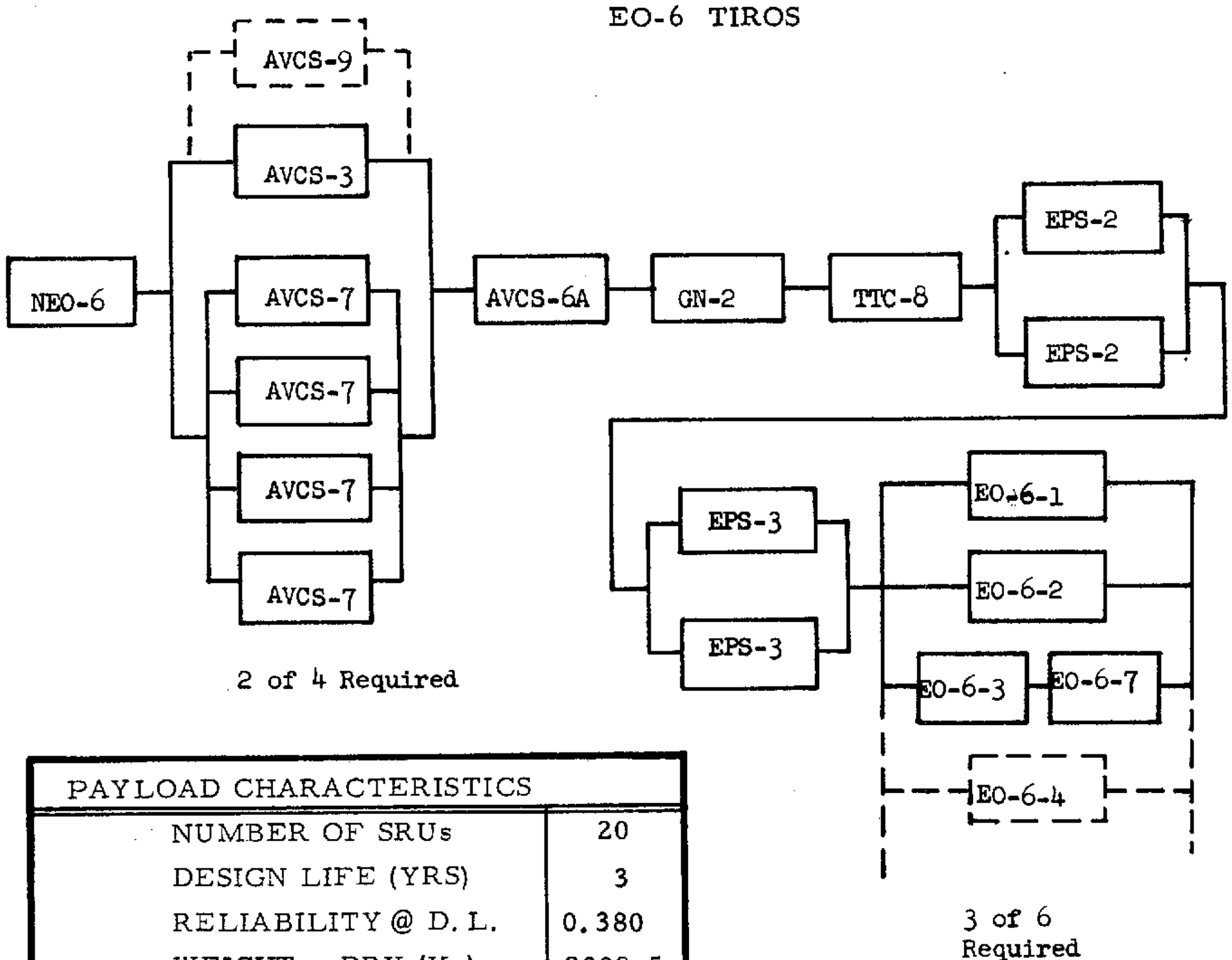
Figure 4-1. Space Serviceable Payload Descriptions

EO-4A Synchronous Earth Observatory Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	12
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.011
WEIGHT - DRY (Kg)	1790.5
PROP (Kg)	133
TOTAL (Kg)	1923.5

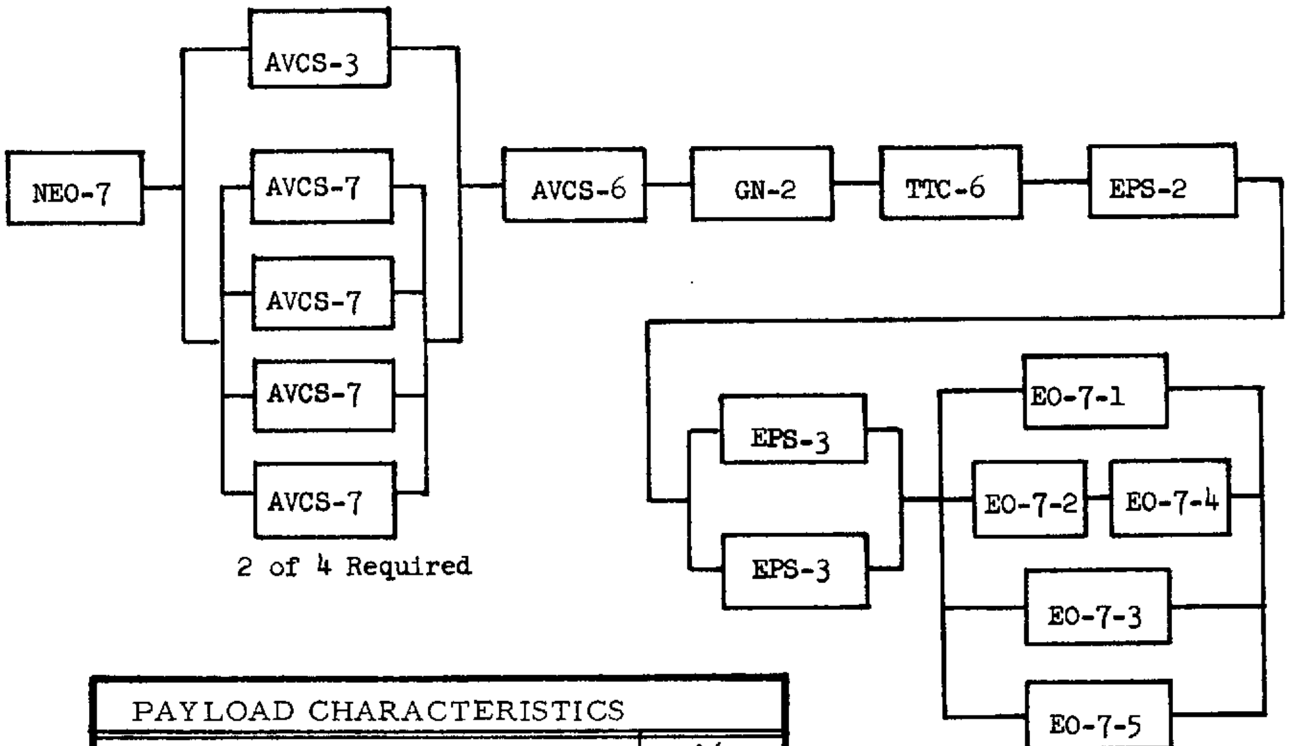
Figure 4-1. Space Serviceable Payload Descriptions



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	20
DESIGN LIFE (YRS)	3
RELIABILITY @ D. L.	0.380
WEIGHT - DRY (Kg)	2008.5
PROP (Kg)	80
TOTAL (Kg)	2088.5

Figure 4-1. Space Serviceable Payload Descriptions

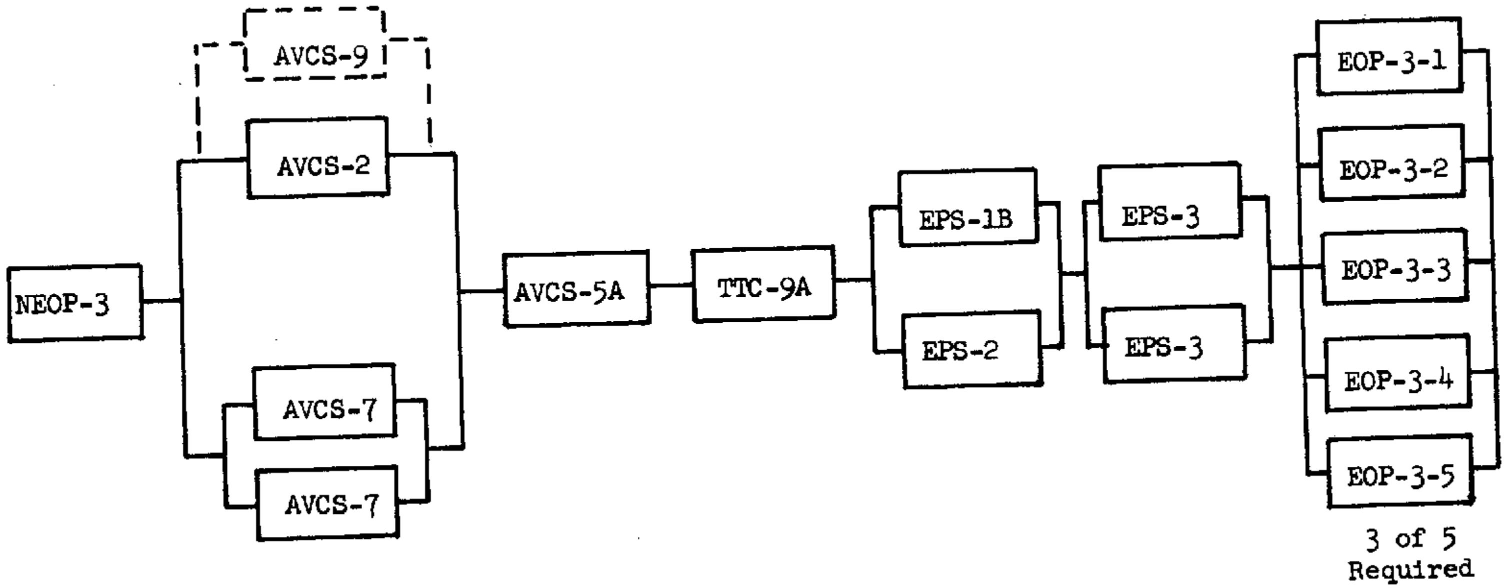
EO-7 Synchronous Meteorological Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	16
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.169
WEIGHT - DRY (Kg)	1519.8
PROP (Kg)	62
TOTAL (Kg)	1581.8

Figure 4-1. Space Serviceable Payload Descriptions

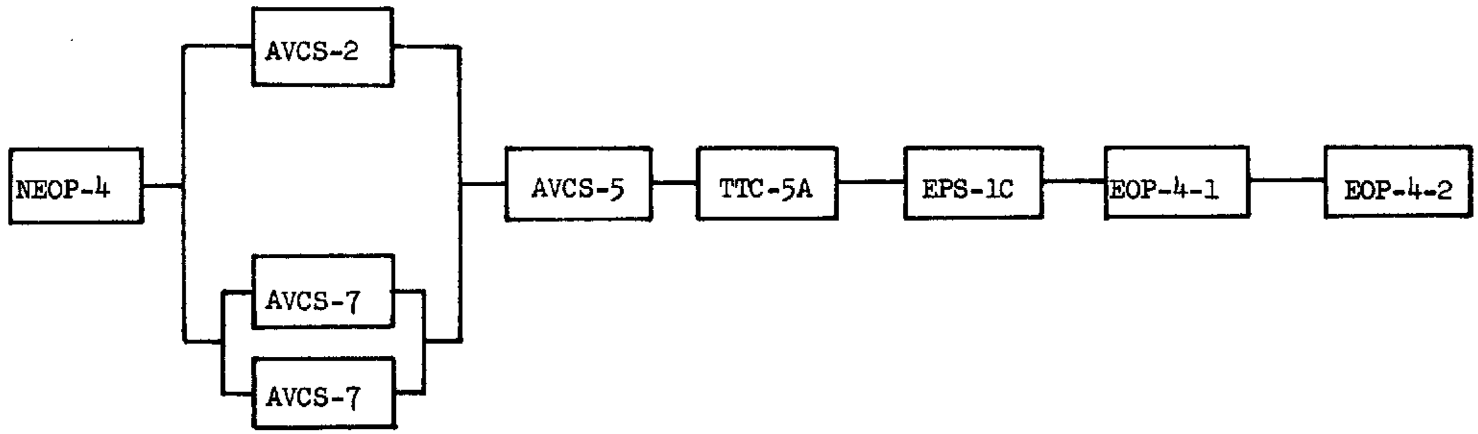
EOP-3 SEASAT-B



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	15
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.137
WEIGHT - DRY (Kg)	1629.1
PROP (Kg)	40
TOTAL (Kg)	1669.1

Figure 4-1. Space Serviceable Payload Descriptions

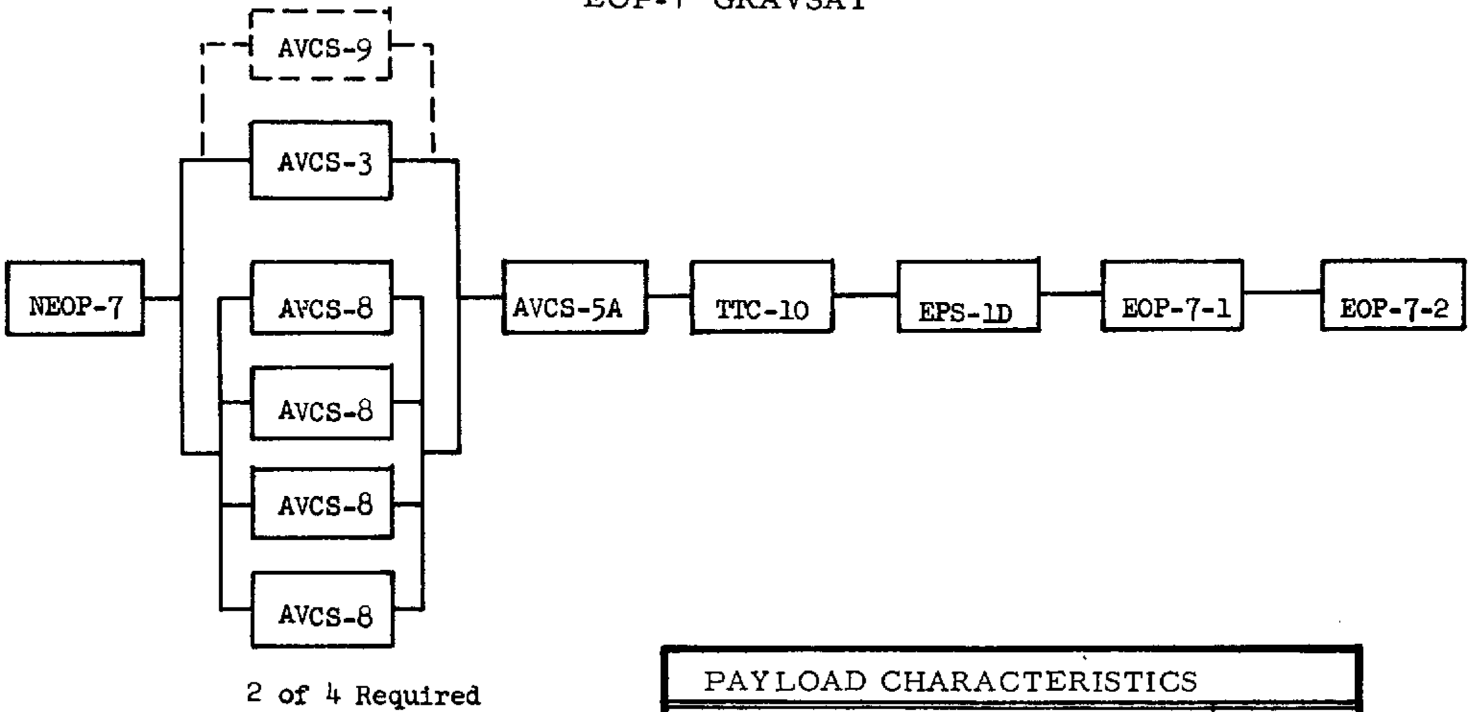
EOP-4 Geopause



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	8
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.007
WEIGHT - DRY (Kg)	916.6
PROP (Kg)	40
TOTAL (Kg)	956.6

Figure 4-1. Space Serviceable Payload Descriptions

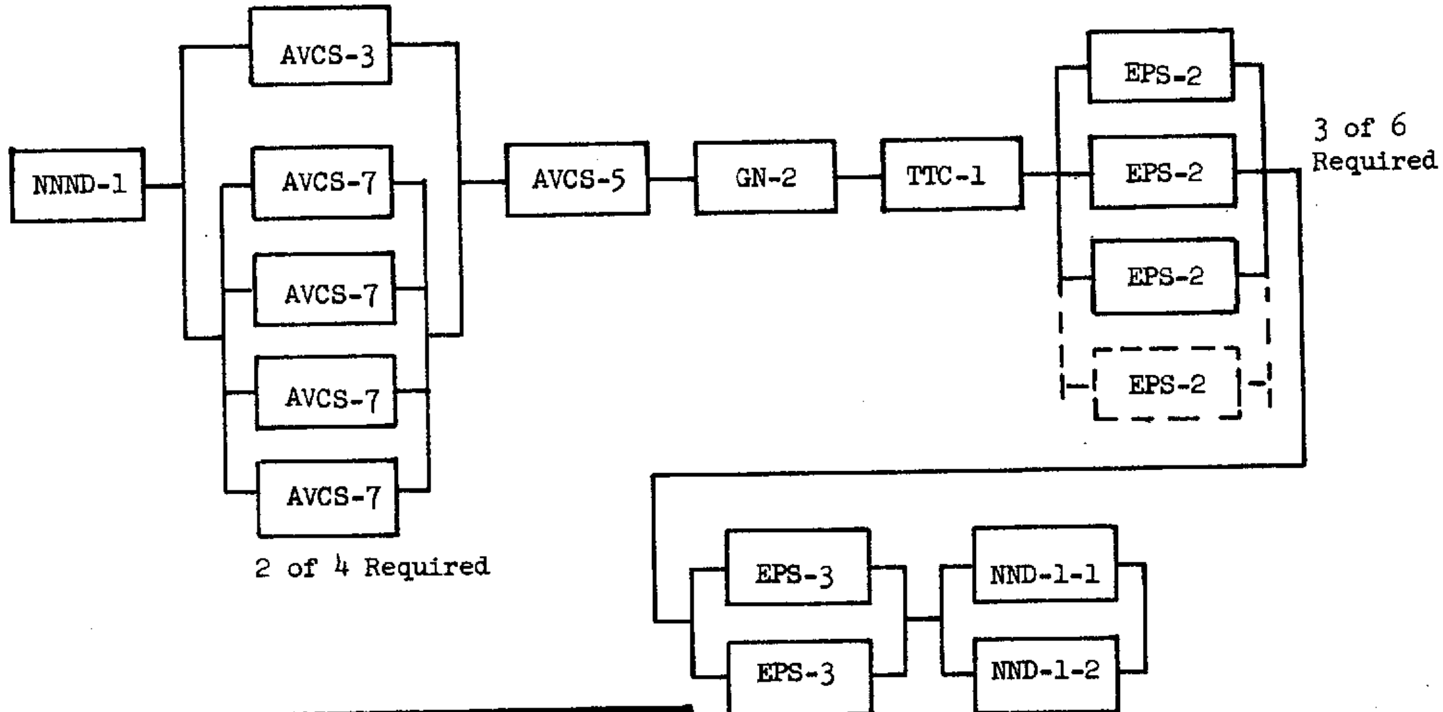
EOP-7 GRAVSAT



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	11
DESIGN LIFE (YRS)	3
RELIABILITY @ D. L.	0.083
WEIGHT - DRY (Kg)	1448.2
PROP (Kg)	255
TOTAL (Kg)	1703.2

Figure 4-1. Space Serviceable Payload Descriptions

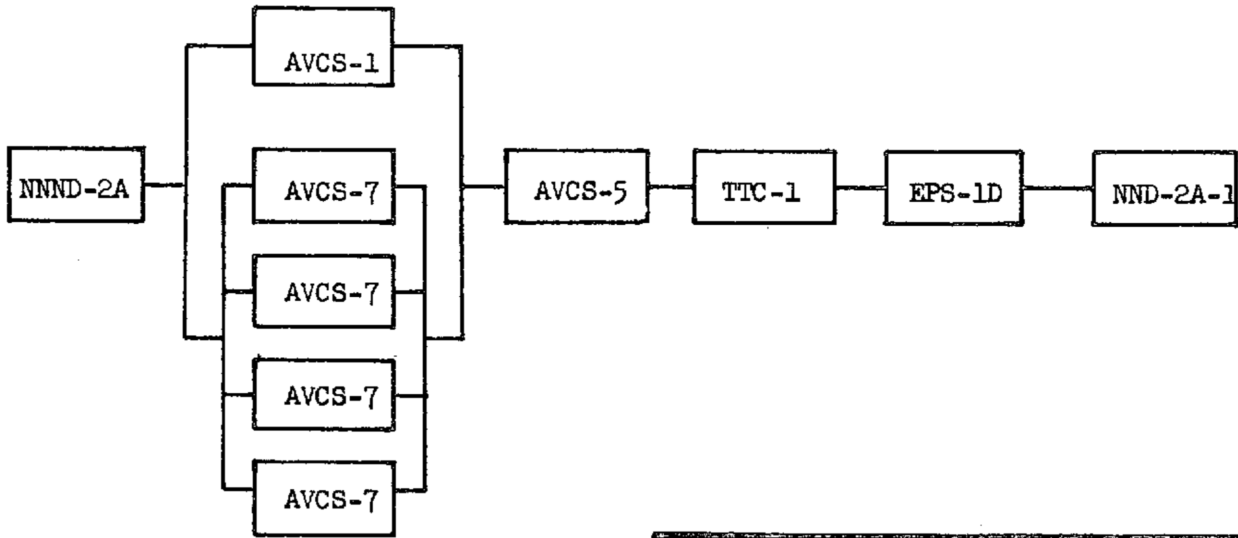
NND-1 International Communications Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	18
DESIGN LIFE (YRS)	10
RELIABILITY @D.L.	0.018
WEIGHT - DRY (Kg)	2645.0
PROP (Kg)	82.0
TOTAL (Kg)	2727.0

Figure 4-1. Space Serviceable Payload Descriptions

NND-2A U.S. Domestic Comsat-A

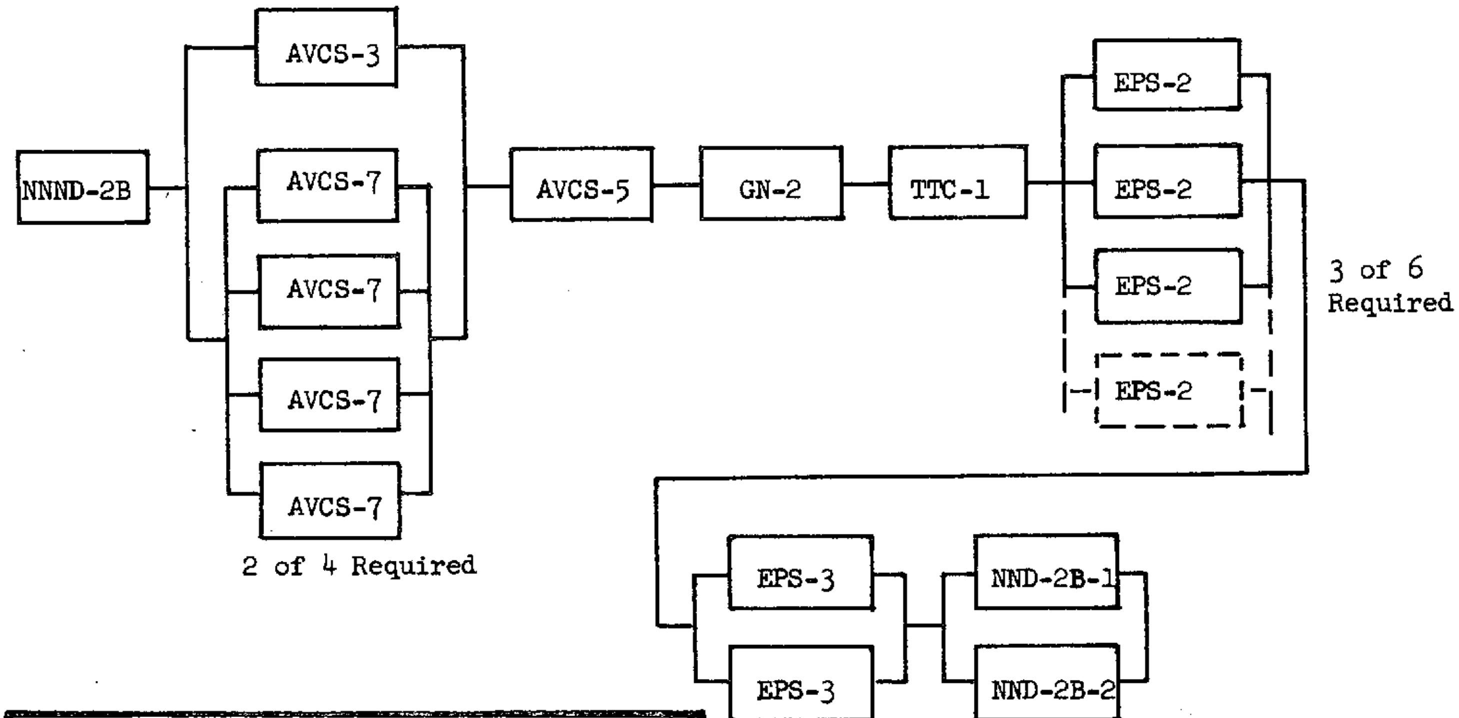


2 of 4 Required

PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	9
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.245
WEIGHT - DRY (Kg)	924.1
PROP (Kg)	60.0
TOTAL (Kg)	984.1

Figure 4-1. Space Serviceable Payload Descriptions

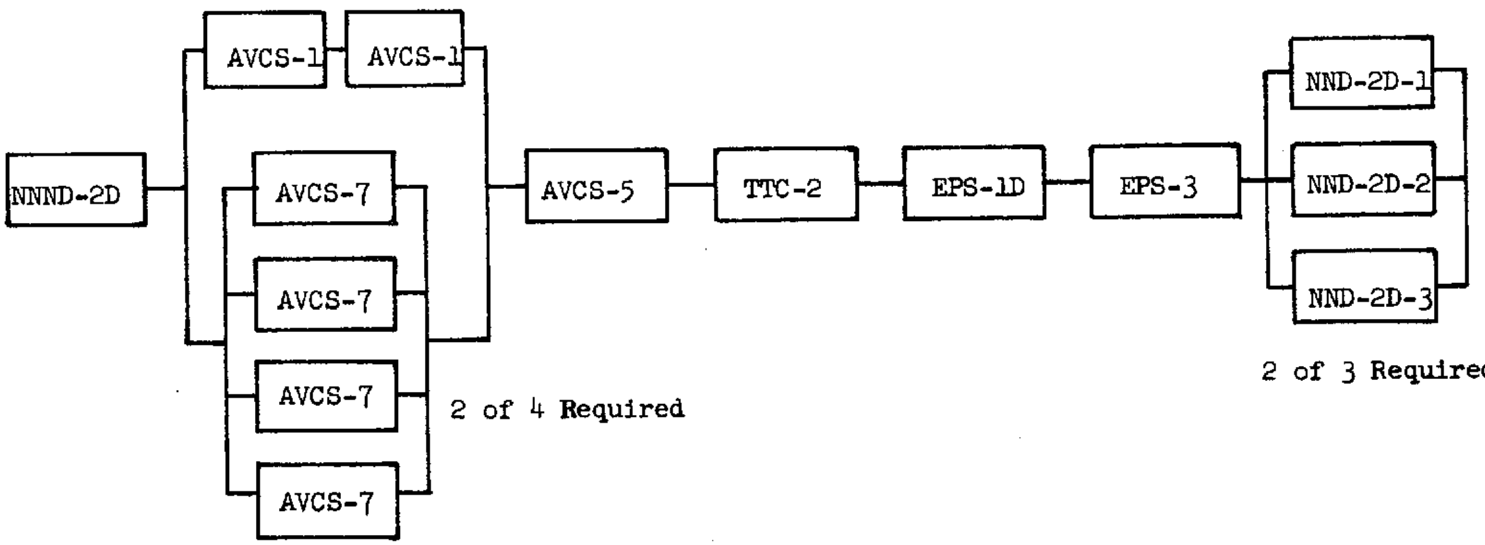
NND-2B U.S Domestic Comsat-B



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	18
DESIGN LIFE (YRS)	10
RELIABILITY @D. L.	0.083
WEIGHT - DRY (Kg)	2645.0
PROP (Kg)	60
TOTAL (Kg)	2705.0

Figure 4-1. Space Serviceable Payload Descriptions

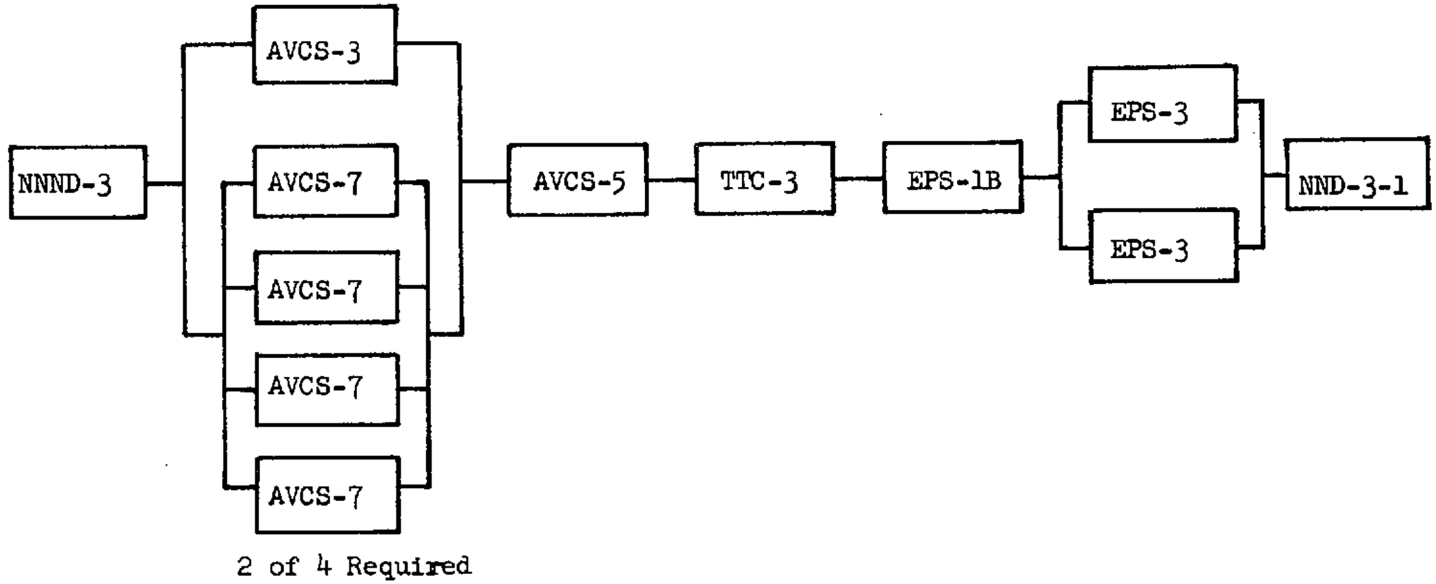
NND-2D U. S. Domestic Satellite-C (TDRS)



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	13
DESIGN LIFE (YRS)	7
RELIABILITY @ D. L.	0.148
WEIGHT - DRY (Kg)	1233.7
PROP (Kg)	81
TOTAL (Kg)	1314.7

Figure 4-1 Space Serviceable Payload Descriptions

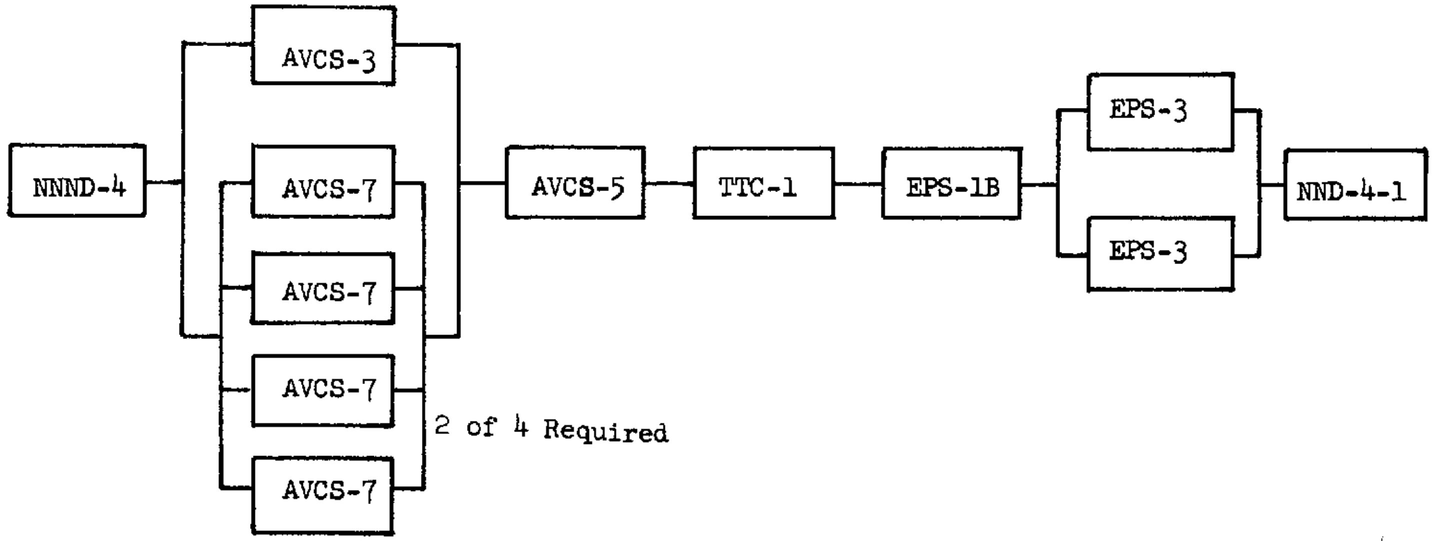
NND-3 Disaster Warning Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	11
DESIGN LIFE (YRS)	7
RELIABILITY @ D. L.	0.262
WEIGHT - DRY (Kg)	1339.5
PROP (Kg)	80
TOTAL (Kg)	1419.5

Figure 4-1. Space Serviceable Payload Descriptions

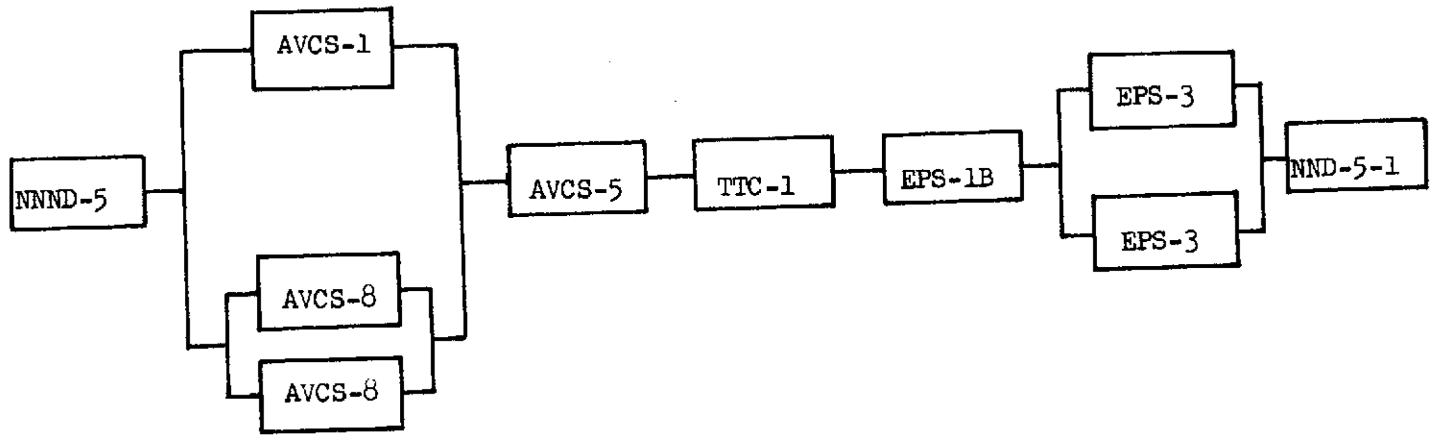
NND-4 Traffic Management Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	11
DESIGN LIFE (YRS)	7
RELIABILITY @ D. L.	0.180
WEIGHT - DRY (Kg)	1084.5
PROP (Kg)	60
TOTAL (Kg)	1144.5

Figure 4-1 Space Serviceable Payload Descriptions

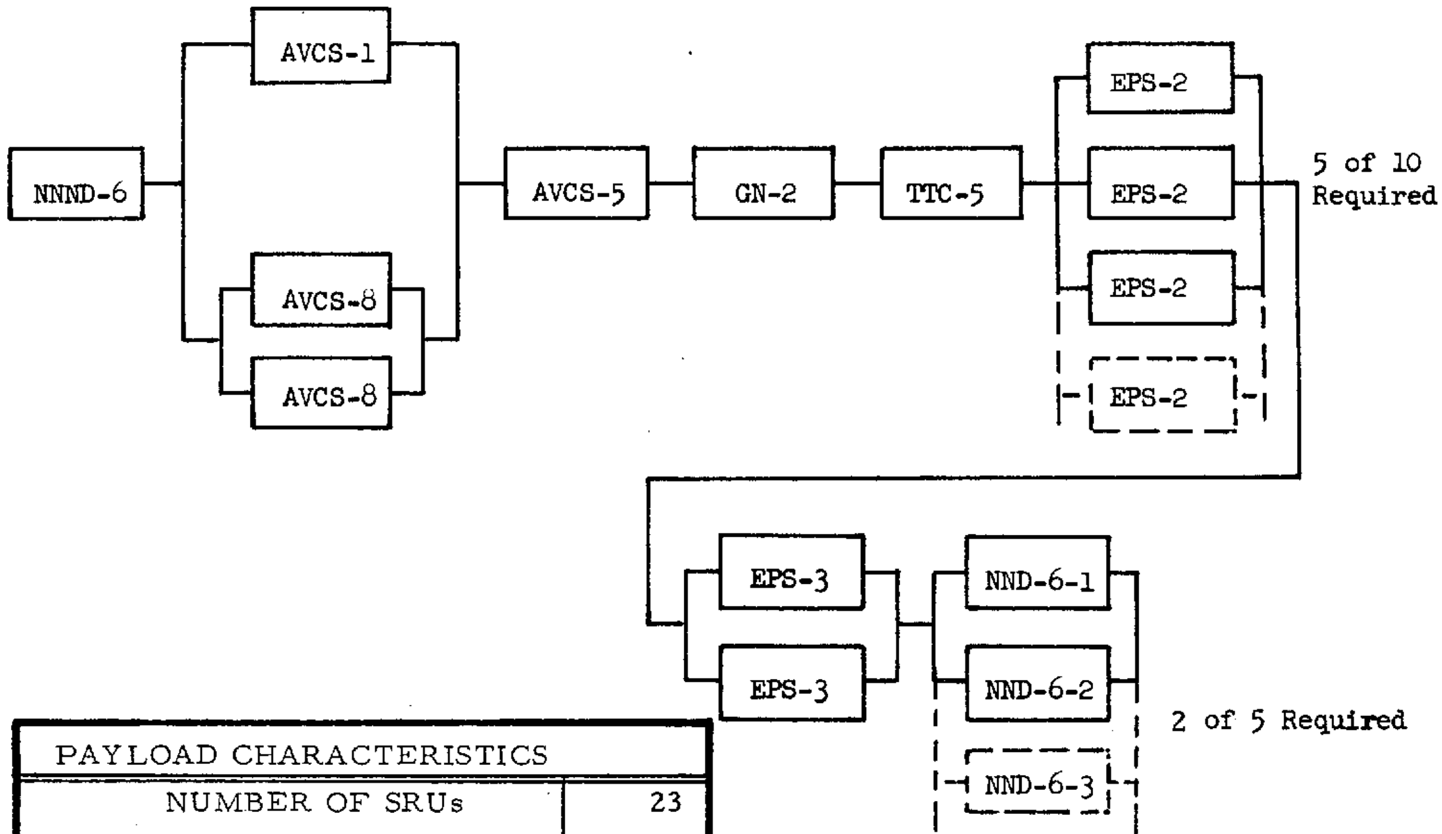
NND-5 Foreign Communications Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	9
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.153
WEIGHT - DRY (Kg)	859.9
PROP (Kg)	115
TOTAL (Kg)	974.9

Figure 4-1. Space Serviceable Payload Descriptions

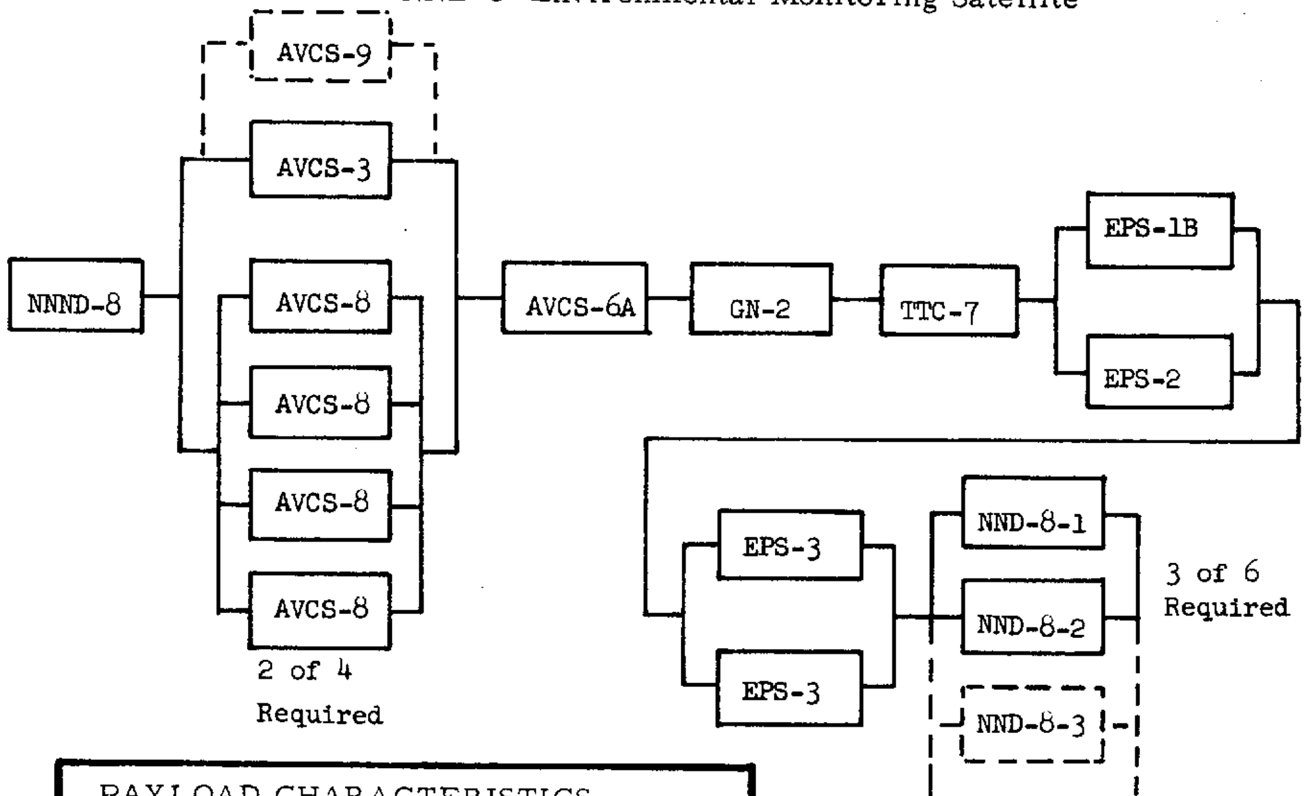
NND-6 Communication R&D (Prototype)



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	23
DESIGN LIFE (YRS)	3
RELIABILITY @ D. L.	0.180
WEIGHT - DRY (Kg)	2932.6
PROP (Kg)	205
TOTAL (Kg)	3137.6

Figure 4-1. Space Serviceable Payload Descriptions

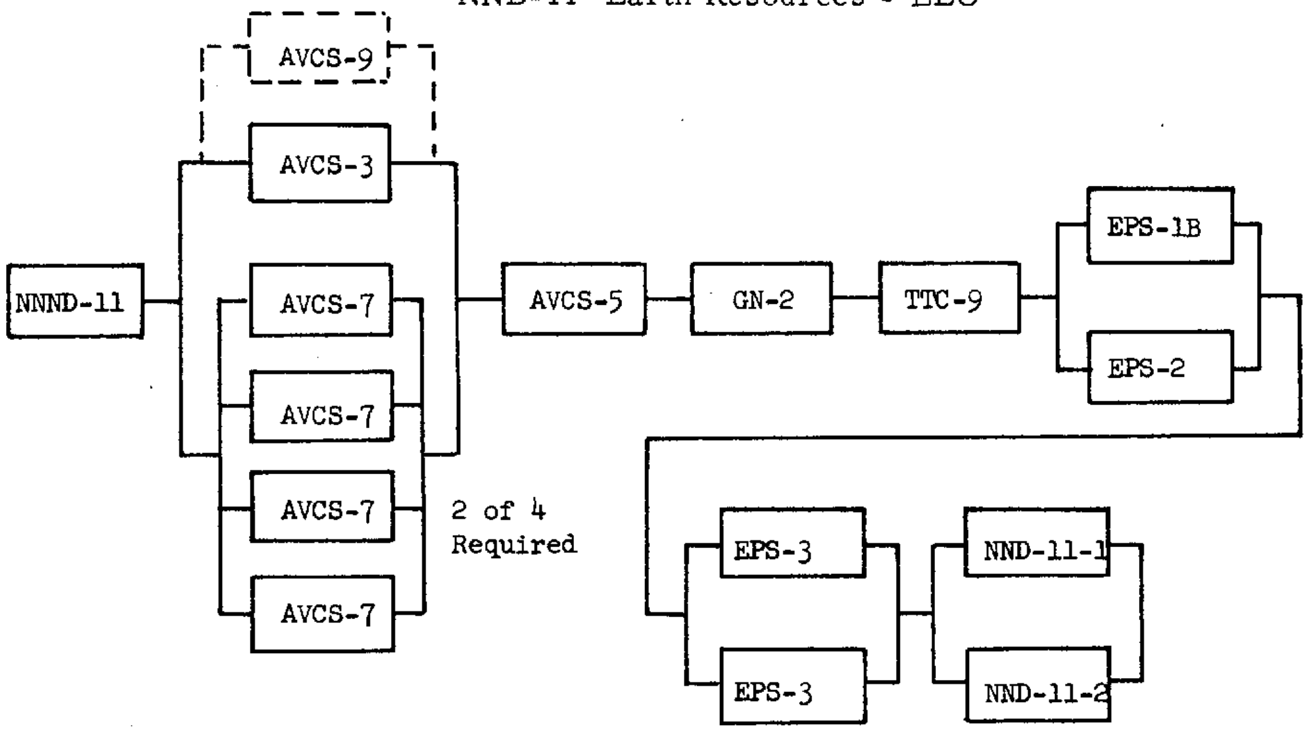
NND-8 Environmental Monitoring Satellite



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	19
DESIGN LIFE (YRS)	10
RELIABILITY @D. L.	0.036
WEIGHT - DRY (Kg)	2009.8
PROP (Kg)	264
TOTAL (Kg)	2273.8

Figure 4-1. Space Serviceable Payload Descriptions

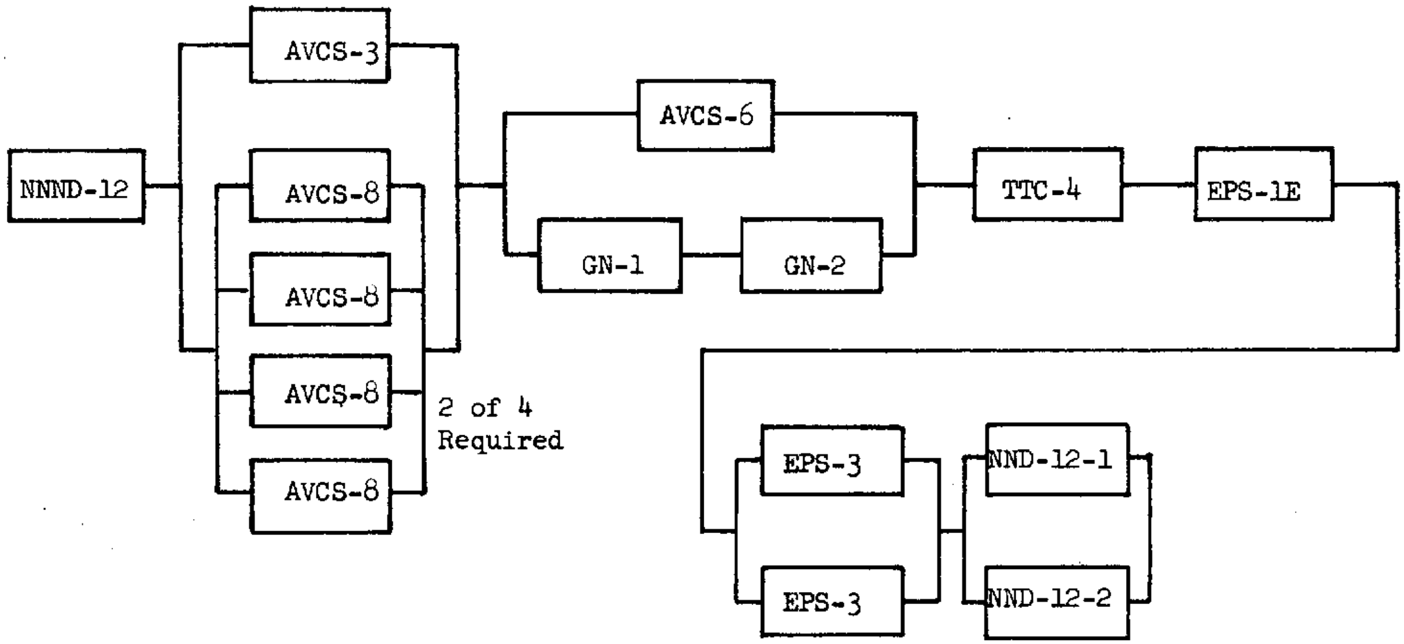
NND-11 Earth Resources - LEO



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	15
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.036
WEIGHT - DRY (Kg)	1390.2
PROP (Kg)	72
TOTAL (Kg)	1462.2

Figure 4-1. Space Serviceable Payload Descriptions

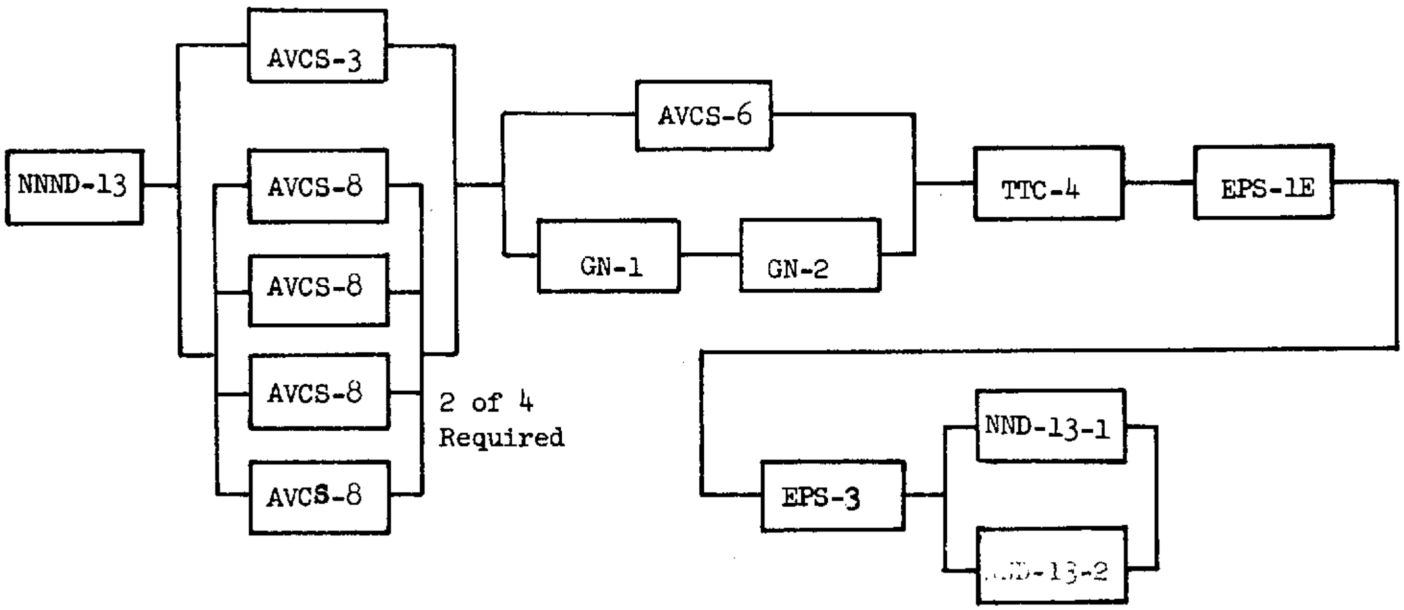
NND-12 Earth Resources - Geosynchronous Orbit



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	14
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.254
WEIGHT - DRY (Kg)	1852.0
PROP (Kg)	349
TOTAL (Kg)	2201.0

Figure 4-1 Space Serviceable Payload Descriptions

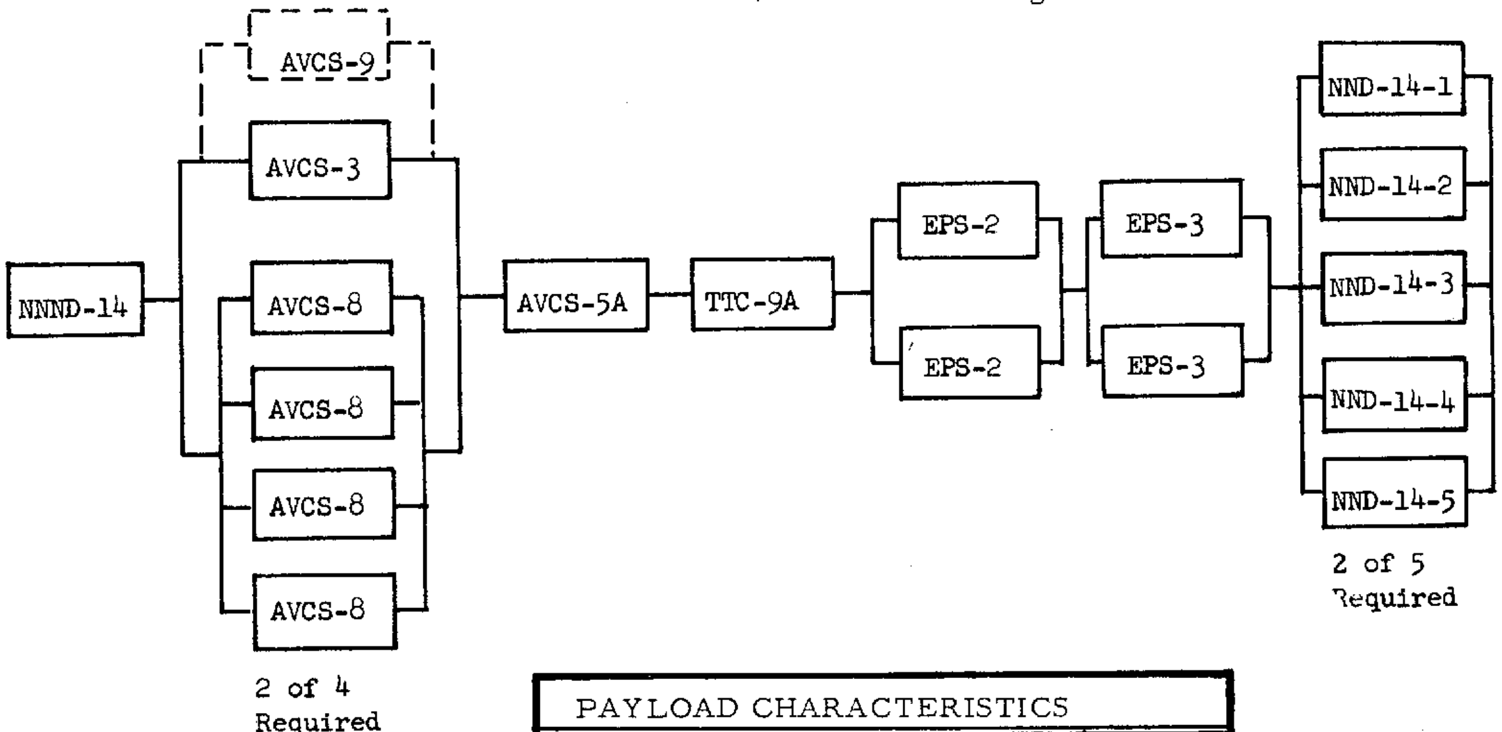
NND-13 Foreign Earth Resources - Synchronous Orbit



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	13
DESIGN LIFE (YRS)	5
RELIABILITY @ D. L.	0.275
WEIGHT - DRY (Kg)	2000.8
PROP (Kg)	343
TOTAL (Kg)	2343.8

Figure 4-1. Space Serviceable Payload Descriptions

NND-14 Global Earth/Ocean Monitoring



PAYLOAD CHARACTERISTICS	
NUMBER OF SRUs	17
DESIGN LIFE (YRS)	10
RELIABILITY @ D. L.	0.136
WEIGHT - DRY (Kg)	1720.2
PROP (Kg)	329
TOTAL (Kg)	2059.2

Figure 4-1. Space Serviceable Payload Descriptions

The reliability estimates shown in Figure 4-1 deserve further explanation. The reliability of each payload is quoted at the design life specified. The design life was derived from the NASA mission model. However, if the design life exceeds the truncation time of the AVCS reaction control modules or the electrical power models, a discontinuity exists. These modules would necessarily have to be replaced and at the time of replacement their individual reliabilities would be unity, creating a step in the Weibull curve for the entire payload. The Weibull parameters were therefore derived by a curve fitting technique which tends to average out the discontinuity created by the truncation of certain consumable SRUs. The reliability parameters of the total payload are not employed in the simulation tradeoffs but are included in the event manual calculations may be desired at some point in the future.

5. RELIABILITY AND WEIGHT COMPARISONS

This section provides a comparison of expendable payload design characteristics versus space serviceable concepts. This comparison is for reference purposes only and does not influence future trade studies. The simulation program (LOVES) operates on the individual parts (SRUs and NRUs) rather than the total satellite. However, there is no other place where these two factors are summarized for easy reference. Consequently, two tables are provided in this section for ease of comparing the two designs in the event that future iterations may require this traceability.

Table 5-1 provides a summary of the 29 different payload configurations selected as candidates for servicing. The reliability estimates for both serviceable and expendable designs are identical since these were derived from the diagrams of Section 4. The weights are different in order to reflect the lighter weight of expendable designs. It should be noted that in a few cases, for large payloads, a weight improvement is achieved. In the process of redesigning these payloads, it was observed that some payloads specified in the mission model were higher in weight. An attempt was made, based upon the reference mission model, to reconstruct the expendable payload design. With the techniques employed within The Aerospace Corporation, it was not possible to arrive at the higher weight values shown. Further efforts should be directed toward improving the level of confidence in the values specified in the reference mission model, since this will continue to be the basis of comparison for some time to come.

Table 5-2 provides similar data for those payloads not considered for space servicing. The reliability values have been estimated based upon current design practice for NASA and DoD payloads. No attempt has been made to prophesy what future reliabilities could be achieved. The important point is that these data provide a consistent basis of comparison for space servicing operations versus expendable designs. The same data are used in either case. As shown in Section 2, the traffic generated, as a statistical average, is consistent with the reference traffic model.

Table 5-1. Comparison of Payload Parameters

Payload*	Reliability Data		Weight Data	
	Design Life (yrs)	Reliability	Expendable (kg)	Serviceable (kg)
AST-1B	3	0.024	623	1312
AST-1C	10	0.113	594	1175
AST-3	10	0.122	1310	2182
AST-9A	5	0.217	7702	6097
AST-9B	5	0.058	10673	7973
PHY-1A	10	0.037	594	1252
PHY-1B	5	0.204	896	1701
PHY-1C	5	0.218	277	993
PHY-2A	5	0.111	786	1673
EO-3A	10	0.023	2944	3155
EO-4A	5	0.011	1210	1924
EO-6	3	0.380	2212	2089
EO-7	5	0.169	270	1582
EOP-3	10	0.137	1012	1669
EOP-4	10	0.007	1168	957
EOP-7	3	0.083	2397	1703
NND-1	10	0.018	1809	2727
NND-2A	10	0.245	283	984
NND-2B	10	0.083	1809	2705
NND-2D	7	0.148	338	1315
NND-3	7	0.262	617	1420
NND-4	7	0.180	319	1145
NND-5	10	0.153	336	975
NND-6	3	0.180	975	3138
NND-8	10	0.036	2184	2274
NND-11	10	0.036	660	1462
NND-12	5	0.254	1210	2201
NND-13	5	0.275	1210	2344
NND-14	10	0.136	1162	2059

*Identical reliability values and redundancy configurations assumed for both serviceable and expendable configurations.

Table 5-2. Non-Serviceable Payload Parameters*

Payload	Design Life (yrs)	Reliability	Weight (kg)
AST-1A	5	0.32	623
AST-4	2	0.64	5428
AST-5A	2	N/A**	7590
AST-5B	2	N/A	9516
AST-5C	2	N/A	5041
AST-5D	2	0.64	6429
AST-6	2	N/A	10400
AST-7	2	N/A	10000
AST-8	3	N/A	1300
PHY-10	2	0.26	426
PHY-2B	2	0.26	349
PHY-3A	5	0.32	1488
PHY-3B	5	0.32	3945
PHY-4	10	0.38	280
PHY-5	2	N/A	18596
PL-7	6	0.36	3283
PL-8	6	0.36	3976
PL-10	2	0.26	684
PL-11	2	0.26	3957
PL-12	2	0.26	5469
PL-13	2	0.26	3495
PL-14	2	0.26	1690
PL-17	10	0.38	508
PL-18	10	0.38	508
PL-19	5	0.32	2669
PL-20	5	0.03	508
PL-21	10	0.38	1515
PL-22	10	0.51	915
PL-23	10	0.38	9752
PL-26	5	0.32	2154
PL-27	5	0.32	580
PL-28	5	0.32	1980

* Sorties are scheduled to meet Reference Mission Model requirements 1980 - 1990.

Number of 7-Day Sorties 357
Number of 30-Day Sorties 37

** Payloads are scheduled for manned maintenance revisits irrespective of random failure characteristics. Impacts Shuttle availability only.

Table 5-2. Non-Serviceable Payload Parameters (Continued)

Payload	Design Life (yrs)	Reliability	Weight (kg)
LUN-2	2	0.26	757
LUN-3	2	0.26	1380
LUN-4	7	0.39	1120
LUN-5	2	0.26	2664
LS-1	1	N/A	682
ST-1	5	N/A	3859
EO5-A	3	0.36	394
EOP-5	2	0.26	3244
EOP-6	7	0.39	102
EOP-8	1	0.26	150
EOP-9	2	0.26	200
NND-9	7	0.39	257
NND-10	7	0.39	257

In the final analysis of space servicing, it will be necessary to vary the reliability of these expendable payload designs to assess the sensitivity of the results to the input data. It is possible that future designs could exhibit improved reliability characteristics which could reflect on the benefits of space servicing. It is also true that a similar improvement could be achieved with space serviceable design approaches, thereby further enhancing space servicing benefits. These influences must be studied further; however, a basis for initiating these sensitivity studies has to be established and that is what has been attempted here.

Until improved data is developed, it is felt this comparison of expendable and space serviceable design concepts is sufficiently valid to allow meaningful trade offs to be performed. Those trade offs will be documented in the final report prepared under this study contract, Study 2.1, Operational Analysis.

6. SUMMARY

This addendum provides one more step in the process of evolving a completely new operational concept for future space programs. It is important to recognize that this effort represents only the first iteration of the basic work presented in the parent document. Further iterations need to be performed to refine the data such that standard subsystem modules can be defined with sufficient confidence that specifications can be developed. The process must eventually lead to hardware development if the benefits of space servicing are to be realized.

The approach taken in this effort was directed at retaining as much freedom as possible for the individual payload programs. Mission equipment development will obviously evolve through numerous paths and the operational concept must not inhibit this freedom. At the same time, the repeated redevelopment of subsystem components and modules can be effectively standardized to reduce their proportionate share of the budget. Combining these two aspects to arrive at space serviceable payload designs will be a substantial challenge. It is compounded further by the need to integrate this process with shuttle operations, developing the service technique and the service unit.

The results of this effort provide a rational design approach for space replaceable units. Component selection and arrangements will meet the fundamental performance requirements for the various payloads of interest. The arrangement of SRUs, relative to redundant paths, is also rational based upon previous experience. The designs are not, however, optimized against a specific criteria. No attempt was made to maximize reliability against incremental weight increases. No attempt was made to optimize the selection of standby versus active redundancy. In addition, the mission equipment descriptions are highly arbitrary because the identified payload programs are only projections of the current trend of space operations and, therefore, do not represent firm program requirements.

In spite of the limitations, these works are felt to provide a rational basis for comparing space servicing concepts versus alternate methods of supporting future space operations. The data provided is obviously somewhat speculative, as is the reference mission model. This should not, however, preclude addressing the problem to develop an understanding of the factors involved. It is hoped that this data will provide the basis for other study efforts directed at improving the confidence in future payload definitions. This basic data forms a set which can be expanded in numerous directions without losing traceability to the original reference NASA mission model. As new mission models evolve, the data should be revised to continue the iteration process, continually improving the quality of information employed for long range planning.

APPENDIX

ERRATA TO ATR-74(7341)-3

PAYLOAD DESIGNS FOR SPACE SERVICING

ERRATA

Page			
3-3	Table 3-1, Lifetime Parameters AST-1B		
		was:	Design Life 10 yrs, MMD of 7 yrs
		now:	Design Life 3 yrs, MMD of 2 yrs
			Reliability at the specified Design Life has been revised for both expendable and space serviceable designs as provided in Table 5-1 of the Addendum.
3-5	Table 3-1		
		was:	Gravity and Reliability Sat
		now:	Gravity and Relativity Sat
4-26	Table 4-3		
		was:	AVCS-1 has a block E in reliability diagram
		now:	AVCS-1 block E should be removed as shown in Table 3-1 of Addendum.
		was:	AVCS-3 has one block A to represent three reaction wheels
		now:	AVCS-3 has three reaction wheels, block A, in series feeding into one block B, wheel electronics as shown in Table 3-1 of Addendum.
4-27	Table 4-3		
		was:	AVCS-5 has block A shown in six different positions
		now:	AVCS-5 block A only exists in one position, after Block B, rate gyro package. Redundant statement should read "2 of 3 required."
		Same note for AVCS-5A, AVCS-6, and AVCS-6A all of which are shown in Table 3-1 of Addendum.	
4-28	Table 4-3		
		was:	AVCS-8, Module Name.... "Small Tank"
		now:	AVCS-8, Module Name.... "Large Tank"
4-29	Table 4-4		
		was:	GN-2, Memory Unit Failure Rate 5000 x 10^{-9}/hr
		now:	GN-2, Memory Unit Failure Rate 7000 x 10^{-9}/hr Therefore, the reliability at design life is 0.207 and α = 6.34 (yrs)

5-26	Figure 5-3		
		Remove reference to 6A in figure title	
5-30	Table 5-12		
		was:	TTC-1 without baseband assembly unit
		now:	TTC-1 add baseband assembly unit as shown for TTC-4. Refer to Table 3-2 of Addendum for increased levels of redundancy.
		was:	Block diagram has multiple items where only single units have been identified in item quantity column
		now:	Revise diagram to agree with quantity specified
		was:	TTC-2 Same note concerning baseband assembly and quantity of items
5-31		was:	TTC-3 Same note concerning baseband assembly
5-32		was:	TTC-5A Recorder failure rate of 10,000 x 10^{-9}/hr
		now:	TTC-5A Recorder failure rate of 40,000 x 10^{-9}/hr Refer to Table 3-2 of Addendum for increased levels of redundancy.
5-33		was:	TTC-7, item A (S-band, 7W)
		now:	TTC-7, item A (S-band, 8W)
		was:	TTC-7, item C Failure rate 25,000 x 10^{-9}/hr
		now:	TTC-7, item C Failure rate 2500 x 10^{-9}/hr
5-33		was:	TTC-7A recorder failure rate of 10,000 x 10^{-9}/hr
		now:	TTC-7A recorder failure rate of 40,000 x 10^{-9}/hr
5-34		was:	TTC-9 without antenna drive
		now:	TTC-9 add item G antenna drive, and change Hybrid to item H, power conditioning to item I, and remote terminal to item J. This change conforms to the block diagram except where the quantity of items is in error as noted above.
		was:	TTC-9A recorder failure rate of 10,000 x 10^{-9}/hr
		now:	TTC-7A recorder failure rate of 40,000 x 10^{-9}/hr

was: TTC-10, item E, Recorder #1, failure rate of $10,000 \times 10^{-9}$/hr

now: TTC-10, item E, failure rate of $40,000 \times 10^{-9}$/hr

7-8 Table 7-4

This table has been completely revised and is provided as Table 3-3 of this Addendum.

9-2 Table 9-1

was: NAST-9A, Stand. Struct. Weight 427 kg

now: NAST-9A, Stand. Struct. Weight 227 kg; total weight changes to 4101 kg

was: NAST-9B, Stand. Struct. Weight 427 kg

now: NAST-9B, Stand. Struct. Weight 227 kg; total weight changes to 7251 kg

10-13 Table 10-2

Note propellant weights shown in this table reflected minimum required propellent with reserves. However, with standard RCS modules, there is in general more propellant on board than will be required. The propellant weights therefore have been revised to reflect tank capacities of 75% to 100%. The small tank (AVCS-7) will hold approximately 21 kg of propellant. The large tank (AVCS-8) will hold approximately 106 kg. The following table reflects the weight changes.

Payload	Dry (kg)	Prop (kg)	Wet (kg)
AST-1B	1228	76	1304
AST-1C	1106	68	1174
AST-3	2093	80	2173
AST-9A	6204	80	6284
AST-9B	9359	80	9439
PHY-1A	1184	60	1244
PHY-1B	1406	293	1699
PHY-1C	967	30	997
PHY-2A	1247	415	1662
EO-3A	2815	227	3042
EO-4A	1716	133	1849
EO-6	2002	80	2082
EO-7	1519	62	1581
EOP-3	1628	40	1668
EOP-4	981	40	1020

Payload	Dry (kg)	Prop (kg)	Wet (kg)
EOP-7	1370	255	1625
NND-1	2645	82	2727
NND-2A	936	60	996
NND-2B	2645	60	2705
NND-2D	1244	81	1325
NND-3	1341	80	1421
NND-4	1084	60	1141
NND-5	872	115	987
NND-6	2943	205	3148
NND-8	2338	264	2602
NND-11	1388	72	1460
NND-12	2047	349	2396
NND-13	1997	343	2340
NND-14	1814	329	2143

11-11 Table 11-1

was:	NND-8, Number of SRUs	27
now:	NND-8, Number of SRUs	26

THE AEROSPACE CORPORATION

EXTERNAL DISTRIBUTION LIST

(REFERENCE: COMPANY PRACTICE 7-21-1)

REPORT TITLE

Operations Analysis (Study 2.1)
Payload Designs for Space Servicing - Addendum

REPORT NO.	PUBLICATION DATE	SECURITY CLASSIFICATION
ATR-74(7341)-3, Add.	30 September 1974	Unclassified

MILITARY AND GOVERNMENT OFFICES	ASSOCIATE CONTRACTORS AND OTHERS

(NOTE: SHOW FULL MAILING ADDRESS; INCLUDE ZIP CODE, MILITARY OFFICE SYMBOL, AND "ATTENTION" LINE.)

NASA Scientific & Technical
Information Facility (3)
P.O. Box 33
College Park, Md. 20740

NASA - Headquarters
Washington, D.C.
Attn: V.N. Huff, Code MTE (50)
R.R. Carley, Code MTE (2)
Dr. J.W. Wild, Code MTE (1)
New Technology Repr,
Code KT (1)

NASA
Mr. Duncan Collins
P.O. Box 92960
Worldway Postal Center
Los Angeles, CA 90009
Bldg. 120, Rm 1406B (1)

AFR 80-45 DISTRIBUTION STATEMENT X'D BELOW APPLIES

☐ NO DISTRIBUTION STATEMENT
(Classified documents only)

☐ A. APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

☐ B. DISTRIBUTION LIMITED TO U.S. GOV'T AGENCIES ONLY;

_______________ (Reason)

_______________ (Date statement applied). OTHER REQUESTS FOR THIS DOCUMENT MUST BE REFERRED TO _______________ (Controlling DOD office)

APPROVED BY [signature] (FOR THE AEROSPACE CORPORATION) DATE 27 Nov 74

APPROVED BY _______________ (FOR COGNIZANT AF OFFICE) _______________ (SYMBOL) DATE _______________

IF LIST COMPRISES TWO OR MORE SHEETS, COMPLETE THIS SIGNATURE BLOCK ON LAST SHEET ONLY

SHEET 1 OF 1

AEROSPACE FORM 2380 REV 7-71